BE-AWARE: Summary Report

Bonn Agreement
Accord de Bonn

Co-financed by the EU –
Civil Protection Financial Instrument

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Executive Summary

The "Bonn Agreement: Area-Wide Assessment of Risk Evaluations" (BE-AWARE) project is the first area-wide risk assessment of marine pollution in the Greater North Sea and its wider approaches using a common methodology. This has enabled risks to be mapped and compared in a systematic way in an increasingly busy and highly used maritime area. The need for the risk assessment was agreed by Bonn Agreement Ministers (for transport) given the increasing competition for space in the Greater North Sea and its approaches from shipping, oil and gas production, offshore renewable energy, as well as other emerging uses. The project was co-financed by the European Union, with participation and support from the Bonn Agreement Secretariat, Belgium, Denmark and the Netherlands, with co-financing from Norway and Belgium.

The overall objective of BE-AWARE was to gain a better understanding of the regional and sub-regional risk of accidents and the potential for marine pollution events in the Greater North Sea and its approaches. This objective was achieved by focusing on the risk of accidents and the potential for spills of oil and hazardous and noxious substances (HNS) from shipping. Risks derived from collisions with offshore installations (both wind farms and oil and gas installations) and from spills from installations themselves, were also included. As a discrete task, a regionally specific methodology for environmental and socioeconomic vulnerability analysis was also developed.

The methodology used was similar to that developed in the BRISK Project that had been undertaken in the HELCOM maritime area, using a multi-model approach, calculating the risk and magnitude of spills. Analysis was undertaken for both 2011, the baseline year for the project, and for 2020, taking into consideration the expected changes in traffic routing and intensities and maritime uses. The methodology was adapted for conditions in the greater North Sea and was adopted as the project Methodology Note. This included defining the key parameters to be taken into consideration, such as: Hazard identification; Ship traffic; Classification of oil; Oil transport model; Traffic prognosis; Frequency and quantity of oil spills; Oil spills related to offshore installations and Qualitative analysis of HNS risks.

The models used a considerable amount of data, including accident statistics, automatic identification system (AIS) data, cargo data, risk-reducing measures, locations of fixed objects, etc. In order to collect a standard set of data for the whole Bonn Agreement area, a Data Collection Note was developed, outlining the data types and formats required from the relevant Contracting Parties. The data was collected in a central Regional Resource Database by the Bonn Agreement Secretariat, to be used as a future resource for the Bonn Agreement.

AIS data for 2011 was provided by the Danish Maritime Authority. Detailed information on oil cargo at ship level was supplied by Mongstad (Norway), Hamburg (Germany), Rotterdam (Netherlands) and Antwerp (Belgium). This was used in the cargo model, allowing an increased level of accuracy. Rotterdam and Antwerp also provided detailed information on HNS shipments which was used in the qualitative HNS analysis.

The ship traffic model, developed by BE-AWARE, was based on the AIS data. From the intensity of the ship traffic a route net was developed that described the primary sailing routes and the number of vessels on those routes. This was then used to develop a traffic model that was a database of identified route passages, including direction and vessel characteristics. The database provided traffic data for the calculation of accident and spill frequencies, which were dependent upon the traffic, its volume and composition.

Using individual vessel information from the World Shipping Encyclopaedia, the model was able to estimate the consequences of an accident, based on the vessel characteristics. This was then combined with the cargo model, which described the probability of a certain ship type and ship size sailing on a specific route being loaded with a certain type of cargo. This used information that included ships routes, lists of substances and port data.

The major modification that was required to adapt the BRISK model to North Sea conditions was the inclusion of the spill risks from collisions with offshore gas and oil installations and offshore wind farms. The assessment therefore modelled several types of spills: spills from ships colliding with platforms or renewable installations; spills from platforms resulting from collisions with ships; and spills from oil platforms from other damage. For oil platforms, risk calculations were related to daily operations and to risks such as blow-outs (noting the infrequent occurrence of these) with distinctions made between normal and high pressure, high temperature wells.

The ultimate results for risks of spills for 2011 and 2020 scenarios were then obtained by undertaking a further integrated analysis to take into account existing and intended Risk Reduction Measures (RRMs) such as pilotage, surveillance, (VTS), obligatory routing (TSS), emergency towing, etc.

As the long-term aim was to identify the best measures to reduce these risks at a sub-regional level the results were then presented for 5 sub regions: the Atlantic, the Northern North Sea, the Eastern North Sea, the Southern North Sea and the Channel.

Sensitivity analysis and vulnerability mapping

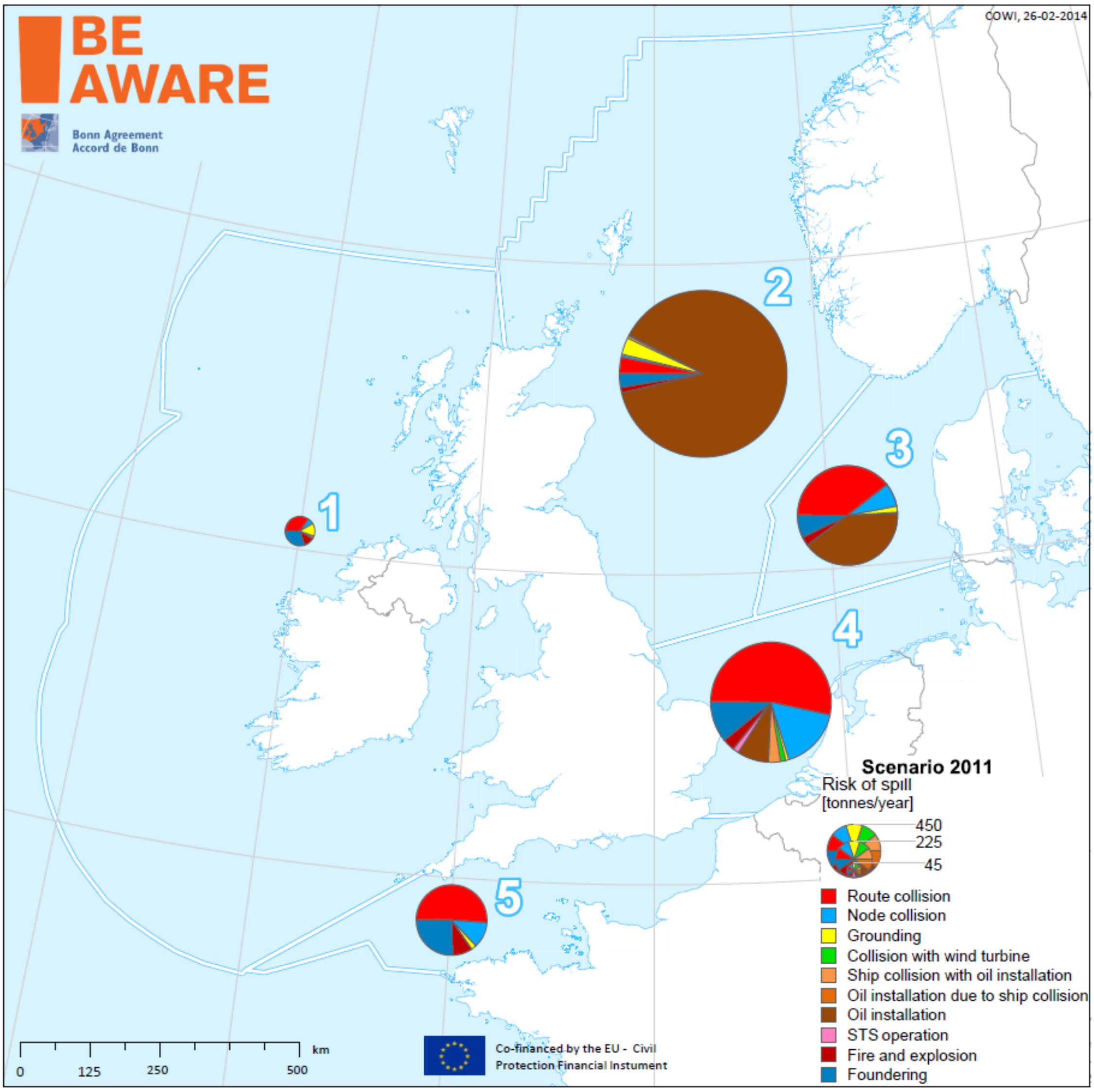
In addition to the above modelling work, BE-AWARE prepared the ground for later projects developing a simple, qualitative and commonly acceptable environmental and socioeconomic sensitivity analysis methodology. This was done via expert workshops and resulted in a BE-AWARE Environmental and Socioeconomic Sensitivity Mapping approach. The common sensitivity mapping approach contained three distinct steps:

- STEP 1 – The identification of sensitive ecological and socio-economic features;
- STEP 2 – The vulnerability assessment and ranking of these features, based on a set of objective criteria and resulting in a seasonal vulnerability score for each feature;
- STEP 3 – The total (seasonal) vulnerability mapping.

Quantitative analysis of oil spill risk

The main output of the project was the result of the quantitative analysis of oil spill risk, which showed significant regional differences. Within each of the BE-AWARE sub regions the frequency of different accident types were calculated for both the existing situation, 2011 and the future 2020 scenario. The frequency for individual spill sizes was also calculated.

