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Efficient, Safe and Sustainable Traffic at Sea

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The Collection of FSA Studies in the Baltic Sea Area

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2 Abbreviations/Definitions

AIS	Automatic Identification System
BaSSy	Baltic Sea Safety
DW	Deep Water
ECDIS	Electronic Chart Display and Information System
ERCC	Expected Reduced Consequence Cost
ERSC	Expected Reduced Societal Cost
ETR	Expected Total Return
FSA	Formal Safety Assessment
GOFREP	The Mandatory Ship Reporting System in the Gulf of Finland
GT	Gross Ton(s), Gross Tonnage
HELCOM	Helsinki Commission (Baltic Marine Environment Protection Commission)
IMO	International Maritime Organization
LCC	Life-Cycle Costs
MSC	Maritime Safety Committee
NPV	Net Present Value (The present value of an investment and the savings from avoiding accidents when the measure is implemented)
RCM	Risk Control Measure
RCO	Risk Control Option
SOUNDREP	The Voluntary Ship Reporting System in the Sound between Denmark and Sweden
SYKE	Finland's Environmental Administration (Suomen ympäristökeskus)
TKK	School of Science and Technology (Teknillinen korkeakoulu)
TSS	Traffic Separation Scheme
TØI	The Institute of Transport Economics (Transportøkonomisk institutt)
VTMIS	Vessel Traffic Management and Information Systems

VTS	Vessel Traffic Service
VTT	Technical Research Centre of Finland (Valtion teknillinen tutkimuskeskus)

1 Introduction

Formal Safety Assessment (FSA) is a method of assessing the risks related to maritime safety and the protection of the marine environment. The main idea of the FSA is to evaluate the costs and benefits of various risk control options (RCOs) in a systematic and rational way and thus to define the most effective measure(s) to prevent marine accidents. FSA consists of a five-step process including following steps:

1. Identification of hazards – What can go wrong?
2. Risk analysis – Risk and its frequency and consequence?
3. Risk control options – What are the options to control the risk?
4. Cost-benefit assessment – What actions are cost effective to be performed?
5. Recommendations for decision-making – What recommendations should be pushed forward?

The Baltic Sea safety and security is very important looking from different perspectives in governmental level and thinking a way how to merge these issues. There are different authorities who are looking from different point of view to safety and security. There is a cross sectoral safety and security research development under safety and security subcommittee of Finnish advisory board for sectoral research[1]. Safety and security subcommittee started a preliminary study (KYAMK et al.) by gathering all FSA studies around the Baltic Sea area. The idea was to get an overview of risk analyses around the Baltic Sea and find out a research methodology for security analysis.

Several FSA studies have been made in the Baltic Sea area, since IMO requires them as a support for decision-making processes concerning maritime safety and the protection of the marine environment. The aim of this text is to introduce and summarize the contents of the main FSA studies done in the Baltic Sea area. Studies including risk analyses following the FSA method as well as traffic analyses in the wider sea area are concerned as main FSA studies, whereas the smaller FSA studies and risk analyses have been left out. As a comparison, one FSA study made in Norway (Røst-Utsira) has been included to this report to give a view of analyses outside the Baltic Sea. The summarized studies are:

1. Navigational Safety in Danish waters, 2002
2. The implementation of the VTMIS system for the Gulf of Finland, 2002
3. Navigational safety in Øresund, 2006
4. Sea Traffic in the Area around Bornholm, 2008
5. Effects of proposed ship routeing off the Norwegian coast - Røst-Utsira, 2009
6. Improved maritime safety in the Sea of Åland, 2010

The areas concerning each study are represented in the figure 1.

[1] http://www.minedu.fi/OPM/Tiede/setu/index.html?lang=en

There is no FSA study concerning the entire Baltic Sea area and these studies do not cover the area either, but they give an overall view of the most hazardous areas in the Baltic Sea as well as how the risks are reduced by various risk control options. The purpose is also to find potential deficiencies in the risk analyses, having a focus on a possible FSA study covering the entire Baltic Sea area with the objective to identify common risks. In addition it is important to find the RCOs which could be suitable for the whole area and which could be accepted by all of the countries in the Baltic Sea area.

This report is made within the framework of the EfficienSea project and the object is to deliver this study to HELCOM as a commitment. The project is founded by EU Baltic Sea Region Programme during 2009-2011. During the project approximately 80 different risk analyses has been found in the Baltic Sea area.

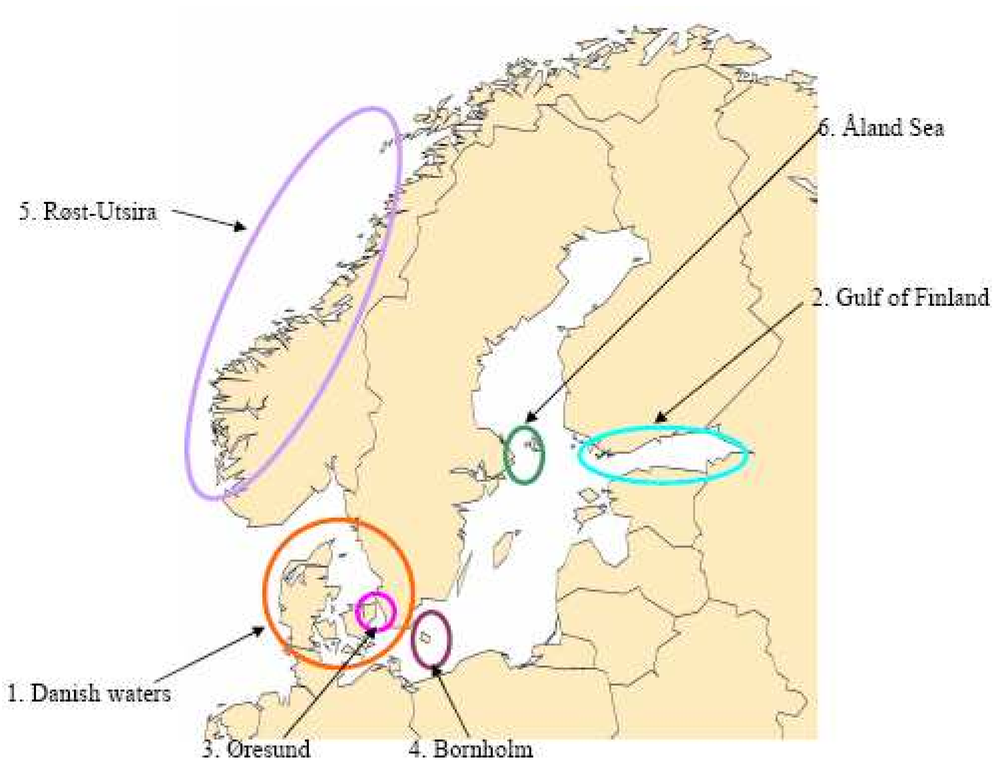


Figure 1. The FSA Studies in the Baltic Sea area

2 COWI A/S 2002: Risk Analysis of Navigational Safety in Danish Waters

2.1 Background and aim

On 29 March 2001 the Tanker 'Baltic Carrier' and the cargo ship 'Tern' collided southeast of the Danish island Møn. The accident caused an oil spill of 2700 tonnes of heavy fuel oil and questions about the navigational safety in Danish waters became current in public. The aim of this study was to establish a basis for deciding which measures could be implemented to reduce the risk of oil spills in Danish waters. The analysis focused on the oil spills caused by ship-to-ship collisions and groundings, and only ships of 50 GT or more were included.

