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# A risk analysis of winter navigation in Finnish sea areas

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ABSTRACT

Winter navigation is a complex but common operation in north-European sea areas. In Finnish waters, the smooth flow of maritime traffic and safety of vessel navigation during the winter period are managed through the Finnish–Swedish winter navigation system (FSWNS). This article focuses on accident risks in winter navigation operations, beginning with a brief outline of the FSWNS. The study analyses a hazard identification model of winter navigation and reviews accident data extracted from four winter periods. These are adopted as a basis for visualizing the risks in winter navigation operations. The results reveal that experts consider ship independent navigation in ice conditions the most complex navigational operation, which is confirmed by accident data analysis showing that the operation constitutes the type of navigation with the highest number of accidents reported. The severity of the accidents during winter navigation is mainly categorized as less serious. Collision is the most typical accident in ice navigation and general cargo the type of vessel most frequently involved in these accidents. Consolidated ice, ice ridges and ice thickness between 15 and 40 cm represent the most common ice conditions in which accidents occur. Thus, the analysis presented in this article establishes the key elements for identifying the operation types which would benefit most from further safety engineering and safety or risk management development.



## 1. Introduction

Maritime transportation is essential for the development of the world economy, as it still constitutes the main means of transporting goods, accounting for approximately 90% of the world trade freight (Mansell, 2009). In Finland, about 80% of the import and export of goods are transported by sea (Asplund and Malmberg, 2011). Therefore, maritime traffic in the Gulf of Finland is recognized as one of the busiest vessel-operated areas in the world (Lappalainen et al., 2012). In this region, maritime traffic is continuously growing due to the constant increase in the transportation of various cargoes to Russia and of oil from Russia (Kujala et al., 2009; Wang et al., 2013). This increment of traffic is also reflected in winter navigation when ice conditions dominate in the area (FTA, 2014a).

Winter navigation in the Finnish maritime areas may begin in mid-November in the Bay of Bothnia and between mid-December and early January in the Gulf of Finland and Sea of Bothnia. The ice conditions commonly remain until mid-April in the Gulf of Finland and beginning of May in the Bay of Bothnia (Jalonen et al., 2005). During this season, the ships entering these areas are subject to restrictions established by the Finnish–Swedish winter navigation system (FSWNS). The system aims at ensuring the safety of the ships and at controlling ship navigation in ice-covered waters (FTSA, 2010). Navigation in ice conditions can be classified into two main categories: ship independent navigation and icebreaker assistance. In order to support winter navigation, each winter the Finnish Meteorological Institute releases daily descriptions and forecasts of ice and weather conditions for all Finnish maritime areas (FMI, 2011). Thus, the combination of the information contained in the FSWNS and the reports of ice and weather conditions provide essential support for developing winter navigation safely (Kotovirta et al., 2009; Montewka et al., 2015).

Different studies have analysed the safety and risks of maritime navigation and the occurrence of accidents in the maritime industry. For example, various models have been put forward to evaluate the accidental risk of shipping in a sea area (Li et al., 2012; Özbaş, 2013; Mazaheri et al., 2014; Hänninen et al., 2014; Goerlandt and Montewka, 2015a; Soares and Teixeira, 2001). Other research has addressed the types of accidents occurring in a certain maritime area (Hänninen, 2003; Hänninen and Kujala, 2014; Mullai and Paulsson, 2011; Qu et al., 2012; Rambøll, 2006; Rosqvist et al., 2002), or focused on specific vessel types, e.g.,

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fishing vessels (Jin and Thunberg, 2005; Wang et al., 2005; Wu, 2008) and oil tankers (Lehikoinen et al., 2013; Lee and Jung, 2013; Montewka et al., 2013).

However, only limited research has been conducted on accidents and the related risks of maritime operation in wintertime conditions in the Baltic Sea area. Limited information on accidents in winter conditions is available in Riska et al. (2007), and a preliminary risk analysis of winter navigation is presented by Jalonen et al. (2005). Furthermore, descriptive information about safety and risk management systems implemented to support maritime navigation is infrequently considered in analyses of this type.

This article identifies hazardous scenarios and analyses accidents during winter navigation in Finnish sea areas. Based on this, a high-level risk assessment is presented. As a background for the analysis of different operation types, a brief description is provided of the ice conditions experienced each year in these sea areas. Subsequently, the operational characteristics of ship independent navigation in ice conditions and icebreaker assistance are presented. Further, the functioning of the Finnish–Swedish winter navigation systems is outlined. Next, two analyses are performed, including a hazard identification of winter navigation made by experts in the field and a review of accident data extracted from four winter periods. Finally, six matrices are depicted for visualizing the risks associated with winter navigation.

