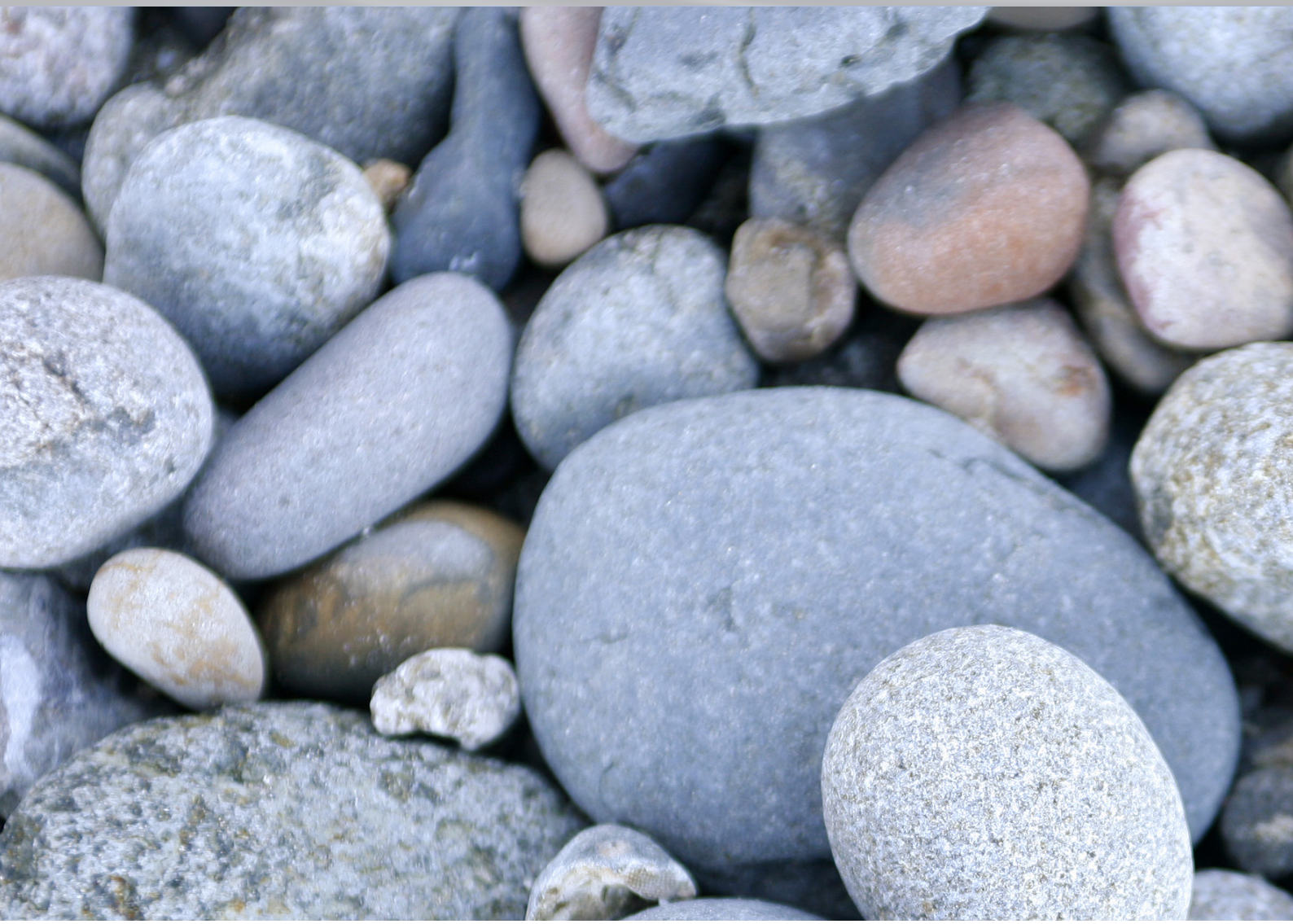
MIMIC



MINIMIZING RISKS OF MARITIME OIL TRANSPORT BY HOLISTIC SAFETY STRATEGIES (MIMIC) FINAL REPORT

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KOTKA MARITIME RESEARCH CENTRE
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MINIMIZING RISKS OF MARITIME OIL TRANSPORT BY HOLISTIC SAFETY STRATEGIES (MIMIC)

Final report

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This Final Report is written and compiled by the authors listed. Many other researchers have also contributed to the MIMIC project. This is reflected in the authorship of the articles, reports and presentations in which the project's results are presented (p. 52 – 59).

This report can be downloaded from:

http://www.merikotka.fi/mimic/index.php/en/deliverables-and-publications

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Executive summary

The MIMIC project (Minimizing risks of maritime oil transport by holistic safety strategies) developed proactive management approaches to risks related to maritime oil transportation, focusing on the Gulf of Finland, in the Baltic Sea. In this sea area, the volume of oil transportation has nearly quadrupled during the past ten years. This has raised concern of major oil accidents. The project

- estimated oil transportation volumes for years 2020 and 2030
- examined the composition of ship crews
- estimated oil accident probabilities
- estimated damage in ships caused by an accident, and the consequent oil outflow
- evaluated optional measures to control oil accident risks and produced a related decision support model
- developed tools for estimating the length of oiled shoreline after an accident
- developed tools for examining the recovery efficiency and optimal disposition of Finnish oil combating vessels and for forecasting the clean-up costs of oil spills
- improved operational tools for guiding oil combating activities
- identified and assessed security threats and pondered their connection to safety
- analysed the prevailing regulatory system related to maritime safety
- developed a proposal for a proactive risk governance approach for the Gulf of Finland

Oil transportation volumes in the Gulf of Finland for the years 2020 and 2030 were estimated by expert elicitation, and six different scenarios were built. The realization of the scenarios depends on several factors, such as political and economic development in Russia, and the policies of the EU. The composition of the crews of ships sailing in the Gulf of Finland and Archipelago Sea were examined. The survey showed that shipping crews are highly international in the Gulf of Finland, as in the whole Baltic Sea. The result involves a requirement to take multiculturalism into account in ship operations, to enhance the understanding of cultural differences and to improve intercultural communication.

Probabilities for grounding accidents were assessed based on accident reports, and probabilities for collision accidents updated. The analysis indicates that inadequate communication and cooperation on the bridge is the most significant contributing factor in a grounding accident. A simulation model (accidental damage assessment model, ADAM) was developed for estimating the damage in ships caused by different types of accidents, and for predicting the consequent amount and duration of oil outflow. It was concluded that a large

number of possible collision scenarios with the current structural configurations of ships would lead to an oil spill. Similarly for groundings, the kinetic energy of a vessel is sufficient to cause severe bottom damage and oil spill, depending on the bottom topology.

The oil transportation scenarios and the results of the accident modelling were integrated into a Bayesian decision support model that enables examining the cause-effect relationships related to oil accidents and their consequences, and evaluating the cost-effectiveness of different types of risk control options in reducing the risks of oil accidents. The cost-effectiveness of the ENSI (Enhanced Navigation Support Information) service, compulsory pilotage, and improved crashworthiness of ships was evaluated. According to the results, the ENSI service is the most cost-effective measure to control oil accident risks.

A Bayesian decision support model was also developed for examining the recovery efficiency and optimal disposition of Finnish oil combating vessels in the Gulf of Finland. It was found out that the environmental and accident conditions have a bigger impact on the recovery efficiency than the disposition of the oil combating vessels. Another model was built for forecasting the clean-up costs of oil spills and for the optimization of a cost-effective oil-combating fleet.

Two approaches were used in assessing the extent of polluted shoreline as a consequence of accidental oil spills. The method developed within the project has potential as a generally applicable tool in estimating the length of polluted shoreline, but needs further development regarding scaling, computing efficiency, and user-friendliness.

The project further developed tools for situation awareness building for oil spill response operations. The integrated Seatrack Web and SmartResponse Web applications enable up-to-date assessment of the oil drifting in the sea and environmental values at risk, and thus facilitate decision making regarding effective oil combating activities. The SmartResponse Web includes also a model (ADAM) for assessing ship damage and leakage in a collision or grounding accident, and a section related to maritime security.

Maritime security threats in the whole Baltic Sea were identified and assessed, and their connection to safety pondered. The study indicates that the current security level in the Baltic Sea is relatively good. A conceptual model was outlined for supporting the analysis and evaluation of security threats and facilitating the development of an integrated view on security and safety.

The competence of the regulatory system and policy instruments in ensuring maritime safety in the Gulf of Finland were analysed and improvements were considered. Reanalysing the effectiveness and cost-effectiveness of the existing policy instruments and supporting shipping companies to voluntarily improve their safety performance is recommended. MIMIC proposes establishing a proactive regional risk governance framework involving stakeholders, for analysing, managing and communicating maritime safety risks in the Gulf of Finland.

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Abbreviations and acronyms

ADAM	Accidental Damage Assessment Model
AIS	Automatic Identification System
BBN	Bayesian Belief Network
BID	Bayesian Influence Diagram
CB	Coupled Beam Method
CEC	Commission of European Communities
DWT	Dead Weight Tonnage
EMSA	European Maritime Safety Agency
ENSI	Enhanced Navigation Support Information
ESI	Environmental Sensitivity Index
EU	European Union
FEM	Finite Element Method
GIS	Geographic Information System
HELCOM	Baltic Marine Environment Protection Commission, Helsinki Commission
HFACS-Ground	Human Factor Analysis and Classification System for Grounding
IBAM	Integrated Bayesian Risk Analysis of Ecosystem Management in the Gulf of Finland, 2009-2011. The project was funded by the BONUS-169 Joint Baltic Sea Research Programme.
IMO	International Maritime Organization
IRGC	International Risk Governance Council
ISPS Code	International Ship and Port Facility Security Code
MARPOL	International Convention for the Prevention of Pollution from Ships
M€	Million Euros
MIMIC	Minimizing risks of maritime oil transport by holistic safety strategies

MMSI	Maritime Mobile Service Identity
Mt	Million tons
nm	nautical mile
OILECO	Integrating ecological values in the decision making process on oil spill combating in the Gulf of Finland, 2005-2007. The project was funded by the European Regional Development Fund (ERDF), and it implemented the Interreg IIIA Southern Finland and Estonia programme.
OILRISK	Applications of ecological knowledge in oil spill risk management, 2009-2012. OILRISK project was financed from the European Regional Development Fund (ERDF) and it implemented the Central Baltic INTERREG IV A Programme, Southern Finland - Estonia Sub-programme.
PROBAPS	Protection of the Baltic Sea: Benefits, costs and policy instruments, 2009-2012. The project received funding from the Finnish Advisory Board for Sectoral Research.
SAFGOF	Evaluation of the traffic increase in the Gulf of Finland during the years 2007-2015 and the effect of the increase on the environment and traffic chain activities, 2008-2010. The project was partly funded by the European Union.
SMHI	Swedish Meteorological and Hydrological Institute
SOLAS	Safety of Life at Sea (Convention)
SYKE	Finnish Environment Institute
UNCTAD	United Nations Conference on Trade and Development
VARELY	Centre for Economic Development, Transport and the Environment of Southwest Finland
VTS	Vessel Traffic Services
WBA	Why-Because –Analysis
WMS	Web Map Services

1. Project context and aims

The Baltic Sea is one of the busiest seas in the world. In recent years, the volume of maritime traffic has increased especially in the Gulf of Finland, due to growing oil production and export activities in Russia. The intensifying ship traffic together with relatively shallow and narrow waterways and ice cover in winter make navigation in the area risky. This has raised concern of a large-scaled oil accident in the area. The Gulf of Finland is a sensitive sea area, in which an oil spill could have severe consequences both in the offshore and the coasts.

Ensuring maritime safety in the Gulf of Finland, and in the whole Baltic Sea, requires a proactive management approach in addition to the current reactive one. Whereas the reactive approach responds to events that already happened, a proactive approach entails that risks are identified, assessed, evaluated and communicated, and that cost-effective measures to manage the risks are implemented. This requires evaluating different management options. It is important *inter alia* to consider how investments should be shared between measures that aim at preventing ships from getting into accidents and measures that can minimize the consequences of an oil accident.

The MIMIC (Minimizing risks of maritime oil transport by holistic safety strategies) project had a holistic approach to risks related to maritime transportation in the Baltic Sea. One of the main aims was to produce a model-based decision support tool that enables examining the risks of oil transportation and evaluating the cost-effectiveness of different types of measures to reduce the risks. For this, the Gulf of Finland was selected as a case study area. The model was based on traffic growth scenarios in the Gulf of Finland, and respective estimations for tanker accidents leading to an oil spill. Further, the size of the oil spill and the potential of the Finnish oil combating fleet to recover the oil from the sea and shore were analysed. The cost-effectiveness of three risk control options aiming at preventing oil spills was estimated in relation to the costs of oil combating. Also, decision support tools for examining the recovery efficiency and optimal disposition of Finnish oil combating vessels and for forecasting the clean-up costs of oil spills were developed. Two approaches were used in assessing the extent of polluted shoreline as a consequence of accidental oil spills.

In addition to the risk modelling, the project improved existing operational tools for guiding oil combating activities. The *Seatrack Web* enables, *inter alia,* oil drift forecasts in the sea under different weather conditions. The *SmartResponse Web* facilitates a dynamic risk assessment in the case of an oil accident by providing information on the sensitivity of coastal areas. Further, the project analysed the prevailing regulatory system related to maritime safety, and provided recommendations for developing it towards better response to the requirements of proactivity. An important part of the project was to identify and

assess security threats, i.e. illegal and/or intentional acts against oil transportation and other types of cargo, and their connection to maritime safety.

MIMIC was a multidisciplinary research project that combined methodologies, knowledge and expertise from the fields of maritime studies, engineering, natural sciences and social sciences. MIMIC integrated results of earlier projects OILECO, OILRISK, SAFGOF, IBAM, and PROBAPS with new knowledge that was produced during the project. MIMIC focused on aspects that had been less studied before. Thus, the project may be considered as a culmination point of current knowledge related to oil accident risks in the Gulf of Finland, and it provides a new basis for developing proactive approaches to risk management in the area.

This report summarizes the work done in MIMIC, and provides recommendations for proactive management of maritime risks in the Gulf of Finland. It is targeted to authorities and decision makers at the international, regional, and state level, and to other stakeholder groups related to shipping. The report can, however, be of interest to other researchers and to the general public as well. Since the report is a general, intended as easy-to-read description of the project and its results, scientific details are not in focus. Methods and other specific information of the individual analyses are described in more detail in the publications and presentations that are referred to in each section and listed at the end of the report. The publications, presentations, and other deliverables of MIMIC, can be found in the web-pages of Kotka Maritime Research Centre (http://www.merikotka.fi/mimic/).

The report is structured as follows. In *Section 2,* alternative future scenarios for oil transportation for the Gulf of Finland are suggested, and the composition of ship crews in the area analysed. In *Section 3*, the analyses of safety and security risks are presented. Sub-section 3.1.1 describes the analysis of factors leading to grounding accidents and the assessment of the likelihood of such accidents in the Gulf of Finland. Sub-sections 3.1.2 and 3.1.3 present how tanker hull damages for different accident scenarios, and the consequent oil leakages, were estimated. Sub-section 3.2 suggests a new innovative approach for estimating the length of oiled shoreline after an oil accident under different conditions. Sub-section 3.3 discusses security threats and their link to safety. *Section 4* summarizes the views of Finnish maritime experts on the current maritime regulatory system and safety policy instruments, and their cost-effectiveness. In *Section 5* the tools and approaches that were developed in MIMIC for controlling the maritime risks, and for supporting the risk-related decisions are presented. These include a model for evaluating the cost-effectiveness of risk control options (5.1.), a model for examining the recovery efficiency and optimal disposition of oil combating vessels, and a model for forecasting the cleanup-costs of oil spills (5.2.), and the situation awareness tools for oil combating (5.3). In *Section 6* we propose a regional risk governance framework for the Gulf of Finland. *Section* 7 presents the main results of the project, and in *Sections 8 and 9 we* provide recommendations for policy makers and future research.

The project was carried out by research teams from the following institutions (text in brackets highlight the main contributions): Kotka Maritime Research Association (project management); Centre for Maritime Studies of the University of Turku (scenarios for oil transportation, analysis of ship crews, evaluation of regulatory system and policy instruments, contributing to the concept of the holistic risk model); Aalto University (accident modelling, estimating the effectiveness of the risk control options, modelling the oil spill clean-up costs, contributing to the development of the holistic risk model and the decision analysis), Technical University of Tallinn (assessment of ship damage and leakage, estimating the effectiveness of the risk control options); Finnish Environment Institute SYKE (assessment of oiled shoreline, editing the final report); Kymenlaakso University of Applied Sciences (analysis of security threats); Estonian Marine Institute, University of Tartu (development of SmartResponse Web); Swedish Meteorological and Hydrological Institute SMHI (improved functionality of Seatrack Web and scenario runs), and Fisheries and Environmental Management Group, University of Helsinki (coordinating the development of the holistic risk model, building the decision support tool and conducting the analyses, proposal of the risk governance framework, compiling and editing the final report).

The MIMIC project was funded by the European Union (European Regional Development Fund, The Central Baltic INTERREG IV A Programme 2007-2013); the City of Kotka; Kotka-Hamina Regional Development Company (Cursor Oy); Centre for Economic Development, Transport and the Environment of Southwest Finland (VARELY); Kymenlaakso University of Applied Sciences; Swedish Meteorological and Hydrological Institute (SMHI); Finnish Environment Institute (SYKE); Tallinn University of Technology, University of Tartu and Environmental Investment Centre of Estonia. The project's cost estimate was 2 072 341 €, and its duration from 1 May 2011 to 31 December 2013.