In the results, significant regional differences were seen. Accidents caused by collisions were predicted to be most pronounced in areas with high intensity traffic, in combination with narrow straits or areas with crossing traffic or complex traffic patterns. These significant regional differences also showed in the risk of spills, which is presented in the figure below for 2011. In the northern part of the North Sea there was limited traffic over a very large area, hence reducing the probability of ship-ship collisions. However due to the presence of a substantial number of oil platforms the risks of spills from the platforms were the largest contributors in this area. In high traffic areas such as along the coast of the Netherlands, Belgium and Germany the ship-ship collision risks became much more pronounced and constitute the largest contribution to the overall picture.



Relative risk of all spills for the different BE-AWARE sub regions in tonnes per year for the 2011 scenario

There were also significant differences overall and on a regional level between the 2011 and the 2020 scenarios. These were related to the changes in the levels of traffic, the development in ship size, the development in risk reducing measures and the increase in new uses of maritime space. In particular an increased risk was predicted from collisions with wind turbines due to the development of new offshore wind farms to meet renewable targets. These changes were most notable in the Channel and Southern and Eastern North Sea.

While large spills can come from offshore installations, overall, the largest contributor of spills was the outflow of liquid cargo as a result of collisions involving large tankers. Minor and medium sized spills were typically from accidents where the vessels had only sustained minor damage. Groundings mainly contributed to the risk of minor and medium sized spills.

Qualitative analysis of HNS spill risk

Another key pollution risk in the Greater North Sea is spills of hazardous and noxious substances (HNS). The project produced a qualitative analysis of this risk. This was because less information was available on the more diverse and complex HNS shipping activity, combined with very different outcomes from spills of different substances into the sea. The project was however able to obtain data for the ports of Rotterdam and Antwerp at the level of detail required for in-depth analysis. The analysis focused on categorising the different hazards posed by the substances in terms of how they react when released in an accident, their risk to public health and their risk to the environment. To the extent possible, the likelihood that HNS cargo was on-board a ship involved in an accident was also modelled using the SAMSON model. It was nevertheless recognised that there were shortcomings with the modelling, particularly that more local trade patterns of HNS were not captured by the analysis.

The results shown the spread of risk for HNS between those substances carried in bulk and those packed in containers as packed goods. This highlighted that higher levels than expected of HNS are transported as packed goods. Extrapolation of the data from HNS cargoes from Antwerp and Rotterdam concluded the following:

- From the 10 collisions that occur every year in the Bonn Agreement area, one collision would involve a vessel that carried substances classified as IMDG 1-9. Approximately 2200 tonnes of HNS would be involved in the collision.
- Approximately 0.3 collisions (once in 3 years) would include a chemical tanker of class I or II. Per year, approximately 3000 tonnes of HNS would be involved in a collision.
- Approximately 0.1 collisions (once in 10 years) would include a vessel that carried substances from the Top 20 ARCOPOL list. Per year, approximately 90 tonnes ARCOPOL HNS would be involved.

For HNS transported as packed goods the following was concluded:

- It was estimated that there would be 0.8 collisions per year that involved a vessel with HNS on board;
- The total amount of HNS involved in a collision would be 843 tonnes per year, which would include 4 different HNS shipments.

Case Study

As part of the BE AWARE project, a benchmarking activity was carried out to examine the result of the BE-AWARE risk assessment against the SAMSON model for a high-risk area. This would allow Contracting Parties that use the SAMSON model for national risk assessments to take these differences into consideration when comparing the BE-AWARE results against national studies. The comparison was done via a case study in the high intensity traffic area in front of the Belgian and Dutch coast. Despite differences in the way encounters, groundings and casualties were calculated, the results of the BE-AWARE and the SAMSON model with respect to collisions and groundings delivered overall figures that were in the same order of magnitude. The largest difference was for the probability and volume of bunker spills. The probability and the volume of a bunker spill seemed to be too high in the BE-AWARE model with respect to the number of ships involved in collisions and the fuel capacity of the ships. However the spill sizes in these cases were much smaller than the liquid cargo spills predicted by both models, where the differences between the two models were minor. In general a closer fit between the models would have been more desirable, but the differences shown were acceptable.

Conclusions

In order to undertake the BE-AWARE risk analysis, a significant amount of data was required as input to the models. This data collection was a major challenge for the project. In future projects better data, for instance from satellite AIS could give better results and more detailed cargo information from more ports would also be desirable. In this project nevertheless, the data received was relatively sufficient to be able to undertake the analysis with confidence in the results.

The BE-AWARE project successfully modified established models to apply them to the Greater North Sea and its Wider Approaches. The inclusion of risk from the offshore oil and gas industry and the expected increase in numbers of offshore wind farms provided useful insight into key risks from spills in the different sub-regions and the change in risk towards 2020.

The project identified that, overall, the main risk for oil pollution was due to collisions involving ships. Generally the largest contributor to oil spills was the outflow of cargo as a result of collisions involving large tankers, even if the risk frequency for this type of event was very low. Minor and medium sized spills were typically from accidents where the vessels had only sustained minor damage or had been grounded. The frequency of collision accidents was mainly spread along the areas of the North Sea with the highest amount of traffic: the Channel and the southern and eastern North Sea.

For the qualitative risk of HNS, the analysis focused on categorising the different hazards posed by the substances in terms of how they react when released in an accident, their risk to public health and their risk to the environment. The analysis again indicated that the main risks existed in the regions with the highest shipping density.

Contents

1. Introduction

The Greater North Sea and its wider approaches is one of the busiest and most highly used maritime areas in the world. With the ever-increasing competition for space comes an increased risk of accidents that could result in marine pollution. Up to the time of the project, the area had no overall risk assessment for marine pollution. The risk was mapped with a variety of national risk assessments, which were undertaken with different methodologies and over different periods of time thus reducing comparability.

The BE-AWARE project therefore undertook the first area-wide risk assessment of marine pollution using a common methodology that allowed the risk to be mapped and compared in a systematic way. The project outcomes will contribute to improving disaster prevention by allowing North Sea States to better focus their resources on areas of high risk.

The project was a two-year initiative (2012-2014), co-financed by the European Union Civil Protection Financial Instrument, with participation and support from the Bonn Agreement Secretariat, Belgium, Denmark and the Netherlands, with co-financing from Norway and Belgium.

1.1 Understanding the risk of pollution

The competition for space in the Greater North Sea and its approaches continues to grow year on year. The area contains some of the busiest shipping lanes in the world and is also a major oil and gas production area, with over 1300 installations. However in recent years there have been new demands for space. Concerns over climate change and the adoption of carbon reduction targets have led to a huge increase in the planning and installation of offshore wind developments, with over 10,000 turbines installed in the Bonn Agreement area. International targets to increase the coverage of marine protected areas have also reduced potential for development in sensitive areas. Emerging uses such as ocean aquaculture also have the potential to use additional space.

The need for an area-wide risk assessment and the associated benefits was recognised by Bonn Agreement Ministers in 2010 (Dublin Declaration). In particular, Ministers noted the enlargement of the Bonn Agreement area as a result of the accession of Ireland in 2010, predicted increased storminess as a consequence of climate change and increased export of oil products from the Russian Federation transiting through the Bonn Agreement area. These factors, along with new maritime uses and activities, were expected to contribute to a complex pattern of sea use and maritime development for which a risk assessment, to look at potential improvements to disaster prevention, was vital. As a consequence, a need was identified to further develop and update hazard identification and risk modelling, drawing lessons learned from past disasters, and to raise awareness and prevention capacities at a regional level, involving multinational participation.

1.2 Project Development

The Bonn Agreement held a Risk Assessment Workshop in May 2011 to look into the different approaches to risk assessment applied in each of the Contracting Parties and decide upon which approach should be considered for an area wide risk assessment, as outlined by the Ministers in Dublin. The workshop also considered the regional risk assessment BRISK (www.briskhelcom.com) which was being undertaken in the Baltic Sea, to see if a similar approach could be applied to the North Sea, particularly as three countries are Contracting Parties to both the Bonn Agreement and HELCOM.

The outcome of the workshop was a decision that the Bonn Agreement should apply for funding to the EU Civil Protection Financial instrument to undertake an area-wide risk assessment for oil and hazardous and noxious substances, which was compatible with the approach used within the BRISK project. An application was therefore submitted to the 2011 Civil Protection call and funding was subsequently awarded for a two-year project starting in January 2012. This was called "Bonn Agreement: Area-Wide Assessment of Risk Evaluations" or BE-AWARE for short.

1.3 Project Objectives

The overall objective of BE-AWARE was to gain a better understanding of the regional risk of accidents and the potential for marine pollution in the Greater North Sea and its approaches. The main focus of the project was the risk of accidents and the potential for spills of oil and hazardous and noxious substances (HNS). However the project also looked at the risk of spills from shipping due to collisions with offshore installations (including wind turbines) and from installations themselves, although in a more generic way. The project also aimed to develop a regionally specific methodology for environmental and socioeconomic vulnerability analysis which could be applied in future work.

1.4 Project Partners

The responsibility for implementation of the BE-AWARE project was borne by the four project partners: Bonn Agreement Secretariat (Coordinating Beneficiary), Admiral Danish Fleet Headquarters, Netherlands' Ministry of Infrastructure and Environment (RWS Nordzee) and Royal Belgian Institute for Natural Sciences (MUMM) (Associate Beneficiaries). The project was also supported by two co-financers, the Norwegian Coastal Administration and the Belgian DG Environment, Marine Environment Unit, which supported the project financially but were not responsible for the project implementation. Finally, two subcontractors COWI and MARIN supported the technical implementation of the project.

