Strategic and operational risk management for wintertime maritime transportation system

Final summary

1. Description of the project’s goals and results

BONUS STORMWINDS has the overall objective to enhance the safety of maritime transportation in the Baltic Sea through science-based decision support and technological developments. Focus is on wintertime conditions in the Northern Baltic Sea, with strong links to regional policies, stakeholder concerns and practical end-user needs. The work addresses three key research themes: “risk management for oil spill response”, “Systems-theoretic analyses of the maritime transportation system” and “e-Navigation and smart response services”.

2. Work performed over the course of the full implementation phase of the project

Research theme “Risk management for wintertime oil spill response”

The work concerning the strategic risk management is the identification of the risk management modelling approach, the development of a conceptual approach for building the model, the definition of an approach for communicating the strength-of-evidence and further uncertainty about the risk model results. Envisaging the compatibility of the modelling approach with results from other projects in the Baltic Sea, focusing on ecological impacts of oil spills and geospatial risk mapping, it was decided to implement the model as a Bayesian Network. This is a versatile modelling approach which can account for complex interdependencies between factors affecting the variables in focus in the analysis. It also explicitly accounts for uncertainties, and can integrate evidence from various sources and formats.

The developed model focuses on the recovery effectiveness of oil in Northern Baltic Sea ice conditions. As shown in Figure 1, it is built up from a set of sub-clusters which information about factors which together can describe a large set of plausible scenarios.

Figure 1. Sub-clusters included in the model for estimating oil recovery effectiveness in ice
Source: Lu et al. (2018)

The clusters include information about the oil spill, the weathering and transport of oil drift in ice conditions, the response fleet, representative climatic scenarios, atmospheric environment, sea ice environment, and mechanical recovery systems. The information for building these scenarios is based on several analyses. These include analysis of wintertime navigational accidents based on integrated data sources, accidental oil outflow from collision and grounding tanker accidents based on newly developed integrated consequence models, climate scenario analyses based on state-of-the-art climate models, spill drift analyses based on an improved version of the SeaTrack Web modelling approach, and information obtained from on-board visits and various workshops with experts on oil recovery systems.
Furthermore, several analyses were performed to build elements of the evidence base as support of the oil pollution risk and response fleet performance model. These include an analysis of the characteristics of wintertime navigational accidents, analysis of the main particulars and spill-size relevant design characteristics of vessels operating in this area, study of operational characteristics of ship convoys in ice conditions, model development and analyses for collision damage scenarios in winter navigation accidents, climate scenario analyses focusing on the future ice cover extent, and modelling of oil spill recovery effectiveness in ice conditions.

**Research theme “Systems-theoretic analyses of the maritime transportation system”**

The work under this theme has focused on the definition of a new STAMP-Mar framework (Systems Theoretic Accident Model and Process), which is a novel approach to link the application of systems-theoretic approach to maritime domain, linking the safety management of a sustainable eco-socio-technical maritime transportation system with maritime spatial planning processes. Its aim is to enhance safety performance in light of the multiple uses of the maritime space. The framework has been applied to a high-level case study of the Gulf of Finland reporting system, in the context of Maritime Spatial Planning. This has been done using the Systems-Theoretic Process Analysis method.

![Figure 2. Functioning of the performance monitoring tool based on the PDCA process](Source: Valdez Banda and Goerlandt (2018))

Significant work has also focused on defining a process for establishing a safety management system of maritime transportation organizations, based on the safety intent specification of the system under study, the Systems Theoretic Accident Model and Process to identify hazards and controls, and realist evaluation as a method for justifying the developed Key Performance Indicators (KPIs). The process results in a theoretically sound safety management system, which simultaneously accounts for the characteristics and functions of the system, and for the regulatory requirements. The developed KPIs are integrated in a performance monitoring tool, as shown in Figure 2. This tool allows the practical use of the safety
management system through monitoring, controlling, and improving organizational safety in line with commonly used plan-do-check-act safety management processes.

The developed process for developing safety management systems is applied to a case study of Finnish Vessel Traffic Services (VTS). A validation process has been defined to evaluate the approach, which has been applied in a workshop with VTS operators and managers. The main outcomes of this validation is that there is good support for the proposed process and monitoring approach, but that some of the proposed KPIs need to be further considered and integrated in existing organizational processes.