MIMIC was accepted as a Flagship project in the EU Strategy for the Baltic Sea Region (EUSBSR) under the heading “Minimizing the risks of transportation of dangerous goods by sea”. The project was included in the Action Plan of the EUSBSR, January 2012 version. As a Flagship project, it was expected that MIMIC supports the Priority Area Safe Coordinators in conveying relevant results and recommendations to the policy discussions and policy development in the Baltic Sea Region.

2. Maritime traffic in the Gulf of Finland – an increasing international business

2.1. Development of oil transportation

The volume of oil transported via the Gulf of Finland has nearly quadrupled during the past ten years: from 43.7 million tons (Mt) in 2000 to 157.9 Mt in 2010 (Brunila and Storgård 2012; Brunila 2012a). It has been assumed that the annual oil transportation can increase up to nearly 200 Mt during the next few years. This is due to the establishment of new oil terminals in Russia. *Inter alia* in the new Russian port *Ust-Luga* the annual volume of transported oil is expected to reach 10…15 Mt at the beginning, and later be 25…30 Mt. Ust-Luga is the termination point of the 1170 km long *New Baltic Pipeline System 2* for transporting Russian oil, which was completed in March 2012.

In MIMIC, oil transportation volumes in the Gulf of Finland for years 2020 and 2030 were estimated by consulting experts (Brunila and Storgård 2012). Three scenarios for 2020 and three for 2030 were developed (Figure 1). The scenarios are based on strategies for energy demand and for political and economic development. The scenarios for 2020 are:

1) *Slow development:* The economy will not grow and the EU's *climate and energy package*[1] will fail to fulfil its aims;

2) *Average development:* The development of population, economy, technology and transportation will continue as today and investments will be made both in green technologies in Europe and oil production technology in Russia.

3) *Strong development:* Investments in oil production and transportation infrastructure in Russia will follow the most ambitious plans, and green technologies and energy sources will not be able to replace oil as an energy source.

The scenarios for 2030 are:

1) *Stagnating development:* Lack of investments and economic growth is the main driver. Environmental goals will not be achieved because political efforts concentrate on balancing the economy.

2) *Towards a greener society:* Energy and climate strategies will succeed, and Europe moves towards a decarbonised society. However, fossil fuels will still remain the main energy source, despite the development of new innovative green technologies.

[1] European Commission. Climate Action. The 2020 climate and energy package. [online] URL: http://ec.europa.eu/clima/policies/package/

3) *Decarbonised society:* The EU will implement strict environmental policies. Demand for oil products will decrease, and the share of biofuels and renewable energy sources will increase.

The experts were asked to estimate the volumes of oil transported in the Gulf of Finland for each scenario. They were asked to specify 1) the most probable volume of oil transportation, 2) the minimum volume (a volume that will at least be transported), and 3) the maximum volume (a volume that will not be exceeded). According to the experts' assessments, the oil transportation volumes will increase only moderately.

Development of oil transportation in 2020:

1) *Slow development*: The minimum volume is 151 Mt and the maximum 187 Mt. The most probable volume is 170 Mt.

2) *Average development:* The minimum volume is 169 Mt and the maximum 207 Mt. The most probable volume is 187 Mt.

3) *Strong development:* The minimum volume is 177 Mt and the maximum 218 Mt. The most probable volume is 201 Mt.

Development of oil transportation in 2030:

1) *Stagnating development:* The minimum volume is 148 Mt and the maximum 177 Mt. The most probable volume is 165 Mt.

2) *Towards a greener society:* The minimum volume is 156 Mt and the maximum 192 Mt. The most probable volume is 177.5 Mt.

3) *Decarbonised society:* The minimum volume is 153 Mt and maximum 190 Mt. The most probable volume is 165.5 Mt.

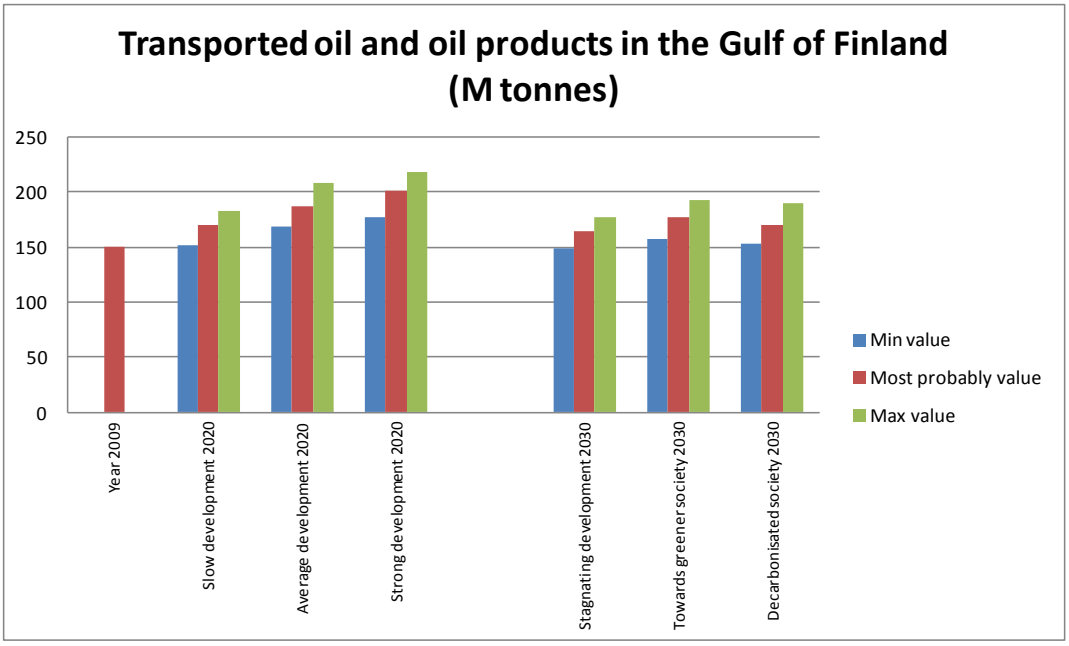

Figure 1. Volumes of oil transportation in the Gulf of Finland in 2020 and 2030 in three different scenarios (Brunila and Storgård 2012).

The future of oil transportation volumes in the Gulf of Finland depends on many factors. The policies and development in Russia, and the policies of the EU related to the development of a greener society will have major impacts. Therefore, and due to constant change in the market and policies, updated forecasts and new scenarios are needed in the future.

2.2. Composition of ship crews

Currently, shipping companies strive to cut their operational costs through decreasing the number of crew on board and hiring seamen from countries with a lower salary level. At the same time, the supply of seafarers in the industrialized countries has decreased. This development has created a global labour market for shipping, and further led to increasingly multicultural crews. There are examples in which language difficulties or other culturally driven differences in communication between crew members or between master and pilot have led to accidents[2]. In MIMIC, communication was found to be one of the most important contributing factors in grounding accidents (section 3.1.1.).

[2] Language difficulties were found to be an underlying factor *inter alia* in the collision between the bulk carrier Xuchanghai and the shuttle oil tanker Aberdeen near Immingham Oil Terminal in the UK in 2000, and in the collision of the passenger ship Silja Opera with three cargo vessels at St Petersburg harbour in 2003. Report of the investigation of the collision between Xuchanghai and Aberdeen. Immingham Oil Terminal, 12 December 2000. Marine Accident Investigation Branch, Southampton,UK. Report No 30/2001. [online] URL: http://www.maib.gov.uk/cms_resources.cfm?file=/xuchanghai.pdf; Passagerarfartyget Silja Opera-SIAP-kollision med fartyg som låg förtöjda vid kaj den 17 september 2003. Rapport. Sjöfartsinspektionen, Sjöfartsverket, Norrköping 2004. [online] URL: http://www.transportstyrelsen.se/Global/Sjofart/Dokument/Haverirapporter/G_2003/2003_09_17_passagerarfartyget_silja_opera_siap_kollision_med_fartyg.pdf

We examined the composition of the crews of the ships sailing in the Gulf of Finland (Storgård et al. 2013a). The aim was to get an insight of the number and ranking of crew members in relation to their nationalities. A survey focusing on 453 crew lists that were reported in the Portnet database was carried out. Portnet is a national system in which all vessels visiting Finnish ports are obliged to report their vessel calls, cargo, ship waste, crew, etc. The survey focused on ships that visited the ports of the Gulf of Finland and the Archipelago Sea during the period from 5th October 2012 to 4th November 2012. Crew lists are maintained in the Portnet system only 30 days due to the Finnish Personal Data Act (529/1999). Therefore it was possible to collect data only from the previous 30 days.

The analysed ship types included dry cargo (160 ships), tankers (125), Ro-Ro (80), container ships (70), and other ships (18). Passenger ships were not part of the study because their crew lists are not fed into the Portnet. About 22 % of the ships were Finnish, 15 % were operated under the flag of the Netherlands, and 10 % under Antigua and Barbuda flag. In total, the ships employed 2530 officers and 3507 other crew members that represented 48 different nationalities.

As much as 85 % of the studied ships had multinational crews. The number of different nationalities per ship varied from one to seven. 28 % of the ships with a multinational crew had three and 26 % of them two nationalities on board. Tankers, container vessels and dry cargo vessels had the most international crews.

The largest group of officers (chief officer, second officer, third officer, chief engineer, second engineer, third engineer and fourth engineer) was Finns (17 %), second largest was Filipinos (15 %) and third largest Russians (14 %). The largest group of other crew (cadets, boatswains, able seamen, oilers, greasers, fifth engineers, cooks and ordinary seamen) was Filipinos (48 %) and second largest Finns (14 %). The third largest group, Russians, comprised only 5 % of other crew members. Finns were the largest group of officers in Ro-Ro vessels, Ukrainians in container ships, Russians in dry cargo ships, and Filipinos in tankers (Tables 1 and 2).

In Table 3, an average crew distribution per one ship in relation to different ship types and nationalities has been calculated, based on the information obtained from the Portnet database. For example in tankers, there were 6…7 officers and 8…9 crew members on board. The survey indicates that on average, one of the officers is Finnish, one to two from Philippines, one from Russia, one from Poland, one from Sweden, and one from other countries. Five of the crew members would be Filipinos, one Finn, one Indian, and 1…2 from other countries.

Table 1. Nationalities by ship types, officers (Storgård et al. 2013a).

Nationality	Number of officers						%
	Ro-Ro	*Container*	*Dry Cargo*	*Tankers*	*Other*	*Total*	
Finnish	211	12	116	81	9	429	17
Filipino	109	43	59	169	1	381	15
Russian	26	75	156	65	21	343	14
Ukrainian	3	130	61	37	1	232	9
Polish	45	22	37	82	5	191	8
Estonian	65	11	50	3	21	150	6
Dutch	25	17	88	12	0	142	6
Swedish	35	0	4	63	2	104	4
German	12	18	23	44	2	99	4
Other	41	89	87	242	0	459	18
Total	**572**	**417**	**681**	**798**	**62**	**2530**	**(101)**

Table 2. Nationalities by ship types, other crew (Storgård et al. 2013a; the %-column is corrected in comparison to the original table 4.3 in the reference).

Nationality	Number of other crew						%
	Ro-Ro	*Container*	*Dry Cargo*	*Tankers*	*Other*	*Total*	
Filipino	376	356	322	605	8	1667	48
Finnish	255	21	90	119	13	498	14
Russian	7	17	77	41	27	169	5
Ukrainian	0	58	75	35	0	168	5
Indian	0	70	0	79	0	149	4
Polish	58	0	22	43	11	134	4
Estonian	17	5	54	2	23	101	3
Other	78	83	246	208	6	621	18
Total	**791**	**610**	**886**	**1132**	**88**	**3507**	**(101)**

The survey shows that international shipping crews occur in the Gulf of Finland and the whole Baltic Sea. The result involves a requirement to take multiculturalism into account in ship operations, to enhance the understanding of cultural differences, and to improve intercultural communication. Training is an important means for this, and it should include the establishment of a shared safety culture on board. Utilizing the potential of *Maritime English* in improving communication is worth considering[3].

[3] The need for clearer communication and precise terms to refer to the parts of ships and procedures in sailing has produced an attempt to establish international standards for English language used in seafaring. Maritime English is a simplified version of English which includes a standard vocabulary for maritime communication. Sampson, H. and Zhao, M. 2003. Multilingual crews: communication and the operation of ships, World Englishes 22(1): 31-43.

Table 3. The average number of crew members, officers [a] and other crew [b], in relation to their nationality, in different types of ships sailing in the Gulf of Finland and the Archipelago Sea. The table is based on a sample from the Portnet database (Storgård et al. 2013a). Legend: Dut.=Dutch, Indon.=Indonesian, Oth.=Other.

[a]

Ship type	Nr Officers /ship	Average number of officers												
		Finnish	*Filipino*	*Russian*	*Ukraine*	*Polish*	*Estonian*	*Dut.*	*Swe-dish*	*German*	*Indian*	*Latvian*	*Croatian*	*Oth.*
Ro-Ro	6.7	2.5	1.3	0.3	0	0.5	0.8	0.3	0.4	0.1	0	0	0	0.4
Container	5.6	0.2	0.6	1.0	1.8	0.3	0.1	0.2	0	0.2	0.6	0.1	0.1	0.5
Dry bulk	6.3	0.8	0.7	1.1	0.4	0.1	0.1	0.9	0	0.2	0	0	0.5	1.6
Dry cargo	3.8	0.7	0.3	0.9	0.4	0.2	0.3	0.5	0	0.1	0	0	0	0.3
Tankers	6.2	0.6	1.3	0.5	0.3	0.6	0	0.1	0.6	0.3	0.3	0.5	0.2	0.9
Other	1.3	0.2	0	0.4	0	0.1	0.4	0	0	0	0	0	0	0
Average	**4.9**	**0.8**	**0.7**	**0.7**	**0.4**	**0.4**	**0.3**	**0.3**	**0.2**	**0.2**	**0.2**	**0.1**	**0.1**	**0.5**

[b]

Ship type	Nr Crew /ship	Average number of other crew												
		Filipino	*Finnish*	*Indian*	*Russian*	*Ukraine*	*Polish*	*Estonian*	*Indon.*	*Swe-dish*	*German*	*Dut.*	*Turkish*	*Oth.*
Ro-Ro	9.1	4.3	2.9	0	0.1	0	0.7	0.2	0	0.3	0.2	0.1	0	0.4
Container	8.8	4.8	0.3	1.5	0.2	0.8	0	0.1	0.1	0	0.2	0	0	0.8
Dry bulk	6.3	2.3	0.6	0	0.1	0.6	0	0	0	0	0	0.1	0	2.6
Dry cargo	4.9	1.7	0.5	0	0.5	0.4	0.1	0.4	0.3	0	0	0.2	0	0.6
Tankers	8.7	4.7	0.9	0.6	0.3	0.3	0.3	0	0.2	0.3	0.1	0	0.4	0.7
Other	1.7	0.1	0.3	0	0.6	0	0.2	0.5	0	0	0	0	0	0
Average	**6.9**	**3.2**	**1**	**0.4**	**0.3**	**0.3**	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.7**

3. Analyses of safety and security risks

One of the main aims of MIMIC was to analyse the risks of a major oil spill that would be caused by an accident involving a tanker, and to evaluate the cost-effectiveness of different management measures to reduce the risks. In this section, we describe how we assessed 1) factors that can lead to grounding accidents, 2) the probability of grounding accidents that, in addition to collision accidents, cause most of the oil spills, 3) the consequent leakage in the case of an accident, either collision or grounding, 4) the likely amount of oil that after an accident would be spilled into the sea, and 5) methods for estimating oiled coastline. The main results of these analyses were used as input in the integrative decision support model, which was built to evaluate the risk control options (Section 5.1). The probabilities of collision accidents in the Gulf of Finland were modelled by Hänninen et al. (2012) in the project SAFGOF[4]. In MIMIC, these results were updated and used in the decision support model. At the end of this section we also summarize our analysis regarding security threats in the Baltic Sea.

3.1. Accident modelling

3.1.1. Evidence based modelling of grounding

The assessment of the probability of grounding accidents was based on knowledge extracted from accident reports (Hyttinen 2013, Hyttinen et al. 2014). This kind of approach is called evidence-based modelling (Mazaheri et al. 2013b, Mazaheri et al. 2013c). A new framework called *Human Factor Analysis and Classification System for Grounding* (HFACS-Ground) was used to discover the most frequent contributing factors in groundings from accident reports (Mazaheri et al. 2013d). We developed the HFACS-Ground from HFACS, which was originally developed for the investigation of aviation accidents, by adding grounding specific elements in the analysis (Mazaheri and Montewka 2014). The analysis framework is structured based on Reason's Swiss Cheese theory[5]. The theory suggests that the immediate cause of an accident is an active failure (unsafe acts), while latent conditions (preconditions, supervisional influence, organizational influence, outside factors) contribute to the accident by providing the canvas for the unsafe act to happen.

Our analysis indicates that the most significant contributing factor in a grounding accident is inadequate communication and cooperation on the bridge (Mazaheri and Montewka 2014). The other most important factors are inadequate bridge and ship resource management, violation of good seamanship practices, inadequate organizational support, and issues

[4] Hänninen, M., Kujala, P., Ylitalo, J., and Kuronen, J. 2012a. Estimating the Number of Tanker Collisions in the Gulf of Finland in 2015. International Journal on Marine Navigation and Safety of Sea Transportation, 6(3):367-373

[5] Reason, J. 1990. The Contribution of Latent Human Failures to the Breakdown of Complex Systems. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 327(1241): 475–484. [online] URL: http://rstb.royalsocietypublishing.org/content/327/1241/475.

related to the waterways, such as poor geometry and markings (Mazaheri 2013). The study shows that traffic density is not significant for the likelihood of a grounding accident, whereas traffic distribution and the complexity of the waterway have more probable effects (Mazaheri et al. 2013a, Mazaheri et al. 2014). In further studies, the significance of the complexity of waterways in grounding accidents should be defined in more detail in order to help better and safer design of waterways. Moreover, a more systematic analysis of incidents and near-misses is needed to enhance the usability of the incident and near miss reports in studies related to maritime safety.