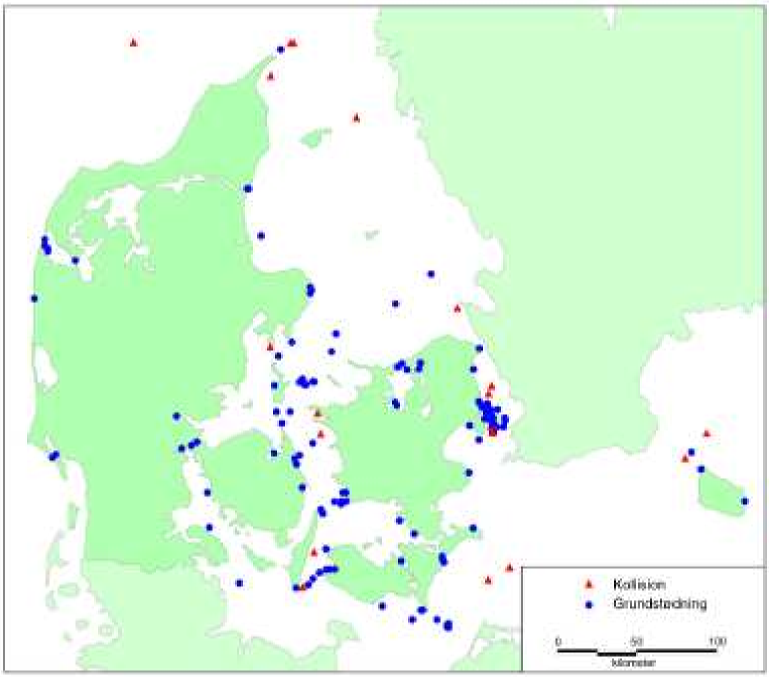


Figure 2. Groundings and collisions observed in Danish waters 1997-2001

2.2 Scope and methods

The Danish waters were analysed by using traffic and accident statistics, and the most oil-spill-risky locations were selected for further analysis. The following areas had the highest accident frequency: Drogden, Langelandsbælt, Hatter area, Kadetrenden and the Sound north. The hazardous factors of the areas were: narrow channel without TSS in

Drogden; many bends in the DW route in Langelandsbælt; narrow DW route with a sharp bend in the Hatter area; dense traffic and many west-going ships mistaking the water depth when leaving the DW route in Kadetrenden; and intense north-south traffic crossing intense east-west ferry traffic in the Sound (Øresund) northern part. Accident scenarios and RCOs were identified for each of these areas and the latter are seen in the table 1.

The costs were calculated for both implementing and operating the RCOs. The expected costs of averted spills were obtained by comparing the entire lifetime costs of the RCOs with the expected number of averted spills attained by each RCO during the same period of time. The costs of an occurred oil spill consisted of direct costs and clean-up costs including loss of human lives, ship repair, lost revenue and lost cargo. These costs were assessed to be approximately 50 million DKK corresponding to an average spill of 400 tonnes of oil.

These numbers were calculated for the year 2001 compared with the estimated numbers of 2008, because AIS was expected to be completed, ECDIS more widely used and the number of single hull tankers reduced in 2008, which all could affect the effect of the RCOs. In addition the study assessed the criteria of how much it would be reasonable to pay for averting a spill by comparing the costs of the occurrence of a spill to the costs of averting a spill. A RCO was worth implementing, if:

Costs of averting a spill < F x Costs of an occurred spill

The 'F' was an insurance factor depending on the decision makers, and the study did not evaluate the amount of it (however, the 'F' would be larger than 1).

2.3 Results

As a result of the study, the four most cost-effective RCOs were associated with the Drogden and Hatter areas, which also had the total highest number of expected spills. The RCOs were:

Widening of the Drogden channel

Incorporation of the Hatter area into the VTS Great Belt surveillance area

Dredging of the main route at Hatter Barn to a minimum depth of 19 m

Introduction of a VTS centre for the area around the Drogden channel

The study pointed out that both the costs of the RCOs and the number of averted spills were uncertain and needed closer investigation in case there would become a need for more accurate numbers. It was also observed that the VTS alternatives require international approval of IMO, as the dredging alternatives do not require it.

Location	RCO	Averted oil spills 2001	Averted oil spills 2008	Cost per averted oil spill 2001 (M DKK)	Cost per averted oil spill 2008 (M DKK)	Recommended
Drogden	VTS Drogden	0,15	0,067	59	135	x
	AIS based surveillance	-	0,039	-	177	
	Widening the channel	0,15	0,081	50	91	x
Langelandsbælt	Incorpora-ting into VTS Great Belt	0,064	0,028	61	140	
	AIS based surveillance from VTS Great Belt	-	0,016	-	167	
Hatter	VTS Hatter area	0,074	0,032	133	305	
	Incorpora-ting into VTS Great Belt	0,074	0,032	54	125	x
	AIS based surveillance from VTS Great Belt	-	0,019	-	144	
	Dredging the main route	0,074	0,04	68	125	x
	Replacing the sharp bend on DW route	0,024	0,013	126	227	

Kadetrenden	VTS Kadetrenden	0,027	0,012	126	227	
	Repeated temporary surveillance	0,0065	0,0015	224	969	
The Sound Northern part	VTS Sound North	0,028	0,012	429	983	
	Equipping buoy M1 with Racon	0,001	0,00051	147	295	

Table 1. RCOs

3 VTT & TKK 2002: The implementation of the VTMIS system for the Gulf of Finland

3.1 Background and aim

The main traffic routes in the Gulf of Finland are heavy oil tanker traffic in the east-west direction and passenger traffic between Finland and Estonia in the north-south direction, intersecting each others in the middle of the gulf. According to researches and statistics, the traffic flow and therefore the risk of an oil spill accident in the Gulf of Finland were expected to increase, since new oil terminals were planned to be built in Russia and Estonia.

The aim of the study was to assess the effectiveness of the new proposed VTMIS system for the Gulf of Finland, which included routeing, monitoring and mandatory reporting systems. The VTMIS system was planned to be implemented in co-operation with Finland, Russia and Estonia to improve the safety of shipping and the protection of the marine environment. The study focused on the risk of ship-to-ship collision, mainly the risk of collision between a tanker and another type of vessel, with an oil spill accident as one of the main fears.

3.2 Scope and methods

The effect of two risk control options on reducing the risk of ship-to-ship collisions and thus protecting the marine environment were compared with the estimated number of traffic during 2010-2015. These risk control options were:

System 1: A new routeing system combined with mandatory reporting system.

System 2: System 1 combined with a radar-based traffic monitoring system.

A group of experts found 50 different hazard scenarios, of which 22 was ranked as the most alarming ones. In addition, hazards concerning winter navigation in the Gulf of Finland were studied and 15 of them were prioritized. The risk analysis used the GRACAT software for the collision risk calculations concerning the collisions between a tanker and another type of ship. The ships were divided into groups according to their size and type for the calculation purposes:

Tankers 20 000 – 30 000 tons

Tankers 80 000 – 100 000 tons

Passenger ships 1500 – 2000 tons

Passenger ships 80 000 – 100 000 tons

Container ships 3000 – 5000 tons

Container ships 10 000 – 20 000 tons

The container ships were representing all types of the cargo ships, i.e. general cargo, dry bulk cargo, ro-ro, container ships and other vessel types carrying neither passengers nor hazardous bulk cargo. Also the winter navigation risks were assessed by using risk matrices. For the details of the highest ranked risks and the risks in relation to winter navigation in the Gulf of Finland, see Appendixes 2 and 3.

The cost-effectiveness analysis consisted of a comparison between the life cycle costs of the implemented RCOs and the expected reduced societal costs. The life cycle costs included costs of equipment, installation as well as annual operational costs in Finland, Estonia and Russia and were calculated for a ten years period. The expected reduced societal costs were defined as a sum of the costs caused by an oil spill, including the cleaning work, harm incurred to the environment and costs of the marine and environmental authorities. The expected reduced societal costs were calculated for the expected decrease in the number of collisions due to the implemented RCOs.

3.3 Results and other remarks

According to the cost-effectiveness assessment, where the costs of an oil spill accident and the costs of risk control options were compared with each others, the System 2 was obviously the most cost-effective alternative. The System 2 had also a remarkable advantage of assisting the icebreakers during wintertime by transmitting information between the icebreakers and vessels.