**Research theme “e-Navigation and smart response services”**

The work on e-Navigation has focused on the establishment of an integrated database combining data from the Automatic Identification System (AIS) with ice data from the HELMI ice model. This database is a new product which allows system-level analyses of the maritime transportation system in the Northern Baltic Sea in winter conditions, as well as specific analyses for selected ship types. The database has been used to map maritime traffic in winter conditions, focusing on the densities of shipping activities and on the attained speed of ice-going vessels in different ice conditions. The database has been used to develop a hybrid model for ship performance in ice, for later use in a newly developed model for ship routing in ice. The hybrid model integrates a data-driven model, where the influence of icebreaker assistance on the attainable speed in various ice conditions, with an engineering-based model, which performs better in harsh ice conditions for which little data is available. The database of ship traffic in ice is finally used to assess the attainable speed of vessels based on satellite imagery, using data mining approaches.

Work has also been attributed to the development of an extendable framework to provide the optimal route for an ice-going vessel, accounting for multiple route planning objectives. The objectives are implemented based on the evaluation of multi-source input data in a novel path-finding algorithm, including the developed hybrid model for ship performance in ice, bathymetric data, and data on ice conditions. Figure 3 shows the elements of the framework, which has been implemented in a Matlab test bed software package “Icepathfinder”. A validation workshop was also performed to test the relevance and performance of the route planning tool in navigational practice.

**Figure 3. Method for multi-objective route planning for ice-going vessels**

*Source: Lehtola et al. (2018)*

The work on smart response services has led to two new integrated tools, which are useful for tactical oil spill response planning, and can also be used in pollution preparedness and response planning. Both tools are implemented as online web services, enabling easy access and ensuring usability. The first tool is the
Accidental Damage and Spill Assessment Model (ADSAM), which can be used to obtain an estimate of the oil outflow in an ongoing or hypothesized grounding damage case. ADSAM requires inputs about the vessel (main dimensions suffice, or more detailed information if available), the impact conditions (ship speed and characteristics of the impacted rock), the transported oil, and –if applicable- the ice conditions.

The model underlying the ADSAM tool integrates new and improved models for ship collision energy and damage, and oil outflow from a damaged hull.

The second tool is known as the Next-Generation Smart Response Web. It is an online software platform, which integrates different information layers which together provide an enhanced situational awareness about an oil spill, for tactical planning purposes. Starting from a defined oil spill (based on ADSAM, or from observations), the oil drift and weathering is determined in open water or ice conditions (using an improved version of SeaTrack Web, the operational HELCOM spill drift tool), and information is displayed regarding the ecosystem sensitivity or human use of the marine space. The tool can also be run using hypothesized scenarios, and used in oil spill preparedness and response planning.

3. Main results achieved during the project, including impact and use

The results achieved in the project includes new scientific knowledge in various areas, many of which are published as articles in high-impact academic journals. Among the published articles, there is an analysis of wintertime navigational accidents, an analysis of climate change effects in the Northern Baltic Sea relevant to shipping, a process for developing and a tool for safety management systems of a maritime system, a model for collision energy and damage in ice conditions, a model for oil outflow in ice conditions, and a hybrid model for ship performance for use in route planning. This work has also been presented in various professional and scholarly conferences, and in talks to several leading research groups.

The results achieved pave the way for meeting the overall STORMWINDS objectives. Impacts in end-user environments is diverse, and varies to some extent for the different research themes. For the theme “risk management for wintertime oil spill response”, the main stakeholders and end-users are oil pollution preparedness and response authorities in the Northern Baltic Sea. The theme was introduced at HELCOM RESPONSE meetings, and connections have been made with the OpenRisk project, led by the Baltic Marine Environment Protection Commission (HELCOM), which focuses on developing guidelines and a toolbox for oil pollution preparedness and response. STORMWINDS was included in the first OpenRisk workshop in Helsinki, Finland (September 2017), and the response effectiveness tool will be included in the OpenRisk guideline, advancing its use by authorities. The outputs have also been communicated to the steering committee of the EU Strategy for the Baltic Sea Region, Priority Area on Maritime Safety and Security.
(EUSBSR PA SAFE), and presented in seminars. The developed model for spill response is also included in reports the ICES Working Group on Maritime Activities in the Baltic Sea (WG MABS).