Using *Why-Because Analysis*[6] *(WBA)*, the discovered factors were then structured into a *Bayesian network* model (Figure 2), in order to estimate the likelihood of a grounding accident. Bayesian modelling means structuring complex problems into cause-effect relationships, defining the strength of each relationship by probabilities, and then analysing the whole of the relationships.

Thereafter, for analysing the accident scenarios, it was assumed that a grounding accident depends on the location of the ship, season, and the size of tankers. In relation to location, the analysis focused on selected waterways in five different sectors of the Gulf of Finland (see Lehikoinen et al. 2013a). In these waterways, the frequency of grounding was estimated based on previously occurred grounding accidents and the volume of traffic in 2010. The probability of grounding for each sector as a whole was calculated as the summation of the grounding probabilities of the waterways inside the sector. The calculations were based on the assumption that grounding accidents occur in shallow waters and that the likelihood of grounding in the open water is zero. In relation to season, the likelihood of grounding was estimated based on expert judgment (Hänninen et al. 2012b). Winter was excluded from the analysis as the affecting factors on the accidents in winter traffic are still unclear. In relation to the size of tankers, the probability of grounding was estimated based on the study by Kite-Powell et al. (1999)[7]. The results of the grounding accident modelling were used as input in the integrative decision support model.

In addition, we analysed how the implementation of enhanced navigation support information (ENSI) service or compulsory pilotage would affect the likelihood of grounding. The ENSI system facilitates information exchange between ships and shore. As a key feature of the service, before departing from the port, ships send their route plans via ENSI to the vessel traffic service (VTS) centre. The route is then automatically checked by the VTS centre equipment, after which the plan becomes available for the VTS operator, who can then visually check it or examine the results of the automatic ENSI check on the screen. In

[6] Why-Because Analysis is a graphical method for accident analysis. It describes causal relations between factors behind an accident.

[7] Kite-Powell, H.L., Jin, D., Jebsen, J., Papakonstantinou, V., and Patrikalakis, N. 1999. Investigation of potential risk factors for groundings of commercial vessels in U.S. ports. International Journal of Offshore and Polar Engineering 9 (1):16-21.

exchange for sending the route plan, ENSI service provides the ship with real-time and route-specific information on the meteorological conditions via the ENSI portal. Since the ENSI system is not yet fully implemented in the area, its effects were assessed based on expert judgment (Hänninen et al. 2014b). The results of the analysis related to the effectiveness of ENSI in reducing the oil accident risks were included in the integrative decision support model (section 5.1.) and evaluated against the costs of ENSI.

The risk control option 'compulsory pilotage' describes a hypothetical situation in which each passenger ship and other vessel with a deadweight exceeding 300 tons is required to have a local pilot on board when navigating within the Gulf of Finland, regardless of whether the ship is within the current pilotage areas or whether the master or mate has a pilot exemption certificate. Currently, it is compulsory for all tankers that carry dangerous cargo to use a local pilot within defined pilotage areas. Analysing the effect of 'compulsory pilotage' informs us about the maximal influence of pilotage in safety. In 2006, only in three cases of 46 groundings in total, a pilot was present on board (HELCOM 2007). The effects of compulsory pilotage were assessed based on modifying the accident causation models of Hänninen and Kujala (2012)[8] and Hänninen et al. (2014), and the results were included in the decision support model (section 5.1.). The costs of compulsory pilotage and the ENSI service are discussed in section 5.1.1.

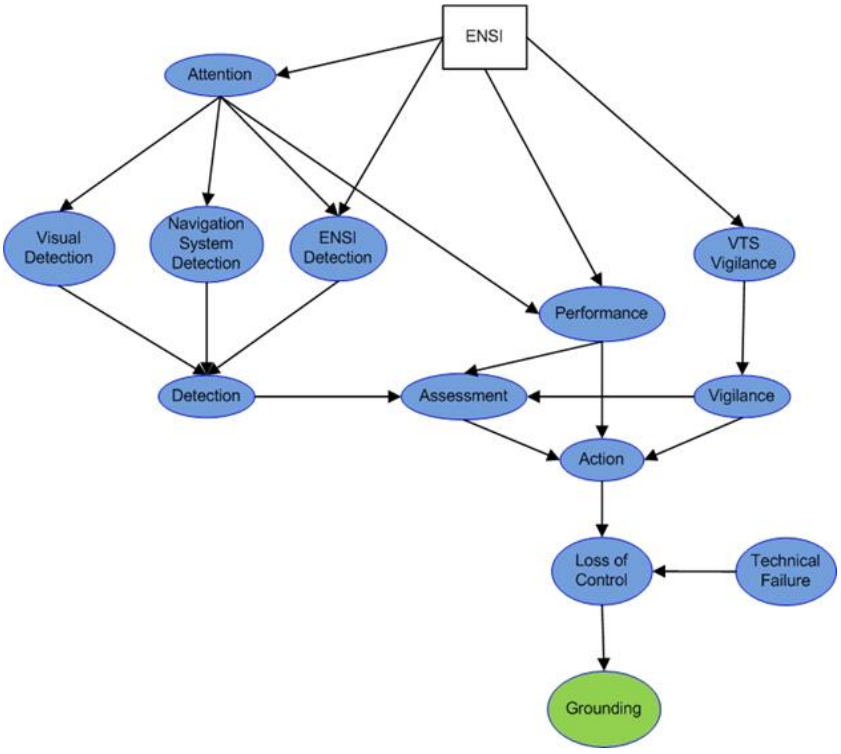

Figure 2. A simplified BBN model for grounding. The model shows how the effect of the ENSI system was analysed. The arrows depict the impact of factors on other factors (Hänninen et al. 2014).

[8]Hänninen, M. and Kujala, P. 2012. Influences of variables on ship collision probability in a Bayesian belief network model. Reliability Engineering and System Safety 102: 27-40.

3.1.2. Ship particulars and AIS database

For the assessment of oil leakage after a collision or grounding accident, particulars of tankers navigating in the Gulf of Finland were examined. The analysed tankers navigated in the Gulf of Finland in the year 2010.

The analysis shows that four types of tankers navigated in the Gulf of Finland: chemical (61 %), oil (36 %), liquefied gas (2.6 %), and bunkering (0.4 %) tankers. Most (96 %) of the chemical tankers transported both oil products and chemicals, 3.4 % only chemicals, and 0.6 % transported vegetable oil. 58 % of the oil tankers were intended to carry crude oil, 41 % oil products, and 1 % asphalt/bitumen. A majority (70 %) of the crude oil tankers just carried crude oil, whereas 26.5 % of them transported both crude oil and oil products, and 3.5 % of them were shuttle tankers[9].

The maximum length of the tankers sailing in the Gulf of Finland was 276.9 m, the maximum design draft was 17.1 m, and the maximum width was 50 m. The average speed was 14 kn (~26 km/h), and the average DWT[10] about 39000 ton (Figure 3). Almost half of the tankers (45 %) had an IA ice class certificate. The rest of them had different (IA-Super, IB, IC, or II) ice class certificates or were ice-strengthened, which made them qualified to navigate in the area in winter. All the tankers were double hull tankers, with 90 % of them following the requirements of MARPOL[11].

The presented particulars regarding the tankers were (through the MMSI[12] and IMO numbers[13] of the tankers) linked to a route-based AIS[14] database that contained the paths and speeds of the vessels that navigated in the area between years 2006 and 2012. The AIS database is created based on the raw AIS data of the ships navigating the Baltic Sea that is extracted from HELCOM statistics. The data were then used to generate scenarios for collision and grounding accidents involving a tanker in the Gulf of Finland. Each scenario contains required data (speed, size, and type of the involved ships, collision angle, location of the accident, and the probability of occurrence for the scenario) for estimating the possible damage and amount of the oil outflow after an accident.

[9] Shuttle tankers transport oil from off-shore oil fields to onshore terminals and refineries. They are an alternative to the use of pipelines for the offshore oil industry.

[10] Dead Weight Tonnage is a measure of how much weight a ship is carrying or can safely carry.

[11] The MARPOL (International Convention for the Prevention of Pollution from Ships) requirements for double hull tankers relate to protective location of segregated ballast tanks. This means that the ballast tanks are positioned where the impact of a collision or grounding is likely to be greatest. This reduces the amount of cargo spilled after an accident.

[12] The Maritime Mobile Service Identity is a unique nine-digit code set into AIS transceiver to identify the vessel or coast station. It is assigned to a ship based on her flag, and may be changed if the ships changed her flag state.

[13] The IMO number is a code that consists of seven digits and is used to identify ships. It is assigned to a ship hull and will not be changed during the whole lifecycle of a vessel.

[14] The Automatic Identification System is an automatic tracking system used on ships and by VTS centres for identifying and locating vessels by electronically exchanging data.

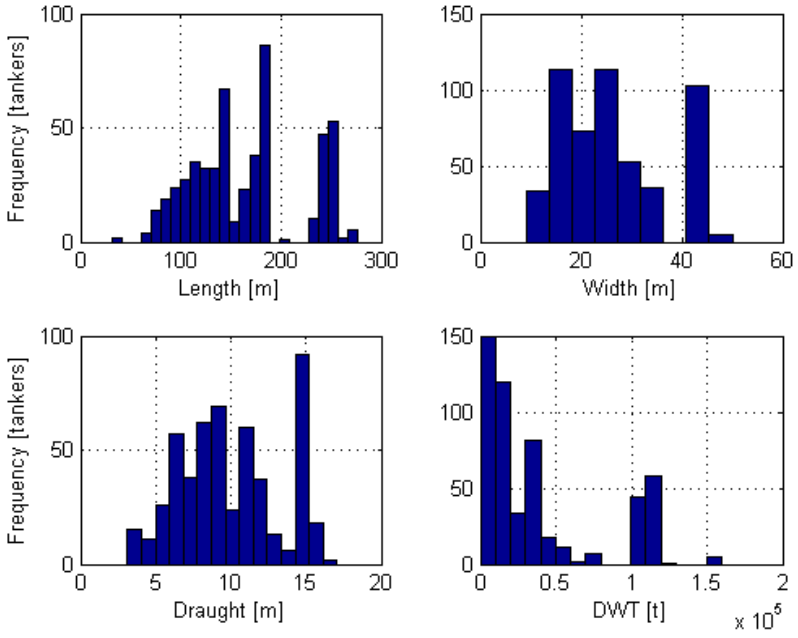

Figure 3. The dimension and size of the tankers navigating in the Gulf of Finland in the year 2010 (Mazaheri et al., unpublished data).

3.1.3. Collision and grounding damage and leakage assessment

A simulation model was developed for estimating the damage in ships caused by different types of accidents, as summarized in the accident scenarios, and for predicting the consequent amount and duration of oil outflow. The accidental damage assessment model (ADAM) combines three separate simulation models: a damage assessment model, an oil leak model, and an ultimate strength model (Figure 4). Such a combined model allows studying the most typical accidents of the Baltic Sea and evaluating possible oil spill characteristics. Simulating the types of accidents that might occur in the Baltic Sea helps in analysing and selecting the most effective measures to control the related risks in the area.

The damage assessment model evaluates the extent and size of damage occurring in ship structures in the case of a collision or grounding accident. In both accident types the inner hull is assumed to be breached once a certain relative penetration depth is exceeded. For tanker groundings, the grounding force and the extent of structural damage were estimated based on different combinations of penetration depth and bottom topology according to Heinvee et al. (2013). The principle of the approach for the collision analysis is presented in Tabri et al. (2012).

The oil leak model predicts the volume and duration of an oil-outflow from the damaged tanker in different types of collision and grounding accidents. A detailed description of the model is presented in Sergejeva et al. (2013). The model binds different variables, such as tanker structure, hydrostatic pressure and the location of damage, into the simulation model.

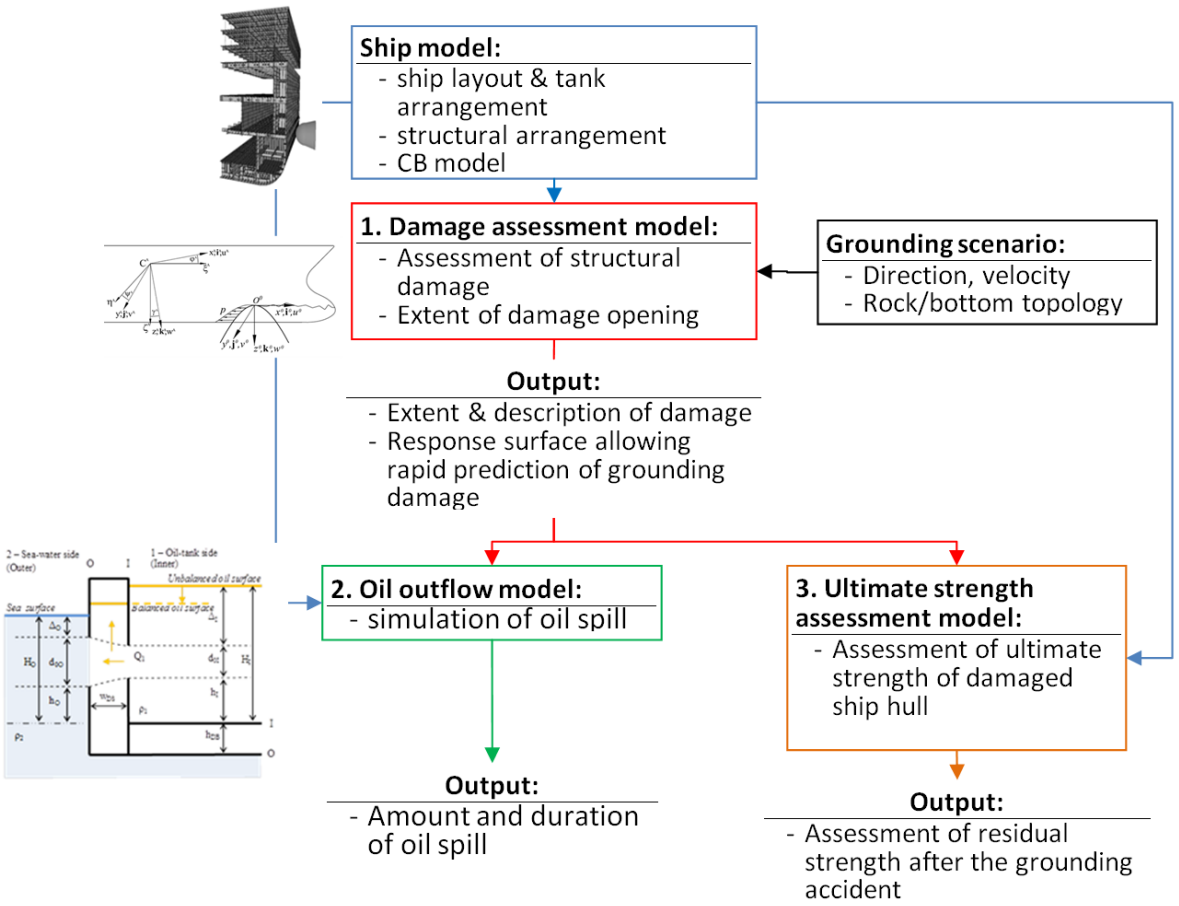

Figure 4. Overview of the ADAM simulation models: 1. damage assessment, 2. oil outflow, and 3. ultimate strength models (Tabri et al., unpublished).

Based on the size of the damage and the main dimensions of the ship, the ultimate strength model enables to estimate the residual strength of a ship hull girder and to assess whether a wave with a certain height might cause a global hull failure. The ultimate strength analysis was conducted by applying the coupled beam (CB) method[15]. The method is based on the idea that the ship hull can be globally modelled as a set of coupled beams that are in interaction with each other. The method can describe the behaviour of ship hull in all its length and not just a single cross-section. The use of beam theory in coupled beams reduces significantly the calculation time, compared to the finite element method (FEM[16]) and thus enables the estimation of a large number of damage scenarios.

[15] Naar H., Varsta P., and Kujala P. 2004. A theory of coupled beams for strength assessment of passenger ships. Marine Structures 17: 590-611.

[16] In the coupled beam approach the ultimate strength problem is solved using a smaller number of elements (so-called coupled beams) compared to the FEM, as the discretization is done using very large structural elements. Thus, also the degrees of freedom are reduced, and the calculation task becomes simpler leading to significantly reduced simulation times.

The ADAM-model was used to study a large number of collision and grounding scenarios typical for the Gulf of Finland. The analysis revealed that a large number of possible collision scenarios with the current structural configurations of ships would lead to an oil spill. Similarly in grounding, the kinetic energy of the ship is sufficient to cause severe bottom damage and oil spill, depending on the bottom topology. The results of the analysis were transferred to the integrative decision support model.

We estimated also how an improved crashworthiness of ships would increase their structural capacity to withstand accidental damage. Classification routines to approve improved ship designs have been proposed by ship classification societies[17], and some ships with improved crashworthiness have already been built[18]. However, under the current regulatory environment, a full benefit from safer ships cannot be obtained. This reduces the motivation for improvement. MIMIC provided a simulation environment for elaborating the issue of improving crashworthiness. To study the effect of crashworthiness it was assumed that the structure's capacity of absorbing energy without the breaching of the inner hull is increased to a certain extent. The exact ship structures with improved crashworthiness were not designed, while the additional investment to achieve better energy absorption was estimated based on the existing crashworthy river ships by Damen Schelde Naval Shipbuilding.