The organisational structure is outlined below:

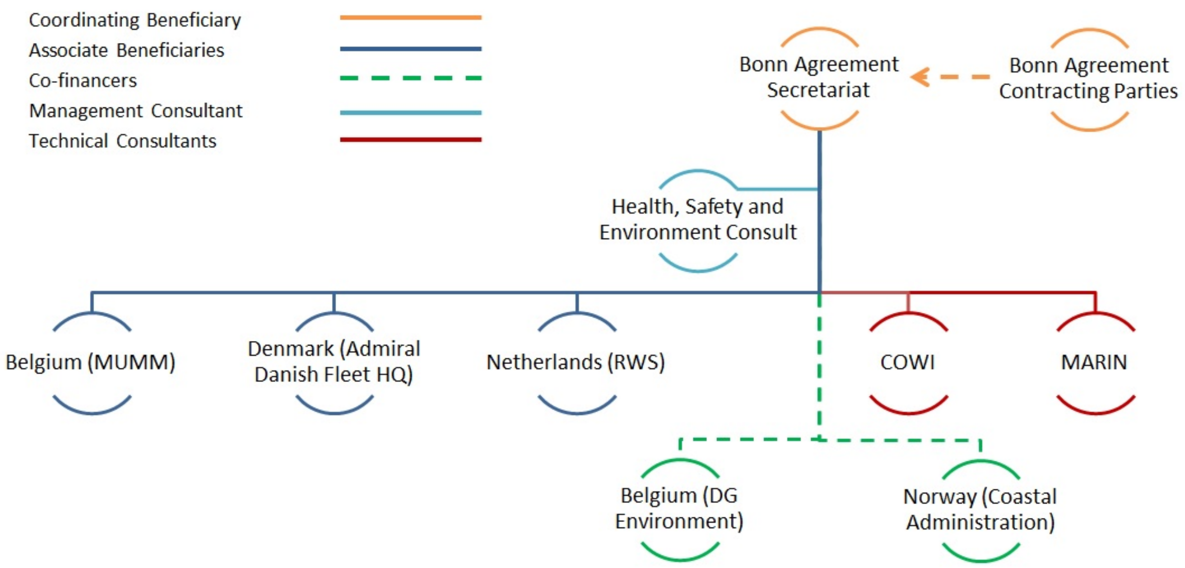


Figure 1-1 Project Organogram

1.5 Project Finance

The project was financed through a partnership approach with the main source of funding provided by the EU Civil Protection Financial Instrument. This accounted for 75% of the €538,300 total project budget with the remaining funding provided by the Project Partners and Co-financers.

1.6 Project Structure

The implementation of BE-AWARE was split into ten main work packages, covering the main objectives of the project. The work products were: Project Management and Communication, Kick off meeting, Regional resource database, Methodology, Area-wide traffic study, Sensitivity analysis, Risk Assessment Workshop, Bonn Agreement area-wide Risk Assessment, Case study and Final Conference. These tasks resulted in the key outputs set out in the rest of this report.

The project was structured so that regular interaction could be made with key stakeholders, including feedback to Bonn Agreement and OSPAR Commission meetings. Stakeholders were also invited to key meetings, such as the Methodology Seminar, Risk Assessment Seminar and Final Conference. The figure below outlines these interactions.

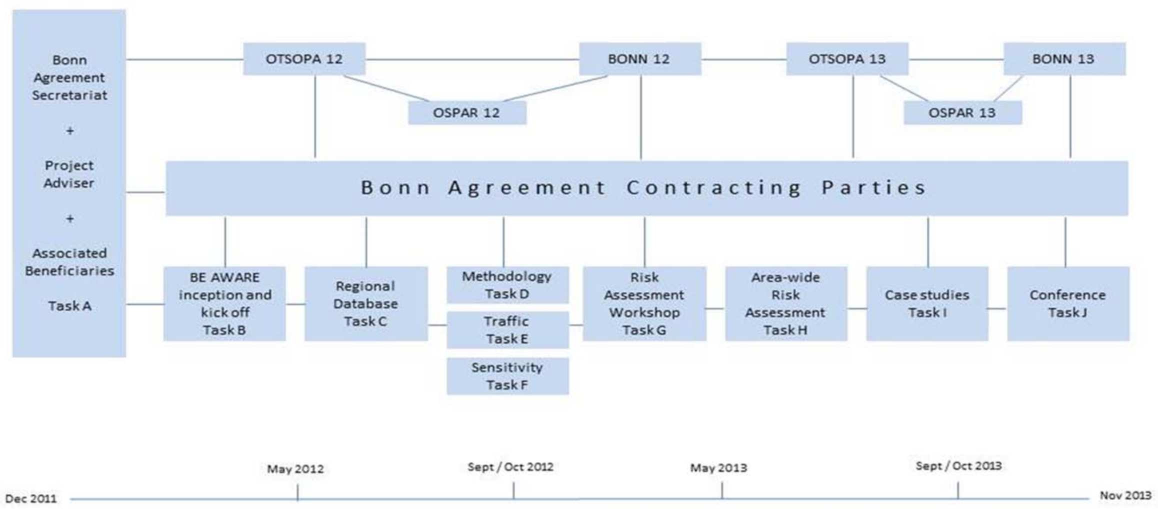


Figure 1-2: Project Structure

1.7 Final Report Structure

This BE-AWARE Final Report is split into two sections: a Summary Report and Technical Sub-reports. The Summary Report also doubles as a layman's report and is aimed at the general public and policy makers and the Technical sub reports are aimed at practitioners. All the sections of the report are available for download from the Bonn Agreement BE-AWARE website (beaware.bonnagreement.org).

2. Methodology

2.1 Development of a Method Note

One of the main objectives of the project was to agree a common methodology for an area-wide risk assessment, compatible with the approach undertaken in the HELCOM maritime area, drawing on established studies (as agreed by the BONN Working Group on Operational, Technical and Scientific Questions concerning Counter Pollution Activities (OTSOPA) 2011). In order to facilitate this, an expert method seminar was held in Copenhagen, Denmark, on 27 March 2012 to discuss the proposed methodology with the Project Partners, Subcontractors and Stakeholders. The main output of the Seminar was an agreed BE-AWARE Methodology Note. The method note outlined the detailed methodology to be undertaken in the technical project tasks and defined the key parameters to be taken into consideration. These included: hazard identification and selection of scenarios; ship traffic; classification of oil; oil transport model; traffic prognosis; frequency and quantity of oil spills; oil spills related to offshore installations and qualitative analysis of HNS risks.

The methodology used was similar to that developed in the BRISK Project using a multi-model approach, but only went as far as calculating the risk and magnitude of spills. The remaining aspects will be addressed in BE-AWARE II project.

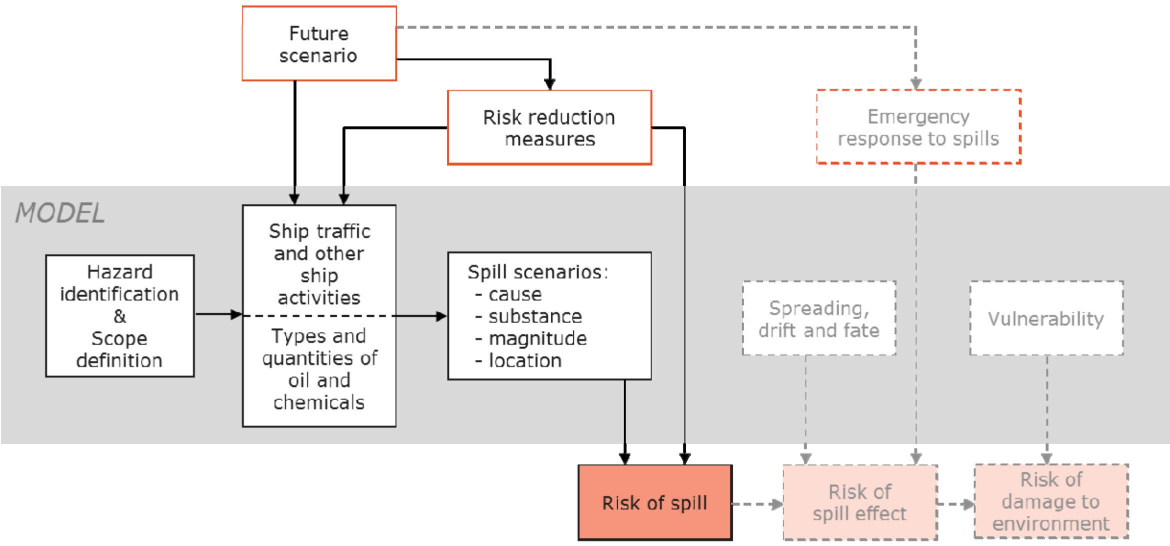


Figure 2-1: Model flow from the BRISK Project. BE-AWARE has progressed as far as the risk of spill, with the remaining aspects being undertaken in a BE-AWARE II project (in dashed lines).

The risk of spills was calculated using 2011 as a baseline year. However, it was also calculated for 2020, taking into consideration future growth in shipping, changes to use of maritime space, such as the growth in wind farms, and new risk reducing measures, such as traffic separation schemes.

2.2 Further methodological development

The methodology was further refined during the implementation of each of the project tasks based upon new knowledge, experience and availability of data. More detailed explanations of the final methodologies are given in the Technical Sub-reports, in particular Sub-reports 7: Offshore installation oil spill risk analysis, 8: Maritime oil spill risk analysis and 9: Qualitative analysis of HNS risks.

