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Risk management model of winter navigation operations

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ABSTRACT

The wintertime maritime traffic operations in the Gulf of Finland are managed through the Finnish–Swedish Winter Navigation System. This establishes the requirements and limitations for the vessels navigating when ice covers this area. During winter navigation in the Gulf of Finland, the largest risk stems from accidental ship collisions which may also trigger oil spills. In this article, a model for managing the risk of winter navigation operations is presented. The model analyses the probability of oil spills derived from collisions involving oil tanker vessels and other vessel types. The model structure is based on the steps provided in the Formal Safety Assessment (FSA) by the International Maritime Organization (IMO) and adapted into a Bayesian Network model. The results indicate that ship independent navigation and convoys are the operations with higher probability of oil spills. Minor spills are most probable, while major oil spills found very unlikely but possible.

1. Introduction

The Gulf of Finland (GOF) is recognized as one of the most transited maritime areas in the world (Kuronen et al., 2009; Lappalainen et al., 2014; Lehikoinen et al., 2015). In this area, ship traffic has gradually increased due to the transport of several goods to Finland and Russia and the increment of oil and liquefied natural gas (LNG) production and export from Russia (Brunila and Storgård, 2012; Kujala et al., 2009). This trend is also found during wintertime when the GOF is partially or completely covered by ice (Finnish Transport Agency, Liikennevirasto, 2014a). The navigational operations of vessels in ice conditions differ significantly from those performed in open water (Finnish Transport Safety Agency, Trafi, 2011). This creates the need for different approaches to analyse the risk of accidents which may lead to catastrophic consequences for people and the natural environment (Afenyo et al., 2015).

The analysis of the risk associated with different maritime operations and its effect on different environmental contexts has been previously carried out (Goerlandt and Montewka, 2014, 2015a; Hänninen and Kujala, 2012; Lee and Jung, 2015; Montewka et al., 2011; Mullai and Paulsson, 2011; Oltedal and Wadsworth, 2010; Qu et al., 2011; Singh et al., 2015; Sormunen et al., 2014; Ståhlberg et al., 2013; Zhang et al., 2015). Moreover, accidental risk in the GOF and the risk of oil spills and their possible devastating consequences in this area has also been previously studied (Kujala et al., 2009; Leiger et al., 2009; Lehikoinen et al., 2015, 2013; Montewka, 2009). However, these studies have been limited to navigational operations in open water, spring–summer–autumn season.

An initial analysis of the risk associated to the navigational operations performed in sea ice conditions is presented in (Valdez Banda et al., 2015a). The study describes particular types of accidents and hazards of winter navigation. This analysis included a description of the system implemented to manage the operations of vessels during winter, and a description of the particular accidental scenarios and their occurrence frequencies. This and other previous analyses (Jalonen et al., 2005; Riska et al., 2007), represent important and necessary information describing the operative performance of ships in a context where limited research has been performed. Notably, these studies have particularly detected the operation types which would benefit most from further risk management developments. However, applicable actions and recommendations for improving winter navigation operations are still lacking.

Risk management aims to develop a coordinated set of activities and methods used to direct an operation and to control the safety system and the risks that can affect the operation performance and the ability to successfully reach its objective (International Organization for

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Standardization, ISO, 2009; Leveson, 2011). Thus, risk management should be linked to the identification and strengthening of the conditions which represent the basis for the successful performance of an operation (Dekker, 2014; Hollnagel, 2014).

Hence, this study presents a model for assessing the risk of winter navigation operations performed in the GOF, extending earlier work to winter conditions. The model describes and assesses the main operations performed by the vessels navigating in this area during wintertime, analyses the risk of ship collisions in the contexts of the mentioned operations, assesses the related oil spill risks, and proposes risk control options for the execution of winter navigation operations.

2. Methodology and data

The methodology utilized for the analysis is based on the structure proposed in the Formal Safety Assessment (FSA) by the International Maritime Organization (IMO). FSA is defined as a rational and systematic process for assessing the risks associated with shipping activity and for evaluating the costs and benefits of IMO's options for reducing these risks (International Maritime Organization, IMO, 2005). Originally, FSA represented a tool for supporting the evaluation of new regulations and compare proposed changes with existing standards (Ruud and Mikkelsen, 2008). Today, FSA is utilized to perform a balanced analysis between various technical and operational issues including the human element, and between safety and costs.