Figure 5 presents the results of analyses of more than 2300 collision scenarios that could occur in the Gulf of Finland. Each point in the figure indicates an accident with oil spill. The amount of spilled oil is given in m^3. The figure on the left shows the oil spills for the ships that satisfy the current minimum structural requirements i.e. are similar to the ships that currently sail in the Gulf of Finland. The figures in the middle and on the right present the oil spills in the same 2300 collision scenarios, but assuming that the whole fleet has improved crashworthiness 2 and 4 times, respectively.

The analysis indicates that improved crashworthiness would significantly reduce the number of accidents that lead to an oil spill. However, given the large size of ships, the additional energy that the structures have to be able to absorb is significant. Thus, to improve the situation from the viewpoint of crashworthiness, the ability of the structure to absorb energy should increase up to four times to have significant impact on safety in the Gulf of Finland. The costs for improving the crashworthiness of ships are discussed in Section 5.1.1.

[17] Zhang, L., Egge, E.D., and Bruhns, H., 2004. Approval Procedure Concept for Alternative Arrangements, In: Proceedings of the 3rd International Conference on Collision and Grounding of Ships ICCGS2004, Japan, pp. 87-96.

[18] van de Graaf, B., Broekhuijsen, J., Vredeveldt, A., and van de Ven, A. 2004. Construction aspects for the Schelde Y-shape crashworthy hull structure. In: Proceedings of 3rd International Conference on Collision and Grounding of Ships ICCSG 2004, Tokyo, Japan, pp. 229-233.

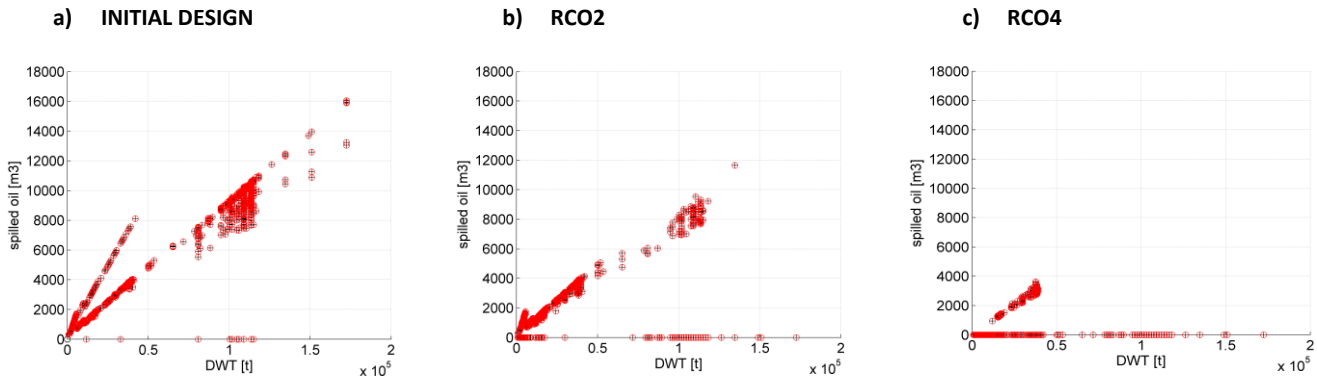

Figure 5. **The results of analyses of more than 2300 collision scenarios that could occur in the Gulf of Finland: (a) initial design; (b) RCO2 design with two times higher energy absorption capacity compared to initial design; (c) RCO4 design with four times higher energy absorption capacity compared to initial design (Tabri et al., unpublished data).**

Finally, likely spill sizes for collisions occurring in the Gulf of Finland under different traffic conditions were estimated in probabilistic terms (Goerlandt and Montewka 2014). For this, a Bayesian network was built in which data from various sources and engineering models were combined.

3.2. Approaches for estimating oiled coastline

Part of the oil introduced into the water as a consequence of a spill may drift ashore. The potential amount of oil stranding depends on evaporation, sinking, physical, chemical and biological degradation and also of oil recovery at sea by technical operations.

Two approaches were used in MIMIC in assessing the extent of polluted shoreline as a consequence of accidental oil spills. Both are developed for the Gulf of Finland and for ice-free periods. The first approach, used previously in the IBAM and PROBAPS projects, is a linear statistical (Bayesian) model that uses the accident variables oil spill volume, distance to shore, and length of polluted shoreline. It also considers the presence or absence of an archipelago. The data used in the statistical analysis consists of 50 oil accidents at open sea, collected from literature. The second approach, which was developed within the project, is based on oil spill drift modelling in combination with mapping of the coastal and archipelago shoreline. Oil spill trajectories, which are calculated paths of oil movement, are considered reaching the shoreline when a calculated spillet radius encounters a line section of the shore. A spillet may be considered as the smallest areal component of an oil slick. A threshold oil film thickness may be defined, representing the lower limit of a physically continuous spill.

The drift model software SPILLMOD/RiskTool generates trajectories by season, using weather and riverine inflow data from several years as forcing. By this approach, natural variability is incorporated in the results. How frequently a spillet meets a specific shoreline section within a specified time period, e.g. 10 days, is interpreted as a probability that this

section will be polluted. These probabilities, within each scenario (emission point, season, spill volume), are considered probabilities in a Bernoulli-distribution, which is sampled repeatedly. The result of repeated sampling is a relative statistical distribution of the length of polluted shoreline for each scenario. The resulting distributions are scaled to harmonize with the results of the linear statistical (Bayesian) model, which is based on real accident cases.

In the pilot phase of the new modelling approach, only crude oil was considered, but other oil types can be readily included in the scenarios. The calculation process in the present version of the system is fairly cumbersome, with a high requirement of computing resources and time. It involves a number of sequential stages, using several different software products. This novel method could have a potential as a widely applicable, fairly realistic, tool in estimating the length of polluted shoreline, but needs development regarding efficiency and user-friendliness.

3.3. Security threats

3.3.1. Analysis of security threats

One of the aims of MIMIC was to identify and assess maritime security threats, i.e. intentional or illegal acts against oil transportation and other types of cargoes in the Baltic Sea, and to ponder their connection to safety (Fransas et al. 2012, Fransas et al. 2013a, Fransas et al. 2013b, Nieminen and Fransas 2013). Such acts can be directed to the marine environment (illegal emissions/discharges, illegal fishing), or against ships or ports (piracy, terrorism, environmental activism, vandalism, theft and violent crimes), and/or they can use a ship as an operative instrument (smuggling of drugs, weapons and people, human trafficking[19]). The analysis is based on expert (authorities, industry, maritime education sector) knowledge, which was collected through interviews, a web-based survey, a Delphi study[20] (Fransas and Nieminen 2013), and workshops.

The results indicate that smuggling of drugs and human trafficking occur in the Baltic Sea, most probably in cargo ships (in containers and trailers). Drugs are also transported in passenger ships, especially in the Schengen area. Illegal fishing is significant, as it is assumed to comprise up to 30 % of all catches of the Baltic Sea. Illegal discharges are still a problem, although effective surveillance has decreased the number of detected spills. Theft and vandalism occur mainly within the passenger traffic. As the social and political conditions in the Baltic Sea region are relatively stable, there are no visible triggers for piracy or organized

[19] Human trafficking means the trade in humans for the purpose of sexual slavery, forced labor, commercial sexual exploitation or the extraction of organs or tissues etc.

[20] The Delphi method is a qualitative technique for forecasting unpredictable or unclear future trends and changes of a phenomenon. Experts are asked a set of questions related to a topic. After a certain period of time, the same experts are asked once again the same set of questions. Then the answers are summarized and the experts' predictions and guesses are discussed.

terrorism. The small size of the sea and surveillance also make such activities difficult. Thus, the likelihood of an attack or other illegal act against an oil tanker or terminal is considered low, as well as potential involvement of tanker companies or their crews in criminal activities. Environmental activism is not seen as a major problem in the Baltic Sea.

The experts saw a connection between security threats and safety in shipping. An attack against a vessel by terrorists, pirates, or other criminals could have severe safety consequences, such as grounding, collision, sinking, fire or explosion. An attack targeting a tanker might also have dramatic consequences for the sea environment. The consequences of, for instance, smuggling, vandalism or illegal discharges on safety are not so obvious.

Cooperation between authorities and other actors, both on a national and an international level, was considered important in ensuring maritime security in the Baltic Sea. Surveillance was regarded one of the most effective controlling measures. According to the experts, especially the problem of illegal fishing could be addressed by increasing control measures. Situational awareness and cooperation makes it possible to prepare for security threats and thus guarantee a safe living environment in the Baltic Sea region.

3.3.2. A conceptual model for security threat analysis

A literature survey related to potential methods for a formal security threat analysis was conducted (Tuominen 2013a), and a conceptual security threat analysis model for oil transports was outlined (Tuominen 2013b). The model supports the analysis and evaluation of potential security threats by different operational stakeholders, and facilitates the development of an integrated view on security and safety. The model structures the analysis process into three interconnected modules: 1) a threat credibility module, 2) an exploitation/vulnerability module, and 3) a consequence module.

Building on this conceptual basis, MIMIC evaluated possibilities for building probabilistic models for maritime security analyses. A preliminary causal model was developed for assessing the credibility of a threat quantitatively in probabilistic terms (Figure 6). The same method (Bayesian networks) was used in building the model that was used in the accident modelling, and in the decision support model related to reducing the risks of collision and grounding accidents. The method is based on updating existing knowledge, and it enables taking into account uncertainty and the knowledge of experts[21]. Thus, it basically works the same way as authorities when they reason security risks based on their pre-understanding and new knowledge. A formal quantitative security assessment including the evaluation of measures to manage the threats could be a way to develop security management. Structuring a security risk into cause-effect relationships might also lead to considering how it relates to safety, and further to an overall risk assessment.

[21] Jensen, F.V. 2001. Bayesian Networks and Decision Graphs. Springer, New York.

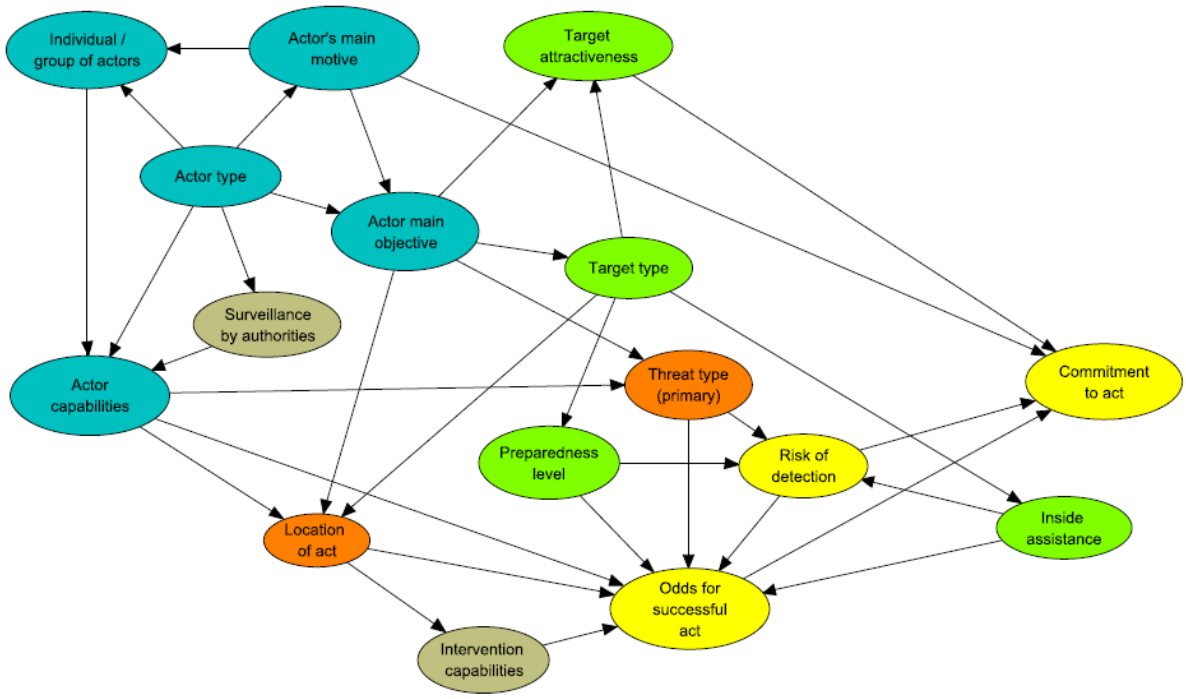

Figure 6. A Bayesian model for assessing the credibility of a security threat (Lehikoinen et al., unpublished).

There are, however, challenges in applying formal assessment frameworks to security, especially in quantitative terms. A threat is influenced by a myriad of factors, the likelihoods of which are difficult to assess. This concerns especially the human factors. As different authorities are responsible for different security threats, it should be considered who could or should build and use such security assessments. Only relevant authorities have access to security-related knowledge which, moreover, is often secret and sensitive, even in relation to other authorities. A security model should cover the whole Baltic Sea, but the borders and exchanging information between countries might also become a problem.

It was concluded that a formal security assessment is possible, but challenging. It would be even more difficult to use a modelling approach to link security with safety. Both the difficulties related to the assessment itself and the institutional framework for it should be thought over. An integrated assessment would also require reconsidering the institutional responsibilities related to safety and security.

3.3.3. Integration of security issues in SmartResponse Web

A separate section of the SmartResponse Web (section 5.3.2. of the report) for security matters was created in MIMIC. The security related reports published by the Kymenlaakso University of Applied Sciences and the EU legislation on enhancing ship and port facility security were uploaded in the SmartResponse Web portal.

In addition, the SmartResponse Web includes annotated interactive map layers that together with the security related information can be used to inform authorities,

stakeholders and a wider public on security related issues. The map layers denote 1) oil terminals in the whole Baltic Sea subject to implementation of the International Convention for the Safety of Life at Sea (SOLAS) and the International Ship and Port Facility Security (ISPS) Code, and 2) the Estonian anchorage areas including the security sensitive anchorage areas for dangerous goods.

4. Overview on the regulatory system

The current global maritime regulatory system has been criticized for not being effective enough to prevent accidents[22]. Based on interviews of Finnish maritime experts, we analysed the competence of the regulatory system and policy instruments in ensuring maritime safety in the Gulf of Finland, and considered how it could be improved (Viertola 2013). In addition, we analysed the topic of cost-effectiveness in relation to maritime safety policy instruments (Viertola and Storgård 2013). The interviewees found that the safety policy system as a whole is comprehensive and maintains maritime safety in the Baltic Sea relatively well, but that some individual policy instruments could be improved. They did not favour the implementation of new legally binding safety policy instruments. Instead, they recommended reanalysing and improving the effectiveness and cost-effectiveness of the existing policy instruments, and supporting shipping companies to voluntarily improve their safety performance.

4.1. Improving the effectiveness and cost-effectiveness of regulatory instruments

In particular, the interviewees questioned the appropriateness of some ship reporting and inspection procedures, because in many cases they are repetitive, or overlap with each other. Some parts of a vessel may be inspected several times by different authorities whereas other parts are relatively rarely inspected. This is not very cost-effective, and may burden the ship crews. In contrast, those maritime safety policy instruments that do not require continuous maintenance or assistance from authorities, such as instrument routeing[23], were considered functional and cost-effective in preventing groundings and collisions. It was emphasized that any policy instrument can be cost-effective only if implemented properly.

The results suggest addressing the repetitive tasks by investigating how authorities' procedures and information systems both at a national and an international level could be integrated, harmonized and automated, and how technological devices could facilitate this. For instance, by sharing vessel inspection information, authorities could focus their inspections on those vessel parts that have not been inspected lately. This would improve the cost-effectiveness of the inspection procedure from the viewpoint of both the shipping companies and authorities. It was assumed that improving the cost-effectiveness of policy instruments can even enhance stakeholders' compliance with them.

The study suggests analysing the effectiveness and cost-effectiveness of individual policy instruments in ensuring maritime safety, especially if new policy instruments are planned. It was acknowledged, though, that cost-effectiveness is a complicated issue to evaluate and

[22] Roe, M. 2009. Multi-level and polycentric governance: effective policymaking for shipping. Maritime Policy and Management: The flagship Journal of International Shipping and Port Research 36(1): 39-56.
[23] Using electronic information systems for planning and following predetermined routes in shipping.

such analyses include high uncertainties. Thus, methods should be developed to enable reliable analyses.

4.2. Voluntary initiatives by shipping companies to enhance safety

Information-based guidance (codes, guidelines, recommendations, voluntary education, certification systems, awards) was supposed to have larger potential in improving maritime safety, than regulatory policy instruments and economic incentives. It was assumed that voluntariness can encourage companies to develop their own safety innovations, and through this to pursue reputational and economic benefits. It could also lead to improved communication with authorities. It was acknowledged that maintaining a high safety level can be costly, but that it can also increase competitiveness.

The concepts of *corporate social responsibility* and *safety culture* were emphasized as ways to improve safety, both by reducing human errors and by improving commitment to regulations. Corporate social responsibility refers to the responsibility of enterprises for their impacts on society, and entails integrating social, environmental, ethical and human rights and consumer concerns into business operations[24]. Safety culture involves the shared values, attitudes, competencies and behaviour by a shipping company and its crew, in relation to safety performance.

It was assumed that the conventional command-and-control role of authorities is changing to a role that entails providing services to the private sector and encouraging it to better safety performance. Thus, it should be considered how shipping companies could be motivated to apply the principles and procedures of corporate social responsibility and improve their safety culture. Our study suggests, for instance, that involving the private sector in policy processes could increase shipping companies' and seafarers' commitment to regulations, and also their trust towards the regulatory system. This could further lead to an improved safety culture. Also risk-based monitoring, i.e. focusing monitoring and inspections on vessels and companies that have shown deficiencies in safety, could support companies to voluntarily develop their safety. By indicating positive safety performance, companies could reduce the frequency of inspections by themselves. This would save time and resources both in the private and public sector.