	Collision frequency, big tankers	Collision frequency, small tankers	Life-cycle cost (M €)	Expected societal reduced cost (M €)	Expected total return	Recommended
Basic situation	0,35247	1,73235	-	-	-	
System 1	0,32213	1,47757	12,8	16,5	1,16	
System 2	0,07349	0,33709	30,5	4126,1	122,1	x

Table 2. The risk control options compared with the basic situation.

As a conclusion both System 1 and System 2 were found to decrease the risk of ship-to-ship collisions. Based on the cost-benefit assessment the System 2 was highly recommended.

The Gulf of Finland mandatory ship reporting system (GOFREP) was commenced in 1 July 2004.

4 Rambøll Danmark A/S 2006: Navigational safety in the Sound between Denmark and Sweden (Øresund)

4.1 Background and aim

The facts that there are narrow navigational routes in some parts of Øresund and the area is highly trafficked by various types of ships and leisure boats cause critical situations when navigating in the area. In the worst cases the critical situations have led to collision or grounding and thus have caused the risks of damages or losses of property, losses of lives and environmental damages.

This study is a part of an idea of compiling an overall description of the navigational safety in Øresund. The purpose of the study was to establish a basis for the data analysis and to determine the risks for collisions and groundings, ensuring that the navigational risks in the area were not at an unacceptable level with respect to human safety, property and environment. In addition the study could give the maritime authorities grounds for making decisions concerning risk reducing measures.

4.2 Scope and methods

The study was limited into the area of Øresund and outside the port areas. The area was divided into six focus areas for the purposes of the data analysis. The hazard identification workshop listed 66 identified hazards, which were ranked by taking into consideration the frequency of the hazards and the extent of the consequences. The original list of the hazards is as the Appendix 4. Two biggest hazards against human safety, property and environment were:

Grounding on the Swedish coast north of Helsingborg-Helsingør due to ship has not turned at the buoy in the middle of the channel

Grounding on the Swedish coast north of Helsingborg-Helsingør due to northbound current

The risk ranking was used as a tool to define the critical locations in Øresund to be further studied in the risk analysis. Also 44 risk reducing measures were listed by the risk reduction workshop.

The risk analysis consisted of calculation models, which estimated the risks concerning collisions and groundings. The following types of accidents were studied:

Ship-to-ship collisions for passing ships

Ship-to-ship collisions for crossing ships

Groundings and ship obstacle collisions

According to the risk analysis, the most hazardous areas were the area at Helsingør-Helsingborg and the Drogden channel.

The cost-benefit criterion was based on evaluating the costs related to the risk reducing measures against the annual risk savings achieved by implementing the risk reducing measures. The consequences were divided into three categories which were fatality, property damage and environmental damage. The annual expected costs caused by collisions and groundings were calculated by combining the accident frequencies and these consequences.

The evaluated economical consequence of a fatality was 18 million DKK. The costs of a property damage were categorized in five classes and they were 120 000 – 4 800 000 000 DKK in case of collisions and 0 - 22 080 million DKK in case of groundings. The costs of environmental damages were also categorized in five classes and they were 19 050 000 – 1 905 000 000 DKK. The costs of environmental damages consisted of clearing and clean-up costs, but did not include long term costs from adverse effect on the environment.

Figure 3. The location of the recommended risk reducing measures

4.3 Results and other remarks

The table 3 shows the cost-benefit criterions for the risk reducing measures. The recommended risk reducing measures are marked with "x" in the table 4. The following risk reducing measures were classified as "may be recommendable depending on additional clarification before implementation":

Convoy sailing in Drogden

Overtaking forbidden in Drogden

Traffic Separation Scheme in Drogden/Flintrännan

Traffic Separation Scheme at Ven

The VTS and the removal of Drogden lighthouse were not clearly recommended, even if they were found to be cost-beneficial, because they were not found to be efficient in the sensitivity analysis of the benefit and needed therefore further analysis.

The voluntary ship reporting system in the sound between Denmark and Sweden (SOUNDREP) was established on 15 August 2007 and is operated by Sound VTS.

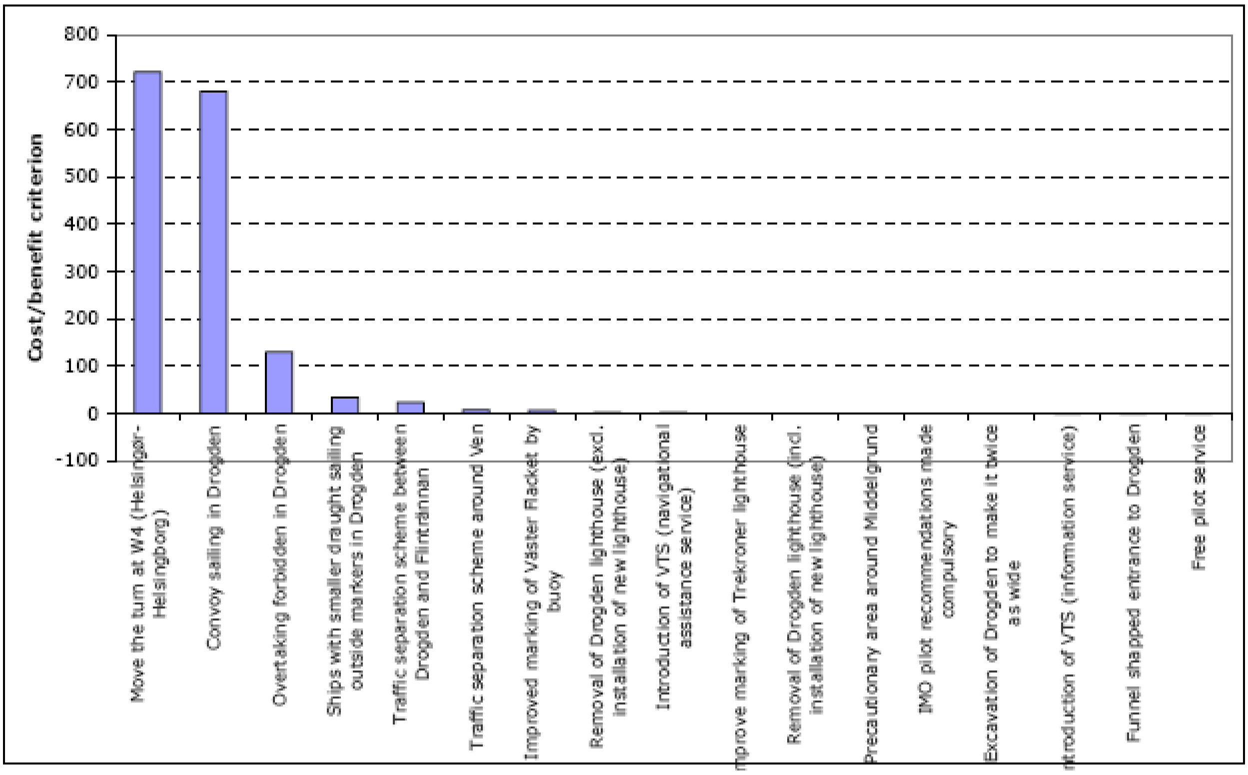


Table 3. Cost-benefit criterions of risk reduce measures.

RCO	COSTS (DKK)	O&M COSTS PER YEAR (DKK)	RISK REDUCTION (DKK/YEAR)	NPV (DKK)	COST-BENEFIT CRITERION	RECOMMEN-DED
Introduction of VTS (navigational assistance)	25 600 000	8 800 000	23 442 476	171 330 925	1,33	
Traffic separation scheme between Drogden and Flintrännan	200 000	140 000	11 585 276	141 934 326	23,02	
Convoy sailing in Drogden	200 000		10 048 326	128 262 657	679,79	
Move the turn at W4 (Helsingør-Helsingborg)	25 000	12 066	9 400 763		721,00	x
Ship with smaller draught sailing outside existing markers in Drogden	50 000	210 000	6 823 575	84 694 625	33,43	x
Improved marking of Väster Flacket by buoy	25 000	70 000	474 092	5 208 104	6,11	x

Table 4. The most efficient and recommended risk reducing measures.

