Department of Applied Mechanics

Hazard Identification in Winter Navigation

Osiris A. Valdez Banda, Risto Jalonen, Floris Goertlandt, Jakub Montewka and Pentti Kujala

Aalto University

SCIENCE + TECHNOLOGY

RESEARCH REPORT

Aalto University publication series
SCIENCE + TECHNOLOGY 15/2014

Hazard Identification in Winter Navigation

Osiris A. Valdez Banda, Risto Jalonen, Floris Goerlandt, Jakub Montewka and Pentti Kujala

Aalto University
School of Engineering
Department of Applied Mechanics
Research Group on Maritime Risk and Safety

Aalto University publication series
SCIENCE + TECHNOLOGY 15/2014

ISBN 978-952-60-5888-7
ISBN 978-952-60-5889-4 (pdf)
ISSN-L 1799-4896
ISSN 1799-4896 (printed)
ISSN 1799-490X (pdf)
http://urn.fi/URN:ISBN:978-952-60-5889-4

Unigrafia Oy
Helsinki 2014

Finland

The report has been carried out as part of the research performed in the winter navigation risks and oil contingency plan (WINOIL) project with funding from the South-East Finland – Russia ENPI CBC programme.

441 697
Printed matter

Aalto University

Aalto University, P.O. Box 11000, FI-00076 Aalto www.aalto.fi

Abstract

Author
Author(s): Osiris A. Valdez Banda, Risto Jalonen, Floris Goerlandt, Jakub Montewka, Pentti Kujala

Name of the publication
Hazard Identification in Winter Navigation

Publisher School of Engineering

Unit Department of Applied Mechanics

Series Aalto University publication series SCIENCE + TECHNOLOGY 15/2014

Field of research Maritime safety

Abstract

In this report, a hazard identification in winter navigation has been performed in order to detect, determine, list and categorize different relevant hazards threatening the safety performance and development of the winter navigation operations. The analysis presented in this report aims to gather all available information from different sources in order to detect hazards for the practice of winter navigation, having a particular consideration of winter navigation hazards of oil tankers operation and/or vessels with similar characteristics.

The report introduces the implemented framework to detect the relevant hazards of winter navigation and describes in details the three utilized sources to detect those hazards: hazard identification workshops with winter navigation experts, accident cases analysis, and analysis of accident statistics of 5 winters. Results obtained are presented after the performed collection and data analysis. Finally, discussion and conclusions are drawn.

Keywords safety, hazard, winter navigation

ISBN (printed) 978-952-60-5888-7 **ISBN (pdf)** 978-952-60-5889-4

ISSN-L 1799-4896 **ISSN (printed)** 1799-4896 **ISSN (pdf)** 1799-490X

Location of publisher Helsinki **Location of printing** Helsinki **Year** 2014

Pages 36 **urn** http://urn.fi/URN:ISBN:978-952-60-5889-4

Hazard Identification in Winter Navigation

WINOIL

Winter Navigation Risks and Oil Contingency Plan

Osiris A. Valdez Banda, Risto Jalonen, Floris Goerlandt, Jakub Montewka and Pentti Kujala

Aalto University, Department of Applied Mechanics, Maritime Risk and Safety Group.

This project is co-funded by the European Union

Contents

1. Introduction...1
2. Methodology Framework 3
2.1 Hazard.. 3
2.2 Hazardous situation.. 4
2.3 Hazardous event 4
2.4 Consequences... 4
3. Hazard identification in winter navigation 6
3.1 Hazard identification workshop with experts 6
3.1.1 Workshop with Icebreaker captains and officers 6
3.1.2 Workshop with Pilots 7
3.1.3 Workshop with VTS officers... 8
3.2 Hazard identification from the analysis of accident cases........................ 9
3.2.1 Categorization of accident cases... 9
3.2.2 Accident cases 10
3.3 Hazard identification from the analysis of accident statistics.................. 16
3.3.1 Accidents statistics winters 2002-2003 and 2009-2013.......................... 16
4. Results 23
4.1 Identified hazards from workshops.. 23
4.2 Identified hazards from cases.. 24
4.3 Identified hazards from statistics 27
4.4 Matrix of winter navigation hazards.. 27
5. Discussion and conclusions... 33
5.1 Discussion... 33
5.2 Conclusions.. 34
References.. 35

List of Abbreviations and Symbols

FSA	Formal Safety Assessment
IB	Icebreaker
IMO	International Maritime Organization
WINOIL	Winter Navigation Risks and Oil Contingency Plan Project

1. Introduction

A hazard identification process aims to detect and define all possible hazards threating the safety of all the components interacting in the development of defined operations (Wells, 1996). In the maritime sector, hazard identification is the first step for formal risk analysis. In 1988, the International Maritime Organization (IMO) developed the Formal Safety Assessment (FSA) as a response to the Alpha disaster in the North Sea (IMO, 2013). The United Kingdom Marine Safety Agency (MSA) proposed to the IMO for first time, that the guideline in the FSA should be applied to ensure a strategic surveillance of safety and pollution prevention in the shipping industry in 1993 (Trbojevic and Carr, 2000). In 2002, the FSA was formally approved for use in the IMO rule-making process (MSC/Circ.1023/MEPC/Circ.392). Today FSA is recognized as a systematic methodology for identifying hazards, assessing risks, and determine the appropriate actions to manage risk in a cost effective mode (IMO, 2013). A factual and standardize methodology for implementing risk assessment, which is nowadays used not only by IMO managers and implementers, but also by Classification Societies and maritime safety designers (Martins and Goyano, 2007).

A hazard identification process should preferably begin with the set of a methodology to identify the hazards treating the safety of specific tasks and/or operations (CASITA, 2003). This process should be aimed to identify safety hazards and issues associated with the operations under analysis, and the results need to provide elements to develop efficient planning of those task (Carter and Smith, 2006). Thus, an established hazard identification methodological framework should provide the necessary elements to identify different scenarios leading to potential accidents (Ferrier and Haque, 2003). An efficient framework must identify; the causes of potential hazardous events (accidents), the specific matters triggering those accidents, and the analysis of the resulting consequences. The aim is to determine possible ways for reducing the likelihood of those events and the extent of it (Wells, 1996).

In this report, a hazard identification in winter navigation has been performed in order to detect, determine, list and categorize different relevant hazards threatening the safety performance and development of the winter navigation operations. The analysis presented in this report aims to gather all available information from different sources in order to detect hazards for the practice of winter navigation, having a particular consideration of winter navigation hazards of oil tankers operation and/or vessels with similar characteristics.

The report is presented as follow. The section 2 introduces the implemented framework to detect the relevant hazards of winter navigation. Section 3 describe in details the three utilized sources to detect those hazards: hazard identification workshops with winter navigation experts, accident cases analysis, and analysis of accident statistics of 5 winters. Section 4 presents the results obtained after the performed collection and data analysis. And finally, discussion and conclusions are drawn in section 5.

2. Methodology Framework

2.1 Hazard

The concept of hazard is commonly known as a source of potential harm or a situation with potential to cause loss (Standards Australia, 2001). In line to this brief definition, an oldest concept was proposed by (Burton et al., 1978); "hazards are those elements of the physical environment, harmful to man and caused by forces extraneous to him". In this description, hazard is only linked to potential affectations threatening humans. However, it can be also expanded with the same perspective to different aspects (e.g. environment, economy, education, knowledge, and property affectations).

In maritime winter traffic, a hazard could be considered as a specific obstacle or physical threat for the safety of several components interacting in the practical development of maritime traffic. These components can be:

- The people involved in the development of maritime traffic
- The assets utilized in maritime traffic
- The environment where maritime traffic is performed
- The economy involved in maritime traffic

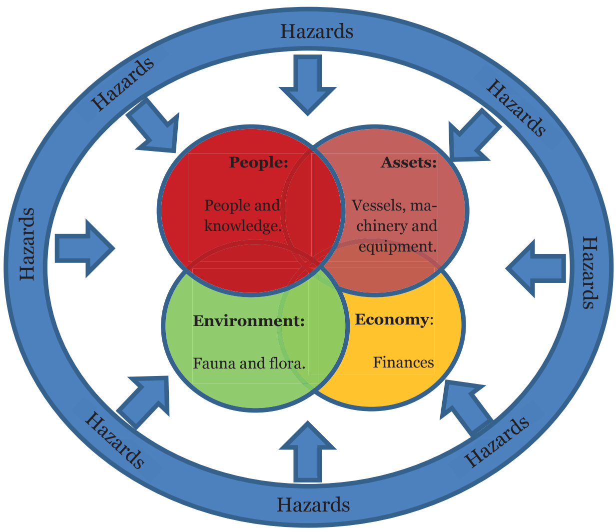


Figure 1. Maritime winter traffic components threatened by winter navigation hazards.

Figure 1 introduces the main components involved in winter navigation which have to consider all possible hazards threatening their safety, integrity, status, etc. For example, a hazard for people, assets, and economy involved in winter navigation, can be a rubble field in the course of a vessel (see Figure 2). However, in the same situation a hazard for the environment is actually the vessel and specifically its content which could pollutes the environment of the zone in the event of a collision between both. Thus, all hazards need of scenario(s) in which they may trigger its potential affectation, this scenario is mentioned in (Critch et al, 2013) as the hazard situation.

2.2 Hazardous situation

The hazardous situation represents a particular scenario which can have a fixed amount of time, a fixed amount of participants, and a pre-established environment of the scenario. In this scenario one or more hazards can be present at any specific time and in any specific location of the scenario. For example, a vessel navigating the under sea ice conditions with a rubble field in the area can be considered as hazardous situation (see Figure 2). In this report, hazardous situations are going to be analyse more in deep in order to have a better understanding of how and in which form hazards can potentially lead to a hazardous event.