Further research is needed for identifying the best practices and measures for motivating companies to spontaneously develop their safety performance.

[24] European Commission, 2011. A renewed EU strategy 2011-14 for Corporate Social Responsibility. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM (2011) 681 final. Brussels 25.10.2011. [online] URL: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0681:FIN:EN:PDF

5. Approaches for controlling maritime risks

5.1. A tool for evaluating risk control options

One of the main aims of MIMIC was to produce a model-based, quantitative decision support tool that enables examining the cause-effect relationships related to oil accidents and their consequences, and evaluating the cost-effectiveness of different types of measures to reduce the risks of oil accidents. The developed tool is based on the Bayesian networks (BNs), a causal inference method resting on probability calculus. A BN consists of two elements: a) the graphic representation on the variables of interest and causal links in the analysed system and b) the numeric (probabilistic) dependencies between the variables. The approach allows for efficient inference in the light of current knowledge and uncertainties. The decision model produced in MIMIC can be used in exploring the effect of its variables on each other. The model is not supposed to give exact answers to management problems, but it can be used in making informed decisions and in increasing the understanding of the functioning of the system. The model is primarily developed to be used in research, and there exists no user interface for its wider use. Thus, it is recommended for policy makers to turn to the researchers if they are interested in using the model. Here we summarize the information that was integrated in the model, and describe how the costs for the risk control options were estimated.

In the decision support model, the updated probabilities for collision accidents[25], and the results of the grounding accident modelling (section 3.1.1.) and ship damage and oil leakage modelling (3.1.2.,3.1.3.), were analysed in relation to each other, and conditioned by the oil transportation scenarios (2.1.), sectors in the Gulf of Finland (Lehikoinen et al. 2013a), and seasons. Against this background information, the cost-effectiveness of the ENSI service, compulsory pilotage, and improving the crashworthiness of ships, was evaluated. Costs related to offshore and onshore oil combating were used as a reference point against which the implementation costs of the different risk control options were compared. It was assumed in the modelling that the predicted accident frequencies would materialize and that the Finnish oil combating capacity (including ten vessels) would be used in oil recovery.

Figure 7 is a simplified depiction of the Bayesian model. Below we describe how the costs of the risk control options were estimated. The methods of assessing the effects of the risk control options are described in sections 3.1.1. and 3.1.3.

[25] Hänninen, M., Kujala, P., Ylitalo, J., and Kuronen, J. 2012. Estimating the number of tanker collisions in the Gulf of Finland in 2015. International Journal of Marine Navigation and Safety of Sea Transportation 6(3): 367-373.

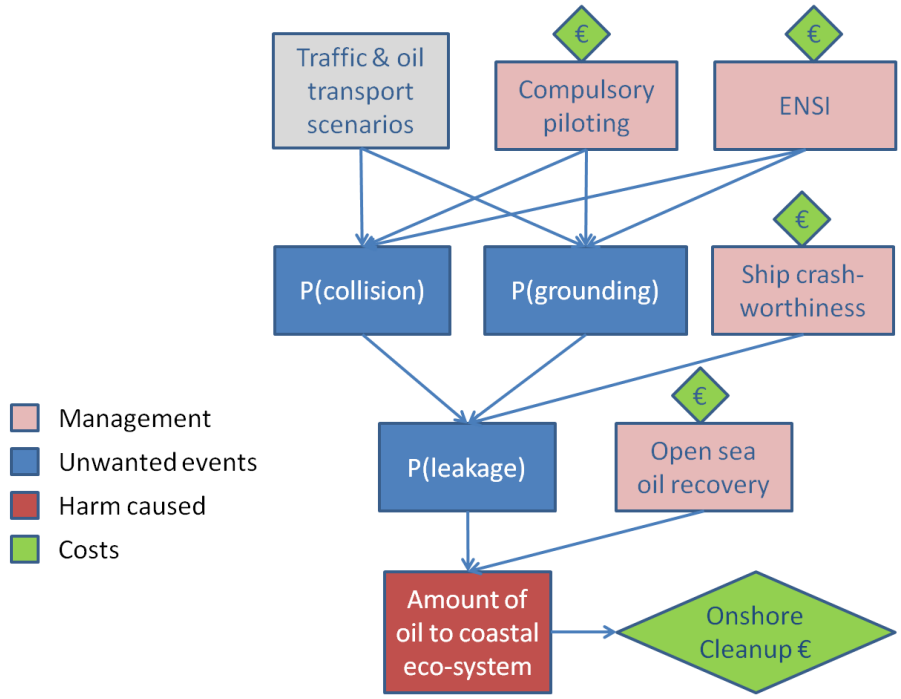

Figure 7. **A simplified figure of the causal relationships that were examined in the decision support model. The grey box includes future scenarios for oil transportation in the Gulf of Finland. The blue boxes include information related to accident risks, and the red box indicates the consequences of an oil accident. The pink boxes denote the risk control options (Lehikoinen et al., unpublished).**

5.1.1. Costs of the risk control options

Compulsory pilotage

As told in section 3.1.1., the current requirement of using a local pilot within the current pilotage area concerns tankers that carry dangerous cargo. Therefore the requirement of compulsory pilotage in that area would only target non-tankers without a pilot exemption certificate. We assumed the probability for a non-tanker using a local pilot to be 0.4 (no pilot exemption certificate), and for not using to be 0.6 (the vessel has a pilot exemption certificate). The costs for the current pilotage area were calculated based on pilotage tariffs from Finland and Estonia. Information was not available from Russia. Therefore costs for Russian waters were calculated based on Estonian tariffs. An average distance of piloting was defined as 19 nautical mile (nm) for Finnish pilotage area, 9 nm for Estonia, and 25 nm for Russia.

Outside the pilotage area, we used the ice advisor summer tariff (1600 €/d). The cost for a distance that exceeds one working day of an ice advisor (12 h) would then be 3200 € including the costs of two advisors (plus the piloting tariff within the pilotage area). This applies in 39 % of all cases in the Gulf of Finland. The costs of taking the pilot to the ship or costs related to road transport were not taken into account. It can be assumed that if

compulsory pilotage were implemented, the logistics related to the system would likely be developed.

The pilotage costs in relation to the estimated distribution of vessel sizes were calculated according to Table 4. For instance, if the share of the vessels belonging to the size class of 75 000…115000 dwt was 21 %, the tariffs of this size class were weighted by 21 % in the cost assessment as well. Table 5 shows the estimated numbers of tankers and other ships that were used in the cost assessment.

Table 4. Size distribution, as fractions of 1, of deadweight tonnage (1000 dwt) of vessels for the different scenarios, based on expert assessment (Lehikoinen et al., unpublished data). The current situation is based on statistical data related to port calls. Explanations for the scenarios, see section 2.1.

Scenario:	Size distribution of deadweight tonnage (as 1000 dwt) of vessels						
	0…10	*10…35*	*35…50*	*50…75*	*75…115*	*115..150*	*>150*
Current traffic (2010)	0.42	0.25	0.12	0.02	0.18	0.01	0
Slow development 2020	0.41	0.25	0.12	0.02	0.18	0.01	0.01
Aver. Development 2020	0.37	0.25	0.12	0.02	0.21	0.02	0.01
Strong development 2020	0.35	0.23	0.13	0.02	0.22	0.04	0.01
Stagnating 2030	0.34	0.24	0.12	0.02	0.21	0.05	0.02
Decarbonized 2030	0.25	0.23	0.14	0.01	0.22	0.13	0.02
Greener 2030	0.30	0.23	0.14	0.01	0.23	0.07	0.02

Table 5. The volume of maritime traffic in the Gulf of Finland in year 2010, and scenarios for the future: number of tankers and other ships (Lehikoinen et al., unpublished data). These estimations were used both in the accident modelling and in the cost analyses. The current situation is based on AIS-data of year 2010. The growth factors for the number of tankers for 2020 and 2030 are based on Brunila and Storgård (2012, tables 6.1, 6.2.), and for the other vessels on Kyster-Hansen et al. (2011)[26]. Explanations for the scenarios, see section 2.1.

Scenario:	Number of vessels	
	Tankers	*Other*
Current traffic (2010)	7000	33000
Slow development 2020	8000	40600
Average development 2020	8700	40600
Strong development 2020	9400	40600
Stagnating 2030	7700	43000
Decarbonized 2030	7900	43000
Greener 2030	8300	43000

[26] Kyster-Hansen, H., Sirén, J., Räsänen, J., Nyberg, J., McDaniel, J., Cardebring, P., Meyer-Rühle, O., Bruber, R., Rich, J., and Volek M. 2011. Report on Task 4: Strategic Network Analysis. Baltic Transport Outlook 2030. [online] URL: http://www.baltictransportoutlook.eu/files/BTO_R4RBF_005_Main%20Task%204%20Report%20-%20final.pdf

Table 6 shows the expected costs of compulsory pilotage (column: implemented) in million euros (M€), as compared to the current situation (column: not implemented) for the different traffic scenarios, and the additional costs of implementing compulsory pilotage in relation to not implementing.

Table 6. The expected annual value (million euros, M€/a) of pilotage in the current situation (Not Implemented) and if pilotage were compulsory for all ships sailing in the Gulf of Finland (Implemented). In addition, the table shows the remainder between these, i.e. the additional costs of compulsory pilotage in relation to the current situation (Lehikoinen et al., unpublished data). Explanations for the scenarios, see section 2.1.

Scenario:	Annual value of pilotage (M€/a)		
	Not implemented	*Implemented*	*Additional costs*
Current traffic (2010)	19	127	108
Slow development (2020)	23	154	131
Average development (2020)	24	157	133
Strong development (2020)	26	159	133
Stagnating (2030)	25	161	136
Decarbonized (2030)	26	164	138
Greener (2030)	25	162	137

If the requirement of compulsory pilotage within the whole Gulf of Finland were applied only to tankers and the current requirements to other ships, the implementation costs would be about 30 % of those presented in Table 4 (column: Implemented), i.e. between 35…47 M€ per year depending on the scenario. It was not examined in MIMIC how this would affect the likelihood of collision accidents, in which non-tankers have a considerable role. Thus this option was not included in the cost-effectiveness analysis. If compulsory pilotage only concerned tankers, the effect of this measure in decreasing oil spill accidents would not be as considerable as if it covered all ships sailing in the Gulf of Finland.

Improving the crashworthiness of ships

The cost analysis related to improving the crashworthiness of ships assumes that only scrapped vessels would be replaced by new ships with improved crashworthiness, and that the crashworthiness of the older ships that are still in service would not be improved. The calculation is based on age distribution of the current tankers and the share of tankers that will likely be scrapped by 2020 and 2030. The estimation related to the number of ships takes into account that the same ships visit the Gulf of Finland several times per year. According to the AIS-data, about 3500 ship visits in the Gulf of Finland during the year 2010 were made by 450 tankers. The same ratio was applied for the scenario-specific numbers of tankers in the area (Table 5). The assumption of the age of the ships at the moment of scrapping is based on a probability distribution in which the highest probability is between 20…30 years and the expected value between 25…30 years (Figure 8). Some tankers can be scrapped earlier due e.g. to accidents. According to the AIS-data, there are currently small

tankers that are even older than 40 years. The probability distribution is based on expert interviews and literature[27].

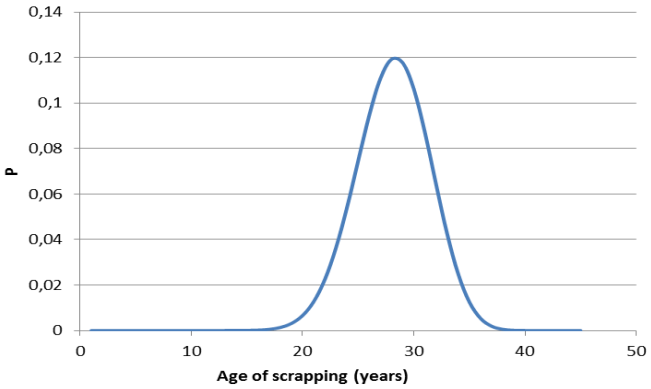

Figure 8. A probability distribution for the scrapping age of tankers. The Y-axis shows probability and the X-axis the scrapping age in years (Lehikoinen et al., unpublished data).

The coefficients that were used for estimating the costs for improved crashworthiness were obtained from the Technical University of Tallinn. In relation to standard tankers (initial design), for which the coefficient was 1, the coefficient for the first crashworthiness option (RCO1) was 1.025, and for the other options (RCO2, RCO3, and RCO4) it was 1.05, 1.15, and 1.25, respectively. The energy absorption capacity of the initial design was 1, and it corresponds to typical crashworthiness of existing ships. For RCO 1 to RCO 4 the energy absorption capacity with respect to the initial design were 1.5, 2, 3 and 4, respectively. The acquisition costs of new tankers were based on price examples found from sources of the United Nations (UNCTAD)[28]. A linear trend line was fitted for these example prices given the tanker's size (the median of the provided size classes was used), and the equation gained through the procedure (y=0.0003x+20.966) was used to extrapolate prices for the size classes used in the model (Table 7). The final costs per year consist of the number of renewed ships and their sizes by the year of the scenario, multiplied by their price depending on their skeletal structure, and divided by the expected useful life of the vessel. The number and size distribution of ships in different scenarios are the same as in the analysis above (section 2.1., Table 4, Table 5). The costs of standard ship design and the four alternatives to improve the crashworthiness (RCO1, RCO2, RCO3, RCO4) in relation to the scenarios are shown in Table 8.

[27] During the period 2000-2005 the average age of scrapped oil tankers ranged from 26.9 to 31.5 years. UNCTAD 2006. Review of maritime transport, 2006. Report by the UNCTAD secretariat. United Nations Conference on trade and development, Geneva. UNCTAD/RMT/2006. United Nations Publication. Sales 92-1-112699-1. [online] URL: http://unctad.org/en/docs/rmt2006_en.pdf.International.

[28] Tanker prices in 2005: 32 000 dwt … 45 000 dwt = 43 MUS$ (= 32 M€), 80 000 dwt … 105 000 dwt = 58 MUS$ (= 43 M€), 250 000 dwt … 280 00 dwt =420 MUS$ (= 89 M€).
UNCTAD 2006. Review of maritime transport, 2006. Report by the UNCTAD secretariat. United Nations Conference on trade and development, Geneva. UNCTAD/RMT/2006. United Nations Publication. Sales 92-1-112699-1. [online] URL: http://unctad.org/en/docs/rmt2006_en.pdf.International.

Table 7. The cost estimates for new tankers, given the vessel's size used for the initial design option (Lehikoinen et al., unpublished data).

Tanker size (dwt)	Cost (M€)
< 10 000	21-24
10 000…35 000	24-32
35 000…50 000	32-36
50 000…75 000	36-44
75 000…115 000	44-56
115 000…150 000	56-66
> 150 000	>66

Table 8. The costs (M€) of standard ship design and four alternatives in which crashworthiness is improved (Lehikoinen et al., unpublished data). Explanations for the scenarios, see section 2.1.

Scenario:	Cost of ship design (M€)				
	Initial design	*RCO1*	*RCO2*	*RCO3*	*RCO4*
Current traffic (2010)	186	189	192	203	209
Slow development 2020	441	448	457	481	496
Aver. Development 2020	515	524	534	563	583
Strong development 2020	594	604	616	650	673
Stagnating 2030	637	648	660	696	721
Decarbonized 2030	668	680	694	732	760
Greener 2030	705	718	732	773	802

Enhanced Navigation Support Information system (ENSI)

The ENSI system would be built to complement the VTS service and operated as part of it. The estimated cost for implementing the system is 1 M€. In the model this was divided into ten years of usage. The cost assessment did not, however, take into account the maintenance costs of the VTS service per year, and the share of the ENSI system in these costs. Neither were we able to consider if the ENSI system would increase the number of people employed in the VTS centre and the related costs. In any case, it is evident that the costs of the ENSI system are much smaller than those of compulsory pilotage and improving the crashworthiness of ships. The analysis regarding the cost-effectiveness of ENSI can be updated in the future, when new information on the costs is available.

Theoretical yearly costs of oil recovery

The costs of the risk control options were analysed in relation to theoretical costs of oil recovery, in order to compare which of them would most decrease the yearly oil recovery costs. The oil recovery costs consist of 1) real yearly maintenance costs of oil combating equipment (Montewka et al. 2013b) and 2) theoretical yearly oil recovery costs in relation to

oil accident risk. The oil recovery costs for one accident are based on the models of Lehikoinen et al. (2013a; oil recovery efficiency and costs offshore) and Montewka et al. (2013b; onshore cleaning costs given the amount of oil that was not recovered offshore), presented below (section 5.2.). The total theoretical costs are based on estimated frequency of accidents. For instance, if a model predicts that an oil accident occurs per every 25 years, the oil recovery costs are divided by 25. It is acknowledged, that in reality accidents occur randomly, independent of each other. Still, a theoretical value of this kind can be useful as it enables comparing the relative risk levels between different traffic and management scenarios. Table 9 shows the expected theoretical costs of oil recovery per year for each scenario, including scenarios of implementing the different risk control options.