5 COWI A/S 2008: Risk Analysis of Sea Traffic in the Area around Bornholm

5.1 Background and aims

Bornholmsgat is a highly trafficked sea area, as the majority part of the traffic between the Baltic Sea and the North Sea passes through it. In addition, ships sailing to and from the ports in the southeast Baltic Sea are using the routes between Bornholm and Adlergrund.

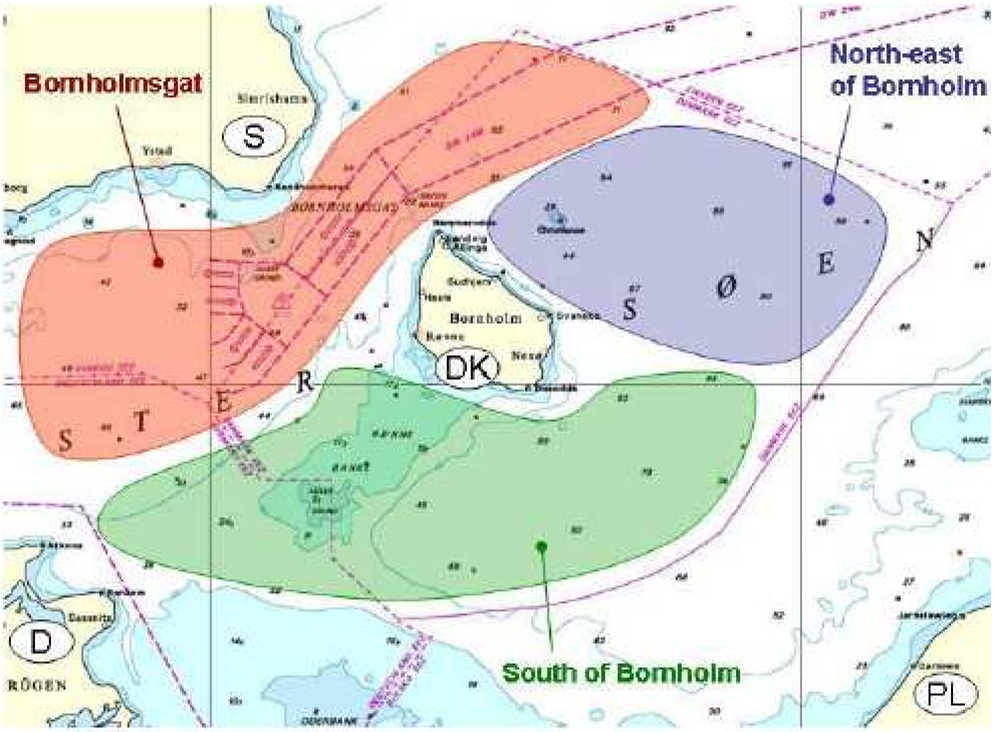


Figure 4. The area around Bornholm

The study concentrated on two separate focuses in the area around Bornholm. The first of them was to retrospectively assess the effectiveness of the Traffic Separation Scheme in the Bornholmsgat, introduced in 2006. The second one was the prospective assessment of a new, proposed route specifications concerning the possible vessel draught limitation in the area north-east and south of Bornholm. The RCOs of the latter were:

All ships sailing north-east of Adlergrund with a draught of 7-10 m should be diverted to the area south of Adlergrund.

All ships sailing south of Bornholm with a draught more than 10 m should be diverted to the area north-east of Bornholm.

5.2 Scope and methods

The data from the AIS records was used to model and calculate the accidents and their frequencies and the information about the physical properties of the ships was collected from Lloyd's Register. The risk image was created by combining the accident frequencies and their impending consequences. Two workshops were held to identify the relevant hazards and to validate and discuss the results. The hazards identified by the workshop are listed in the Appendix 5.

The risk was calculated for three types of collisions (head-on, crossing and overtaking) and two types of groundings (due to imprecise navigation and due to lacking attention), and the situations before and after were compared. The consequences of the accidents were converted into monetary units as follows: value of a statistical life (= loss of life), cleanup costs after a spillage, loss of assets and so called direct costs (not accident-related costs), like for example fuel and capital costs as well as costs caused by damage due to ship engine exhaust fumes. Loss of life and assets were combined into one group. The direct costs were included only in the traffic diversion investigation, since the traffic separation scheme had already been introduced.

5.3 Results and other remarks

RCO	Change in the accident frequency	Differences of the costs compared with the situation 'before'	Recommended
Traffic Separation Scheme in Bornholmsgat	-37 %	-1 400 000 €	x
Traffic diversion system in the Gdańsk Bay	- 2 %	+490 000 €	

Table 5. The RCOs

As a result, the Traffic Separation Scheme had had a significant risk reducing effect. It had reduced the expected accident costs by 37 % and thus appeared to be advantageous. The traffic diversion would have changed the frequency of the accident by decreasing them by 13 % in south of Bornholm and meanwhile increasing them by 7 % in northeast of Bornholm. The traffic diversion appeared to have a slight risk reducing effect, especially if the expected increase in large vessel traffic would be realized. However, the system was not found to be recommendable, since the cost-benefit balance became negative if the direct costs were taken into account.

6 TØI 2009: Effects of proposed ship routeing off the Norwegian coast. Part 1 Røst – Utsira

6.1 Background and aim

Since the year 2002 the oil transported in the Barents Sea for Russia has increased remarkably and a 60 % increase in the oil transport and a tenfold increase in the gas transport are estimated to be topical by the year 2015. In addition, the number of groundings has unfortunately increased in the Norwegian waters since 2004 and there have been several accidents and near misses that could have lead to oil spill pollution.

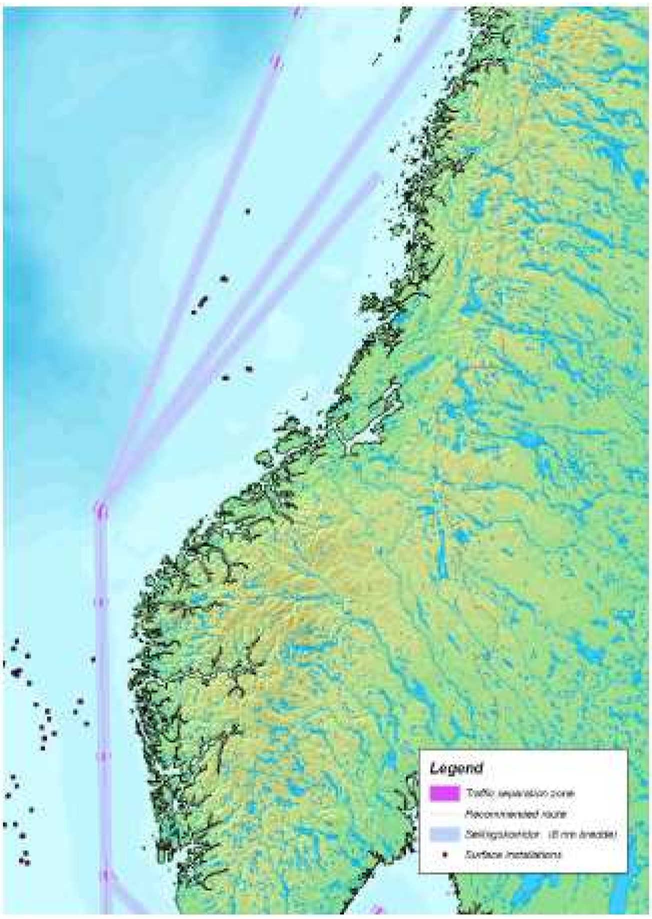


Figure 5. The proposed new routeing

The Norwegian Coastal Administration had proposed a new routeing measure from Røst to Oslo fjord. The study was divided in two parts and this one covered the area between Røst and Utsira. The proposed risk reducing measure was to transfer vessels with size of

5000 GT or more and vessels carrying dangerous goods farther away from the coast and to establish a traffic separation scheme for the transferred traffic. The main purpose for this proposal was to reduce oil spills and their negative effects on the shoreline by giving more time for the authorities to react in case of an accident occurring farther off the coast. An additional advantage was that the largest part of the spilled oil could evaporate before reaching the coast.