2.3 Hazardous event

A hazardous event can be represented as an accident and/or incident. The hazardous event basically exist at the instant when one specific hazard, within a hazardous situation, has finally affected one of the components integrating the winter navigation. One hazard can triggers several hazardous events when it has reached one or more of these components. Commonly, these events are sequentially aligned and may derived in one or several consequence (Reason, 1997). For example, in the hazardous situation when a vessel is navigating under ice conditions, and there is hazard (rubble field) situated exactly in the planned route of the vessel, and the vessel which is no able to accurate detect the location and dimensions of the rubble field finally collide it (see Figure 2). Thus, in this example the hazardous event number 1 (as there can be more triggered events after) is the instant when the vessel hit the rubble field. Finally, the hazardous events experienced in one or several hazardous situations are naturally linking those event(s) to one or more specific consequences.

2.4 Consequences

Basically, consequences are those outcomes derived from the suffered accidents or incidents (hazardous events). For example, in the case of a vessel colliding a rubble field, the consequence number one can be exemplified as the rupture in the waterline of vessels hull (see Figure 2). And a consequence number two could be a potential oil spill derived from the hull rupture. As defined by (Oxford dictionary, 2014), consequences are the result or effect, typically one that is unwelcome or unpleasant. Thus, in the process of identifying hazards, the mentioned definition of consequences is properly connected to the purposes of this report.

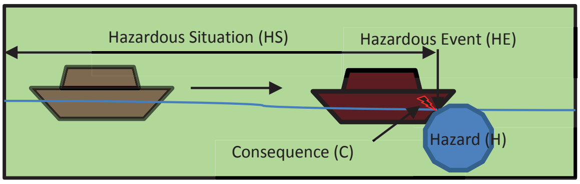


Figure 2. Hazard, Hazardous Situation, Hazardous Event and Consequences.

Thus, the framework previously introduced aims to integrate the different winter navigation hazards, hazardous situations, hazardous events and their possible consequences collected in this report. After this information is collected, the first step is to cluster all this data, and presented in next sections according to the introduced methodology. In this proposed proposed framework, hazardous situation are the course of several actions in which the safety of the main components of maritime winter navigation may be exposed. Thus, in those situations several hazards may reside, and an unfortunately alignment of these actions may lead to an accident with consequences of different magnitudes, including damage to people, assets and environment. In the *criterion for comparison of risk at planning of navigation in ice conditions (CRFIN)*, Goncharov (2013) has presented a model for linking the impact of the combination of parameters that characterize the ice and weather conditions with the economical losses from insurance, repairs, port demurrages, delivery delays and cost of icebreaker assistance.

3. Hazard identification in winter navigation

3.1 Hazard identification workshop with experts

During summer 2013 three hazard identification workshops were arranged as part of the research performed within WINOIL project. Basically, the workshops have served to update the data of previous hazard identification for winter navigation performed in (Jalonen et al, 2005). The participant groups of this workshops were composed by icebreaker captains and officers, pilots, and VTS operators who have long experience in the performance of their duties. For elicitating the experts, a general brain storming exercise to identify winter navigation hazards was implemented. Thus, the experts had the option to write down its opinion in a form which suited better to them.

3.1.1 Workshop with Icebreaker captains and officers

The session was arranged with experts onboard of an icebreaker. The first question opening this workshop was about the allocated waiting points for the ships approaching to Finnish ports, and the common expended time for waiting icebreaker assistance. Additionally, the experts were consulted about the grounds selection of these locations and the possible need for a re-allocation. The opinion expressed by the experts was that; if possible, the waiting points should be located within the protection of the archipelago. This proposal was considered based on the ice and weather conditions of the season. For example, wind speed and direction and its forecast are the main issues to analyse for selecting the waiting points.

A second question about the most demanding places during winter navigation periods and the reasons for it was asked to the experts. The most relevant factor mentioned again was the ice conditions. Ice ridges, drifting pack ice, and ice compression were expressed as the most challenging ice conditions. Furthermore, areas with narrow fairway in where vessels sometime require assistance were considered also as high demanding.

The types of collisions and groundings expected every ice season were similar to previously identified in (Jalonen et al., 2005). The hazards related to the operations of icebreakers were mentioned as the components involved in those operations (e.g. icebreaker, vessel, machinery and equipment, ice and weather conditions, and rocks), and the hazardous situations where they interact (e.g. IB operations such as: escorting, towing, convoy, and breaking ship lose). Additionally a potential weakness in the icebreaker operation processes was also mentioned; the end shift reports with lack of relevant and needed data for allowing the new officer in duties to properly perform his work. Finally, the hazardous situation when a ship navigating alone provides breaking ship lose assistance to a ship stuck in ice was particularly pointed by the experts. This operation generates a compromising situation for the officer responsible of the operation in which is not an expert.

3.1.2 Workshop with Pilots

This session was organized by the staff of Finnpilots in one of their stations. The first hazardous situation expressed by the consulted experts on this workshop was about large ships (e.g. oil tankers, large bulk carriers and container ships) navigating and operating under ice conditions independently (i.e. without Icebreaker assistance). According to the experts, this situation primarily increases the risk of these vessels grounding, especially during spring (March and/or April) when the ice is thick and ice fields start to move. In the context of tankers, the risk of groundings and/or collisions and the possible devastating consequences have been analysed in several previous studies (Goerlandt, et al. 2012a, 2012b; and Montewka, et al. 2011). Thus, in narrow places and places with the vicinity of shallow water areas containing rocks which represent the main hazard because in limited and considered short distances an unintended movement may get these kind of ships more easily on the ground. Another different latent hazard during this time period was pointed to the situation when vessels navigate surrounded by ice large floes that may be located even in an established ice channel and cause damage in several sections of the hull. Also, a large ice floe situated in a channel could push a ship from its intended course drastically hitting vessel's hull, and even pushing the vessel out of the channel and potentially causing a grounding. About the location of the waiting points for vessels approaching to Finnish ports, this group of experts has expressed their preferences in also locating these points in sheltered areas with the protection of the archipelago.

Collisions were the hazardous events particularly analysed by the experts. The experts mentioned that collisions may occur in narrow ice channels when two ships are on the route to opposite directions. In this case, the ships commonly try to take a sufficient distance from each other in order to perform a safety passing of the vessel coming on route. However, the ice conditions in the edges of the ice channel may bounce the vessel trying to go out of the channel back to the channel and trigger a collision with the ship located in the channel. The high speed normally implemented in this operation was another aspect mentioned by the experts because it may also leads to a more severe impact between the vessels. Another mentioned event was bow to stern collisions which are considered as the typical collisions in ice conditions. For example, at the moment ships are navigating in convoy, if the speed of a ship drops drastically and the ship gets stuck in ice, the vessel following it can collide its rear. Apparently, breaking out of the channel is the commonly adopted option to avoid collisions in the mentioned situations, and it is because slowing down the speed may derive in a new vessel getting stuck in the ice.

According to the experts, there are several factors that can increase the risk on hazardous situations. For example, wet fall snow which can add noise on radar and screens. Frost smoke, a particular weather condition which can be very dense and it could significantly reduce the visibility, increasing the risks linked to the situation of not making appropriate observations e.g. in convoy operations. And finally freezing, in the case of old ships or ships with inadequate warming and ventilations systems, which can lead to windows and windscreens on the bridge getting frozen.

3.1.3 Workshop with VTS officers

This session was organized in the Finnish Transport Agency (liikennevirasto). The first hazardous events identified by the experts were groundings and collisions. According to the experts, groundings in winter time are not always connected with the severity of ice conditions, but mainly because the crew of some vessels is not familiar to ice navigation. Another issue mentioned during winter navigation was about vessels which need to operate closer to coast lines due to the ice conditions of the zone. Particularly, in the case of tankers stuck in ice and waiting for assistance several days. In this scenario, a hazardous situation may exist if the tanker stuck in ice starts to drift towards an area with shallow waters. In such case, an icebreaker is contacted to provide assistance to free the beset ship. However, in the case of having many ships waiting for assistance, perhaps some other vessels may need to wait longer time and expose themselves to new hazards. At the end, the designation of turns to receive assistance will depend on the prioritization of vessels situation, normaly the vessels in most hazardous situations are going to be assisted first.

Convoy operations were also mentioned in this session. When navigating in ice ships are usually seeking for the easiest route to proceed. Therefore, in severe ice conditions, the first ship that breaks the channel in the ice is commonly escorted by another ships. The problem mentioned here was mentioned as the distance between those ships included in the convoy, and also the speed implemented in the operation. Apparently, there are not many new options for improving the above mentioned, because short distance and high speed are needed to avoid getting stuck in the channel. Continuing with the analysis of convoys, the experts have mentioned that a critical hazardous situation can be the blackout of a ship in the convoy because, the ship behind may have problems to correctly estimate distances.

And again, the particular case when a ship stuck ice ask for assistance from other vessel passing by was mentioned. The possible lack of experience in this kind of operation and also the characteristics of the vessel providing the assistance (which is not an icebreaker) may create a hazardous situation which could leads to a collision between both ships.

3.2 Hazard identification from the analysis of accident cases

3.2.1 Categorization of accident cases

In the shipping industry, the typical accidents are rather well known by the experts of the sector. Accident cases analysis are commonly categorized based on the type of accident suffered. Table 1 introduces the common categories of different marine accidents, this list is adopted from (IMO, 2013).

Table 1. Marine accident types (IMO, 2013).

Accident	Description
1. Collision	Striking or being struck by another ship (regardless of whether under way, anchored or moored).
2. Grounding	Being aground, or hitting/touching shore or sea bottom or underwater objects (wrecks etc.)
3. Contact	Striking any fixed or floating object other than those included in 1-2
4. Fire and/or explosion	Regardless of if one is product of the other or vice versa.
5. Hull failure or failure of watertight doors/ports, etc.	Not caused by 1-4
6. Machinery damage	Not caused by 1-5, and which necessitated towage or shore assistance
7. Damages to ship or equipment	not caused or covered by 1-6
8. Capsizing or listing	by 1-7
9. Missing	Assumed lost
10. Other	All casualties, which are not covered by 1-9

During winter, the accident types have effects on causes and consequences which are different to the ones experienced in the open water season. Furthermore, there are unique types of accidents connected only to winter ice season. Table 2 introduces the common types of accidents during winter navigation.