Table 9. **Theoretical annual costs of oil combating (expected value M€/a) for each scenario (Lehikoinen et al., unpublished data). Column "No effort" indicates the oil combating costs when none of the risk control options is implemented. The columns "CP" (compulsory pilotage), "RCO4" (the strongest structural strength of tankers), and "ENSI" indicate oil combating costs in the case that the mentioned risk control option were implemented. The column "Max effort" indicates a situation in which all of the risk control options mentioned were implemented. Explanations for the scenarios, see section 2.1.**

Scenario:	Annual costs of oil combating (M€/a)				
	No effort	*CP*	*RCO 4*	*ENSI*	*Max effort*
Current traffic (2010)	11.5	9.2	5.8	10.3	4.8
Slow development 2020	10.9	8.9	5.5	9.8	4.7
Aver. Development 2020	12.9	10.3	5.9	11.5	5.0
Strong development 2020	14.4	11.3	6.1	12.7	5.1
Stagnating 2030	12.6	10.1	5.5	11.3	4.8
Decarbonized 2030	16.9	13.1	5.9	14.8	5.0
Greener 2030	14.8	11.7	5.9	13.1	5.0

5.1.2. Decision support model: results and discussion

The results based on the above described assumptions indicate that ENSI would be the most cost-effective measure to control the oil accident risks (Table 10). The implementation of this option would cause relatively low yearly costs (0.1 M€). Still it would have a significant effect (-18…20%) in reducing the expected oil accident frequency, and it would reduce the theoretical oil recovery costs by about 10 %. Thus, from a purely monetary perspective, the model suggests that the system should be managed by implementing the ENSI service, and using the existing oil recovery resources in the case of an accident.

Compulsory piloting and solutions for increasing the crashworthiness of the ships would have even more remarkable effects in decreasing the probability of an oil accident (-33…35 % and -30…60 % respectively) and the consequent oil recovery costs (-17…20 % and -27…63 % respectively), but they are quite expensive options (Table 10). Thus, in this context, they can hardly be characterized as cost-effective.

Table 10. Summary of the results of the decision support model. The second column shows annual costs of the risk control options. The third column indicates how much the options would decrease the expected oil accident frequency, and the right hand column demonstrates the decrease in the yearly oil recovery costs if the different risk control options were implemented (Lehikoinen et al., unpublished data).

Risk Control Option	Evaluated additional costs (M€/a)	Decrease in the expected oil accident frequency	Decrease in the yearly (theoretical) oil recovery costs
Compulsory pilotage	131…138	-33…35%	-17…20%
ENSI	0.1	-18…20%	-9…11%
Crashworthiness 1	7…13	-30…34%	-27…35%
Crashworthiness 2	16…27	-41…48%	-39…52%
Crashworthiness 3	40…68	-43…50%	-42…55%
Crashworthiness 4	55…97	-50…60%	-48…63%

It must be taken into account, however, that the model did not cover the storage, transportation, and disposal costs of the oiled waste. According to a previous study[29], these costs can be multifold compared to the costs of collecting oil from the sea and shore.

In addition, the model evaluated environmental risk only through the amount of oil ending up to the ecosystem and the oil recovery costs. The oiled environment was not valuated in monetary terms. In MIMIC, development work for defining a monetary value for the oiled environment was done and progression made, but the timeframe of the project did not allow incorporating environmental values in the decision support model.

There are diverse approaches to valuate the ecosystem. One option would be to integrate the results of the modelling related to the length of the oiled coastline (section 3.2.) in the decision support model, and then define a value per length unit for the shore. Other options are based on, *inter alia*, a globally estimated value of ecosystem services provided by the coastal areas, and people's willingness to pay for clean and healthy, un-oiled coast[30]. Still, several questions will remain unanswered. For example, what is the value of the existence of threatened species or unique habitats? In MIMIC we had the possibility to only scratch the surface of the field of environmental valuation. The decision support model, however, demonstrated how remarkable a role valuation plays in risk analysis. We see this as one of the areas that should be paid more attention to in the future.

[29] Hyytiäinen, K., Ahlvik, L., Ahtiainen, H., Artell, J., Dahlbo, K., Ekholm, P., Fleming-Lehtinen, V., Heiskanen, A.-S., Helle, I., Inkala, A., Juntunen, T., Kuikka, S., Kulmala, S., Lankia, T., Lehtiniemi, M., Lehtoranta, J. Lignell, R., Luoma, E., Maar, M., Pitkänen, H., and Tuomi L. 2012. Itämeren suojelun taloudelliset hyödyt ja kustannukset. In: Hyytiäinen K. & Ollikainen M. (eds.), Taloudellinen näkökulma Itämeren suojeluun (Economic Aspects of Baltic Sea Protection), pp. 11-100. Ympäristöministeriön raportteja 22/2012, Helsinki. In Finnish, abstract in English

[30] Juntunen T. 2013. Steps towards comprehensive Bayesian decision analysis in fisheries and environmental management. Academic dissertation. University of Helsinki, Faculty of Biological and Environmental Sciences, Department of Environmental Sciences. [online] URL: https://helda.helsinki.fi/handle/10138/41888

Likely, adding costs related to the management of oiled waste and environmental values in the model would change the results. If a major oil spill occurred in the Gulf of Finland, the total costs, including those related to the contaminated environment, could be so high, that implementing all three risk control options (ENSI, compulsory pilotage, improving the crashworthiness) were reasonable. But what is the acceptable risk level, and what are the tolerable costs to control it? Who should pay for decreasing the risks of oil accidents: the public or the private sector? These questions should be discussed and decided by the society.

5.2. Models for analysing the efficiency and costs of oil recovery

A Bayesian decision support model was developed also for examining the recovery efficiency and optimal disposition of the Finnish oil combating vessels in the Gulf of Finland (GoF) (Figure 9, Lehikoinen et al., 2013a). Four alternative home harbours (Kotka, Helsinki, Kirkkonummi and Turku), five accident points and ten oil combating vessels were included in the model, the purpose of which was to find out the optimal disposition policy for the vessels for maximizing the recovery efficiency. Comparison between the current dispositioning and the one suggested by the model is presented in table 11. Based on the results, the current placement of the oil combating vessels is not optimal. However, the value of the applied utility function is very close in the case of current locations, as compared with the optimal one. Thus there is no obvious need to change the home harbours if some other aspects support the current policy. This is due to the fact that the disposition has a minor effect on the estimated recovery efficiency of the oil combating fleet, while the environmental and accident conditions have the biggest impact. The process seems to be strongly controlled by certain random factors independent of human action, such as wave height and stranding time of the oil. Therefore, the success of oil combating is rather uncertain. This highlights the importance of developing activities that aim at preventing accidents.

In addition to the disposition optimization, the developed model is a valuable tool for testing different “what-if” scenarios, for example what is the likely oil recovery efficiency with fixed leak size, oil type and weather conditions. The model then calculates probability distribution for the oil recovery efficiency based on the settings made by the user, still taking into account the prevailing uncertainty arising from those variables that are not locked to any particular state. The model code (originally created with the commercial BN software Hugin researcher 7.6) is freely available in the internet:
http://www.helsinki.fi/science/fem/files/oilrecovery.oobn .

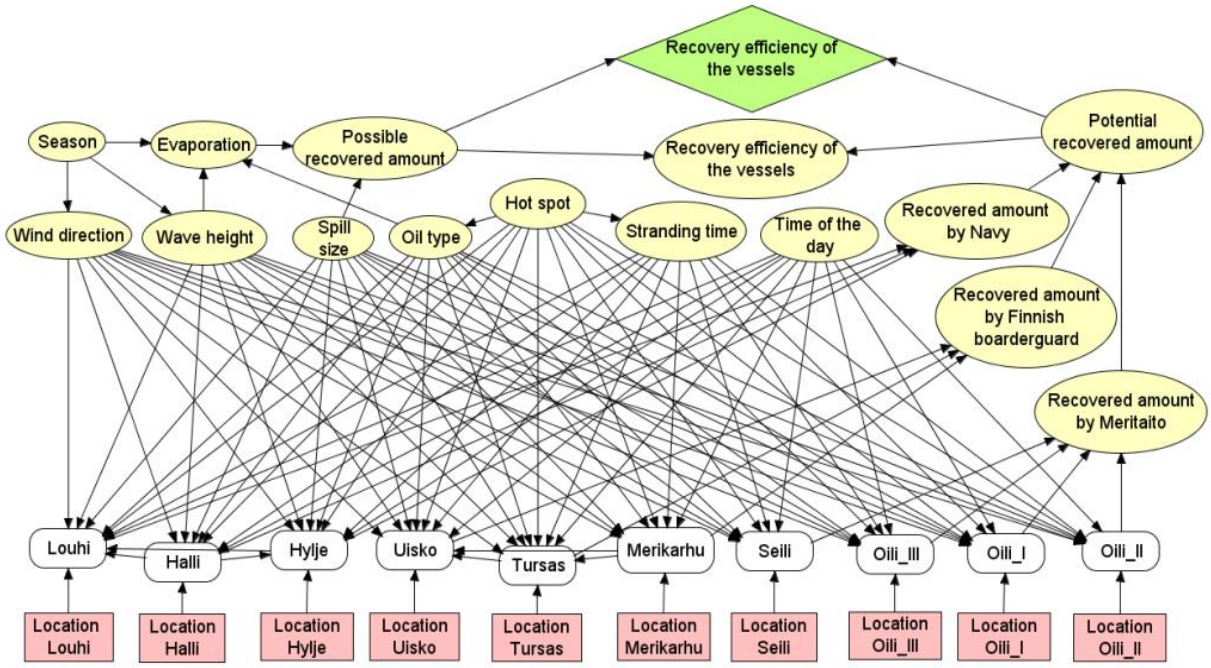

Figure 9. The graphic representation of the Bayesian influence diagram model for evaluating and optimizing the open sea oil recovery efficiency by ten Finnish combating vessels (Lehikoinen et al. 2013a).

Table 11. Current and optimized home harbours of the analysed open sea oil combating vessels. "EU" (Expected Utility) depicts the expected recovery efficiency when the magnitude of the accident and the weather conditions during the combating are uncertain (different alternative scenarios weighted by their realization probabilities) (Lehikoinen et al. 2013a).

Vessel name	Current harbour	Optimization result
Louhi	Kirkkonummi	Kotka
Halli	Turku	Kotka
Hylje	Kirkkonummi	Kotka
Merikarhu	Helsinki	Kotka
Tursas	Turku	Kotka
Uisko	Turku	Kotka
Seili	Helsinki	Helsinki
Oili I	Helsinki	Helsinki
Oili II	Turku	Helsinki
Oili III	Kotka	Helsinki
EU	**76.64**	**77.20**

By utilizing the above described model by Lehikoinen et al. (2013a), expert knowledge, available data, and literature, a separate Bayesian model was developed (Montewka et al. 2013b) for forecasting the clean-up costs of oil spills. The model takes into account the effects of changes in the oil combating fleet and the location of the oil spill. The model

(Figure 10) can thus contribute to the optimization of a cost-effective oil-combating fleet. The characteristics of the model makes it suited for a particular sea area like the Gulf of Finland which is very sensitive and heavily trafficked by oil tankers.

The model allows the user to define the location of the oil spill, its size, type of oil, season (winter is excluded), and the number and type of anticipated oil-combating ships. As its output, the model delivers the total costs of the clean-up operations, which can be divided into offshore and onshore costs.

The model code (originally created with the commercial BN software Hugin researcher 7.8) is freely available in the internet: http://dx.doi.org/10.1594/PANGAEA.816576.

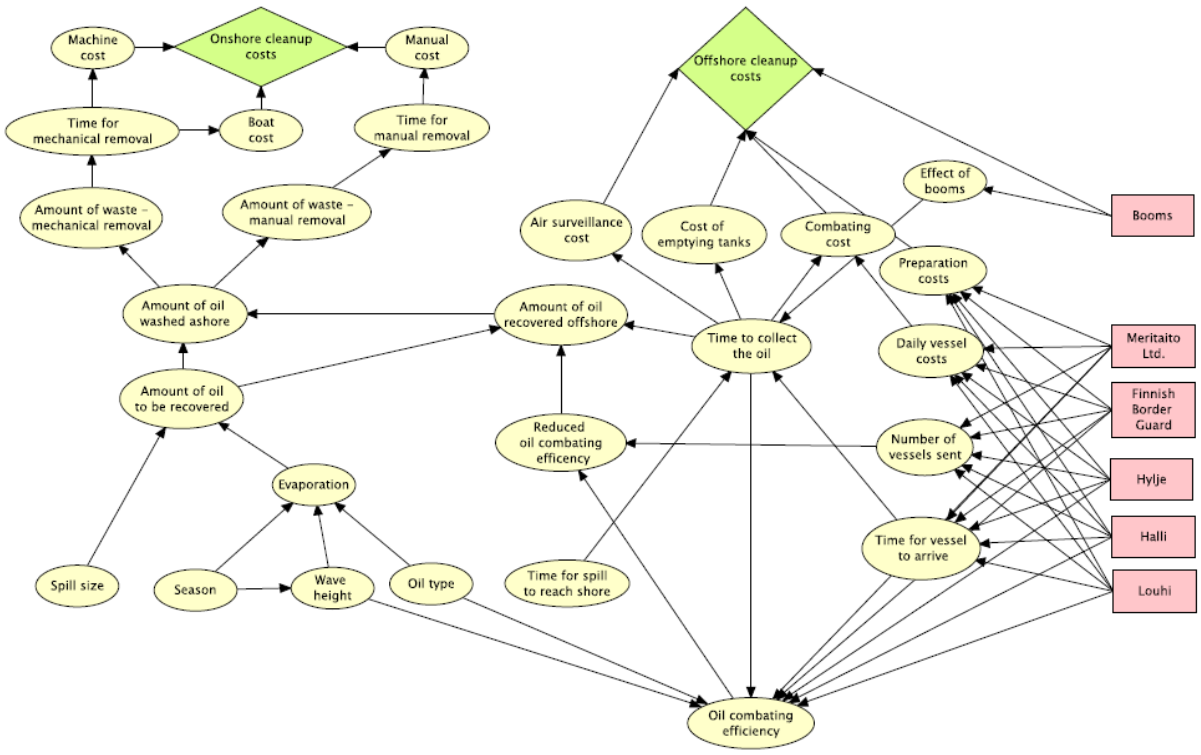

Figure 10. The model for assessing the costs of oil combating for a defined accident type (Montewka et al. 2013b).

5.3. Situation awareness tools

MIMIC developed tools for dynamic situation awareness building for oil spill response operations. Situation awareness implies that the state of the environment is perceived, that the situation as a whole is comprehended, and that it is projected into the near future, in order to form a basis for decision making[31]. The integrated Seatrack Web and SmartResponse Web applications enable up-to-date assessment of the drift of oil in the sea and of

[31] Endsley M.R. 1995. Toward a theory of situation awareness in dynamic systems. Human Factors 37(1): 32-64.

environmental values at risk, and thus facilitate decision making regarding effective oil combating activities.

5.3.1. Seatrack Web

Seatrack Web is the official oil drift forecasting system used by the Baltic Marine Environment Protection Commission (HELCOM). Based on information of the amount and type of oil, duration of the oil spill, and the location of the accident, the tool allows making forecasts for areas affected by oil. Thus, it assists in building scenarios and assessing risks.

Within MIMIC, the Seatrack Web was developed further to better assist the response agencies in real oil spill situations. The system was augmented by adding the possibility of analysing the use of booms in the forecast, and by displaying multiple forecasts based on different weather and ocean models in the same chart. A new user friendly web interface was developed based on latest web techniques, and the first operational version of this is available. The new web interface also provides a possibility to start the oil drift calculation from a predefined polygon. This makes it possible e.g. to make a forecast from an oil spill detected by a satellite.

Seatrack Web has a backtracking function that makes it possible to track possible polluters by using the oil drift pattern and AIS to see where these intercept. Within the MIMIC project, the search function was improved for simpler handling of AIS information.

The web interface has been presented for the Swedish Coastguard, which is the national authority for oil combating in Sweden, and the Swedish Civil Contingency Agency. To fully move to the new web interface from the present operational interface, some more user cases need to be implemented.

5.3.2. SmartResponse Web

The SmartResponse Web enhances the potential provided by the Seatrack Web for dynamic situation awareness building, by adding a dimension related to the properties and characteristics of the sea environment. Its performance is based on Web Map Services (WMS) with Geographic Information System (GIS) map layers. The Web Map Services are grouped according to the Environmental Sensitivity Index (ESI) framework, and include the following map layers (Aps et al. 2014):

1. Shoreline classification, ranked according to a scale relating to sensitivity, natural persistence of oil, and ease of clean-up.

2. Biological resources that are sensitive to oil spills, include oil-sensitive plants, animals or habitats, or are used by oil-sensitive species.

3. Human-use resources, i.e. areas with increased sensitivity and value because of their use, such as beaches, parks and marine protected areas of different level, and historic/cultural sites.

The SmartResponse Web enables working with any spatial data and maps, and thus it is of universal use regarding the geographical area concerned. The application is seen as complementary to most of the national or regional accidental oil spill response systems, such as BORIS in Finland.

The SmartResponse Web application includes also a model for assessing ship damage and leakage in a collision or grounding accident, based on simulations by the accidental damage assessment model (ADAM) (section 3.1.3.). Thus, it enables an online support to decision making in emergency situations. In addition, the tool has a section related to maritime security as referred to in section 3.3. It contains the relevant EU legislation in four languages, the map layers of the oil terminals, and the Estonian vessel anchorage places, including those for dangerous goods.

The integrated Seatrack Web / SmartResponse Web system can be used to combine information related to the development of an oil spill and information on environmental sensitivity of the Baltic Sea coastal waters. The system enables the identification and assessment of environmental risks as a continuous cyclic process with the aim to support decision on how to reduce or eliminate the risks. A new feature is that the Seatrack Web simulation results are imported into the SmartResponse Web and can be used to analyse if the oil is threatening sensitive resources.