This study adopts FSA as a process for structuring a risk management model which serves as a tool for exploring the safety performance of the most common winter navigation operations of ships navigating in the ice covered waters of the GOF. Thus, the model represents an instrument for further reflection on the performance of the stakeholders involved in the execution of these operations.

FSA consist of six steps, which are taken as a basis for defining the risk management model structure. Table 1 presents these six steps as part of the methodology for developing the model, as well as the results obtained after execution of each step.

Table 1
The six steps of the FSA used as a basis to define the model structure.

FSA step	Task
Methodology and data (Section 2)	
0	System description
1	Hazard identification
2	Risk analysis
3	Risk control options
Results (Section 3)	
4	Improve–benefit analysis
5	Recommendations

2.1. System description (Step 0)

A clear understanding of the components and context of the system and their relation to accidents is essential for defining the model scope and for identifying the main factors influencing the performance of winter navigation operations.

2.1.1. Ice conditions

In the GOF, the first sea ice cover appears in the eastern part (Russian coastal areas) and it gradually extends westwards. The type of ice experienced every winter in this area includes different forms of floating and fasted ice, starting from the formation of new ice and ending with the most extreme formations of consolidated packed ice. Ice ridges and very thick ice levels can be also experienced in this area, representing the main challenges to the execution of the ship traffic operations. The formation of different types of ice in the GOF depends on the severity of the winter experienced, mild winters (e.g. winter 2014–2015) with few spots of light ice conditions, and/or severe winters (e.g. winter 2003–2004) with a total ice covered GOF. A more elaborated description of ice types and ice formation in the GOF is presented in Riska et al. (2007).

2.1.2. Winter navigation operations

Winter navigation operations are categorized in two general types: ship independent navigation and icebreaker assistance operations. Ship independent navigation is described as the navigational operation that begins when a merchant vessel enters areas covered with sea ice and navigates in them without in site assistance of any other type of vessel. Icebreaker assistance includes four main operation types: escorting, a single ship, leading convoy of several ships, cutting loose when a vessel got stuck in ice, and towing a ship (Rosenblad, 2007).

2.1.3. The Finnish–Swedish winter navigation system (FSWNS)

The FSWNS guides and rules the navigational operations performed by ships every winter at the Baltic Sea, including operations performed in the GOF (Riska et al., 2007). The FSWNS aims at ensuring the safety of the vessels and crew navigating in ice conditions and protecting the natural environment (Finnish Transport Agency, Liikennevirasto, 2014b). The system is ruled by ice class regulations which define the technical requirements for the vessels attempting to navigate in ice conditions. This is complemented with additional requirements for cargo handling and with the meteorological and ice information received from ice services. Based on this information, traffic restrictions are settled in different zones of the Baltic Sea. The restrictions aim at supporting ship traffic flow and better coordination of icebreaker assistance. The complete description of the FSWNS is presented in Finnish Transport Safety Agency (Trafi) (2010).

2.1.4. Input from the human performance

The input from the human performance in this study is limited to the interaction among the crew performing operations on the ship's bridge during the execution of the four described operations. The analysis of the human performance assesses several common performance conditions for performing the tasks included within the execution of the operations. An extended description of the implemented method for this analysis is presented in Section 2.3.6.

2.2. Hazard identification (step 1)

In previous studies, extreme ice conditions and the expertise of the people performing winter navigation operations have been pointed as the main challenging factors for ensuring the safety of navigation in ice conditions (Valdez Banda et al., 2015a,b). These studies present detailed information given by the accidents commonly reported in the GOF, the ice condition in which these accidents occurred, and detailed description of hazardous scenarios based on accidental data and expert consultation. This section summarizes the findings of these studies and posteriorly adopts these into the structure of the proposed model.

2.2.1. Accident types

The most common accident occurring during winter navigation operations is collision, including mainly ship-to-ship collision, ship-to-icebreaker collision and few cases of icebreaker-to-ship collision. This accident accounts for almost 50% of the accidents occurred in ship independent navigation and around 95% of the accidents occurred in icebreaker assistance operations. The second most common accident is propeller damage, which is mainly reported by ship independent navigation.