Table 2. Frequent types of accidents occurring during winter navigation (Jalonen et al., 2005).

Accident type	Winter navigation
Collision	Collision between ships Collision with an assisting icebreaker Collision with a fixed object
Grounding	Powered grounding Drift grounding
Fire	Fire Explosion
Ice damage	Damage to the vessel hull - Damage to hull plating (outer) - Damage to hull stiffeners (frames) - Damage to hull plating (inner) - Damage to hull appendages (e.g bilge keels) - Damage to other parts of the hull Rudder damage Propeller damage Machinery damage Damage to the ship systems Damage to the ship equipment
Icing	Loss of ship stability Loss of freeboard Loss of visibility

3.2.2 Accident cases

A) Collisions

A.1. Collision between ships

Case A.1.1 (HS, 1985)

On the 6 of April 1985, at around the time of daybreak, a general cargo ship collided on the port side of another cargo vessel in the Gulf of Finland. The latter vessel listed and took fire at the afterbody, so its whole crew and three passengers on board had to be evacuated in a life boat. An icebreaker came on the scene and rescued the people and a helicopter picked 3 persons to hospital. Then, a tug towed the ship in a safer location in shallow water to avoid the ship sinking. The fire was extinguished on the next day and the ship was towed to a nearby harbor and after that to the repair yard.

Case A.1.2 (FMA, 2001)

On the 6 of March 1987, a passenger vessel collided with another in darkness at 03:05 in a snowfall. The ships were passing each other port-to-port at a small distance in a narrow ice channel. Thus, a suction effect due to the pressure fields of the vessels was evident. However, local variations in the ice conditions had also some influence on the motion of the ships. Ship number one got some material damage on its port side plating and ship number two got a 20 cm wide and 15 m long rupture above water-line. Lifeboats and the davits of the latter vessel were also damaged.

Case A.1.3 (FMA, 2001)

On the 7 of March 1994, a general cargo ship and a tanker of about 8 500 dwt were on meeting courses in a narrow old ice channel in the Gulf of Finland. It was planned that the tanker with ice class IA would give way and break out from the channel. However, the channel edge was harder than expected and the tanker could not get out from the channel. The distance between these two ships diminished quickly and finally they collided bow to bow in the ice channel. Fortunately the extent of damage was rather small in both vessels

Case A.1.4 (Wang et al., 2007)

During the night of the 5th of March 2006, a general cargo ship was collided by another in the Gulf of Finland when proceeding in a convoy after an icebreaker. Details of the accident have not been reported well in public, but the consequences of this collision were so severe that the ship sank and an oil spill occurred. It is presumed that this collision was a by the bow to the rear end of the other ship.

A.2. Collision with an assisting icebreaker

Case A.2.1 (FMA, 2001)

On the 15 of March 2000, an icebreaker towed a cargo vessel in heavy ice conditions in the Bay of Bothnia. When the towing was finished, it appeared that the cargo vessel had a dent and a rupture in its stem. The damage was located totally above the waterline.

Case A.2.2 (Trafi, 2013)
On the 24 of January 2010, a chemical tanker and an icebreaker collided during assistance work. The icebreaker speed dropped due to heavy ice conditions, and the chemical tanker could not react. The tanker got minor damages on the bow stem. The damages were inspected by port state control officers, cracks or holes were not observed but class verification for the hull was required. The icebreaker's stern plate was buckled caused by the anchor of chemical tanker.

Case A.2.3 (Trafi, 2013)
On 3 of March 2010 between 16:35 and 20:45 Finnish time, a general cargo vessel was towed by an IB. During this towing, heavy ice conditions were experienced. However, there were apparently not strange turns or collisions, but after the operation was completed, the crew of the general cargo noticed a big hole and dent in the bow exactly on the nose at the same height where the stern of the icebreaker was fastened.

Case A.2.4 (Trafi, 2013)
On 28 of February 2011, an icebreaker was cutting out a general cargo from ice, during the operation the steering place of icebreaker's starboard hand was not properly working and on the left hand steering place an error occurred. Thus, the list of starboard outside of the icebreaker hit the left outside of the general cargo. This generated that in the CO2-room of the general cargo were several dents over the collided list, and upper the water line a considerable crack was also detected.

A.3. Collision with a fixed object

Case A.3.1 (Trafi, 2013)
On 30 of April 2010, a general cargo sailing out from the quay of harbor was returned back to middle of the harbor basin. After that, the ship started to turn from the starboard side to the ship route, at the end of turning the ship started to go straight hitting the port side to the corner of the other side of gas berth. The engine was half ahead, and the wheel and bow thruster was hard starboard. The damages were not bad only some plates and frames were dented. No cracks, holes or leakages on the ship hull were found.

B) Groundings
B.1. Powered grounding

Case B.1.1 (FMA, 1996)
On the 9 of March 1982, a 12 year old general cargo vessel grounded in the Gulf of Finland in poor visibility caused by dense fog. The navigation during vessel's

approach to port was further complicated by effects of drifting ice floes. According to the pilot, it was impossible to make difference between the echoes from the ice floes and the echo from the radar deflector because everything appeared as similar echoes on the radar. The ship suffered large bottom damage and water entered in the machinery room. The ship sunk in shallow water almost down to the level of its main deck, and it had to be towed to the harbor. No damage to the crew was reported.

Case B.1.2 (Lukkonen, 1999)
On the 11 of January 1991, a ro-ro ship grounded when it was approaching port on the coast of the Sea of Bothnia in heavy snowfall and hard wind. This accident was caused by the problems in understanding the movements of the vessel and a sudden loss of visibility. Furthermore, irregular and unexpected conditions of sea currents and the dead light of waterway edge mark may have also strongly contributed for the grounding of the vessel. The damaged area on the ship's bottom was about 50 %, so a visit to a repair yard was inevitable.

B.2. Drift grounding

Case B.2.1 (Vapalahti, 1997)
On the 14 of February 1966, an 8 Beaufort eastern wind started to move ice from the Gulf of Finland towards the coast of Sweden. Two passenger ships were stuck in the heavy ice conditions near Almagrundet. The whole ice field drifted towards underwater rocks with the jammed ships. An icebreaker was called out to help, and it arrived to the scene and managed to free the ships from their hazardous positions. One of the passenger vessels used 66.5 hours for the voyage of about 170 nautical miles. The extremely low average speed of 2.6 knots on this trip, long parts of which were made through the sheltered waters of archipelago, tells a lot about the severe ice conditions.

Case B.2.2 (Hänninen, 2003)
On the 21 of January 2003, a tug was traveling in an ice lead. The ship got stuck and started to drift sideways along the ice masses with speed of 2-3 knots. Ice pieces piled up against ship's side shell. Pile-up and drifting lasted about 20 minutes, and after that ice pieces started slide below the ship's bottom. When the compression eased off, the ship drove to the fast ice field and waited for icebreaker assistance. Icebreaker towed the ship to the nearest harbor.

C) Fire and explosions
C.1. Fire

Case C.1.1 (Trafi, 2013)
On the 11 of January 2010, a floodlight were left on in the closed general cargo hold which was full-loaded with timber cargo. Increased heat set fire on the timber packet which were closely loaded in front of floodlight. The floodlight burnt as well. Ship's crew started firefighting and the fixed CO2 system was released.

Extra work was performed to support firefighting by cooling the area with water. The vessel didn't presented harmful damages, but the timber cargo got some damages mainly because of used foamed water and to a lesser degree caused by the fire.

C.2. Explosion

Case C.2.1 (Trafi, 2013)
On the 15 of February 2012, a container ship was berting and just in the final of the operation there was explosion in the engine room. The cause was detected as an overheating due to breakage of the piston.

D) Ice damage
D.1 Damage to the hull

Case D.1.1 (Vapalahti, 1997)
On the 22 March 1971, a 15 year old general cargo ship of around 3600 tons deadweight was sailing to the Finnish coast of the Bay of Bothnia close to the Quarck area. In the evening, a winter storm from north – northeast with force 9 arose to the area. Thus, large masses of drifting ice were moving and the visibility was deteriorating due to snowfall which was gradually getting denser. Ice floes started to be pressed and crushed on the ship sides. An assisting icebreaker took the cargo ship for towing in to a safer area. However, the bollard on to which the towing line was attached broke and it detached from the deck. After a while a new attempt to get the cargo ship moving was made, but it did not succeed. The cargo ship was so tightly pressed by the ice that it did not move anymore. The pressure on the cargo ship sides was so strong that they were bent inwards and a small leakage was detected. The compression was continued and the steel structures, frames and decks were deformed. Two frames were totally broken and water started to spurt into the vessel from the ruptures. The main deck of the vessel started to get bent and the bulkheads between holds were also buckling manifestly due to strong stresses.

CASE D.1.2. (Hänninen, 2003)
On the 11 of January 2003, an oil tanker was on her way with full cargo while she got stuck in compressive ice in the Gulf of Finland. During the compression in the 10-30 cm thick ice, field ice blocks piled up against the SB side of this Aframax class vessel. The ship had an ice class equivalent to the Finnish-Swedish ice class IC. The longitudinally framed flat side plating in the mid-ship area of this ship got permanent deflection in the area of two frame spacing for length of about 100 m with maximum indents being about 30 mm. The damaged area was in the ice strengthened belt about 1.5 m below waterline. According to the ship's master the vertical extension of the ice belt was too narrow.