The main purpose of this article is to gain a high-level insight into which winter navigation operations pose the highest risk to life, property and the environment. In addition, the conditions under which accidents occur are investigated. Such a high-level analysis is primarily useful for identifying which operations and accident events should be prioritized in devising strategies for reducing the risk of winter navigation.

The rest of the article is organized as follows. Section 2 defines the risk perspective adopted for the elaboration of this analysis. Section 3 describes the background of maritime winter navigation in Finnish maritime areas. Section 4 presents the methods and available data adopted for this study. Section 5 identifies hazardous scenarios in winter navigation performed by experts in the field, analyses accident data extracted from four winter periods and concludes by presenting a risk analysis of winter navigation. Section 6 discusses the research findings, and Section 7 provides the final conclusions and recommendations for future research.

## 2. Risk perspective

An important consideration in risk analyses concerns the conceptual understanding of risk and the corresponding risk perspective. In this article, risk is understood as uncertainty about and severity of consequences with respect to something that humans value (Aven, 2010). This implies adopting a constructivist basis for risk analysis, based on an interpretation of the views of experts and risk assessors about the possible occurrence of events of interest, in light of available evidence (Goerlandt and Montewka, 2015a). One fundamental issue in this approach is that the analysis should not be seen as a revelation of truth, but rather as a reflection of the most reliable knowledge available at a given time. The aim is to put forward an argument about the occurrence of events and consequences (Watson, 1994).

In line with this, the following risk perspective, i.e., the systematic approach to measure and describe risk, is adopted:

$$R \sim (A, C, OU, SE|BK) \quad (1)$$

In the above, risk R is described by ("$\sim$") as a set of events A, consequences C, occurrence uncertainties OU and strength of evidence assessment SE. The risk analysis is performed based on the available background knowledge BK, which can consist of data, models, judgments and assumptions.

Uncertainties about the possible occurrence of the events A and consequences C are described. In the current analysis, subjective probabilities are applied to measure the occurrence of events A. Such probabilities are defined as an assessor's degree of belief in light of the available evidence BK (Watson, 1994). For the consequences C, a categorical measurement scale is applied, in line with the accident severity classification adopted by IMO (IMO, 2013).

The assessment of strength of evidence of BK, i.e., the available background knowledge on which the assessment is based, is performed by means of an ordinal measurement scale suggested in Abrahamsen et al. (2014). The purpose of this assessment is to qualitatively convey how warranted the measurements of A and C are.

## 3. Background

This analysis of winter navigation in Finnish sea areas focuses on accident occurrence in the main navigational operations performed after implementing the components included in the FSWNS. Therefore, understanding the aspects covered and controlled by the system is essential for the detection of different clusters influencing the performance of winter navigation. Ice conditions represent the context of the navigational environment in which the FSWNS is applied. Thereby, knowledge of the ice types formed in Finnish sea areas is essential for understanding the peculiarities of winter navigation. Ship independent navigation in ice conditions and icebreaker assistance are the resulting general navigational operation types after the implementation of the winter navigation system. Therefore, the description of the common characteristics of these navigational operations is another key aspect in interpreting the functioning of the system.

### 3.1. Ice conditions

The hazards of maritime winter ice navigation typically induce loads on a vessel due to contact with sea ice (Riska et al., 2007). Finnish maritime areas may experience several forms of floating and fasted ice each winter, with the sea ice cover extending to the south from the Bay of Bothnia and to the west from the eastern Gulf of Finland. In the Bay of Bothnia, sea ice is present every year and the ice period may be longer than the open water season (Leppäranta, 1998). On the other hand, ice may form in the Gulf of Finland and the Sea of Bothnia for shorter periods, which depend on the severity of the winter (BIM, 2010).

The formation of sea ice starts with the appearance of the first small ice spicules above few centimeters of the water. The falling of snow over those ice spicules results in the creation of a layer of shuga. Waves and winds move and regroup the shuga, transforming it into what is called "new ice". As the cooling process continues, ice nilas start to build up. These ice nilas may be from five to ten centimetres thick, and they appear in several individual fields which are later grouped into very open and open packed ice by wind and water current stresses. The very open and open packed ice continue to freeze, so that the space between packed ice diminishes, creating close packed ice.

Once sea water is no longer visible between the packed ice, the ice is regarded as level ice or consolidated and/or very compact packed ice. Sea ice is generally classified into two categories based on its mobility: drift and fast ice. Drift ice is continually in motion, affected by wind and current forces, and fast ice is firmly attached to coasts or islands. The pressure between the encountering fields of drifting ice creates a deformation of the ice surface. These