The integrated Seatrack Web / SmartResponse Web system and accidental damage assessment model (ADAM) is used by Estonian oil spill response authorities for contingency planning, training and in emergency situations.

In MIMIC, the drifting of oil to the Estonian shoreline was assessed based on 98 oil spill simulations for the ice-free period from spring to winter 2012. According to the results, the mean area (km^2) impacted by oil was lower in the spring than in the winter (December 2012). This indicates that the rough weather conditions in the winter (wind, waves and currents) contribute to a wider spreading of the spilled oil.

6. A regional governance framework for managing risks

The MIMIC project stressed the importance of adopting a proactive approach for managing maritime safety and security, and developed related tools. Proactivity entails that risks are identified and analysed, and that appropriate measures are taken to reduce them. Making the best use of risk analyses and their results, and developing them further, however, requires systematic discussion by a wide variety of stakeholders.

The results of MIMIC (section 4.2.) indicate that involving stakeholders in policy processes has potential to increase their commitment to regulations and their trust towards the regulatory system, which further can improve safety culture. Stakeholder participation in governance is called for in the Baltic Sea Action Plan[32] of the HELCOM, and in the EU Strategy for the Baltic Sea Region[33] (EUSBSR). It is also written into the principles of European Governance[34] (CEC 2002).

We propose an international risk governance framework involving stakeholders, to be established in the Gulf of Finland, for analysing, managing and communicating maritime safety risks at the regional level. The proposal is based on the theoretical risk governance model that was introduced by the International Risk Governance Council and developed by Aven and Renn[35], and practical examples from the maritime sector, fisheries management and nuclear safety management.

We reviewed the risk governance procedures that were realized in Alaska after the grounding accident of the oil tanker *Exxon Valdez* in the Prince William Sound, in 1989[36]. A steering committee representing all local stakeholders was formed for agreeing on objectives and scope for risk management, and for building trust and common understanding of risks related to oil transportation among all parties. The work of the stakeholder committee in combination with risk assessment conducted by hired consultants produced effective measures to reduce the risks of oil spills in the area, accepted by all stakeholders.

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[32] HELCOM Baltic Sea Action Plan 2007. HELCOM Ministerial Meeting. Krakow, Poland, 15 November 2007. online [URL]; http://helcom.fi/Documents/Baltic%20sea%20action%20plan/BSAP_Final.pdf.

[33] CEC 2009. Commission of the European Communities (CEC) 2009. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions concerning the European Union Strategy for the Baltic Sea Region. COM(2009) 248 final. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0248:FIN:EN:PDF

[34] CEC 2002. Commission of the European communities (CEC) 2002. Communication from the Commission. Towards a reinforced culture of consultation and dialogue – general principles and minimum standards for consultation of interested parties by the commission. COM (2002) 704 final, Brussels. online [URL]: http://ec.europa.eu/governance/docs/comm_standards_en.pdf.

[35] International Risk Governance Council (IRGC). 2005. Risk governance: Towards an integrative approach. White Paper No. 1. O. Renn with an annex by P. Graham. Geneva; Aven T and Renn O. 2010. Risk management and governance. Risk, Governance and Society 16. Springer-Verlag, Berlin, Heidelberg.

[36] Merrick, J.R.W., van Dorp, J.R., Mazzuchi, T., Harrald, J.R., Spahn, J.E., and Grabowski, M. 2002. The Prince William Sound Risk Assessment. Interfaces 32:25-40.

Procedures related to defining the total allowable catches (TAC) for commercially important fish stocks in the EU provided an example of systematic annually conducted risk analyses, structured information flows between institutions, and an explicit role of stakeholders. In 2004 the European Council decided to establish six regional advisory councils to help meet the management goals through enhanced communication between different stakeholder groups[37]. Nuclear power industry is an example of advanced risk assessment, management and review practices with an acknowledged role of communication. The concept of 'safety culture' was first developed in the nuclear industry, to instill an organisational culture that fosters a systematic approach to safety[38].

An effective maritime risk governance framework for the Gulf of Finland would require 1) the establishment and active operation of a permanent risk committee representing shipping companies, seafarers, authorities, pilots, oil industry, environmental non-governmental organisations, local citizens, scientists and other relevant stakeholders; 2) the establishment of an internet-based risk database accepting reports related to potentially unsafe acts or conditions from a wide variety of users: shipping companies, seafarers, pilots, the VTS centre, the AIS operators, inspectors, authorities, boaters, local citizens etc., and 3) the adoption of an active role by HELCOM or another international body in maintaining the risk database, monitoring the incoming risk reports, and carrying out regular assessment of maritime risks in the Gulf of Finland. The framework would be based on active communication within the risk committee and between the risk committee and the body responsible for the risk analyses, and regular reporting and informing relevant actors and society about the risks.

We see a proactive maritime risk governance process in the Gulf of Finland as a self-updating system, which includes the following steps:

1. Making a summary of the reports recorded in the risk database and identifying potential risk factors, by the maintainer of the risk database/risk analysts.

2. Discussing the findings and defining the risks, and targets for safety governance, by the stakeholder committee.

3. Conducting a scientific risk assessment by risk analysts, based on up-to-date information from the risk database and other potential sources, and the views of the stakeholder committee. The risk assessment answers the following questions:

[37] Commission of European Communities (CEC) 2004. Council decision of 19 July 2004 establishing Regional Advisory Councils under the Common Fisheries Policy. 2004/585/EC. Official Journal of the European Union. L 256/17.

[38] International Atomic Energy Agency (IAEA) 2001. Risk management: A tool for improving nuclear power plant performance. IAEA-TECDOC-1209, Vienna.

- What technical, environmental and human factors can cause shipping accidents?
- What is the likelihood of accidents?
- What kind of consequences can the accidents lead to?
- Where are the most accident-risky areas?
- What could be the most cost-effective ways or measures to control the risks?

The risk assessment also summarizes trends in the safety performance of shipping, by using agreed indicators in relation to agreed targets. A review by an independent reviewer ensures the quality and adequacy of the risk appraisal.

4. A discussion on the acceptability and tolerability of the risks and potential ways to control them, by the stakeholder committee. Documentation of different views.

5. Releasing a public report including recommendations for risk management, targeted to all stakeholder groups, decision makers of the involved states, the EU, and the IMO. Anonymity related to all analysed and documented information is a priority.

We admit that realizing this kind of a risk governance framework is challenging, and the model may not be applicable as such. We, however, hope that the proposal will initiate discussion related to the development of proactive regionally focused risk governance practices in the Gulf of Finland.

7. Synthesis of MIMIC results

It is expected that the volume of oil transportation in the Gulf of Finland will increase in the future. How much it will increase is, however, uncertain as it depends on the market and policies in Russia, in the EU, and at the global level. The globalization of the world has brought about international ship crews, which has set new challenges for ensuring safety.

It is essential to understand risks behind maritime accidents. It was found out in MIMIC, that inadequate communication is one of the most significant contributing factors in grounding accidents, which is the major accident type in the studied area. Other important risk factors are inadequate bridge and ship resource management, violation of good seamanship practices, inadequate organizational support, and issues related to the waterways, such as poor geometry and markings.

Also security related issues have a link to safety. An attack against a vessel by terrorists or pirates can in principle lead to grounding, collision, sinking, fire or explosion. An attack targeting a tanker might also have dramatic consequences to the sea environment. It was, however, concluded in MIMIC that piracy or terrorism are not very likely in the Baltic Sea. More probable are smuggling of drugs, human trafficking, illegal fishing, illegal discharges, theft, and vandalism. Surveillance was regarded one of the most effective controlling measures for security threats.

In MIMIC, the probabilities for grounding accidents in the Gulf of Finland were assessed, and the most risky spots were identified. Damage and oil leakage were estimated for groundings and collisions and it was found out that with the current structural configurations of ships, a large number of possible collision scenarios would lead to an oil spill. Similarly in grounding, the kinetic energy of the ship is sufficient to cause severe bottom damage and oil spill, depending on the bottom topology. A novel probabilistic approach was applied, and software systems developed, for the purpose of estimating the extent of oiled shoreline in different conditions.

Based on the information gained from these analyses, we evaluated the cost-effectiveness of compulsory pilotage, the ENSI system, and the improving of the crashworthiness of ships, in reducing the risks of oil accidents in the Gulf of Finland. In addition, we developed a related decision support tool. The results indicate that ENSI would be the most cost-effective measure to control oil accident risks. Compulsory piloting and the solutions for increasing the crashworthiness of the ships would have remarkable effects in decreasing the probability of an oil accident, but they are quite expensive options. It must, however, be noted that costs related to the management of oiled waste were not included in the analysis. Neither was the oiled ecosystem valuated in monetary terms. Including these analyses would likely change the results.

Decision support tools were also developed for optimizing the use of the oil-combating fleet in Finland. The model built by Lehikoinen et al. (2013a) enables examining the recovery efficiency and optimal disposition of the oil combating vessels. The model built by Montewka et al (2013b) can be used for forecasting clean-up costs of oil spills.

One of the important outputs of MIMIC was the further improvement of the oil drift simulation tool Seatrack Web, and the development of SmartResponse Web, for environmental risk assessment and informing the oil recovery activity. Seatrack Web allows forecasting the drift of oil and analysing e.g. the use of booms in a real oil spill situation. SmartResponse Web includes map layers that summarise resources that are at risk if an oil spill occurs (shoreline sensitivity, biological resources, and resources used by humans). Thus, the coupled SeatrackWeb/SmartResponseWeb/ADAM system enables dynamic identification and assessment of environmental risks, and deciding ways to reduce or eliminate the risks. The SmartResponse Web also has a section related to maritime security.

Based on interviews of Finnish maritime experts, MIMIC analysed the competence of the current regulatory system and policy instruments in ensuring maritime safety in the Gulf of Finland. According to the interviewees, the regulatory system maintains maritime safety relatively well, but the effectiveness and cost-effectiveness of some individual policy instruments could be improved. In addition, the results suggest supporting shipping companies to voluntarily improve their safety performance. Involving the private sector in policy processes was seen as a way to develop safety culture.

The MIMIC project stressed the importance of adopting a proactive approach for managing maritime safety and security. This means that risks are identified and analysed, and that appropriate measures are taken to reduce them. MIMIC developed proactive risk assessment approaches for managing maritime risks. Making the best use of the analyses and their results, and developing them further would, however, require systematic discussion by a wide variety of stakeholders.

We propose an international risk governance framework involving stakeholders, for managing maritime safety risks in the Gulf of Finland. Risk assessment and efficient communication between stakeholders would form the core of the framework. It would require establishing a stakeholder committee, a risk database, and the adoption of an active role by HELCOM or some other international body for maintaining and organizing the risk database, monitoring the incoming risk reports, and carrying out regular assessment of maritime risks in the Gulf of Finland.

We admit that realizing this kind of a risk governance framework is challenging, and that the model might not be applicable as such. We, however, hope that the proposal will initiate discussion related to the establishment of a regional risk governance framework in the Gulf of Finland. We believe that a regional governance framework based on a proactive approach

to risks could produce more effective tools for managing safety than the current reactive top-down approach. In addition, participatory governance has potential to enhance safety culture in shipping companies and among seafarers. The framework would provide an arena for discussing environmental values, the tolerability of risks and the costs of reducing them, and for the systematic development and use of decision support tools.

Although the risk analysis conducted in MIMIC focused on the Gulf of Finland, the methods and findings of the project may be useful in other parts of the Baltic Sea as well, such as the sensitive and shallow areas of the Belts.

8. Recommendations for policy makers

Based on the results of MIMIC, we recommend the following procedures to improve maritime safety and to minimize risks related to oil spills in the Gulf of Finland:

1) Harmonisation of authorities' procedures, automation of information flows, and improvement of cooperation between authorities both within the Baltic Sea states and between them. This concerns especially policy instruments that are repetitive or overlap with other similar tasks, such as ship reporting and vessel inspections.

2) Supporting shipping companies to voluntarily improve their safety culture and to adopt the principles and processes of corporate social responsibility.

3) Involving stakeholders in policy making. This might improve safety culture by increasing shipping companies' and seafarers' commitment to regulations, and their trust towards the regulatory system.

4) Applying risk-based monitoring, i.e. focusing monitoring and inspections on vessels and companies that have shown deficiencies in safety. This can support companies to voluntarily develop their safety.

5) Establishing a regional risk governance framework involving stakeholders. Such a framework would enable addressing risks at the regional level. The framework would involve identifying, assessing, evaluating and communicating risks, and it would aim at giving recommendations on risk management.

6) Cooperation between actors both at the national and international level is recommended in managing security threats. Surveillance is regarded one of the most effective controlling measures.

7) Evaluating the effectiveness and cost-effectiveness of policy instruments is recommended, especially regarding new measures.

8) The MIMIC decision analysis supports the implementation of the ENSI service, in addition to the existing oil recovery resources.

9) Establishing a required minimum level of crashworthiness for the ships sailing in the Baltic Sea or establishing guidelines how shipowners and operators could benefit from improved crashworthiness. A similar approach has been applied for inland shipping within Europe, where the ships with increased crashworthiness are allowed to carry larger cargo tanks.

10) Utilizing the potential of the situation awareness building systems Seatrack Web, SmartResponse Web and BORIS, in cases of oil accidents. We also recommend

investing in extending the systems to wider sea areas and promoting international cooperation.

11) Clear communication and precise terminology are prerequisites for safe maritime traffic. Thus, multiculturalism and difficulties in communication should be taken into account in maritime operations. The understanding of cultural differences should be enhanced and intercultural communication and cooperation improved.

12) The acceptable risk level, and the tolerable costs to control it, should be discussed and defined by the society. It should also be discussed, who should pay for decreasing the risks of oil accidents, the public or the private sector. The stakeholder committee proposed in this report (section 6) would promote this.

9. Recommendations for future research

We conclude with some identified needs for future research.

1) Updating scenarios related to the volumes of maritime traffic and oil transportation for the future.

2) Identifying best practices and measures that can motivate companies to develop their safety culture and adopt the principles of corporate social responsibility, and overall to initiate voluntary actions to improve their safety performance.

3) Developing methods for the valuation of the environment and other non-monetary issues, such as the existence of threatened species or unique habitats. Such valuations are needed in risk analyses.

4) Analysing the significance of the complexity of waterways in grounding accidents. This would help in designing better and safer waterways.

5) A more systematic analysis of incidents and near misses is needed. This could enhance the usability of the incident and near miss reports in maritime safety studies.

6) A systematic study of the topic of cost-effectiveness and a review on potential methods is recommended. In MIMIC, we applied a Bayesian methodology in a consistent way in all analyses that were related to the decision analysis.

7) Further investigating the possibilities to apply formal assessments, including the evaluation of management measures, to security. This could also concern the possibilities of linking security with safety.

8) Extending the approaches used within MIMIC to encompass the winter season.

9) Development of new e-Navigation concepts and tools for accident prevention, both for open water and ice conditions, and evaluating their risk-reduction potential.

10) Develop a concept how ship-owners and operators could benefit from improved crashworthiness in order to increase the motivation for safer ships.

11) Improved oil drift forecasts in ice conditions.

12) Refining the methodology for estimating oil stranding, the length of oiled shoreline, and the proportion of oiled shoreline within areas of interest.

Deliverables of MIMIC

Articles and reports

Agoshkov, V.I., Zayachkovskiy, A.O., Aps, R., Kujala, P. and Rytkönen, J. 2014. Risk theory based solution to the problem of optimal vessel route. Russian Journal of Numerical Analysis and Mathematical Modelling 29(2): 69-78. DOI: 10.1515/rnam-2014-0006, [online] URL: http://www.degruyter.com/view/j/rnam.2014.29.issue-2/rnam-2014-0006/rnam-2014-0006.xml

Aps, R., Tõnisson, H., Anfuso, G., Perales, J.A., Orviku, K., Suursaar, Ü. 2014. Incorporating dynamics factor to the Environmental Sensitivity Index (ESI) shoreline classification – Estonian and Spanish example. Journal of Coastal Research 70: 235 - 240.

Aseev, N.A., Agoshkov, V.I., Zalesny, V.B., Aps, R., Kujala, P., and Rytkönen, J. 2014. The problem of control of oil pollution risk in the Baltic Sea. Russian Journal of Numerical Analysis and Mathematical Modelling. Volume 29, Issue 2, Pages 93–105, ISSN (Online) 1569-3988, ISSN (Print) 0927-6467, DOI: 10.1515/rnam-2014-0008, April 2014.

Brunila, O-P. 2012a. Development of oil transportation in the Gulf of Finland. Expert article 1071. Baltic RIM Economies, Quarterly Review 4(2012): 16. [online] URL: http://www.utu.fi/fi/yksikot/tse/yksikot/PEI/BRE/Documents/BRE%204-2012%20web.pdf

Brunila, O-P. and Storgård, J. 2012. Oil transportation in the Gulf of Finland in 2020 and 2030. Publications from the Centre for Maritime Studies A 61. University of Turku, 2012. [online]URL: http://www.merikotka.fi/julkaisut/Brunila_and_Storgrd_2012_Oil_transportation_in_the_Gulf_of_Finland_in_2020_and_2030.pdf

Brunila, O-P. and Storgård, J. 2013a. Future development of oil transportation in the Gulf of Finland. In: Marine navigation and safety of sea transportation: maritime transport and shipping. Eds: A. Weintrit A and T. Neumann. Taylor and Francis Group, London.