CASE D.1.3 (Hänninen, 2003)

On the 19 of March 2003, a handymax bulk carrier of around 45 000 dwt with no known ice strengthening (ice class II) was following an icebreaker with full power in ridged and rafted ice. The ice conditions were severe in the eastern parts of the Gulf of Finland, level ice thickness was about 55-75 cm and the speed of the vessel was about 8 knots. The beam of this bulker was approximately 2.5 m wider than the beam of the icebreaker. The weather data was as follows: temperature –2°C, pressure 1009 mbar, wind W-4. As a consequence of ice loads on the ship hull, two fractures and several dents were formed on the hull plating. Water started to leak in the foremost hold so that the forward draught of the vessel increased gradually by more than 2.7 m. around the fractures. The permanent deformation of the plating was about 200 mm. The length of the fractures was 2 m in horizontal direction.

D.2. Rudder damage

Case D.2.1 (Hänninen, 2003)
On the 22 of April 2003, a new general cargo ship of ice class IA and a deadweight of nearly 8 000 tons was proceeding in the Bothnia Bay without icebreaker assistance in moderate to heavy ice conditions (level ice thickness about 35-60 cm). The ship was almost in ballast condition with draught forward being about 65 % and aft about 70 % of the full load draught. Occasionally, the ship was stuck in ice but it could free itself by reversing the pitch. According to the statement of the master, the rudder was kept midships during repeated rams and reversals, this operations were performed in full power ahead and with a speed between 2 and 3 knots. During one repeated ram towards the ice, it was noticed that the ship was turning to port with the rudder midships. Starboard rudder was given, but it had no effect. The ship was stopped and the rudder position was checked. It was found out that the rudder was pushed out of its centre position. The owners of the ship and the nearest icebreaker were informed of the condition of the vessel.

CASE D.2.2 (Trafi, 2013)
On the 10 of January 2011 at 20:00 Finnish time, a container ship was disabled due to ship's rudder damage in ice during sea passage from Tallinn to Lulea. In the position of the incident, the containership has experienced heavy ice condition which derived in the unfortunately damage of the rudder.

D.3 Propeller damage

Case D.3.1 (Hänninen, 2003)
On the 23 of February 2002, a rather new ro-ro vessel of nearly 9 000 dwt with ice class IA Super suffered a propeller damage in the Bay of Bothnia. The accident happened in the evening at 21:20 during a voyage about 3.5 hours after departure from port. The ship had been navigating in an old ice channel without icebreaker assistance. Due to an occasional stop, the ship was backed with reversed pitch and the main engine was overloaded and stopped. Repeated trials

to start the main engine again didn't succeed. The propulsion system was checked, and it was found out that the engine could not be started due to the propeller failure. Later, an icebreaker arrived and the ship was towed to its port of destination.

D.4 Machinery damage

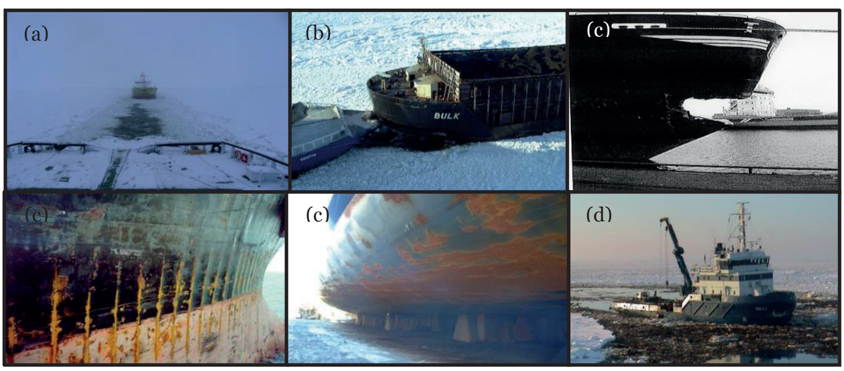
Case D.4.1. (Trafi, 2013)
On the 21 of February 2011, a general cargo was filling the wing ballast tanks when the goose necks (ventilators) were clogged with ice. The overpressure caused a deformation and a crack in the hull. As a result, ballast water flooded into the cargo hold of the vessel.

E) Icing
E.1 Loss of ship stability

Case E.1.1 (SST, 1963)
On the 18 of January 1963, a general cargo ship sank in mid-January at a distance of 6 nautical miles from a port in the southern Baltic Sea due to icing and consecutive cargo shift. However, the crew of the ship could be rescued by local vessels.

Case E.1.2 (HS, 1987)
On the 13 of January 1987, a fast passenger car ferry with about 400 passengers was on its way to north in open water in the middle of January in the southern Baltic Sea. Stormy wind started to blow very hard from north to east, with a speed of 20 to 25 m/s, and the temperature was decreasing down to -10°. Ice started to accumulate on the ship's bow deck and also on the upper deck structures. In similar weather conditions about eight years ago, the ship had succeeded in ending its voyage to the port of destination. However, this time when the excessive icing, stormy wind and heavy waves the ship stability and visibility was totally compromised. Therefore, it was considered better to turn back and returned safely to its port of departure where the ice removal operation could be started.

Photos by A. Mazaheri(a), T. Leiviskä(b), S. Hänninen(c), and Merikotka online presentations(d)



3.3 Hazard identification from the analysis of accident statistics

3.3.1 Accidents statistics winters 2002-2003 and 2009-2013

Collisions and propeller damages were the most common accidents in the Baltic Sea during these winter periods. The accident data analysed covers only accidents reported in Finnish waters and/or to Finnish vessels which are registered by the Finnish Transport Safety Agency. The statistics presented here aim to describe which are the most common accidents occurring in the Baltic Sea during winter time, how are these accidents taking place, in which ice conditions the accidents commonly happen, and the severity of these accidents.

The total number of casualties in the mentioned periods, covering only accidents occurred under ice conditions is 70. Figure 1 presents the type of vessels involved on those accidents. Figure 2 presents the type of accidents occurred in the mentioned period.

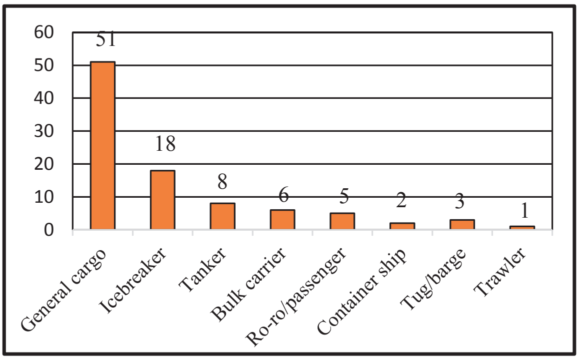


Figure 3. Type of vessels involved in accidents during winters 2002 – 2003 & 2009 – 2012 (FMA, 2003; Trafi, 2013).

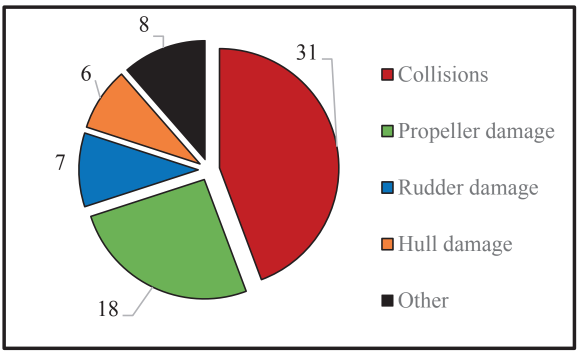


Figure 4. Type of accidents under ice conditions during winters 2002-2003 & 2009-2013 (FMA, 2003; Trafi, 2013)

Table 3 presents the type of accidents occurred under ice conditions and their respective designated severity during the periods 2009-2013. Unfortunately, the database of the winter 2002-2003 had not such classification.

Table 3. Type of accidents under ice conditions and their severity (Trafi, 2013)

Accident type	Less serious	Serious	Very serious	Total
Collisions	14	2	0	16
W/ other ship	13	2	0	15
W/ other ship not under way	0	0	0	0
W/ a fixed object	1	0	0	1
Groundings	1	0	0	1
Power	1	0	0	1
Drift	0	0	0	0
Loss of containment	1	0	0	1
Oil spill	1	0	0	1
Rudder damage	0	2	0	2

In the 31 collisions experienced during the analysed winters, 18 (4 in winter 2002-2003 and 14 in winters 2009-2013) were related to the assistance operations of icebreakers. The information of the accidents occurred under ice conditions during the winters 2009-2013 included the specification of the operations performed when the accidents have took place. Figure 6 introduces the operations performed by the IB when 14 collisions in winters 2009-2013 occurred.

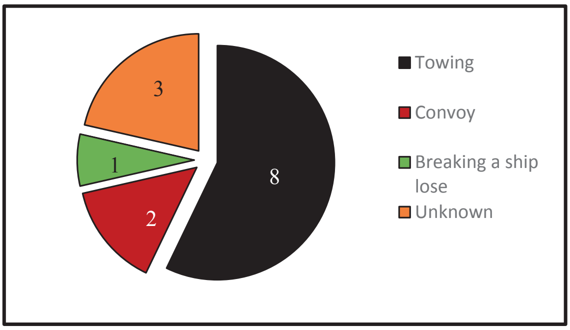


Figure 5. Icebreaker operations involved in collisions (Trafi, 2013).

Figure 6 presents the resulted outcome of the collisions occurred under sea ice conditions during the 5 analysed winter periods. These outcome are presented as the common damages and ship affectations derived from the accident.

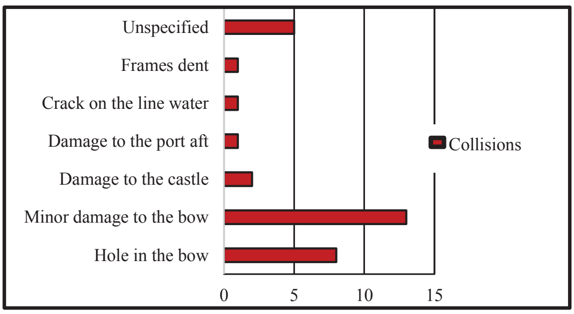


Figure 6. The damages of the 31 collisions in the analysed winters (FMA, 2003; Trafi, 2013).