3. Regional Resource Database

3.1 Development of a Data Request Note

In order to undertake a risk assessment for oil and HNS pollution, a considerable amount of data was required to be input to the models. Data needed included: accident statistics, automatic identification system (AIS) data, cargo data, risk reducing measures, fixed objects, etc. In order to collect a standard set of data for the whole Bonn Agreement area, a Data Collection Note was developed outlining the data types and formats required. This was then circulated to all Bonn Agreement Contracting Parties who were asked to supply the data required for the project.

In the project application it was also envisaged that data would be collected from existing national risk assessments for use in the project. However, in practice this proved difficult as national assessments used different methodologies and covered different time periods. Therefore it was agreed that efforts should be focused on the collection of the data outlined in the Data Collection Note.

3.2 Regional Resource Database

The project data was collected in a central Regional Resource Database by the Bonn Agreement Secretariat for use in the project and as a future resource for the Bonn Agreement. In addition to the information supplied by Contracting Parties, supplementary information was sought, particularly in relation to AIS data and cargo data, from major ports in the region. The AIS data was collected from the Danish Maritime Authority from their AIS server in Copenhagen and covered the whole of 2011, the base year for the project. Data on ship movements and cargo types was also collected from the European Maritime Safety Agency (EMSA) SafeSeaNet database, the first time this type of data had been made available for a regional risk assessment, although ultimately it was not possible to include it in the cargo model due to the format it was stored in.

In order to ensure that the risk calculations were as accurate as possible it was important that the cargo model was as realistic as feasible by gathering cargo data at a ship level from the major ports in the region. This was a major challenge for the project as this information was commercially sensitive. Therefore the project entered into confidentiality agreements with the major ports to ensure the data would not be used for other purposes. On this basis detailed information was supplied by Mongstad (Norway), Hamburg (Germany), Rotterdam (Netherlands) and Antwerp (Belgium) on oil shipments, which was used in the cargo model, significantly improving its accuracy. Rotterdam and Antwerp also provided detailed information on hazardous and noxious substances shipments, which was used in the qualitative HNS analysis. The project is very grateful for the willingness of the above mentioned ports to participate in the risk assessment.

4. Ship Traffic

The first key building block for the project was the development of a model to describe ship traffic in the Bonn Agreement Area that could feed into the risk assessment model. To do this, a traffic model was developed, starting with an analysis of AIS data from the period 1 January 2011 to 31 December 2011. Based on the intensity of the ship traffic, a route net was then developed that described the primary sailing routes. The movements off all vessels received in the form of AIS data were applied in order to calculate the number of vessels on the individual routes (as outlined in Technical Sub Report 1: Ship Traffic). The project decided to only include ships of 300 gross tonnage or more in the model, given the limited spill potential of smaller ships and the availability of such vessel traffic data. The project used the AIS data from the Safety@Sea server in Copenhagen.

Route generation and analysis included:

- Definition of a geographic route net, to represent the vessel's movements with good precision
- Mathematical analysis of the route net, i.e. to determine the shortest possible paths through the net between any two locations
- Mapping of the AIS trace, i.e. to associate each AIS point with a route net segment
- Determination of relevant statistics for each route segment, e.g. the distribution of the vessels' deviation from the route segment axis
- A route net consisting of nodes (defined by their longitude and latitude) and route segments connecting the nodes.

The route net approach avoided boundary problems with mapping of AIS traces inside the analysis area. In general, analysis was more detailed in areas with heavy traffic than in other areas.

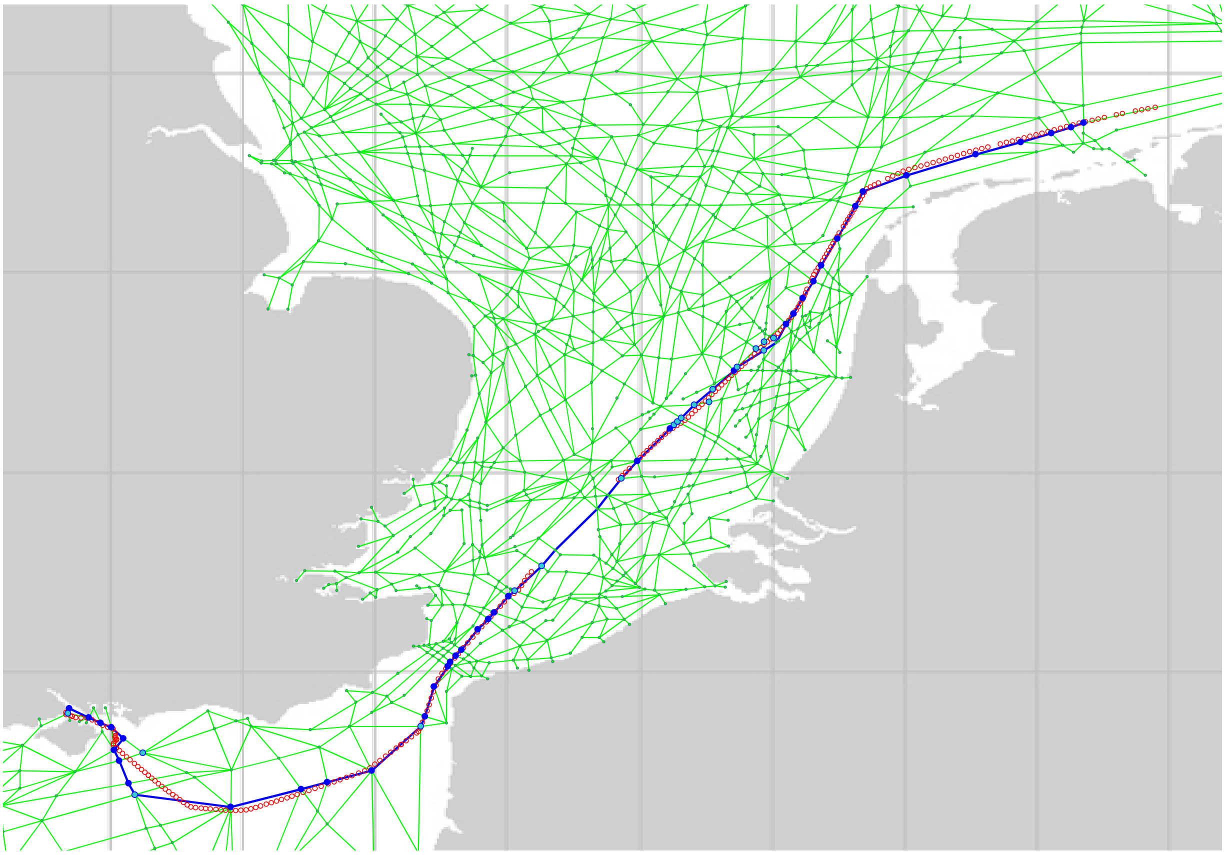


Figure 4-1: Example of the mapping of the AIS trace on the route net with clear AIS report dropout.

Although the AIS data is usually very comprehensive there were drop outs in the AIS data (see figure 4-1) and areas of lower coverage due to the limited range of the VHF signal. Therefore an algorithm was used to fill the gaps. After mapping of AIS reports onto the route net it became clear that some AIS traces in the German Bight were also finishing short of the destination harbour. This was corrected using factors obtained by comparing the plots with harbour data and vessel numbers at key crossing points, provided by the ACCSEAS project and based on AIS.

The resulting traffic model was essentially a database of identified route passages (a vessel passing a route segment) combined with information about passage direction and vessel characteristics. Each vessel was allocated to the nearest route leg based on the AIS signal. Each route leg comprised traffic in two directions. The traffic characteristics were represented statistically for each specific route leg and route direction. No artificial risks were introduced in the model related to traffic separation schemes.

This detailed model had the following advantages:

- traffic surveys were performed based on the detailed ship characteristics from IHS database
- the actual journeys of the respective vessels were contained in the description, tied together by a common track number and the date information
- the passages of the vessels through the respective nodes in the route net were contained in the description and could be used in the ship collision mode.

The output database contained information about the vessels on each route leg (types, sizes, etc.) as well as information about the specific distribution parameters of each route leg. In carrying out the analysis, the project noted the different sailing patterns and the contributions from different ship types, for instance, separating analysis of merchant and offshore vessels resulted in maps with much clearer traffic patterns.

The database provided traffic data for the calculation of accident and spill frequencies which were directly dependent upon the traffic, its volume and composition.

An illustrative graphical representation of the movements of oil and chemical tankers along the route net is seen below (Figure 4-2).