6.2 Scope and methods

The traffic data for the study was collected from the AIS database and the study area was divided into nine main lanes and six crossing lanes between Røst and Utsira. The used traffic data consisted of ships with length of 100 meters or more. In addition to the ship traffic, there were 421 installations in the study area, mainly oil platforms, which were to taken into account. The ship accidents were categorized into seven generic accident types, for details, see the Appendix 6.

A MARCS program was used to calculate accident and oil spill probabilities and thus to assess the risk of oil spills per year. The calculations were limited to concern only the accidents affecting the marine environment. The accident probabilities and consequences were compared both for the present routes and for the new proposed route by using given traffic data of 2008 and the traffic forecasts for the year 2025. Two accident scenarios were also studied to assert the effects of transferring the ship traffic to the proposed route by simulating the consequences of an oil spill. One of them was situated at Stad and the other one at Sotra.

6.3 Results and other remarks

According to the study, the effects on both the probability of accidents and the expected reduction in oil spill volumes were significant, especially when the traffic forecasts for the year 2025 were used. Analyzing the tankers separately, the effects were even more remarkable. The table 6 shows the effects of transferring the tanker traffic to the proposed route. The probability of oil tanker collisions became smaller along with the new traffic route, since there would be two separate lanes for the ships going in the different directions. Also oil spill volumes from groundings were reduced, because the routing scheme would move the ship traffic farther away from the shore. In addition, in case of an oil spill accident, the authorities would have more time to react and the portion of the oil reaching the shoreline would be notably reduced and thus the expected consequences of oil spill accidents would be reduced.

The proposed new route would lead to an increase in total ship miles travelled between Røst and Utsira and thus increase the shipping costs. The study did not calculate the shipping cost increases because there was no access to sufficiently reliable unit cost data.

Therefore any cost-benefit assessment was not determined. However, the ships travelling between the Norwegian ports would not be obliged to use the proposed traffic separation scheme.

Traffic figure/forecast	Reduction in all accidents /all ships	Reduction in oil spill volumes /all ships	Reduction in all accidents /tankers	Reduction in oil spill volumes /tankers
2008	-5 %	-13 %	-28 %	-15 %
2025	-6 %	-29 %	-23 %	- 29 %

Table 6. The effect of the proposed new route

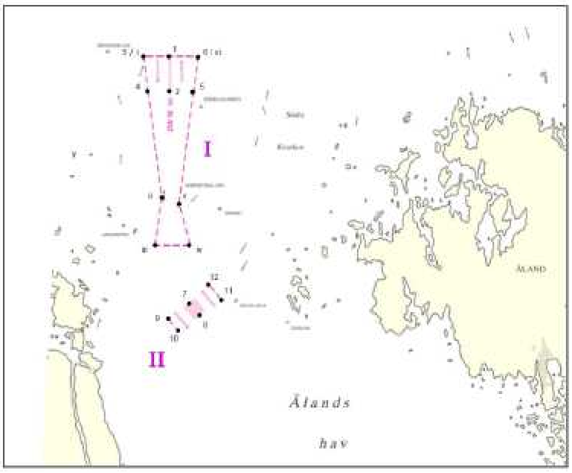
The study raised also a concern considering the fact that by adopting the proposed routeing, a potentially larger coastline impact area would be threatened by an oil spill in case of an accident. However, the implementation of the new proposed route with traffic separation scheme proved to give a significant risk reduction, both for the probability of accidents and the consequences of them. The expected reduction in total oil spill volumes was predominantly.

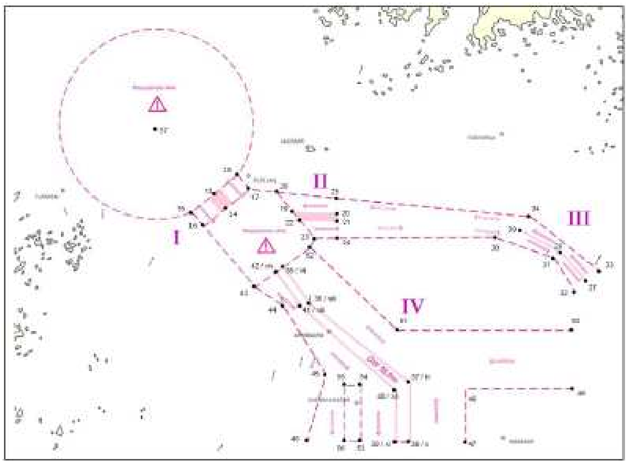
The proposal has been sent to IMO and it is waiting for an approval in the IMO MSC assembly in December 2010. If the proposal is accepted, the TSS will be introduced earliest in June 2011.

7 VTT 2010: Åland Sea FSA study

7.1 Background and aim

There are two main traffic flows intersecting each others in the Åland Sea: vessels sailing in the north-south direction, i.e. between the Gulf of Bothnia and the Gulf of Finland or the central Baltic Sea, and passenger ferries sailing in the east-west direction, between Sweden and Finland. Since there was no Traffic Separation Scheme in the Åland Sea, the traffic had been unorganized and raised the concern of collision, which could cause environmental damage due to oil spills.





Figures 6 and 7. Proposed TSSs and deep water routes in the Åland Sea

This study was a part of the Nordic BaSSy project and the actual aim of the study was to assess the effectiveness of the proposed routeing systems supported with monitoring, reporting and navigational assistance systems, intended to improve maritime safety and the protection of environment. In addition, the work consisted of the development of harmonized methods for the FSA study and followed the development phase of the BaSSy tool (risk analysis software). The study focused on ship-to-ship collision and grounding risks of ships of 300 GT or more. VTT cooperated with the Danish University of Technology in matters related to the BaSSy tool.

7.2 Scope and methods

The work was carried out by analysing the traffic pattern using the AIS information and statistics, and after that arranging four expert workgroups. In the first of them 45 hazards were identified and the risks were prioritized so that the most significant ones were taken into account in the next phases of the study. The list is to be found in the Appendix 7. The second workshop consisted of identifying and prioritizing the RCMs, which were then defined in more detail and rated in the third workgroup and the result was the preliminary grouping of the RCOs. In the last workgroup the effectiveness of the RCOs was estimated, leading to the regrouping of the RCMs into four RCOs.

The idea of the RCOs was that every "higher" RCO includes always the "lower" RCOs. The RCOs were:

RCO 1: Traffic Separation Scheme + deep-water route

RCO 2: RCO 1 + monitoring system

RCO 3: RCO 2 + ship reporting systems

RCO 4: RCO 3 + VTS navigational assistance service

In the risk analysis the collision and grounding risks were estimated comparing these RCOs with the baseline, i.e. do nothing situation. Five collision types and two grounding types were examined. These types were: overtaking collision, head-on collision, crossing collision, merging collision and bend collision respective groundings in the situations concerning ships following the ordinary direct route at normal speed and ships that failed to change course.

The beta version of the BaSSy tool software was used to calculate the collision and grounding frequencies. As a result of the risk analysis, all of the four RCOs were found to decrease both of the risks. Furthermore, the more expensive the RCO was, the more it decreased the grounding risk.

The prime assessment problem of the study was the economic feasibility of the proposed RCOs. The RCOs were compared in terms of ETR (expected total return), which was calculated by dividing ERCC (expected reduced consequence cost) by LCC (life-cycle costs) – in other words calculating the difference between the life-cycle costs and the benefit of improved safety in terms of expected reduced consequence costs (compared with the accidents in the baseline situation). The consequences of collisions and groundings were measured in monetary terms only and were divided into cost categories including costs of oil spill combating at sea, reparation of the struck ship, cleaning of shorelines, damages caused to environment as well as damages caused to fishing, tourism and fish farming. The costs of RCOs consisted of implementation and maintenance costs.

7.3 Results and other remarks

As the final recommendation, based on the cost-benefit analysis, the investment in RCO 1 was highly recommended. In addition RCO 3, i.e. the similar ship reporting system as the GOFREP is, was also recommendable. RCO 4 was not recommendable at all and it was more worth to invest to RCO 3 than to RCO 2.