Most of the accidents in the period 2009-2013 occurred in ice sea areas with consolidated, compact or very close pack ice, and with an average ice thickness of 20 – 40 cm. Figure 7 presents the ice conditions and ice thickness experienced during the analysed accidents.

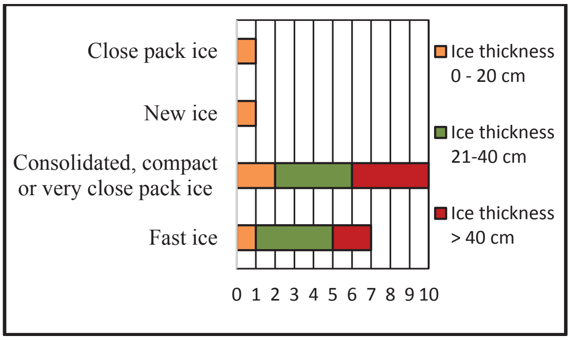


Figure 7. Ice type and ice thickness experienced when the accidents occurred in winters 2009-2013 (SMHI, 2013)

The most frequent accidents occurred under ice conditions during the analysed period were collisions. The table 4 presents the frequency of the 31 collisions occurred under ice sea conditions.

Table 4. Frequency of collisions during winter navigation

	Jan	Feb	Mar	Apr	..	Oct	Nov	Dec	Total
2002									
2003	2	6	4						12
...									
2009									0
2010	1	1	4	2					8
2011		2	3	4					9
2012		1	1						2
2013									0
Total	3	10	12	6					31
Freq. (1/month.)	0.6	2	2.4	1.2		0	0	0	**6.2**
									(1/winter)

The other frequencies of the accidents reported during sea ice conditions were: propeller damage with a 3.6 frequency per winter, rudder damage 1.4 frequency, groundings 0.2 frequency, and loss of containment 0.2 frequency.

The major number of accidents under sea ice conditions during the analysed winter periods has occurred in the Gulf of Finland and Bay of Bothnia. The Bay of Bothnia had 24 accidents reported, Gulf of Finland also 24, Gulf of Riga 7, Central Baltic 5, Sea of Bothnia 2, Saimaa Lake 1, and 7 unknown locations. Figure 8 presents the locations of those accidents within the Baltic Sea.

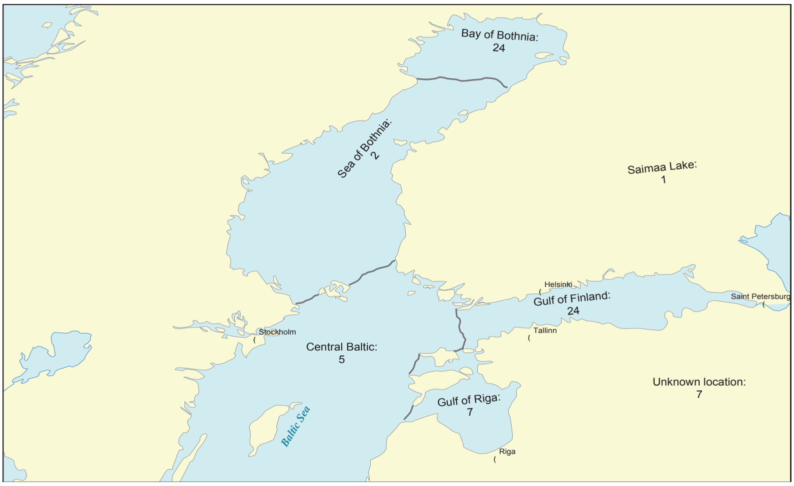


Figure 8. Number of accidents in different zones of the Baltic during winters 2002 – 2003 & 2009 – 2013 (FMA, 2003; Trafi, 2013)

Regarding the collisions experienced during icebreaker operations in those 5 winters, in 5 cases when a collision occurred in consolidate compact or very close pack ice, the conditions have also presented ridge and hummocked ice. The ice thickness when collisions occurred were in 5 cases an ice thickness of 1 – 20 cm, 8 cases 21 – 40 cm, and 6 cases with more than 40 cm ice thickness. Figure 9 introduces the reported months of the collisions during IB assistance in the 5 analysed winters.

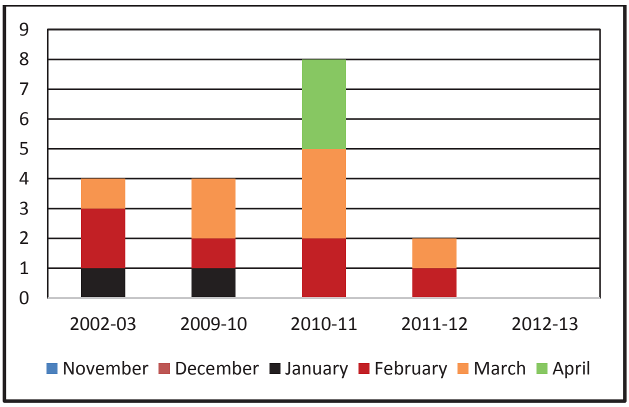


Figure 9. Collisions by winter month 2002-2003 & 2009 – 2013 (FMA, 2003; Trafi, 2013)

Mapping the sequence of the accidents occurred (e.g. during IB's towing, convoy and breaking ship lose operations), enable recognizing the specific ice characteristics of the hazardous situations of the operations which ended in accidents. Figure 10-12 introduces all different accident sequences followed during those operations in the analysed data. These sequences are differentiated by arrows (connectors) with different sizes which represent the amount of accident occurred on those sequences.

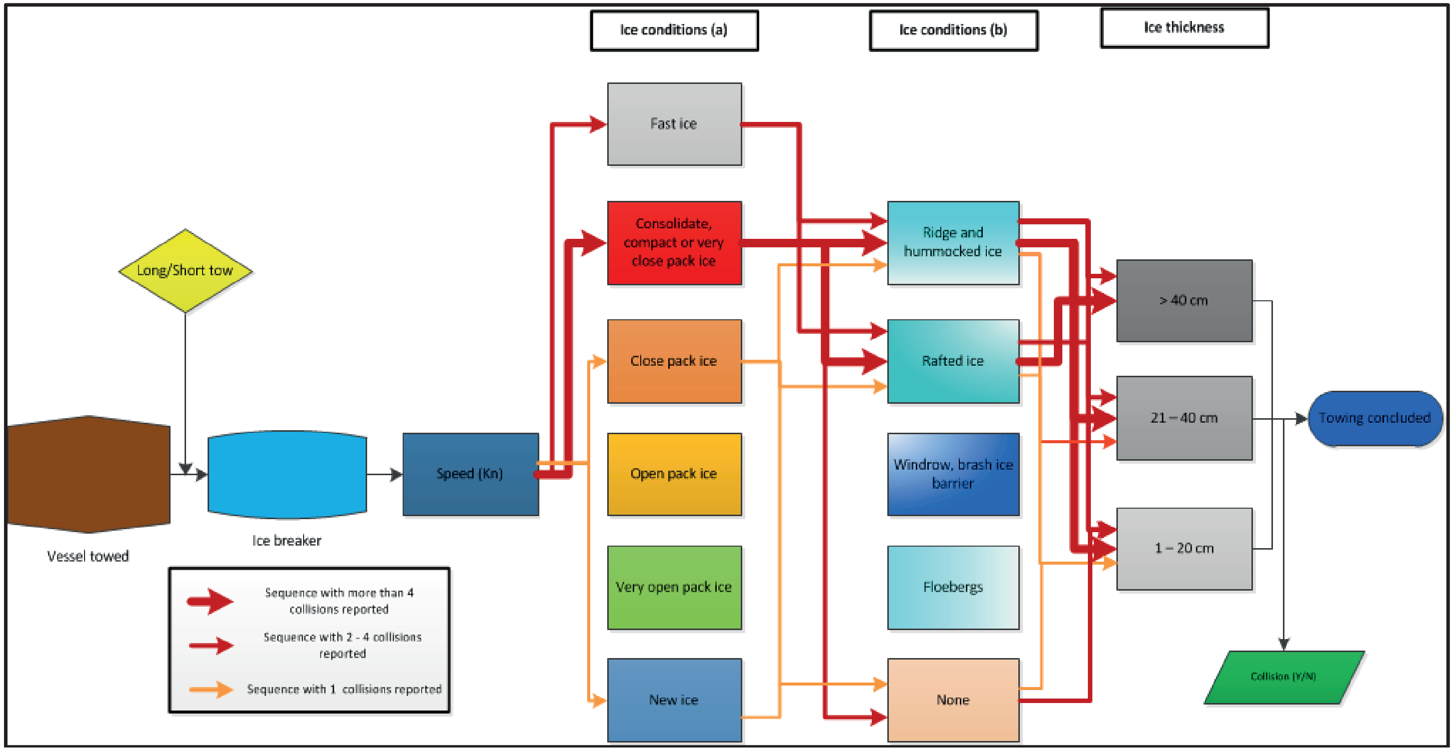


Figure 10. Flow chart of the towing operation and the sequence of the collisions reported.