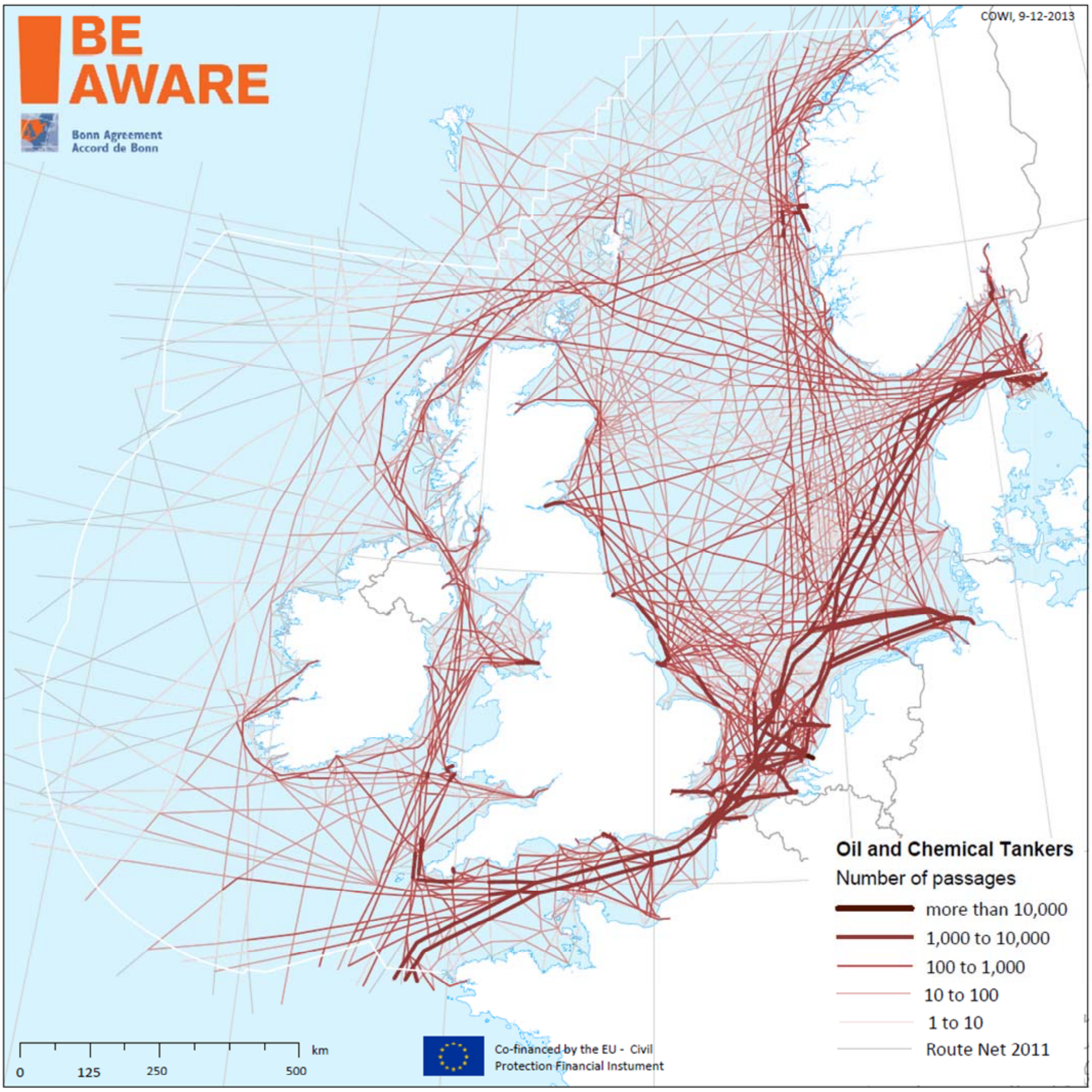


Figure 4-2: Map of the total traffic intensity on route segments of oil and chemical tankers larger than 300GT in 2011

The World Shipping Encyclopaedia (WSE), issued by IHS Fairplay, was used to extract information about the individual vessel's characteristics such as type, size, hull specifications etc. The traffic model database resulted from a combination of vessel specific information with the movement information of all vessels. This model could then be used, both to calculate the probabilities of ship-ship collisions and other accidents, but also as a basis for estimation of the consequences of an accident, based on the vessel characteristics.

5. Cargo Transport

Along with the traffic database a key input for the risk calculation was the “cargo-model”. This model described the probability that a certain ship type and ship size sailing on a specific route was loaded with a certain type of oil. To determine these probabilities the following steps were followed:

- Determine main transport routes;
- Determine a list of substances and oil types;
- Determine per port the total number of ships (per type and size) with a certain oil type on board on a certain route;
- Determine the total number of ships (per type and size) on a certain route (based on AIS and the traffic database created by COWI);
- Determine the percentage of ships (per type and size) that were loaded with a certain type of oil on a certain route

The detailed information required was not available for all ports/countries that were outlined in the Method note (Annex 1); therefore the main transport routes were selected based on the data received. An overview is given in Figure5-1 of the different selected port areas. These areas were selected based on the analysis of the transported GT and the received information. For example Amsterdam is one of the relevant ports based on the transported GT; however no detailed information was received from Amsterdam so this port area was not selected separately.

The ships leaving the Bonn Agreement area were grouped into three “destinations”:

- North: ships passing the Norwegian coast line toward Murmansk;
- Baltic: ships passing Skagerrak and sailing to or from a port in the Baltic area;
- Other: ship leaving or entering the area at other locations.

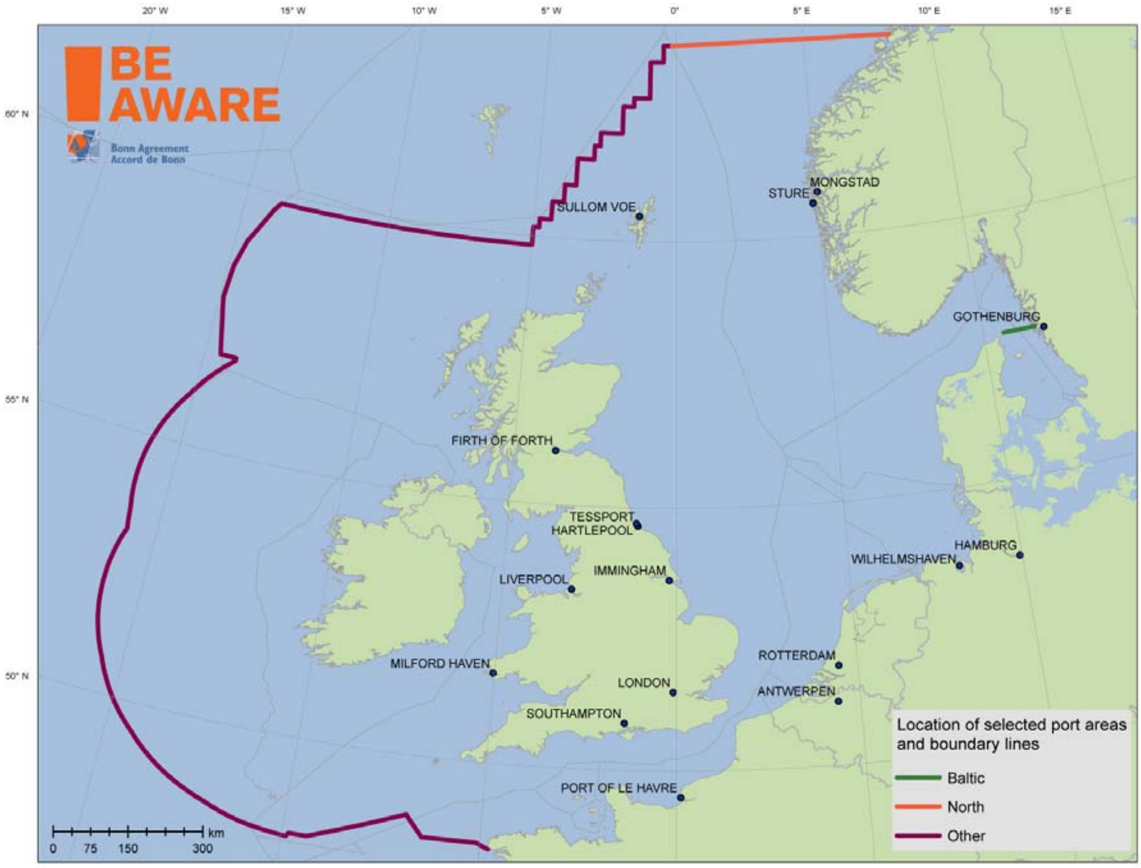


Figure5-1 Overview of the selected port areas and boundary lines for the transport routes

The level of detail of the received information varied for the different port areas. For the further analysis the information from the following ports was used:

- Antwerp
- Rotterdam
- Mongstad
- Hamburg

However, the information received from all the other ports and countries was used to verify the final results and therefore was indispensable.

In addition to the data received from the port (port data) three other databases were used when analysing the data:

- *Ships database:* this database contained the ship type and ship size for each IMO number. The database was based on the AIS data and the traffic database developed during the project. This means that throughout the whole project the same ship type and ship size categories were used for the same ship.
- *Port areas list:* the port of origin and destination given were the “port data”. It was a long list of various port names. These names were “assigned” to the different defined port areas as shown in Figure5-1.
- *Substance list*: states whether or not the substance was oil and if so what type of oil.

By combining these three additional lists with the original port data, a processed port data set was created (see also Figure 5-2). Example: a 30.000GT tanker calling at Rotterdam reported that it had unloaded crude oil and that its previous port was a port in the Middle East. This means that this ship carried crude oil on the route starting in the English Channel to Rotterdam.

From this processed port data the aggregated port data could be created. This last dataset contained per ship type and ship size the total number of ships in 2011 that carried a certain type of oil on a certain route to or from the port.