1 January 2010 the new routeing system consisting of two-way traffic lanes, precautionary areas and the deep-water route as well as the surveillance system were introduced in the Åland Sea.

RCOs	Collision frequency (times/ year)	Grounding frequency (times/ year)	Benefits of reduced societal costs due to averted accidents (k €)	Life-cycle costs of the investments (k €)	ETR	Recommended
Baseline	0,2486	0,792				
RCO 1	0,1503	0,753	1391,1	20	83,40	x
RCO 2	0,1187	0,751	1885,2	562,2	3,95	
RCO 3	0,0971	0,642	2241,2	662,2	5,28	x
RCO 4	0,0971	0,511	2241,2	5640,0	0,82	

Table 7. The effectiveness of the RCOs.

8 Conclusion

8.1 Background and aims

A common feature of the studies is fear of an accident leading to oil spill pollution. The accident types that can be prevented by the proposed risk control options are groundings and collisions, which have been investigated during the formal safety assessment processes. Following issues have been the triggers for the studies:

- collision
- concern about the growing traffic volumes and their effects on safety and the marine environment
- implementation of the proposed RCO(s)
- provision and the planning of it
- functionality of fairway infrastructure
- assessment of an existing RCO

8.2 Cost-benefit analyses

The cost-benefit analysis in most of the studies was carried out by calculating the costs caused by accidents and oil spill consequences compared with the costs of RCOs. The contents of the costs varied from one study to another and therefore it has been impossible to make any commensurate comparison between the studies. In addition, some studies took also into account the direct costs, e.g. capital, fuel and other shipping costs as well as costs of the harms caused by exhaust fumes.

Costs of RCOs	Danish Waters	Gulf of Finland	Øresund	Bornholm	Røst-Utsira	Sea of Åland
Lifecycle costs	x	x	x			x
Equipment		x				
Initial	x	x	x			x
Maintenance			x			x
Operational	x	x	x			
Direct costs				x		

Oil spill costs	**Danish Waters**	**Gulf of Finland**	**Øresund**	**Bornholm**	**Røst-Utsira**	**Sea of Åland**
Authority costs		x				
Clean-up costs	x	x	x	x	x	x
Environmental damage		x				x
Direct costs	x			x		
Loss of human life	x		x	x		
Property damage	x		x	x		
Ship repair	x			x		x
External costs				x		x

Table 8. Costs included in the studies

The table 9 represents which value of costs caused by one tonne of spilled oil has been used in each study. As can be seen, the value varies between the studies and different to other studies, is measured for one cubic meter in the Norwegian study. All of the costs include cleaning work.

STUDY	OIL SPILL COSTS	COSTS INCLUDING
Danish Waters 2002	125 000 DKK/t	- direct costs - clean-up costs
Gulf of Finland 2002 *Additional average costs per spill:*	10 400 e/t 402 500 €/spill of an average size 610 709,33 €/t	- the cleaning work - costs of the marine and environmental authorities - the harm incurred to the environment

Øresund 2006	12 700 USD/t (≈ 76 200 DKK/t)	- clearing and clean-up costs
Bornholm 2008	12 700 USD/t	- clean-up costs
Røst-Utsira 2009	Crude oil: 200 000 NOK/m^3 Heavy fuel: 500 000 NOK/m^3	- clean-up costs
Åland Sea 2010	1670 €/t + 24 828 €/t = 26 498 €/t	- oil combating costs at sea - oil combating costs onshore

Table 9. Oil spill costs per one tonne of spilled oil

8.3 Differences and similarities

There was a number of similarities as well as number of differences between the studies. Most of the studies focused on the risk of collisions and groundings leading to an oil spill, with the main focus on minimizing the accident frequency, i.e. how to best minimize the possibility of an accident. An exception was the Norwegian study concerning the proposed ship routeing from Røst to Utsira, which did not entirely follow the FSA method by lacking the cost-effectiveness part and meanwhile having two imaginary case scenarios.

Common features of used methods were comparing the present traffic situation with the estimated traffic situation in future as well as comparing the present accident frequencies with the evaluated accident frequencies after an implementation of a RCO/RCM. Other similarities were the use of traffic statistics and/or AIS database to develop the situation image as well as the use of expert panels and different kinds of software to calculate or simulate the accident frequencies and consequences. The expert panels were used to find the possible hazards and evaluating their severity in the FSA studies concerning the Finnish territorial waters, the Sound (Øresund) and the area around Bornholm. Other used methods were e.g. the use of expert interviews, risk matrixes and traffic simulation programmes.

Nevertheless, there were differences between the used software and working methods. Also the used costs were varying and so did the used values for oil spill costs, too. In addition, the direct costs were taken into account in some of the studies, but not in all of them. However, all of the studies took into account both cargo and bunker oil spills.

Some of the RCOs were developed during the process of the studies, whereas some studies focused on investigating the effectiveness of the already proposed RCMs/RCOs. A part of the study concerning the sea traffic in the area around Bornholm was exceptional in order of assessing afterwards the effectiveness of an already existing risk control option. The studies concerning Danish Waters and Øresund were the most innovative ones in terms of the number and variety of RCOs/RCMs.

The most common risk control options were TSS and various levels of VTMIS systems. Different from other studies, the recommended risk reducing measures of the Øresund FSA were moving a turn in a fairway, ships with smaller draught sailing outside fairway and improved marking. In addition, other recommended risk control options were e.g. widening or dredging routes and increasing the oil combating capacity.

A part of the studies have been sent to IMO as a documentation of the cost-effectiveness of the recommended RCO in order to get IMO's acceptance before the implementation. On the other hand, the purpose of some studies has been mainly to assess the safety situation in the studied area.

Used methods	**Danish Waters**	**Gulf of Finland**	**Øresund**	**Bornholm**	**Røst-Utsira**	**Sea of Åland**
Expert interviews	x	x				x
Workshops		x	x	x		x
Software, calculation and/or simulation models		x	x	x	x	x
Fault tree technique		x				
Risk matrices		x	x			x
Bayesian network	x		x			x
Case scenarios					x	
Used sources	**Danish Waters**	**Gulf of Finland**	**Øresund**	**Bornholm**	**Røst-Utsira**	**Sea of Åland**
Literature review	x	x			x	x
Accident database & statistics	x	x	x	x		x

Accident reports	x					
VTS data	x		x			x
AIS data			x	x	x	x
Port data			x	x		x
Pilot registrations			x			
Register or database from classification societies				x	x	
Traffic statistics	x		x			
Ferry schedules			x			x
Meteorological data					x	
Geographical information				x		x

Table 10. Used methods and sources

As can be seen in the table 10, the AIS data has been useful in all of the studies made after the implementation of AIS in 2004.

8.4 Results

As mentioned above, the direct numerical comparison between these studies has been impossible, since the risks are determined differently and the calculations have been done by various methods. The calculated numbers are not comparatively with each others, since they do not include equal costs for the accident consequences, and to a minor extent, there are also changes in money values. In addition, the age of the studies varies, which contributes to the changed traffic volumes and situations caused by that some of the RCOs have been implemented.