Figure 11. Flow chart of the convoy operation and the sequence of the collisions reported

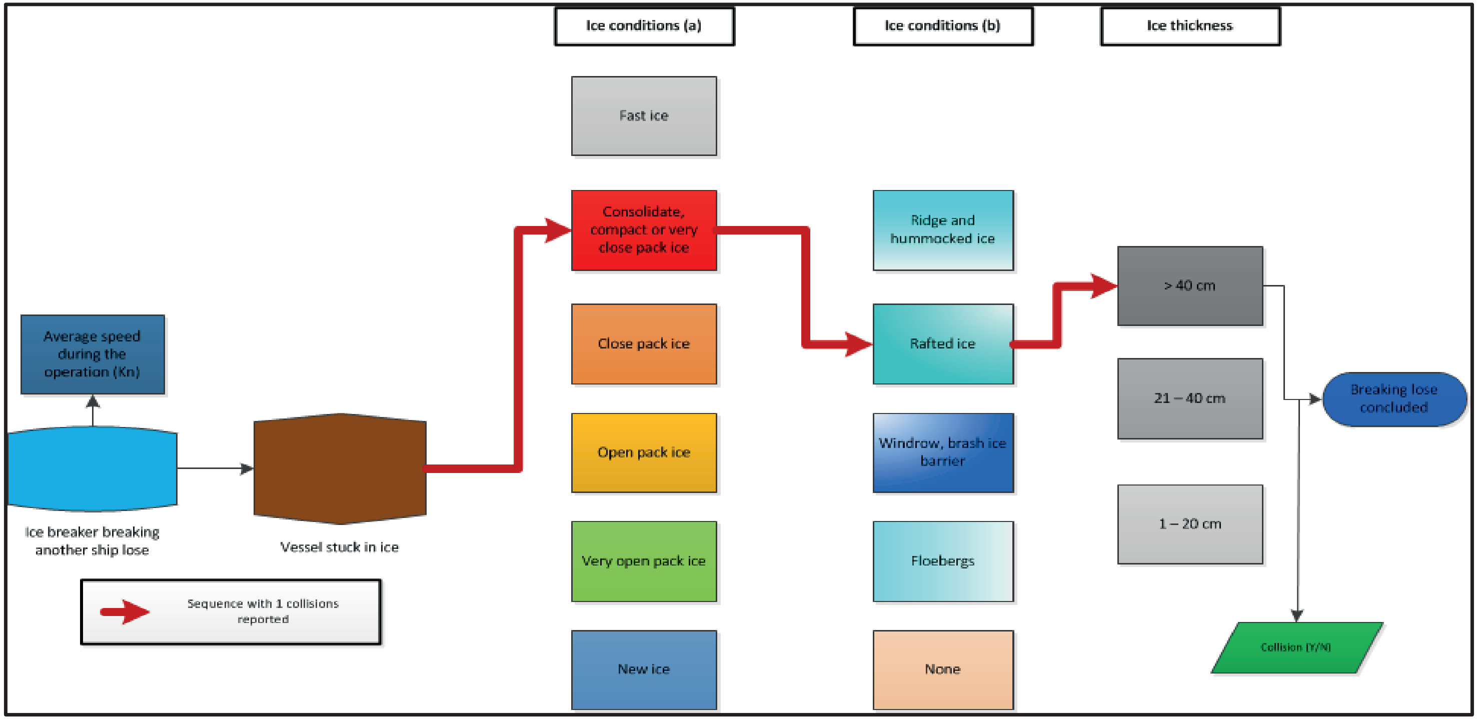


Figure 12. Flow chart of the breaking a ship lose and the sequence of the collisions reported

4. Results

4.1 Identified hazards from workshops

The tables 5-7 present the specific hazards, hazardous situations, hazardous events and consequence in winter navigation detected by the consulted experts during the workshops. This information is an update of the previous hazard identification for winter navigation performed in (Jalonen et al, 2005).

Table 5. Hazard identification workshop with captains and officers

Hazard	Hazardous situations	Hazardous events	Consequences
Ice conditions *Ice ridges* *Drifting pack ice*	Weather conditions *Wind speed* *Wind directions*	Collisions Groundings	
Ice compression	A narrow fairway		
Vessels	Icebreaker escorting other ships		
Icebreakers	Icebreaker on towing		
Ship's machinery	Icebreaker on convoy		
	Icebreaking cutting lose of ship stuck in ice		
	Ship cutting lose of another ship stuck in ice		

Table 6. Hazard identification workshop with pilots

Hazard	Hazardous situations	Hazardous events	Consequences
Ice conditions	Navigation during march and April with thick ice and ice fields moving.	Collisions	Hull damage
Ice large floes	Navigation in an ice marrow channel	*Stern collisions*	Failure of radars and screens
Edges of the ice channel	Independently navigation during winter	Groundings	A frozen bridge
Rocks	Ships navigating in opposite directions within a narrow ice channel	Ship stuck in ice	Frozen windows
Large bulk carriers	Passing a vessel in a same coming route		
Large container ships	A vessel navigating at high speed in convoy		
	A vessel dropping considerably its speed		
	Navigating with wet fall snow		
	Convoy operations with frost smoke		
	Old ship navigating with inappropriate warning and ventilation systems		

Table 7. Hazard identification workshop with VTS officers

Hazard	Hazardous situations	Hazardous events	Consequences
Ice conditions	Navigating without experience of winter navigation	Groundings	
Vessels	Vessels operating closer to coast lines	Collisions	
	A ship stuck in ice starts to drift towards an area with shallow waters.		
	Convoy operations and the distance between ships		
	A blackout of a ship in convoy		
	Ship cutting lose of another ship stuck in ice		

4.2 Identified hazards from cases

The tables 8-19 present the specific hazards, hazardous situations, hazardous events and consequence in winter navigation detected by the consulted experts during the workshops.

Table 8. Hazard identification in cases of collisions between vessels

Hazard	Hazardous situations	Hazardous events	Consequences
Case A.1.1			
Vessels		Collision	Fire at the after body
			Evacuation of crew and passenger
			Helicopter and icebreaker assist the vessel
			3 persons end in the hospital
Case A.1.2			
Vessels	Ship passing each other in a narrow ice channel with night darkness and snow falling	Collision	Material damage on a vessel port side plating
Ice conditions			Long rupture above water line
			Life boats damaged
			Davits damaged
Case A.1.3			
Ice conditions *Ice channel edge*	A tanker and a general cargo meeting courses in a narrow ice channel, and tanker trying to go out of the channel to give way to the other vessel.	Collision	Hull rupture of the tanker
			Oil spill
			General cargo sank
Case A.1.4			
General cargo vessel	Navigation in convoy	Collision	Oil spill
			Ship sank

Table 9. Hazard identification in cases of collisions during icebreaker operations.

Hazard	Hazardous situations	Hazardous events	Consequences
Case A.2.1			
Ice conditions	An icebreaker towing a cargo vessel	Collision	Dent in the stern
Icebreaker			Rupture in the stern
Vessel			
Case A.2.2			
Ice conditions	Icebreaker escorting a tanker in heavy ice conditions	Collision	Minor damage on the bow of the tanker
Icebreaker			Icebreaker stern plate buckled
Chemical tanker			
Case A.2.3			

Icebreaker	Icebreaker on towing in heavy ice conditions	Unnoticed collision	Hole in the bow
Cargo vessel			Dent in the bow
Case A.2.4			
Icebreaker	Icebreaker cutting out a general cargo from ice without properly functioning of the IB's starboard	Collision	Dents on the CO2 room of the general cargo
General cargo vessel			Crack on the hull over water line

Table 10. Hazard identification in cases of collision with a fixed object.

Hazard	Hazardous situations	Hazardous events	Consequences
Case A.3.1			
Vessel	A vessel sailing out from the quay of harbour	Collision with a fixed object	Plates dented
Port side			Frames dented

Table 11. Hazard identification in cases of powered groundings.

Hazard	Hazardous situations	Hazardous events	Consequences
Case B.1.1			
Vessel	Navigating with poor visibility due to dense fog, and with the presence of ice floes. This generated poor quality information from the radar monitor.	Grounding	Damage on the bottom of the vessel.
Large ice floes			Water enter in the machinery room
			The ship sunk in shallow water almost to deck level
			Icebreaker assistance to tow the vessel was needed
Case B.1.2			
Vessel	Approaching to the port with heavy snow falling and hard wind	Grounding	Damage on the ship bottom
Sea bottom in shallow waters	Loss of visibility due to dead light of water way edge mark		

Table 12. Hazard identification in cases of drift groundings.

Hazard	Hazardous situations	Hazardous events	Consequences
Case B.2.1			
Severe ice conditions	Ships stuck in ice and ice field moving the stuck ships towards underwater rocks	Grounding	Need for icebreaker assistance
Vessels			
Rocks			
Case B.2.2			
Vessel	A ship stuck in ice drift sideways along ice masses	Grounding	Damage in the bottom
Ice conditions		Ice compression	Need for icebreaker assistance

Table 13. Hazard identification in cases of fire.

Hazard	Hazardous situations	Hazardous events	Consequences
Case C.1.1			
Floodlight on	Increased heat set fire on the timber packet which were closely loaded in the front of floodlight	Fire	Cargo burnt
Cargo			Floodlight burnt
			Firefighting to cool the area

Table 14. Hazard identification in cases of explosion.

Hazard	Hazardous situations	Hazardous events	Consequences
Case C.2.1			
Gas	A container ship berting gas	Overheating a piston	Engine damages
		Explosion	

Table 15. Hazard identification in cases of ice pressure to the hull.

Hazard	Hazardous situations	Hazardous events	Consequences
Case D.1.1			
Large masses of drifting ice	Navigating during winter storm with poor visibility due to a dense snowfall.	Break of the bollard during towing	Rupture in the hull
	Ice floes pressing and crushing the ship sides	Ship stuck in ice	Frames broken
	Towing assistance by icebreaker when ice floes pressing the ship	Ship pressed by the ice	Water leakage
	Towing assistance by icebreaker when ice floes pressing the ship		Main deck get bent
Case D.1.2			
Ice blocks (10-30 cm)	Ice blocks pilling up against the SB	Stuck in compressive ice	Permanent deflection in an area below water line
Case D.1.3			
Ridged and rafted ice	A vessel ice class two following an icebreaker in full speed during hard ice conditions	Ice loads on the ship hull	Ship bow shoulders were buckled
Ice with a thickness 55-75 cm			Fracture of several dents in the hull plating
			Leakage of water in the foremost

Table 16. Hazard identification in cases of rudder damage

Hazard	Hazardous situations	Hazardous events	Consequences
Case D.2.1			
Ice with a thickness 35-60 cm	A ship ice class IA and in ballast condition navigating alone in moderate to heavy conditions	Ship stuck in ice	
		Rudder damage	
Case D.2.2.			
Consolidated and very compact pack ice	Navigating under heavy ice conditions	Rudder damage	

Table 17. Hazard identification in case of propeller damage.