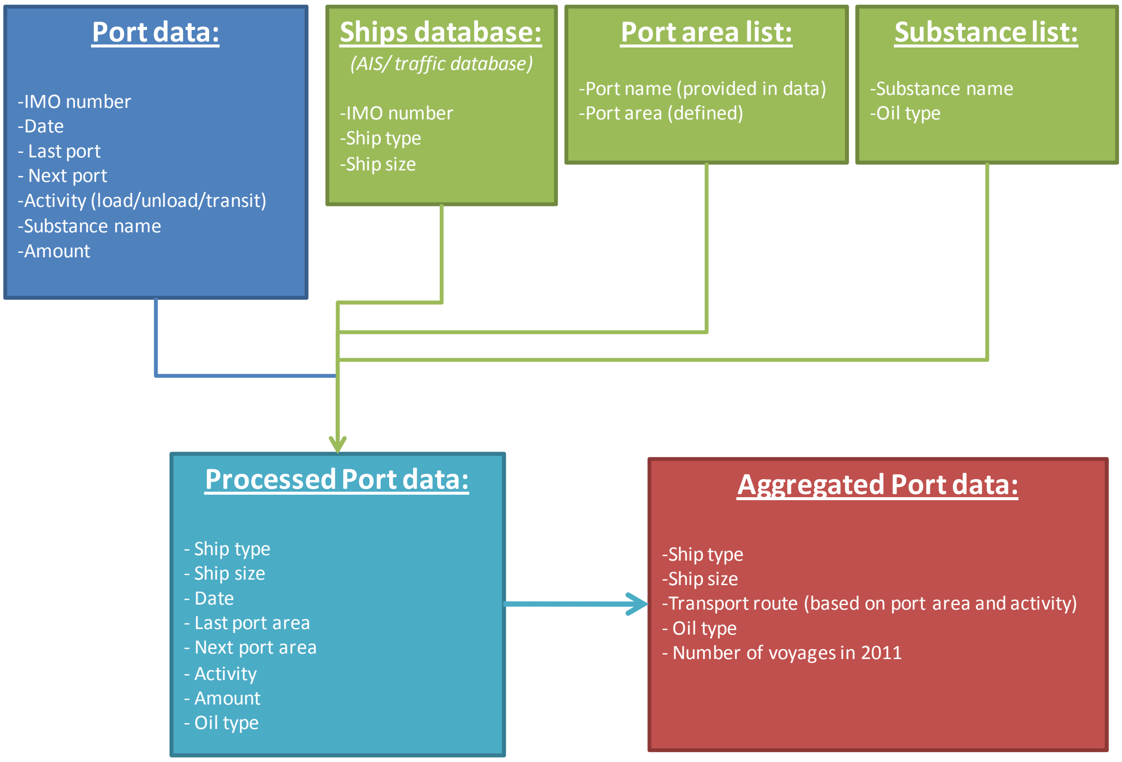


Figure 5-2 Overview of the process of analysing the port data

Finally the aggregated port data and the traffic data from AIS were combined to determine the actual percentage of the voyages per ship type and ship size that were loaded with oil.

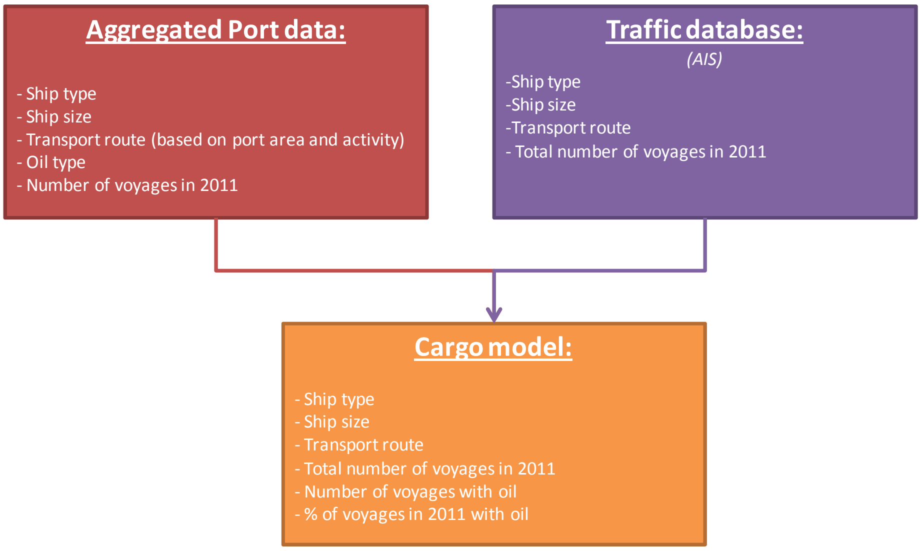


Figure 5-3 Overview of the process of determining the percentage of loaded tankers.

A detailed overview of these results is given in Technical Sub Report 2: Cargo Model, however **Error! Reference source not found.**1 shows the average loading percentages for the whole region. The percentages given in the table are the percentages of tankers that are loaded with a substance classified as oil, e.g. on average 45% of all product tankers of size class 6 are loaded with oil.

The percentages for chemical and gas tankers appear to be low. However the numbers only show the results for oil, so this does not automatically mean that the tankers are sailing empty but that they are not loaded with oil in particular.

Tanker type	Size class [based on GT]							
	1	2	3	4	5	6	7	8
Tanker, chemical incl. Tanker, others	31%	0%	16%	5%	22%	0%	0%	0%
Tanker, chemical/prod.	29%	7%	27%	30%	40%	25%	0%	0%
Tanker, crude oil	0%	0%	0%	0%	30%	21%	41%	29%
Tanker, gas	0%	6%	8%	10%	9%	0%	0%	0%
Tanker, product	36%	22%	41%	34%	68%	45%	57%	0%

Table 5-1 Overview of the average loading percentages for the different tanker types.

6. Future Traffic Model

The BE-AWARE project did not only develop a risk assessment for 2011 based on historical data but also a future prognosis for 2020. To be able to make the calculations for 2020, an estimation of the traffic in that year was needed. As part of the analysis the traffic growth over the years was analysed and growth rates for cargo and passenger traffic between 2011 and 2020 were modelled, as outlined in Technical Sub Report 3: Future Traffic Model 2020.

To prepare the traffic database for 2020, a different method was used for cargo ships from that used for passenger ships. The information from the SAMSON traffic database from 2000 and 2008 was used to prepare the prognosis for 2020 for the cargo traffic. SAMSON is the Safety Assessment Model for Shipping and Offshore in the North Sea, a model that can also be applied to perform risk assessment studies on maritime safety. For cargo ships, general growth factors were used for the total Bonn Agreement area, while the growth rates for passenger traffic were based on specific origin and destination countries. The future passenger traffic prognosis was based on the data supplied by Bonn Agreement Contracting Parties for the Regional Resource Database.

The final output was to determine the number of voyages in 2020 per ship type and ship size category.

6.1 Cargo traffic

The annual growth rates were determined for the number of voyages; the results are given in **Error! Reference source not found.**. Some adjustments were made to accommodate expected changes in the growth from 2011 to 2020 compared with the situation from 2000 to 2008 taking into account published information and the results of the EX-TERMIS project. The numbers on the right hand side were therefore used for the analysis. The following adjustments were made after the initial calculations were undertaken:

- The annual growth rate for the number of voyages of container ships was slightly reduced to accommodate the large increase in Gross tonnage. The volume transported and the number of voyages was expected to grow, but with a smaller growth rate than calculated based on the data between 2000 and 2008.
- The annual growth rate for the number of voyages of LNG/LPG/Gas carriers was increased.
- The annual growth rate for the number of voyages of dry cargo ships was increased.

Also the annual growth rates for the growth in ship size were determined; these results are shown in **Error! Reference source not found.**.

Ship type	Total based on 2000-2008	Totals adjusted
Bulk	0.9%	0.9%
Oil/Bulk/Ore	-4.0%	-4.0%
Oil tankers	0.4%	0.4%
LNG/LPG/Gas	0.1%	1.2%
Chemical tankers	1.3%	1.3%
Tankers, Food	0.8%	0.8%
Car carrier	-0.4%	-0.4%
Container	1.9%	1.2%
Reefer	-0.4%	-0.4%
RoRo	0.0%	0.0%
Dry Cargo	-0.8%	0.4%
Total	0.3%	

Table 6-1 Annual growth rates for the number of voyages per ship type

Ship type	Total
Bulk	1.7%
Oil/Bulk/Ore	-3.4%
Oil tankers	1.2%
LNG/LPG/Gas	2.3%
Chemical tankers	4.9%
Tankers, Food	5.3%
Car carrier	2.3%
Container	5.2%
Reefer	0.7%
RoRo	3.0%
Dry Cargo	-0.3%
Total	3.5%

Table 6-2 Annual growth rates for the Gross tonnage per ship type

6.2 Passenger traffic

For passenger traffic the growth rates were determined for domestic routes and international routes.

	United Kingdom	Denmark	Norway	Sweden	France	Ireland	Germany	Netherlands	Baltic	Spain
United Kingdom	-3.8%	0.0%	N/A	N/A	-4.5%	0.0%	N/A	-0.5%	-12.7%	6.8%
Denmark		N/A	1.7%	-4.9%	N/A	N/A	N/A	N/A		
Norway			0.8%	1.7%	N/A	N/A	1.7%	N/A		
Sweden				N/A	N/A	N/A	-4.9%	N/A		
France					N/A	1.7%	N/A	N/A		
Ireland						1.7%	N/A	N/A		
Germany							N/A	N/A		
Netherlands								N/A		

Where no values are available, the average 1.7% of BRISK can be used (MRIL, 2011)
N/A means that there are no ferry routes in the BE-AWARE route network
The Swedish data is based on the number of passengers, not on the number of crossings
From Norwegian future traffic prognosis data

Table 6-3 Annual growth rates for the number of voyages of passenger ships between countries

Cruise vessels

For cruise ships, insufficient data was received to develop a prognosis therefore the growth rate of 6% outlined in the BRISK report was used, reflecting a long term five year world-wide average.