9 References

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Appendix 1

List of FSA Studies made in Baltic Sea area

Year	Area/Ship types	Country	Aim	Report
2004	Gothenburg	Sweden	Fairway alternatives	
2006	Norrköping	Sweden	Fairway alternatives	
2009	Gävle	Sweden	Fairway alternatives	
2009	Asköleden	Sweden	Fairway alternatives	Not yet finished
2008	Vänern	Sweden	Altered pilotage	
200x	Horstensleden	Sweden	Fairway alteration	
200x	Värmdö-Garpen	Sweden	Fairway alteration	
2010	All fairways	Sweden	Need for VTS	Not yet finished
2006	Gulf of Finland	Finland	VTS/VTMIS/TSS	
2009	Sea of Åland	Finland/Sweden	TSS	
200x	Great Belt	Denmark	VTS	
2007	Bornholm Gat	Denmark/Sweden	Unknown	
2006	The Sound	Denmark/Sweden	FSA	
2007	Danish waters	Denmark	Oil spill risk	
2005	Gulf of Finland/Baltic Sea	Finland/Sweden??	Assess risks with winter navigation	A preliminary risk analysis of winter navigation in the Baltic Sea
2008	Kriegers Flak	Sweden	Wind farm and shipping	
2007	Storgrundet	Sweden	Wind farm and shipping	Risk assessment of planned wind farm in Storgrundet
2007	Baltic Sea	Sweden	Estimating oil spill costs	Socioeconomic impacts of major oil spills- prediction methods and

				scenario studies
1998	The Sound	Denmark/Sweden	Ship interaction with the Öresund link	The Öresund Lin. Operational Risk Analysis ORA-98
2000	The Sound	Denmark/Sweden	Identify and assessing risks for maritime accidents	Risk inventory in Öresund
2002	The Sound	Denmark/Sweden	Assessing oil spill risk in Öresund	Oil spills in Öresund - Marine oil spill events, causes and claims
1992	The Sound	Denmark/Sweden	Collision with bridge	
200x	The Sound	Denmark/Sweden	Unknown	
2006	The Sound	Denmark/Sweden	IWRAP	
2006	The Sound	Denmark/Sweden	PAWSA	
2008	Trelleborg municipality		Oil pollution risk	
			Oil spill consequences	Socioeconomic
200x	Kriegers Flak	Germany	Wind farm and shipping	
2008	Pipelines	Sweden	NordStream - ship influence on pipeline	
2009	Hoburgs bank	Sweden	NordStream - delayed anchorage effect	
201x	Baltic Sea area	Baltic Sea	Oil combating preparedness	
2009	Røst-Utsira	Norway	TSS	
2009	Utsira-Skagerrak	Norway	TSS	
2008	Skåretrebåen	Norway	Waterway	
2008	Lepsøyrevet	Norway	Waterway	
2008	Bodø innseiling	Norway	Waterway	
2008	Finnsnesrenna	Norway	Waterway	

2007	Borg innseiling	Norway	Waterway	
2007	Stad skipstunnel	Norway	Waterway (ship tunnel)	
2004	Brevikstrømmen	Norway	Waterway	
2004	Seilingsled Bergen	Norway	Waterway	
2004	Svolvær innseiling	Norway	Waterway	
2003	Northern Norway	Norway	VTS	
2000	Svelvikstrømmen	Norway	Waterway	
1996	Brønnøysundet	Norway	Waterway	
1995	Risøyrenna	Norway	Waterway	
1994	Rogaland	Norway	VTS	
?	Gunnhildvågen	Norway	Unknown	
?	Drøbaksundet	Norway	Unknown	
2008	Gulf of Finland	Finland	Accident probabilities	Accident probabilities in selected areas of the Gulf of Finland
2010	Svalbard	Norway	Pilotage	Risk assessment regarding piloting service or pilot exemption certificate on Svalbard
2010	Gothenburg	Sweden	Addressing maritime risk with a proposed LNG-terminal	Maritime risk analysis of handling of LNG in port of Gothenburg
	Container	Global	Establish risk level of ship type	Formal Safety Assessment
	LNG	Global	Establish risk level of ship type	Formal Safety Assessment
	RoPax	Global	Establish risk level of ship type	Formal Safety Assessment
	Crude Oil	Global	Establish risk level of ship type	Formal Safety Assessment
	CruiseLine	Global	Establish risk level of ship type	Formal Safety Assessment
	Dangerous cargo -	Global	Unknown	Formal Safety Assessment

	container vessels			
2006	ECDIS	Global	Unknown	
2009	Gulf of Finland	Estonia/Finland /Russia	Collision probability	Ship-Ship Collision Probability of the Crossing Area between Helsinki and Tallinn
2002	Danish waters	Denmark	Risk analysis of navigational safety	Risikovurdering af sejladssikkerheden i de danske farvande
			Unknown	
1990			Unknown	Study of the Risk for Accidents and the Related Environmental Hazards from the Transportation of Chemicals by Tankers in the Baltic Sea Area
2007	Southern Baltic Sea	Denmark, Germany and Sweden	Unknown	Offshore wind farm development and the issue of maritime safety. Case study Kriegers flak i, II and Iii.
2000		Denmark	Risk analysis wind farm	Havmøllepark ved Rødsand. VVM-redegørelse. Baggrundsraport nr 21.
	Oslo fjord	Norway	Establish risk model for sea transportation in the Oslo fjord	A method for assessing the risk of sea transportation: Numerical examples for the Oslo fjord
2005	Kattegatt	Sweden	Unknown	Risk- och sårbarhetsanalys för den kommersiella sjöfarten i Kattegatt
2010	Malmö and Södertälje	Sweden	Unknown	
2002	Gulf of Finland	Estonia/Finland	FSA Collisions	The implementation of the VTMIS system for the Gulf of Finland. Formal Safety Assessment study
2007	Gulf of Finland	Estonia/Finland /Russia	Aim is to identify the possible safety gaps in the maritime transportations and consequently make recommendations on how to improve the	Risks in oil transportation in the Gulf of Finland "Not a question of if - but when"

			safety situations in the form of actual policy proposals.	
2004	Archipelago (of Åland and Turku)	Finland	Fairway alternative	The risk analysis of the planned fairway in Kökar (Kökarin väyläsuunnitelman riskianalyysi)
2002		Finland	Unknown	(Särkkä-Kustaanmiekka-väyläparin tarpeellisuusselvitys)
2002	Gulf of Finland	Finland	Unknown	Suomenlahden meriliikenteen riskitekijät
2010	Gulf of Finland	Finland	Ship-ship collision and grounding frequency	Modelling marine accident frequency
2003		Finland	Fairway	(Väylien syvyyskäytäntöä koskeva riskianalyysi)
2003		Finland	ROPAX	Risk analysis of a ROPAX-vessel in powered hard grounding

Appendix 2

Hazards in the Gulf of Finland traffic ranked highest by the expert panel

Risks based on human factor

1 Professional skills among the navigators will decrease in the sea area

2 High traffic density will cause problems / increase risk of accident

3 Recreational boating lacks the skills to navigate

4 Vessels wandering off from their route

5 The options of the traffic situation

6 Long working hours cause fatigue

7 The intentional disregard for the safety of marine traffic

Risks based on external factors

1 Heavy crossing traffic between Helsinki and Tallinn

2 Substantial growth in vessel calls, especially the number of tankers

3 Heavy high speed craft traffic crossing the main traffic streams

4 Growth in passenger ship traffic. New routes to east, especially to St. Petersburg

5 Recreational boating streams between Estonia and Finland

6 “Traffic jam” off Hanko peninsula / congested traffic in the area

7 Heavy recreational boating traffic in reduced visibility

8 During heavy seas high speed crafts will have to use optional and unexpected routes

Risks based on technical factors

1 Heavy growth in tanker traffic will lead to increasing number of substandard tankers transiting the Gulf of Finland

2 The average technical standard of ships will decline

3 Explosion or fire onboard

4 Fire/explosion on a large tanker

5 Not under command -vessels

6 Hazardous cargoes (flammable, explosive, toxins)

7 Sinking, capsizing, dangerous listing

Appendix 3

Prioritized list of hazards in relation to winter navigation in the Gulf of Finland

1 Heavily increasing tanker traffic

2 Increasing traffic volumes between Helsinki and Tallinn

3 Single bottom tankers

4 Rescue operations in heavy ice conditions

5 Vessels unable to give way according to regulations because of heavy ice conditions

6 Oil combating measures in ice conditions

7 Crews which are unfamiliar with ice conditions or inexperienced in winter navigation

8 Lack of escort towing

9 Getting stuck in compressive ice

10 Occasional disruptions in icebreaker activities

11 Problems in radio communication

12 Navigation errors, which happen when trying to avoid difficult ice conditions

13 Lack of routing system in ice conditions

14 Cold weather, rapidly changing ice conditions

15 Icing

Appendix 4

Hazards identified by the workshop in the Øresund study

The hazard identification workshop resulted in following list of 66 identified hazards.