Hazard	Hazardous situations	Hazardous events	Consequences
Case D.3.1			
	A hip navigating alone in an old ice channel	Propeller damage	Icebreaker assistance needed (towing)
	An unexpected stop of the ship		

Table 18. Hazard identification in case of machinery damage.

Hazard	Hazardous situations	Hazardous events	Consequences
Case D.4.1			
	A general cargo filling he wing ballast tanks during severe weather conditions	Ventilators were clogged with ice	Deformation of the hull
			Crack of the hull
			Ballast water flooded into the cargo

Table 19. Hazard identification in case of icing.

Hazard	Hazardous situations	Hazardous events	Consequences
Case E.1.1			
	Icing of the vessel and consecutive cargo shift	A general cargo vessel sank	Rescue operation performed by local vessels to save the vessel's crew
Case E.1.2			
	Navigating with heavy winds and a weather of -10° C and heavy winter waves. Thus, ice started to accumulate in the vessel's bow and upper deck structures.		Ship turn back to port of origin.
			Ice removal operations needed

4.3 Identified hazards from statistics

The table 20 presents the specific hazards, hazardous situations, hazardous events and consequence in winter navigation detected by the consulted experts during the workshops.

Table 20. Hazard identification based on statistics analysis

Hazard	Hazardous situations	Hazardous events	Consequences
Vessels	Icebreaker on towing	Collisions	Oil spill
Icebreakers	Convoy operation	Propeller damage	Minor damage to the bow
Rocks	Icebreaker breaking a ship lose	Rudder damage	Hole in the bow
Ice conditions; *Consolidate, compact or very close pack ice* *Fast ice* *Close pack ice* *New ice* *Ice thickness 21-40 cm* *Ice thickness >40 cm* *Ice thickness 01-20 cm*	A ship breaking another ship lose	Hull damage	Damage to the castle
	Ship navigating alone in heavy ice conditions	Groundings	Damage to the port aft
		Fire/Explosion	Crack in the hull
		Technical failure due to ice and weather conditions	Frames dent

4.4 Matrix of winter navigation hazards

In this section, the report introduces a matrix of winter navigation hazards where the previous extracted hazards, hazardous situations, hazardous events and their respective consequences were systematically organized. The matrix classified the hazardous situations in 2 categories differentiated by two different colours. The situations in the green cells are the specific ship winter navigation operations performed during this season, and the situations in the white cells are detected situations belonging to the category of the specific winter navigation operation (green cell) preceding these listed hazardous situations in the white cells.

	Hazardous situation	Hazard	Hazardous event(s)	Consequence(s)
1	Independent navigation during winter	Ice conditions	Collision Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	Casualties Personnel injured Vessels machinery and equipment damage Hull damage Hull and tanks rupture Cargo spill Oil spill Pollution Ship sinking Emergency assistance Monetary loss
2	Navigation with strong wind speeds	*Ice conditions; > Ice ridges > Drifting pack ice >Large masses of drifting ice Rocks Sea bottom in shallow waters	Grounding Collision Ship stuck in ice Hull damage	(1) Same consequences as in no. 1
3	Approaching to the port with heavy snow falling and hard wind	Other vessels Port facilities Ice conditions; > *Ice compression* Sea bottom in shallow waters	Grounding Collision Ship stuck in ice	(1) Same consequences as in no. 1 + Port's infrastructure damage
4	Navigation in a narrow fairway (e.g. ice channel)	Ice conditions; > Ice large floes > Edges of the ice channel Vessels; > Large bulk carriers > Large container ships > Tankers	Collision Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
5	Ships navigating in opposite directions within a narrow ice channel	Ice conditions; > Ice large floes > Edges of the ice channel Vessels; > Large bulk carriers > Large container ships > Tankers	Collision Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
6	Ship passing each other in a narrow ice channel with night darkness and snow falling	Ice conditions Vessels	Collision Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
7	A tanker and a general cargo meeting courses in a narrow ice channel, and tanker trying to go out of the channel to give way to the other vessel.	Vessels Ice conditions; > Ice large floes > Edges of the ice channel	Collision Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
8	Navigating with poor visibility due to dense fog, and with the presence of ice floes. This generated poor quality information from the radar monitor.	Ice conditions; > Ice large floes	Collision Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....

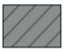
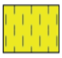
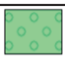
9	Navigating during winter storm with poor visibility due to a dense snowfall.	Ice conditions	Collision Grounding Ship stuck in ice Propeller damage Rudder damage	(1)....
10	A ship ice class IA and in ballast condition navi-gating alone in moderate to heavy conditions.	Ice conditions	Collision Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
11	A ship navigating alone in an old ice channel.	Ice conditions	Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
12	Navigation during march and April with thick ice and ice fields moving.	Ice conditions; > Ice large floes	Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
13	A vessel dropping consid-erably its speed	Ice conditions; > Ice pressure	Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
14	An unexpected stop of the ship due to technical failure	Ice conditions; > Ice pressure	Ship stuck in ice Propeller damage Rudder damage Hull damage Machinery damage	(1)....
15	Vessels navigating with wet fall snow	Vessels Ice and weather conditions	Collision Grounding Failures in radar and screens	(1)....
16	Old ships navigating with inappropriate warning and ventilation systems	Vessel Ice and weather conditions Machinery	Icing	Personnel injured Vessels machinery and equipment damaged Emergency assis-tance Monetary loss
17	Navigating without expe-rience of winter naviga-tion	Vessels Ice and weather conditions	Collision Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
18	Vessels operating closer to coast lines	Ice conditions Rocks Sea bottom in shallow waters	Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
19	A ship stuck in ice drift sideways along ice masses	Ice conditions; > Ice pressure	Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
20	Ice floes pressing and crushing the ship sides	Ice conditions; > Ice pressure > Ice large floes	Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
21	Ice blocks pilling up against the vessel	Ice conditions; > Ice pressure > Ice blocks	Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....

22	A ship stuck in ice starting to drift towards an area with shallow waters.	Ice conditions Rocks Sea bottom in shallow waters	Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
23	Ships stuck in an ice field moving and taking the stuck ships towards underwater rocks	Ice conditions Rocks Sea bottom in shallow waters	Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
24	A vessel sailing out from the quay of harbour in heavy ice conditions	Other vessels Port facilities Ice conditions	Collision Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)+ Port's infrastructure damage
25	Loss of visibility due to dead light of water way edge mark	Other vessels Ice conditions	Collision Grounding Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
26	Increased heat set fire on the timber packet which were closely loaded in the front of floodlight	Inflammable material Heat generator sources (e.g. flood light)	Fire	Casualties Personnel injured Vessels machinery and equipment damage Pollution Ship sinking Need for emergency assistance Monetary loss
27	Icing of the vessel and consecutive cargo shift	Ice and weather conditions	Loss of stability	Sinking Casualties Personnel injured Vessel loss Monetary loss
28	Navigating with heavy winds and a weather of -10° C and heavy winter waves. Thus, ice started to accumulate in the vessel's bow and upper deck structures	Ice and weather conditions	Loss of stability	(27)....
29	An Icebreaker escorting other ships	Vessels Icebreaker Ice conditions	Collision Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
30	Icebreaker escorting a tanker in heavy ice conditions	Tanker Icebreaker Ice conditions	Collision Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
31	A vessel ice class two following an icebreaker in full speed during hard ice conditions	Vessel Icebreaker Ice conditions	Collision Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
32	An Icebreaker on towing	Vessel Icebreaker Ice conditions	Collision Propeller damage Rudder damage	(1)....
33	Icebreaker on towing in heavy ice conditions	Vessel Icebreaker Ice conditions	Collision Propeller damage Rudder damage Hull damage	(1)....

34	Towing assistance by ice-breaker when ice floes pressing the ship	Vessel Icebreaker Ice conditions; > Ice large floes > Ice pressure	Collision Propeller damage Rudder damage Hull damage	(1)....
35	An Icebreaker or vessel leading convoy operations	Vessels Icebreaker Ice conditions	Collisions Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
36	A vessel navigating at high speed in convoy	Vessels Ice conditions	Collisions Propeller damage Rudder damage Hull damage	(1)....
37	A vessel dropping considerably its speed in the convoy	Vessels Ice conditions	Collisions Ship stuck in ice Propeller damage Rudder damage Hull damage	(1)....
38	Inappropriate the distance between ships	Vessels Ice conditions	Collisions Ship stuck in ice Propeller damage Rudder damage	(1)....
39	Convoy operations performed with frost smoke	Vessels Ice conditions	Collision Ship stuck in ice Propeller damage Rudder damage	(1)....
40	A blackout of a ship in convoy	Vessels Ice conditions	Collision Ship stuck in ice Propeller damage Rudder damage	(1)....
41	Icebreaking cutting lose of ship stuck in ice	Vessels Icebreaker Ice conditions; > Ice pressure	Collisions	(1)....
42	Icebreaker cutting out a general cargo from ice without properly functioning of the IB's starboard	Vessels Icebreaker Ice conditions; > Ice pressure Machinery	Collision	(1)....
43	Ship cutting lose of another ship stuck in ice	Vessels Ice conditions; > Ice pressure	Collision Hull damage	(1)....
44	A container ship berting gas during heavy weather conditions	Gas Heat generator sources (e.g. flood light)	Explosion Fire	(26)....
45	> A general cargo filling the wing ballast tanks during severe weather conditions	Ice and weather conditions	Machinery damage	Casualties Personnel injured Vessels machinery and equipment damage Pollution Need for emergency assistance Monetary loss

* Ice conditions as hazard refers to the ice types and thickness which are consider as problematic. Table 21 presents the common ice types which represent winter navigation hazards.