7. Historical Accidents

One of the important input parameters for the risk assessment was the overview of historical accidents and spills in the area. The data was collected from Bonn Agreement Contracting Parties and the results are given for two main groups:

1. Accidents and spills caused by shipping activities
2. Spills with causes other than shipping accidents

7.1 Accidents and spills caused by shipping activities

In **Error! Reference source not found.** the average number of accidents within the area, for the period 2002-2011, is given per accident type. Also the average number of accidents that result in a spill is presented in the third column. Most of the accidents in the area involved a collision with a vessel or grounding. The total annual average was almost 107 accidents. In order to verify this, the total accident numbers for the entire region were compared to the IHS Fairplay Casualty statistics for the period 2008-2011. It was found that in the represented area, during the years 2008 – 2010 about 168 accidents took place involving ships larger than 300 GT and excluding machinery failures without consequences. This corresponds to 56 accidents every year.

There seemed to be a large difference between the average number of 56 from the Fairplay data and the 107 accidents resulting from the collected data from the different countries. However this difference was mostly explained by the type of ships that were included in the Fairplay dataset. Also only the more serious accidents were included in this dataset, while in the data from the project partner countries a larger number of small accidents are included.

Error! Reference source not found. shows that the type of accident that has the highest probability of resulting in a spill is sinking of ships (as to be expected). On average 2.7% of all shipping accidents resulted in some kind of spillage.

Accident type (2002 - 2011)	Annual number	Number of cases resulting in a spill	% of cases resulting in a spill
Collision with vessel	27.5	1.0	3.6%
Collision with object	6.7	0.0	0.0%
Grounding	42.7	0.4	0.9%
Fire	12.3	0.2	1.6%
Sunk other cause	0.9	0.8	88.9%
Hull damage other cause	1.9	0.1	5.3%
Unknown	14.9	0.4	2.7%
Total	**106.9**	**2.9**	**2.7%**

Table 7-1 Number of accidents resulting in a spill, per accident type

For the reported incidents resulting in a spill the size of the spill and the type of oil was analysed. The results are shown in Figure 7.2. Only 5 reported spills were larger than 5000 tonnes.

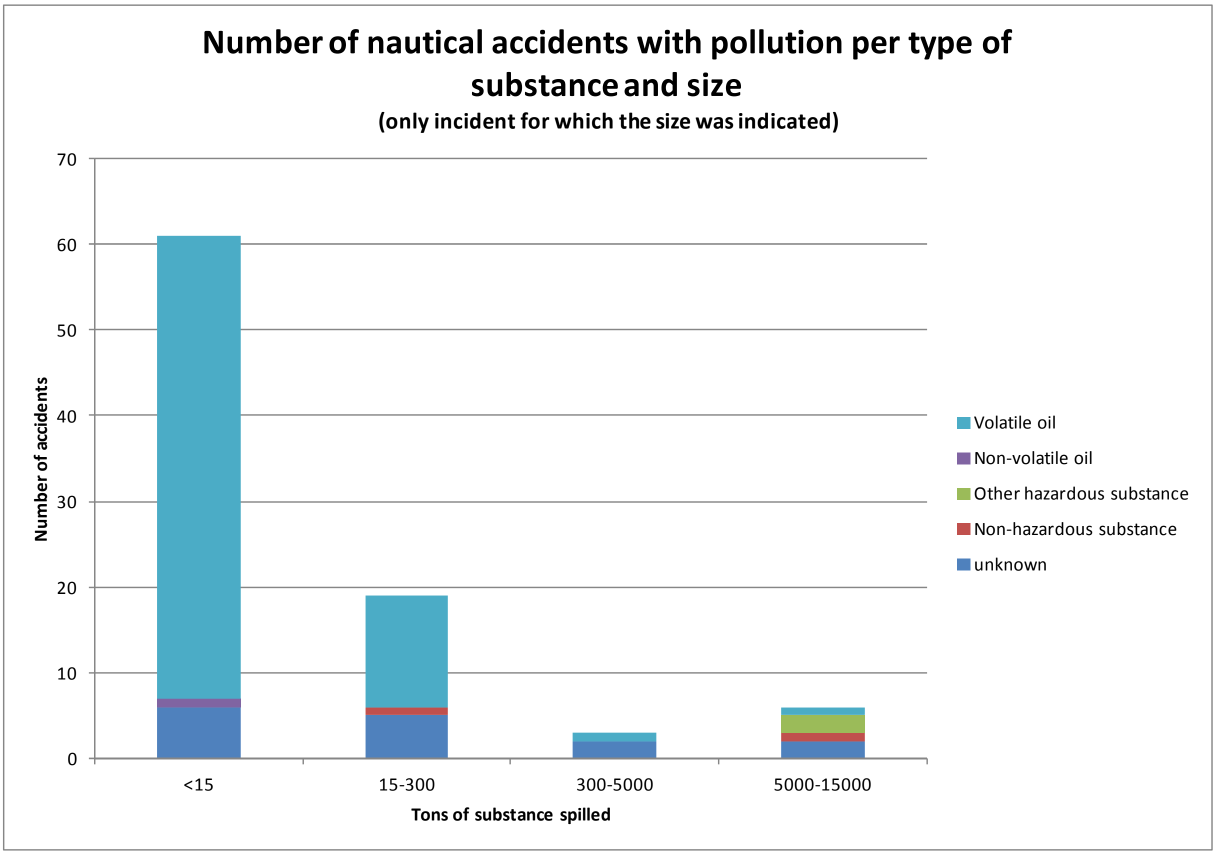


Figure 7-1 Spill sizes per substance

The contribution of "volatile oils" was dominant: they accounted for 87% of all spills. The second largest group was "unknown". It is likely that many spills in this category were in fact also related to volatile oils. Norway and France reported by far most of the accidents of this type. Unfortunately the size of the spills was not expressed in terms of quantities, but in spill area. There is no direct relationship between the amount of substance spilled and the area of the spill, as this depends on the substance characteristics and, more importantly, on how long the substance has been in the water.

7.2 Spills from offshore activities

The data used in the analysis of offshore activities was derived from OSPAR, but with the removal of data from countries which were not Contracting Parties to the Bonn Agreement. An overview of the results is given in Table 7.2

The number of spills from offshore installations decreased over the period 2000 - 2011 from 722 spills to 485 spills per year. As the number of platforms had been increasing, this indicated a strong decrease in the average number of spills per platform: this number decreased from 1.5 in 2000 to 0.6 in 2009.

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Number of installations	[-]	489	537	586	592	649	666	677	725	741	743	784	741	641
Number of oil spills	[-]	722	768	801	621	678	655	509	515	491	485	467	454	7166
Oil spills per installation	[-]	1.48	1.43	1.37	1.05	1.04	0.98	0.75	0.71	0.66	0.65	0.60	0.61	0.94
Quantity of oil	[t]	514	605	214	824	199	399	173	3907	305	180	131	63	7320
Quantity per platform	[t]	1.05	1.13	0.37	1.39	0.31	0.60	0.26	5.39	0.41	0.24	0.17	0.09	1.11
Quantity per spill	[t]	0.7	0.8	0.3	1.3	0.3	0.6	0.3	7.6	0.6	0.4	0.3	0.1	1.0

Table 7-2 Oil spill statistics derived from OSPAR

The total quantity that is spilled each year did not show such a clear trend. Especially notable was the large amount of oil spilled in 2007: 3907 tonnes, 3815 tonnes of which could be accounted for by a single spill. This shows that most spills can be regarded as small while the effect of a single large spill can be significant. Only one such spill was reported during the period 2000 – 2011. This spill happened in the Bonn Agreement area, offshore from Norway, during loading operations of a tanker at a loading buoy.

8. Risk-reducing Measures

The accident model used in BE-AWARE treats all vessels in an idealised way that ignores many ship-specific and regional characteristics, for example pilotage, surveillance such as VTS centres, or obligatory routing, such as Traffic Separation Schemes (TSS). Most of these characteristics have a risk-reducing effect, whereas some others can lead to additional risk. Therefore in assessing overall risks, BE-AWARE undertook a further analysis to take into account Risk Reducing Measures (RRMs) of various kinds that were already established in the wider North Sea Area, and those that would be in place before 2020. Additional RRMs that may be decided to be implemented in the future would be discussed and potentially implemented in the model in a next phase of the project BE-AWARE II.

The list of different risk reduction measures considered is given below:

- Pilotage
- Systematic calls to vessels falling under the pilotage recommendation
- VTS centres
- Traffic separation schemes (TSS)
- Electronic Chart Display and Information System (ECDIS)
- Bridge Navigational Watch Alarm System (BNWAS)
- Alcohol limits
- Double hull at the cargo tank
- Double hull at the bunker
- International reporting systems
- Escort towing in narrow shipping lanes
- Emergency towing of ships with problems

For each of the above issues the measures are described in detail in Technical Sub report 5: Existing and Decided Risk Reducing Measures. Detailed analysis was done since each measure affected the overall risk level within different processes in the maritime activities and their related risks. The risk reducing effect for all measures was described along with the process that is affected. Some measures were described in terms of maps showing the locations in the North Sea they are applied, see figure 8.1. Much of this description was in a narrative form, given the very different character of the measures.

