Safety Science 92 (2017) 66–84

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

An analysis of wintertime navigational accidents in the Northern Baltic Sea

Floris Goerlandt [a,*], Habtamnesh Goite [a,b], Osiris A. Valdez Banda [a], Anders Höglund [c], Paula Ahonen-Rainio [b], Mikko Lensu [d]

[a] Aalto University, School of Engineering, Department of Mechanical Engineering, Marine Technology, Research Group on Maritime Risk and Safety, P.O. Box 12200, 00076 Aalto, Finland
[b] Aalto University, School of Engineering, Department of Built Environment, Research Group of Geoinformatics, P.O. Box 15800, 00076 Aalto, Finland
[c] Swedish Meteorological and Hydrological Institute, Research Department, Norrköping 60176, Sweden
[d] Finnish Meteorological Institute, 00560 Helsinki, Finland

ARTICLE INFO

Article history:
Received 3 April 2016
Received in revised form 5 July 2016
Accepted 20 September 2016
Available online 5 October 2016

Keywords:
Winter navigation operations
Accident data analysis
AIS data
Visual data mining
Maritime safety
Maritime risk

ABSTRACT

Navigational accidents in wintertime conditions occur relatively frequently, yet there is little systematic knowledge available about the circumstances under which these occur. This paper presents an analysis of navigational shipping accidents in the Northern Baltic Sea area which occurred in the period 2007–2013. The analysis is based on an integration of various data sources, aiming to reconstruct the accident conditions based on the best available data sources. Apart from basic accident information from the original accident databases, data from the Automatic Identification System is used to obtain insight in the operation type during which the accident occurred, as well as into other dynamic aspects of the accident scenario. Finally, atmospheric and sea ice data is used to reconstruct the navigational conditions under which the accidents occurred. The analysis aims to provide qualitative insights in patterns and outlier cases in the accidental conditions. Correspondingly, visual data mining is selected as analysis approach, because of its utility in obtaining qualitative knowledge from data sources through a combination of visualization techniques and human interaction with the data. Special attention is given to the strength of evidence of the identified accident patterns. The results are primarily useful for improving risk analyses focusing on oil spill risks in winter conditions and for developing realistic training scenarios for oil spill response operations.

1. Introduction

Maritime transportation is an important activity in the Northern Baltic Sea, with maritime trade of vital economic importance for several countries in the area. Harsh winter conditions result in sea environments with complex and dynamic ice. Together with winter darkness reigning over these northern areas, these conditions present specific operational risks for ships navigating in these conditions (Riska et al., 2007).

The ice cover depends on the severity of the winter, but typically extends southwards from the Bay of Bothnia from around mid-November and from the eastern Gulf of Finland westwards from around mid-December. In harsh winters, significant parts of the Baltic Proper can become ice-covered as well. Ice conditions usually remain until mid-April in the Gulf of Finland and early May in the Bay of Bothnia (Jalonen et al., 2005). During the ice season, ships navigating these areas are subjected to specific restrictions and regulation through the Finnish-Swedish winter navigation system (FSWNS). This system consists of various mechanisms to ensure the safety of shipping by placing constraints to the ships trading in these areas. The FSWNS consists of five main components: ice class regulations, additional requirements, ice services, traffic restrictions and icebreaker assistance. These amongst other ensure that ships are adequately ice-strengthened, have sufficient propulsion power, are adequately loaded, receive

Abbreviations: AIS, Automatic Identification System; DWT, deadweight; ECMWF, European Centre for Middle Range Forecasts; FMI, Finnish Meteorological Institute; FSWNS, Finnish-Swedish winter navigation system; GISIS, Global Integrated Shipping Information System; GT, Gross Tonnage; HFACS, Human Factors Analysis and Classification System; HIRLAM, High Resolution Limited Area Model; HIROMB, High Resolution Operational Model for the Baltic; IMO, International Maritime Organization; MESAN, Mesoscale Analysis System; MMSI, Maritime Mobile Service Identity; PCP, parallel coordinate plot; SMHI, Swedish Meteorological and Hydrological Institute; SoE, strength of evidence.

* Corresponding author.
E-mail address: floris.goerlandt@aalto.fi (F. Goerlandt).

http://dx.doi.org/10.1016/j.ssci.2016.09.011
0925-7535/

up-to-date information on ice conditions, operate in areas corresponding to the technical characteristics and receive timely and appropriate assistance by icebreakers (TraFi, 2010). For a concise description of these components, see Valdez Banda et al. (2015, 2016).