Table 21. Winter ice conditions (Ice types)

Symbols	Ice type (characteristic a)	Sybols	(+) Ice type (characteristic b)
	Consolidated, compac or very closed pack ice		Rafted ice
	Fast ice		Ridge and hummocked ice
	Close pack ice		Floebergs
	Open pack ice		Window, brash ice barrier
	Very open pack ice	10-20	Estimated ice thickness
	New ice		

5. Discussion and conclusions

5.1 Discussion

The results obtained in this analysis have identified the main hazards in winter navigation based on the information collected from accidents cases analysis and accident statistics, and strengthened with information provided from the experience of the main expert participants in the development of maritime winter navigation. The main hazards detected in this research were the vessels as such, ice conditions and sea rocks. And the main hazardous events (accidents) were collisions and groundings. However, in this report instead of, focusing on the hazards as such or the main hazardous events (accidents), the report has focused on the hazardous situations linked to the operations of the vessels during winter navigation. This approach allowed to have a more general perspective of the stages included within the development of particular operations performed in winter navigation. Thus, analysing those situations enabled detecting the specific threats (physical and nonphysical), the possible outcome or a chain of outcomes in case the hazard negatively reach any component in the analysed situation, and also the possible derived consequences of those events.

Initially, the workshop with experts has provided valuable input information regarding the specific hazardous situations and hazards of winter navigation. This was an important initial step to detect the main concerns of the actual practitioners of maritime winter navigation. The analysis of accident cases has brought key information strengthing the kind of events and consequences resulted from specific situations already experienced. And the analysis of the accident statistics of 5 winters has provided more evidenced of the specific amount of hazardous situations, hazards, hazardous events and consequences experienced in different winter seasons. Together, all this information has been used to feed a structured database built according to the initial proposed framework.

Thus, the data collected from the three different sources utilized in this identification exercise, and the implementation of the proposed framework in this paper, have identified 45 specific hazardous situations in the performance and development of winter navigation operations. These hazardous situations are organized in groups representing the main operations of winter navigation (e.g. ships navigating alone, convoy operations, IB on towing, etc.). And some of these main operations have subsequent hazardous situation(s) which are linked to those operations. This categorization has served to directly detect specific scenarios in which several winter navigation hazards reside. The such called matrix of winter navigation hazards, is aimed to have a subsequent main role in a future task within WINOIL project where a structured risk assessment, based on the basis of the methodology established in this paper and the identified hazards in this process, is going to be performed.

5.2 Conclusions

This report has presented a framework methodology to identify maritime winter navigation hazards and a set of specific hazardous situation of winter navigation, including the specific physical and nonphysical threats residing in those situations, the potential accidents which may occur on the situations and their respective consequences. The exact information of aspects above mentioned, was collected from three main sources which integrate expert knowledge and actual accident data. The analysis of the data collected in this report has produced the construction of a matrix of winter navigation hazards. This matrix identified particular situations, tasks and operations in which identified hazards represent a constant risk for having specific accidents and negative outcomes to people, assets, environment and the monetary aspects involved in those operations. It can be concluded that while the proposed framework and the identified hazardous situations, hazards, hazardous events and consequences has yet room for including more information not detected in this report, the work produced in this report seems to be an adequate base for performing a proficient risk assessment of maritime winter navigation.

Acknowledgements

The report has been carried out as part of the research performed in the winter navigation risks and oil contingency plan (WINOIL) project. The project is carried out by Kotka Maritime Re-search Centre, Aalto University, Baltic salvage & towage company, Central Marine Research and De-sign Institute, Agency of ecological consulting and nature protection design, Saint-Petersburg State Marine Technical University and Finnish Environment Institute (SYKE) in co-operation with the associate members: Finnish Transport Agency, Finnish Boarder Guard, Finnish Meteorological Institute, Finland's Ministry of the Environment, Ice Advisors Ltd, Arctia Shipping Oy, Finnpilots Ltd, Port of Hamina-Kotka Ltd., Meritaito Oy, Rosmorrechflot, State marine pollution control and salvage administration, Federal State Organization "Administration of Maritime port 'Great port St. Petersburg, Committee for Nature Use, Environmental Protection and Ecological Safety, WWF Finland, Finland’s Ministry of Transport and Communications and Finnish Transport Safety Agency (Trafi).

References

Burton, I., Kates, R., White, G. (1978). The Environment as Hazard. New York: Oxford University.

Carter, C. and Smith D. (2006). Safety Hazard Identification on Construction Projects. *Journal of Construction Engineering and Management*. DOI: 10.1061/ (ASCE) 0733-9364(2006)132:2(197).

CASITA (2003). Hazard identification. Capacity Building in Asia using information Technology Applications (CASITA). Asian Disaster Preparedness Center, Bangkok, Thailand.

Critch S., Goerlandt F., Montewka J., and Kujala P. (2013). Towards a risk model for the Northern Baltic maritime winter navigation system. IWNTM Conference 2013, Delft, the Netherlands.

Ferrier, N. and Haque, C.E. (2003). Hazard Risk Assessment Methodology for Emergency Manager: A Standardized Framework for Application. *Journal of Natural Hazards* 28, 271-290.

FMA (2003). Statistics of ships visited Finnish ports in foreign traffic, winter 2002-2003. Received data sheet from Finnish Maritime Administration, Information Service Department.

Goerlandt F., Stahlberg K., and Kujala, P. (2012a). Influence of impact scenario models on collision risk analysis. Ocean Engineering 47: 74-87.

Goerlandt F., Hänninen M., Stahlberg K., Montewka, J. and Kujala, P. (2012b). Simplified Risk Analysis of Tanker Collisions in the Gulf of Finland. International Journal on Marine Navigation and Safety of Sea Transportation, Volume 6, Number 3.

Goncharov, V. (2013). Criterion for comparison of risk at planning of navigation in ice conditions. Department of Ocean technics and Marine Technology, St. Petersburg State Marine Technical University, St. Petersburg, Russia.

Hänninen, S. (2003). Incidents and accidents in winter navigation in the Baltic Sea winter 2002 – 2003. Winter Navigation Research Board. Research Report No. 54

IMO (2013). Formal Safety Assessment. MSC/Circ.1180-MEPC/Circ.474 and MSC-MEPC.2/Circ.5.

Jalonen, R., Riska, K. and Hänninen, S. (2005). A Preliminary Risk Analysis of Winter Navigation in the Baltic Sea. Winter Navigation Research Board Research Report 57.

Lukkonen (1999). Damage statistics of groundings in the Finnish territorial waters. Helsinki University of Technology, Ship Laboratory, Report M-240, Espoo 1999. (In Finnish).

Martins, M.R. and Goyano, C. (2007). Preliminary Hazard Analysis of Fire Systems of Tankers. Porceedings of the Seventeenth International Offshore and Polar Engineering Conference. Lisbon, Portugal, July 1-6, 2007.

Montewka, J., Krata, P., Goerlandt, F., Mazaheri, A., and Kujala P. (2011). Marine Traffic risk modelling – an innovative approach and case study. Journal of Risk and Reliability, 225(3) 307-322.

Oxford Dictionaries (2014). The Oxford English dictionary. Oxford University Press 2014.

Reason J. (1997). Managing the risk of organizational accidents. Aldershot: Ashgate Publishing Limited.

SMHI (2013). Winter Ice Conditions 2009 - 2013 and maps and ice symbology of the Finnish – Swedish Winter Navigation System. The Swedish Meteorological and Hydrological Institute.

Standards Australia (2001) AS/NZS 4801 Occupational Health and Safety Management Systems – Specification with guidance for use. Sydney, Australia.

Trafi (2013). Accident statistics of winter navigation at the Baltic Sea - winters 2009 – 2013. Finnish Transport Safety Agency (Trafi) 2013.

Trbojevic V., and Carr, BJ. (2000). Risk based methodology for safety improvements in ports. *Journal of Hazardous Material* 71, 467-480.

Vapalahti, H. (1997). Finnish ship accidents 1953-1973. Judicor Oy, 176 p. (In Finnish)

Wang, K., Leppäranta, M., Gästgifvars, M. and Vainio, J. (2007). A comparison of drift between sea ice and oil spills in the Baltic Sea: the runner 4 case. Recent Development of Offshore Engineering in Cold Regions, Yue (Ed.). POAC-07, Dalian, China, June 27-30, 2007.

Wells, G. (1996). Hazard Identification and Risk Assessment dolor. Institution of Chemicals Engineers, Davis Building. ISBN 0 85295 463 8, Rugby Warwickshire HQ, United Kingdo

This report presents the results of the hazard identification process that has been performed in order to detect, determine, list and categorize different relevant hazards threatening the safety performance and development of the winter navigation operations.

The report introduces the implemented framework to detect the relevant hazards of winter navigation and describes in details the three utilized sources to detect those hazards: hazard identification workshops with winter navigation experts, accident cases analysis, and analysis of accident statistics of 5 winters. Results obtained are presented after the performed collection and data analysis. Discussion and conclusions drawn are also presented.

The work resulting in this report has been carried out as part of the work in the Winter navigation risks and oil contingency plan (WINOIL) project (SE680) acknowledging the funding from the South-East Finland - Russia ENPI CBC Programme.

Aalto-ST 15/2014

9789526058887

ISBN 978-952-60-5888-7
ISBN 978-952-60-5889-4 (pdf)
ISSN-L 1799-4896
ISSN 1799-4896
ISSN 1799-490X (pdf)

Aalto University
School of Engineering
Department of Applied Mechanics
www.aalto.fi