For the theme “systems-theoretic analyses of the maritime transportation system”, the main contacts are Vessel Traffic Services, who could benefit from implementing the process to develop a rigorous and scientific theory-based safety management system. In STORMWINDS, the Finnish VTS authorities have expressed interest to implement some ideas resulting from the work, but further confirmation and validation is considered necessary. Other VTS authorities have been informed about the developed process in meetings and seminars of the EUSBSR PA SAFE, where representative of some states expresses interest in the approach, and possible future implementation work was discussed.

For the theme “e-Navigation and smart response services”, the work on e-Navigation support for route planning in ice was introduced and discussed with icebreaker crew and ice navigation trainers, and discussed with maritime information service providers at the Finnish Meteorological Institute. The approach to map the ship performance onto satellite imagery was considered potentially very useful by all actors, but it was highlighted that further testing and validation of the approach would be necessary to implement in practice. The multi-objective routing tool “Icepathfinder” was considered interesting as well, and could be useful in setting waypoints for icebreaker services or in ice navigation training, but also here further testing and validation was found necessary by the end-users.

There is commitment of end-users to use the outputs of the work on SmartResponse Services. Through discussions at HELCOM RESPONSE and within the context of the HELCOM-led OpenRisk project, it was decided to include both the online ADSAM tool and the NG-SRW web application into the OpenRisk guideline for risk management for oil pollution preparedness and response. The tools were tested in the third OpenRisk workshop in Valletta, Malta (April 2018) by operational responders and oil spill managers from authorities across Europe, where the tools received positive feedback.

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The significance of the work done in STORMWINDS is evidenced as the project has been selected as a Flagship project of the EU Strategy for the Baltic Sea Region, Policy Area SAFE, in which it contributes to reducing the environmental impact of shipping, reinforcing the preparedness and response capacity, and developing new e-Navigation tools.

4. Continuity plan for the future after project completion

As discussed in Section 3, several outputs will be used in practice by end-users, and are included in relevant operational guidelines. Nevertheless, it is evident that some developed testbed tools will require further validation and testing to complete the transfer from science to policy and operational practice.

For the research theme “risk management for wintertime oil spill response”, further development could be made by integrating the model with other Bayesian Network based models for spatial oil spill risk analysis and management. The network in the ICES WGMABS can lay at a basis for this, and discussions on preparing a project for developing an integrated software for strategic risk management in line with the OpenRisk guidelines are ongoing. Several funding opportunities have been identified for this, for instance the Interreg BSR programme.
For the theme “systems-theoretic analyses of the maritime transportation system”, there has been discussions to extend the developed STAMP-based process to develop a harmonized safety management system for the Baltic Sea area, for use by coastal states (maritime authorities) to monitor and evaluate organizational safety performance and shipping safety, and take proactive improvement actions. This idea was strongly supported by Finnish, Estonian and Swedish maritime authorities, and a seed project was developed and implemented to advance this idea. However, funding was not obtained for a full project. Discussions on how to advance this issue are ongoing.

For the theme “e-Navigation and smart response services”, the work on e-Navigation support for route planning in ice will be further developed through future projects. The developed database of ship traffic and ice conditions will also be used in future ice navigation related projects. The work on the smart response services provides opportunities to extend the ADSAM tool to collision accidents, while also accounting for input uncertainties. The NG-SRW can be further developed to cover more geographical areas. Discussions are ongoing with the OpenRisk project team to incorporate these ideas into a project application focusing on developing an integrated software for strategic oil spill risk management, for which funding from e.g. the Interreg BSR would be sought.

References

Acknowledgements
BONUS STORMWINDS has received funding from BONUS (Art 185) funded jointly from the EU, and from the following Baltic Sea national funding institutions: the Academy of Finland (Finland), the Estonian Research Council (Estonia), the Research Council for Environment Agricultural Sciences and Spatial Planning (FORMAS) (Sweden).