Brunila, O-P. and Storgård, J. 2013b. Changes in oil transportation in 2020 and 2030. Case Gulf of Finland. Paper ID 43. International Association of Maritime Economists (IAME) 2013 Conference, July 3-5, Marseille, France. [online] URL: http://www.merikotka.fi/mimic/images/stories/Brunila_Olli_Pekka_Changes_in_oil_transportation_IAME2013_Final.pdf

Fransas, A. and Nieminen, E. 2013. Merenkulun uhat selville eDelfoilla. Koskinen 02(2013). [online] URL: http://www2.kyamk.fi/Koskinen/Flash_Koskinen/Koskinen%202-2013.pdf

Fransas A, Nieminen, E. and Salokorpi M. 2013a. Maritime security and safety threats. Study in the Baltic Sea area. Publications of Kymenlaakso University of Applied Sciences, Series B Research and Reports, No 92.

Fransas A., Nieminen E. and Salokorpi M. 2013b. Maritime security and security measures. Mimic study in the Baltic Sea area. Publications of Kymenlaakso University of Applied Sciences, Series B Research and Reports No 106. [online] URL: https://www.theseus.fi/xmlui/handle/10024/68155

Fransas, A., Nieminen, E., Salokorpi, M. and Rytkönen, J. 2012. Maritime safety and security. Literature review. Publications of Kymenlaakso University of Applied Sciences. Series B, Research and reports, No 77. [online] URL: https://publications.theseus.fi/handle/10024/46235

Goerlandt, F. and Montewka, M. 2014. A probabilistic model for accidental cargo oil outflow from product tankers in a ship-ship collision. Marine Pollution Bulletin 79:130-144. [Online] URL:http://ac.els-cdn.com/S0025326X13007595/1-s2.0-S0025326X13007595-main.pdf?_tid=4e187342-956e-11e3-9105-00000aacb361&acdnat=1392378854_97e6fa3ee84faee4ff86f2cf6f0bcca9

Haapasaari, P., Lehikoinen, A., ja Hänninen, M. 2014. Uusia strategioita öljyturman ehkäisemiseksi. Näkökulma. Kymen Sanomat 1.4.2014. [online] URL: http://www.mv.helsinki.fi/home/phaapasa/Omattekstipdf/Kymen%20Sanomat%202014.pdf

Heinvee, M., Tabri, K. and Kõrgesaar, M. 2013. A simplified approach to predict the bottom damage in tanker grounding. In: Proceedings of International Conference on Collision and Grounding of Ships and Offshore Structures: International Conference on Collision and Grounding of Ships and Offshore Structures, 17-19.06.2013,Trondheim, Norway. Taylor & Francis, 2013.

Hyttinen, N. 2013. The effect of experience on knowledge extraction from accident reports. Master's thesis, School of Science, Aalto University, Espoo, Finland.

Hyttinen, N., Mazaheri, A., Kujala, P. 2014. Effects of the background and experience on the experts' judgments through knowledge extraction from accident reports. Proceedings of 12th Probabilistic Safety Assessment and Management Conference (PSAM), 22-27 June 2014, Honolulu, Hawaii, USA (accepted).

Hänninen, M., Mazaheri, A., Kujala, P., Laaksonen, P. and Salmiovirta, M. 2012. The effects of an Enhanced Navigation Support Information service on maritime traffic risks in the Gulf of Finland. Proceedings of 11th Probabilistic Safety Assessment and Management Conference (PSAM) and the Annual European Safety and Reliability Conference (ESREL) 7:

5518-5527, 25-29 June 2012, Helsinki, Finland. [online] URL: http://toc.proceedings.com/16286webtoc.pdf

Hänninen, M., Mazaheri, A., Kujala, P., Montewka, J., Laaksonen, P., Salmiovirta, M. and Klang, M. 2014. Expert elicitation of a navigation service implementation effects on ship groundings and collisions in the Gulf of Finland. Proceedings of the Institution of Mechanical Engineers, Part O, Journal of Risk and Reliability 228(1): 19-28. [online] URL: http://pio.sagepub.com/content/early/2013/09/02/1748006X13494533.abstract

Kuikka, S. 2013a. Ympäristölainsäädännössä kaivattaisiin uusia menetelmiä. Turun Sanomat 21.2.2013. [online] URL: http://www.merikotka.fi/julkaisut/TS_210213_pdf.pdf

Kuikka S. 2013b. Meriosaamiseen tiukempaa ohjausta. Kymen Sanomat 16.5.2013. [online] URL: http://www.kymensanomat.fi/Mielipide---Kolumni/2013/02/11/Meriosaamiseen+tiukempaa+ohjausta/2013315167997/68.

Lehikoinen, A., Luoma, E., Hänninen, M., Storgård, J. and Kuikka, S. 2012a. Evaluation of the traffic increase in the Gulf of Finland during the years 2007-2015 and the effect of the increase on the environment and traffic chain activities. Proceedings of 11th Probabilistic Safety Assessment and Management Conference (PSAM) and the Annual European Safety and Reliability Conference (ESREL) 7: 5528-5535, 25-29 June 2012, Helsinki, Finland. [online] URL: http://toc.proceedings.com/16286webtoc.pdf

Lehikoinen, A., Luoma, E., Mäntyniemi, S., and Kuikka, S. 2013a. Optimizing the recovery efficiency of Finnish oil combating vessels in the Gulf of Finland using Bayesian networks. Environmental Science and Technology 47:1792-1799. [online] URL: http://pubs.acs.org/doi/abs/10.1021/es303634f.

Mazaheri, A., Montewka, J. and Kujala, P. 2013a. Correlation between the ship grounding accident and the ship traffic. A case study based on the statistics of the Gulf of Finland. International Journal of Marine Navigation and Safety of Sea Transportation 7(1): 119-124. [online] URL: http://www.transnav.eu/Article_Correlation_between_the_Ship_Grounding_Mazaheri,25,418.html

Mazaheri, A., Montewka, J. and Kujala, P. 2013b. Modeling the risk of ship grounding. A literature review from a risk management perspective. WMU Journal of Maritime Affairs. DOI: 10.1007/s13437-013-0056-3 . [online] URL: http://download.springer.com/static/pdf/933/art%253A10.1007%252Fs13437-013-0056-3.pdf?auth66=1392289102_0047d3e0536678b66f961c56e9e72868&ext=.pdf

Mazaheri, A., Sormunen, O. V. E., Hyttinen, N., Montewka, J. and Kujala, P. 2013c. Comparison of the learning algorithms for evidence-based BBN modeling. A case study on ship grounding accidents. Safety, reliability and risk analysis: beyond the horizon, pp. 193-

200. Eds: R.D.J.M. Steenbergen, P.H.A.J.M. van Gelder, S. Miraglia, and A.C.W.M. Vrouwenvelder. Taylor and Francis Group, London.

Mazaheri, A., Montewka, J., Kotilainen, P., Sormunen, O. V. E., Kujala, P. 2014. Assessing grounding frequency using ship traffic and waterway complexity. Journal of Navigation (accepted).

Mazaheri, A. and Montewka, J. 2014. Usability of accident and incident reports for evidence-based risk modelling of ship grounding. Proceedings of the Annual European Safety and Reliability Conference (ESREL), 14-18 September 2014, Wroclaw, Poland (accepted).

Montewka, J., Goerlandt, F. and Kujala, P., 2013a. On a risk perspective for maritime domain. Journal of Polish Safety and Reliability Association 4(1): 101-108. [online] URL: http://jpsra.am.gdynia.pl/upload/SSARS2013PDF/VOL1/SSARS2013-Montewka.pdf

Montewka, J., Weckström, M. and Kujala, P., 2013b. A probabilistic model estimating oil spill clean-up costs. A case study for the Gulf of Finland. Marine Pollution Bulletin 76: 61-71. [online] URL: http://ac.els-cdn.com/S0025326X13005821/1-s2.0-S0025326X13005821-main.pdf?_tid=53352ca8-930c-11e3-816f-00000aab0f27&acdnat=1392116869_e3fd57feb0e09580056c4ba6ca051e42

Nieminen, E. and Fransas, A. 2013. Itämeri on turvallinen ja valvottu alue. Navigator 5(2013): 29-30. [online] URL: http://navigatormagazinefi.virtualserver24.hosting.fi/tutkimuskin-osoittaa-itameri-on-turvallinen-ja-valvottu-alue/

Sergejeva, M., Laanearu, J. and Tabri, K. 2013. Hydraulic modelling of submerged oil spill including tanker hydrostatic overpressure. In: Analysis and Design of Marine Structures, p: 209-217. Ed by J. Romanoff. CRC Press 2013. Taylor and Francis Group, London. [online] URL: http://www.crcnetbase.com/doi/abs/10.1201/b15120-29

Storgård, J., Berg, N. and Brunila, O-P. 2013a. Insight in ships crews. Multiculturalism and maritime safety. Proceedings of the International Scientific Meeting on Corporate Social Responsibility (CSR) in Shipping. Eds: V. Kunnaala and J. Viertola. 2nd International Maritime Incident and Near Miss Reporting Conference (IMISS 2013). 11-12 June 2013, Kotka, Finland. Publications of the Centre for Maritime Studies University of Turku, A71. [online] URL: http://www.merikotka.fi/mimic/images/stories/Storgard_Berg_Brunila_InsightInShipCrews.pdf

Tabri, K., Ehlers, S., Kõrgesaar, M., Ståhlberg, K. and Heinvee, M. 2012. Collision consequence assessment of ROPAX vessels operating in the Baltic Sea. Proceedings of the ASME 2012, 31st International Conference on Ocean, Offshore and Arctic Engineering, 1-6 July 2012, Rio de Janeiro. [online] URL: http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1732655

Tuominen, R. 2013a. Methods for security threat analysis. Literature survey for the MIMIC-project. Restricted report. VTT Technical Research Centre of Finland, Tampere, Finland.

Tuominen, R. 2013b. Security threat analysis model for the MIMIC-project. Restricted report. VTT Technical Research Centre of Finland, Tampere, Finland.

Viertola, J. 2013. Maritime safety in the Gulf of Finland. Evaluation of the regulatory system. Publications from the Centre for Maritime Studies, University of Turku, A67. [online] URL: http://www.doria.fi/handle/10024/94150

Viertola, J. and Storgård, J. 2013. Overview on the cost-effectiveness of maritime safety policy instruments. Publications from the Centre for Maritime Studies, University of Turku, A66. [online] URL: http://www.doria.fi/bitstream/handle/10024/94149/A66-overview%20of%20cost%20effectiveness.pdf?sequence=2

Zalesny, V., Gusev, A., Chernobay, S., Aps, R., Tamsalu, R., Kujala, P. and Rytkönen, J. 2014. The Baltic Sea circulation modeling and assessment of marine pollution. Russian Journal of Numerical Analysis and Mathematical Modelling 29(2): 129-138. DOI: 10.1515/rnam-2014-0010 , [online] URL: http://www.degruyter.com/view/j/rnam.2014.29.issue-2/rnam-2014-0010/rnam-2014-0010.xml

Presentations

Agoshkov, V., Aseev, N., Aps, R., Kujala, P.,Rytkönen, J. and Zalesny, V. 2013a. Oil spill risk management in the Baltic Sea. Baltic Sea Oil Spill Conference, 20-21 November 2013, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/AgoshkovOilSpillRiskManagement.pdf

Agoshkov, V., Zayachkovskiy, A., Aps R., Kujala, P. and Rytkönen J. 2013b. Optimum ship routes – a risk theory based solution. Baltic Sea Oil Spill Conference, 20-21 November 2013, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/food/agoshkovapszay.pdf

Aps, R., Agoshkov, V., Fetissov, M., Jönsson, A., Kopti, M., Kotta, J., Orviku, K., K. Tabri, Tõnisson, H. and Zalesny, V. 2013. SmartResponse Web – enabling dynamic situation awareness. Baltic Sea Oil Spill Conference, 20-21 November 2013, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/ApsSmartResponseWeb.pdf

Brunila, O-P. 2012b. Oil transportation in the Baltic Sea and MIMIC-project. 14th International Conference of Maritime transport and infrastructure 2012, 26-27 April 2012, Riga, Latvia. [online] URL: http://www.merikotka.fi/mimic/images/stories/Olli-Pekka_Brunila_Riga_presentation.pdf

Brunila, O-P. 2012c. Itämeren öljykuljetukset ja MIMIC -hanke. Oral presentation. Kotkan Seniorit Ry, 18 April, Kotka, 2012.

Brunila, O-P. 2013. Forecasting of oil transportation and insight in ships`s crew. Baltic Sea Oil Spill Conference, 20-21 November, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/BrunilaForecastingShipsCrew.pdf

Brunila, O-P. and Storgård, J. 2013c. Future development of oil transportation in the Gulf of Finland. 10th Jubilee International Conference TRANSNAV 2013, 19-20 June 2013, Gdynia, Poland. [online] URL: http://www.merikotka.fi/mimic/images/stories/Olli-Pekka_Brunila_Future_development_of_oil_transportation_in_the_Gulf_of_Finland_TransNav_2013.pdf

Brunila, O-P. and Storgård, J. 2013d. Changes in oil transportation in 2020 and 2030 – Case Gulf of Finland. International Association of Maritime Economists (IAME) 2013, 3-5 July 2013, Marseille, France. [online] URL: http://www.merikotka.fi/mimic/images/stories/Olli-Pekka_Brunila_Changes_in_oil_transportation_in_2020_and_2030.pdf

Dahlbo, K., Ivchenko, A., Vanhatalo, J., Similä, M., Raateland, A. and Sane, M. 2013. Estimating length of polluted shoreline after a spill. Generating metrics for the extent of polluted shoreline as a consequence of accidental oil spills. Baltic Sea Oil Spill Conference, 20-21 November 2013, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/DahlboLengthPollutedShoreline.pdf

Haapasaari, P., Storgård, J. and Lappalainen, J. 2013. A risk governance framework to improve maritime safety. Baltic Sea Oil Spill Conference, 20-21 November 2013, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/HaapasaariRiskGovernanceFramework.pdf

Lehikoinen, A., Luoma, E., Kuikka, S., Hänninen, M., Jolma, A. and Storgård, J. 2012b. Probabilistic risk assessment and decision support tools for the evaluation of oil transport in the Gulf of Finland, North-Eastern Baltic Sea. Oral presentation by A. Lehikoinen. IEMSs conference 4.6.2012, Leipzig. [online] URL: http://www.helsinki.fi/science/fem/articles/1365paper_long.pdf, http://www.merikotka.fi/julkaisut/mimic_annukka_iemss12.pdf

Lehikoinen, A., Luoma, E., Kuikka, S., Hänninen, M. and Storgård, J. 2012c. Evaluation of the traffic increase in the Gulf of Finland during the years 2007-2015 and the effect of the increase on the environment and traffic chain activities. 11th Probabilistic Safety Assessment and Management Conference (PSAM) and the Annual European Safety and Reliability Conference (ESREL), 25-29 June 2012, Helsinki, Finland. [online] URL: http://www.merikotka.fi/julkaisut/23s-mo3-3_lehikoinen.pdf

Lehikoinen, A., Haapasaari, P., Hänninen, M., Brunila, O-P., Mazaheri, A., Tabri, K. and Dahlbo, K. 2013b. A metamodel for evaluating measures to minimize oil spill risks. Baltic Sea Oil Spill Conference, 20-21 November 2013, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/mimic/lehikoinen_metamodel_nettiversio.pdf

Lehikoinen, A., Haapasaari, P., Hänninen, M., Storgård, J., Mäntyniemi, S. and Kuikka, S. 2013c. Multi-disciplinary lego-bricks: building an integrative metamodel for policy analysis by using Bayesian networks. Oral presentation by A. Lehikoinen. ICES Annual Science Conference 2013, 23-27 September 2013 Reykjavik, Iceland. [online] URL: http://www.merikotka.fi/mimic/images/stories/mimic/icesasc13_esitelm_final_nettivers.pdf

Mazaheri, A., Hyttinen, N. and Sormunen, O.V.E., 2013d. Evidence-based modeling by utilizing accident/incident reports. Lessons to be learnt: Opportunities and Barriers. 2nd International Maritime Incident and Near Miss Reporting Conference (IMISS), June 11th - 12th, Kotka, Finland. [online] URL: http://www.merikotka.fi/cafe/images/stories/Mazaheri_Evidence-basedModeling.pdf

Mazaheri, A. 2013. Contributors to a grounding accident. What does evidence tell. Baltic Sea Oil Spill Conference, November 20th - 21st, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/MazaheriContributorsGroundings.pdf

Storgård, J., Berg, N. and Brunila, O-P. 2013b. Insight in ships crews. Multiculturalism and maritime safety. 2nd International Maritime Incident and Near Miss Reporting Conference 11-12 June 2013, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/Brunila_InsightInShipCrews.pdf

Storgård, J., Berg, N. and Brunila, O-P. 2013c. Composition of ships crew. Sailing Chaplains programme 30 years. Oral presentation by O.-P. Brunila. Seminar at Helsinki Seafarers' Centre in Port of Vuosaari, 7 November, 2013,Helsinki.

Tabri, K. 2012. Simulation of maritime accidents. 14th International Conference of Maritime transport and infrastructure 2012, 26-27 April 2012, Riga, Latvia. [online] URL: http://www.merikotka.fi/mimic/images/stories/Riga%20Tabri.pdf

Tabri, K., Heinvee, M., Laanearu, J., Sergejeva, M., Naar, H., Kerge, E.H. 2013. Assessing the consequences of collision and grounding accidents. Baltic Sea Oil Spill Conference, 20-21 November 2013, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/TabriConsequencesCollisionGrounding.pdf

Zalesny, V., Aps, R., Chernobay, S., Gusev, A., Kujala, P. and Rytkönen J. 2013. The Baltic Sea circulation and assessment of marine pollution. Baltic Sea Oil Spill Conference, 20-21 November 2013, Kotka, Finland. [online] URL: http://www.merikotka.fi/mimic/images/stories/food/zalesnykotka__13.pdf

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