1	Ship-ship collision at Falsterborev due to crossing ship traffic.
2	Ship-ship collision at Falsterborev due to inattention in connection with the use of radar navigation
3	Ship-ship collision north of Drogden lighthouse due to limited space when two northbound ships enter Drogden at the same time.
4	Ship-ship collision north of Drogden lighthouse due to a ship being set by the current.
5	Ship colliding with buoy 16 north of Drogden lighthouse.
6	Ship-ship collision at the south entrance of Drogden.
7	Grounding at Quartus ground due to limited space for passing of ships in Drogden.
8	Grounding at Quartus ground because buoy 16 is missing.
9	Ship-ship collision where Drogden meets Flintrännan.
10	Ship looses the manoeuvring ability and drifts towards areas where the water depth is not sufficient and grounds.
11	Ship looses the manoeuvring ability and drifts towards obstacle.
12	Grounding at Sandflyttan when northbound ship takes a shortcut on the route.
13	Ship looses the manoeuvring ability and drifts towards another ship and collides.
14	Ship-ship collision in Drogden because ships are passing too close to each other.
15	Leisure boats grounding at Saltholm.
16	A ship with difference between true heading and course over ground collides with passing ship.

17	Ships colliding with protective islands surrounding the central piers of the Øresund Bridge.
18	Collision of the girder between two bridge piers of Øresund Bridge.
19	Collision of the girder between two piers of the Øresund Bridge because a ship with a too large air draught (deck house height) tries to pass the bridge outside the channel.
20	Grounding in the marked route in Flintrännan passing the Øresund Bridge.
21	Ship-ship collision north of Port of Malmö (east of Sjollen) because northbound ships do not follow the recommended route and thus pass close to southbound traffic.
22	Grounding in the entrance to Port of Malmö.
23	Grounding at Middelpunkt.
24	Ship-ship collision at Middelpunkt.
25	Ship-ship collision in Kongedybet.
26	Grounding due to interference between ship radar and the instruments landing system (ILS) of the Copenhagen Airport.
27	Ship-ship collision due to interference between ship radar and the instruments landing system (ILS) of the Copenhagen Airport.
28	Ship-obstacle collision due to interference between ship radar and the instruments landing system (ILS) of the Copenhagen Airport.
29	Ship colliding with stone wall in the entrance/exit of the Port of Copenhagen.
30	Ship-ship collision at exit of Port of Copenhagen (in area where lighthouse sectors cross) due to crossing traffic.
31	Grounding in the entrance of Port of Copenhagen.
32	Ship-ship collision with ships leaving anchor site no. 2.
33	Ship-ship collision with leisure boats.
34	Grounding at Lous Flak.
35	Grounding by southbound ships that should pass east of Pinhättan but instead pass on the west where the water depth is down to 7 m.
36	Ship-ship collision at buoy outside Landskrona.
37	Grounding between Pinhättan and Landskrona at Stengrund.

38	Ship-ship collision west of Ven due to sudden change of course.
39	Ship-ship collision due to ships sailing close to each other in waters around Ven because of narrow lighthouse sectors.
40	Grounding around Ven.
41	Grounding at Väster Flacket off of Landskrona.
42	Ship-ship collision with coaster in the Helsingør-Helsingborg area.
43	Grounding on the Swedish coast north of Helsingør-Helsingborg due to ships not turning at the buoy in the middle of the channel.
44	Grounding on the Swedish coast north of Helsingør-Helsingborg due to northbound current.
45	Ship-ship collision between the Helsingør-Helsingborg ferries.
46	Ship-ship collision with fishing vessel fishing in the lane.
47	Ship-ship collision in waters north of Helsingør-Helsingborg.
48	Collision with sports divers in area around Helsingør-Helsingborg and around Ven.
49	Ship-ship collision with fishing vessel in waters around Ven.
50	Ship-ship collision in waters around Ven.
51	Ship colliding with buoy 16 north of Drogden lighthouse.
52	Ship-ship collision in Drogden if a large ship in ballast meets another ship when the wind is strong.
53	Ship-ship collision in Drogden due to queue up of ships.
54	Grounding in Drogden due to queue up of ships.
55	Ship-ship collision in traffic separation system at Helsingør due to slowly sailing ships.
56	Grounding in traffic separation system at Helsingør due to slowly sailing ships.
57	Ship-ship collision in traffic separation system at Helsingør due to blurring of radar image.
58	Ship-ship collision between southbound ships in traffic separation and Helsingør-Helsingborg ferries.
59	Ship-ship collision in Drogden due to missing buoy.

60	Grounding in Drogden due to missing buoy.
61	Ship-obstacle collision in Drogden due to missing buoy.
62	Grounding in Drogden because of a too large draught.
63	Grounding at Sundby Hage.
64	Ship-ship collision outside Helsingborg due to background lightning.
65	Ships colliding with the piers of the Øresund Bridge.
66	Air plane colliding with ship with large air draught.

Appendix 5

Hazard identification in the area around Bornholm

This is a shortened version of the hazards identified by the workshop, in other words each hazard is mentioned only one time in this list. In the original list (Appendix F in the Bornholm study) the hazards identified by the workshop are categorized for different areas and therefore some hazards are mentioned several times, having specified explanations related to the typical characteristics of traffic in each area.

Hazards in the area around Bornholm

Collision with a ferry

Collision with another ship

Collision with a ship in a parallel course

Collision with a ship in an opposite course

Collision with a fishing vessel or being tangled up in the drift nets

Collision with a sailing vessel

Collision with a boat

Collision with a vessel having a diver in the water

Collision with traffic in connection with an establishment of a windmill park

Collision with oncoming traffic due to missed turn

Grounding

Grounding near route

Grounding due to missed turn

Accident due to sailing in the shooting area during shooting

Damaging a cable

Damaging a gas pipe

Sailing across an electric cable causes a deviation in the magnetic compass. This can cause a ship to wander off her course.

Contact with Hammeren

Part-financed by the European Union

Appendix 6

Generic ship accident types

According to the study concerning the fairway alternative between Røst and Utsira, almost all of the shipping losses occurred in the open water can be categorized into seven accident types as follows:

Accident type:

Ship-ship collision

Powered grounding (groundings which occur when the ship has the ability to navigate safely yet goes aground, such as the *Exxon Valdez*)

Drift grounding (groundings which occur when the ship is unable to navigate safely due to mechanical failure, such as the *Braer*)

Structural failure/foundering whilst underway

Fire/explosion while underway

Powered ship collision with fixed marine structures such as platforms or wind turbines (similar definition to powered grounding)

Drifting ship collision with fixed marine structures such as platforms or wind turbines (similar definition to drift grounding)

Appendix 7

Prioritized list of hazards in the Åland Sea

Risks with at least four "yes" votes from experts voting "yes" on the hazards they found to be most significant or "no" on the others. The risks below were considered to be the most significant ones and they were taken into account in the following expert panels.

Hazard	Yes votes
Fatigue: Officer of the watch and crew are tired (e.g. due to long journey in rough weather	12
Blackout	10
Navigators rely too much on the modern navigation equipment	9
Poor visibility due to fog or darkness making navigation and observation of pleasure crafts difficult	9
Unpredictable traffic picture because there is no traffic separation scheme (TSS) in the area. The situation is especially bad in the southern part of the area.	9
Ship violates COLREGs	8
Leisure boats disturb safe navigation during summer time	7
Crew is not competent to navigate in ice	7
Multinational crew navigating at this sea area for the first time	6
Failures in the navigation systems	6
Collision between a passenger vessel and a vessel carrying dangerous cargo	5
Collision in crossing traffic area Nyhamn – Söderarm	5
Dangerous meeting and overtaking situations in narrow ice channels	5
Communication problems between vessels in VHF radio communication due to insufficient language skills	4
Misunderstanding while agreeing on actions to be taken over VHF radio causing e.g. collision	4
Rough sea and high winds concentrate traffic to a small sea area	4
Icing with high seas	4