Understanding maritime accidents is an important aspect of improving maritime safety, and several authors have presented analyses to increase this understanding, e.g. Samuelides et al. (2008), Kum and Sahin (2015), Yip et al. (2015), Eliopoulou et al. (2016) and J. Zhang et al. (2016). Despite the importance of wintertime maritime transportation in the Baltic Sea, very little research has been dedicated to improving the understanding of wintertime accidents or their related risks in this area. Jalonen et al. (2005) presented a preliminary risk analysis of winter traffic, including a short description of selected number of winter accidents. Valdez Banda et al. (2016) performed a risk analysis of winter navigation in Finnish waters based on limited accident data and expert judgments. Their main finding is that while navigational accidents in ice typically lead to less serious consequences, especially ship collisions and groundings can lead to very serious consequences, particularly in relation to marine environmental pollution (Valdez Banda et al., 2016). The presence of the ice cover is an important reason for this, as it can be very challenging to retrieve oil spilled as a result from navigational accidents, as evidenced by the Runner-4 accident in the Gulf of Finland in 2006 (Wang et al., 2008). Therefore, a more elaborate risk management model, focusing on the probability of different oil spill sizes in collision accidents and the feasibility of different actions to reduce these risks is presented by Valdez Banda et al. (2015, 2016). Notwithstanding the above work, the understanding of wintertime accidents in the Baltic Sea area is very limited, both concerning the processes resulting in accident occurrence as well as the conditions under which these occur.

Therefore, this paper presents an analysis of wintertime navigational accidents. Given their comparatively high risks due to their potential for accidental large-scale oil spills, focus is on collisions and groundings. In particular, it is investigated under which conditions these accidents occur in Northern Baltic winter conditions. Such knowledge is useful for reducing uncertainty in risk analyses focusing on oil spill risks in winter conditions (Valdez Banda et al., 2016) and related response preparedness assessments (IMO, 2010), for increasing understanding and planning focused risk management actions (Valdez Banda et al., 2015), and for developing realistic and relevant training scenarios for oil spill response operations. The knowledge obtained on impact conditions in ship-ship collisions in ice conditions is useful for maritime waterway risk analysis, as also for open water conditions the related uncertainties are significant (Goerlandt et al., 2012).

The research questions addressed in this paper are as follows. What are the prevailing sea ice and meteorological conditions during the accidents? In which winter operation type has the accident occurred? For ship-ship collision accidents: what are the impact scenarios, i.e. under which angles, at what speeds and at which impact locations does the striking vessel impact the struck vessel?

The remainder of this paper is organized as follows. In Section 2, the data sources used in the analysis are introduced and in Section 3, the analysis methods are described. Section 4 presents the results, while a discussion is made in Section 5. Section 6 concludes.

2. Data sources

In this section, the data sources used in the presented analysis are briefly described. The basic data source used is the North BAceD database, an integrated maritime accident database for the Baltic Sea area. As this database only contains consistent information about a limited number of basic characteristics of the accidents, additional data sources were added to this database to enable a reconstruction of the accident scenario based on the best available sources. In light of the research questions stated in the introduction, especially data from which the operation type and impact conditions can be obtained, and the prevailing environmental conditions, were needed. The utilized basic data sources are briefly introduced next. These were further processed into the database which is used for further analysis, as described in Section 3.

2.1. Maritime accident databases

Various challenges in using maritime accident databases have been reported. First, databases are known to suffer from various levels of underreporting, so that obtaining a "complete" image of the accidents in a given area cannot be achieved (Grabowski et al., 2009). Lützen (2002) addressed this issue in the context of accidents leading to water ingress. Second, different databases do not contain the same information and moreover apply different taxonomies of similar information types (Ladan and Hänninen, 2012). Third, several databases have changed their taxonomy over time, further complicating a consistent analysis over aggregated periods. Finally, databases suffer from missing and incorrect data, leading to gaps in the analysis and potentially to misleading results.

In order to obtain an as complete as possible picture of the accidents which occurred in the Northern Baltic Sea, the North BAceD database available from the Finnish Transportation Safety Agency is used. This is an integration of four maritime accident databases covering different geographical areas, all including the Baltic Sea. These concern the Lloyd's Marine Intelligence Unit database, the HELCOM database, the DAMA database and the EMCIP database. Details about these, including a description of the included data fields, are provided by Ladan and Hänninen (2012). The method for integrating these is described by Mazaheri (2015).

The North BAceD database contains only very generic information about the accidents, so that e.g. detailed analyses of the progression of the accident over time, the systemic factors involved in the accident development or the crew actions and related human or organizational "errors" are not possible based on the available data. For knowledge acquisition about such factors, more in-depth analyses of specific accident investigation reports is needed. Hence, analysis of such factors is beyond the current scope.

Furthermore, while the accident databases distinguish different accident types, such as collision, grounding and sinking, none of the databases contain information about the winter navigation operation type during which the accident occurred. This information, however, is important for maritime risk analysis and management, because the oil spill risks associated with the different operation types differ significantly (Valdez Banda et al., 2016). The operation types can be identified using dynamic visualization of maritime traffic data, see e.g. Goerlandt et al. (2016). Details about the applied methodology to determine these are given in Sections 3.2 and 3.3.

Finally, the database does not contain consistent information about the environmental conditions. For instance, the EMCIP database does not contain this information, whereas in databases where the information fields are provided, different taxonomies and missing data made the recorded data very difficult to process in a meaningful way. For instance, the DAMA database applies standardized categories for wind direction, speed and sea state, but contains no information about sea ice conditions. The HELCOM database only distinguishes "ice-free" and "sea ice present" conditions. Having no other specific fields for environmental conditions,