The effect of the respective RRMs was expressed by means of a risk reduction factor in the analysis within the models. A risk reduction of 20 percent, for instance, meant that the risk was reduced to 80 percent of its initial value and corresponded to a risk reduction factor of 0.8.

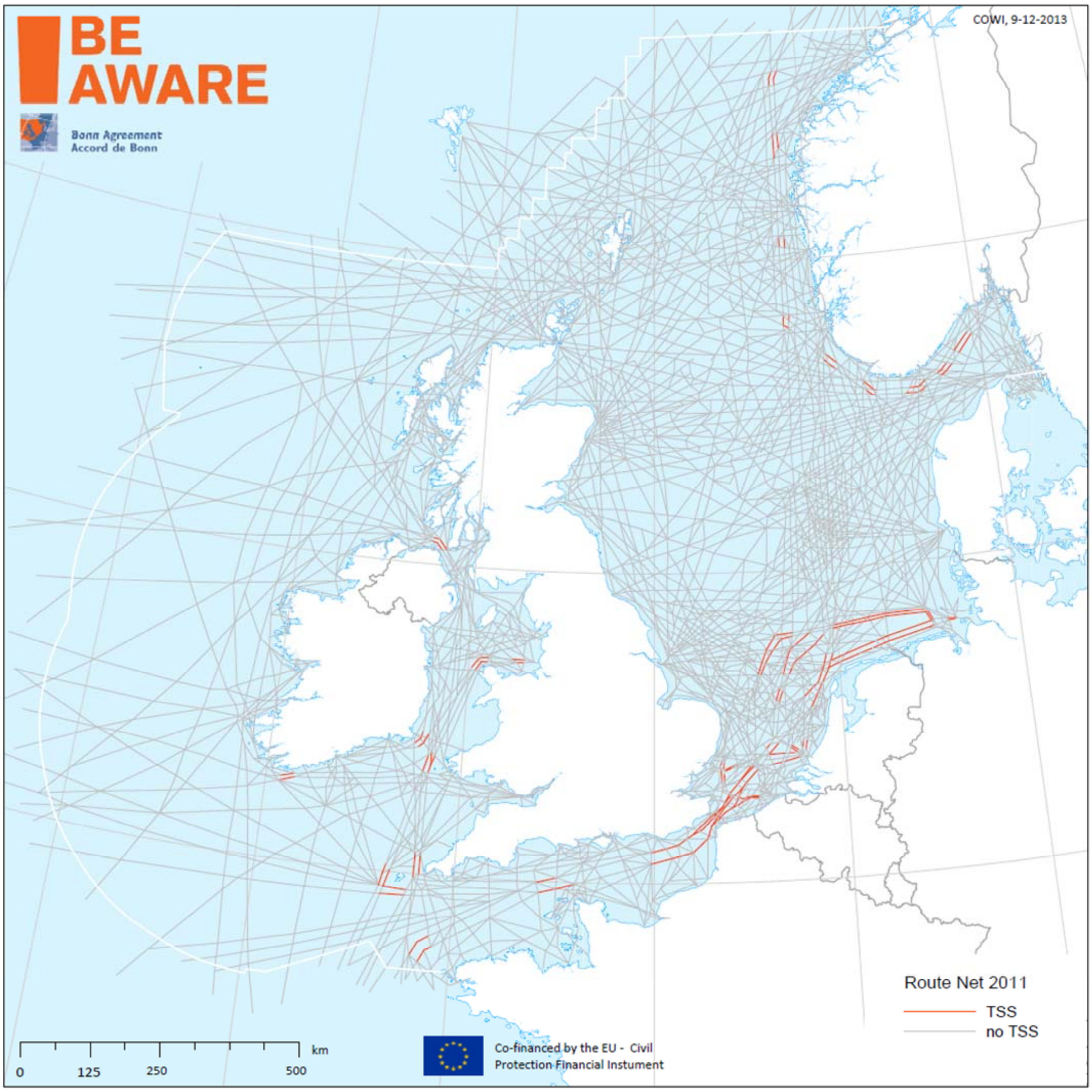


Figure 8-1 Idealised route net representing traffic in year 2011. TSS routes have been marked in orange.

9. Environmental and Socioeconomic Sensitivity

9.1 Common Methodology

Although not directly related to the risk assessment undertaken in the project BE-AWARE developed a simple, qualitative and commonly acceptable environmental sensitivity analysis approach. National experts from Bonn Agreement Contracting Parties (BA CPs) were invited to two BE-AWARE Sensitivity Mapping Workshops organised in Belgium, and discussed various possible approaches on joint sensitivity mapping, based on proposals from MUMM (Task Leader) and international best practice.

The HELCOM area-wide vulnerability mapping approach applied to the Baltic Sea, *i.e.* the so-called BRISK approach, can be considered as international best practice. This is because it is a simple, qualitative and stepwise approach based on principles that are fully in line with previous Bonn Agreement findings and conclusions on sensitivity mapping as well as with the generally agreed definition of “vulnerability” as a function of exposure to oil, oil-sensitivity, and the potential for recovery. It was therefore agreed to use the BRISK approach as a basis for the BE-AWARE methodology, but to adapt it to the specific context of the BA area, with different habitats and ecosystems, high natural energy, and different response options, taking into account the wish expressed by BA CPs to consider socio-economic vulnerability in more detail.

Following these discussions, the Workshop participants came to an agreement on a common Bonn Agreement area-wide vulnerability mapping approach which is presented in detail in BE-AWARE Sub-report 6: Environmental and Socioeconomic Sensitivity Mapping. In line with the BRISK approach, the BE-AWARE Workshop participants defined a common sensitivity mapping approach in three distinct Steps:

- STEP 1 – The identification of sensitive ecological and socio-economic features;
- STEP 2 – The vulnerability assessment and ranking of these features, based on a set of objective criteria and resulting in a seasonal vulnerability score for each feature;
- STEP 3 – The total (seasonal) vulnerability mapping.

9.2 Sensitive ecological and socio-economic features

With regard to **STEP 1**, a list of 31 sensitive ecological features were identified which jointly reflected the ecological sensitivity of the study area. These were:

- 22 ‘Habitat’ features, divided into shoreline and coastal habitats (15) and open sea habitats (7);
- 8 ‘Species’ features, related to sensitive population, life-cycle and life stage aspects;
- 1 ‘Protected Area’ feature which comprised all coastal and marine protected areas under *inter alia* the EC Habitats and Birds Directive, RAMSAR Convention, and OSPAR Convention.

Furthermore, a list of 18 sensitive socio-economic features were identified for the study area, categorized into 8 major socio-economic groups: Fisheries, aquaculture, tourism and recreation, coastal communities and heritage sites, coastal facilities with water inlet, ports, mineral extraction zones and renewable energy.

9.3 Ranking of features

With regard to **STEP 2**, it was agreed to apply the BRISK ranking approach based on a set of objective ranking criteria, 4 scores and 4 seasons, but to adapt it to the deeper offshore impact scenarios in the BA area and to broaden the socio-economic vulnerability assessment objective. This adaptation resulted in the definition of 4 objective ranking criteria, based on which the vulnerability assessment and ranking of each sensitive feature could be performed:

a. 'Fate of oil': In terms of oil weathering, natural degradation and removal, onshore as well as in open water (3D);

b. 'Impact of oil': In terms of physical and toxic effects, tainting, and population and life-cycle considerations;

c. 'Length of interruption': Describing socio-economic impact in terms of the length of interruption of a human activity or service;

d. 'Compensation possibility': In terms of whether economic compensation can be sought for a damaged feature - or not.

9.4 Vulnerability Mapping

With regard to **STEP 3**, it was agreed to use the BRISK approach for total vulnerability mapping (by summing up individual vulnerability scores of all features in a particular area and reclassifying the total scores into 5 different overall vulnerability classes) as a basis for total vulnerability mapping, but to adapt it in such a way that all BE-AWARE objectives (broader socio-economic assessment; 3D spill impact scenarios) were met:

- It was therefore agreed to first produce separate total ecological and total socio-economic vulnerability maps for each season;
- For producing integrated total vulnerability maps, an adapted reclassification approach was preferred. This would integrate both series of seasonal (ecological and socio-economic) vulnerability maps, based on the use of a weighting ratio, in order to take account of the 'compensation' factor for socio-economic damage. With respect to 3D impact scenarios in the BA area, it was furthermore agreed to produce a single annual total ecological vulnerability map for deeper waters.

The resulting integrated total vulnerability maps would then be used as input in the BA area-wide assessment of the overall risk for damage in BE-AWARE II.

10.Quantitative analysis of oil spill risk

The main deliverable of the BE-AWARE project was the Quantitative Analysis of Oil Spill Risk which is built on the other sub components (traffic analysis, cargo model, traffic prognosis 2020, historic accident and risk reducing measures) outlined in this report. Unlike previous similar risk studies (such as BRISK) there were additional challenges that had to be addressed by BE-AWARE particular to the North Sea context. The two principle challenges were how to include the risk from offshore oil installations and offshore wind farms over and above the risk from shipping related to on route and node collision, groundings, foundering, etc.

The analysis was therefore undertaken in two sections which were combined to provide the overall result. One analysis focused on the risk of spills caused by collisions with offshore installations (oil and gas) and wind farms; spills from ships and installations due to collisions and spills directly from installations. The other analysis focused on the risk of spill caused by collisions between ships and other accident types such as foundering, fire and explosion and groundings. These were then brought together to produce the final risk picture for the 5 BE-AWARE sub regions identified by the project (see figure 10-1).

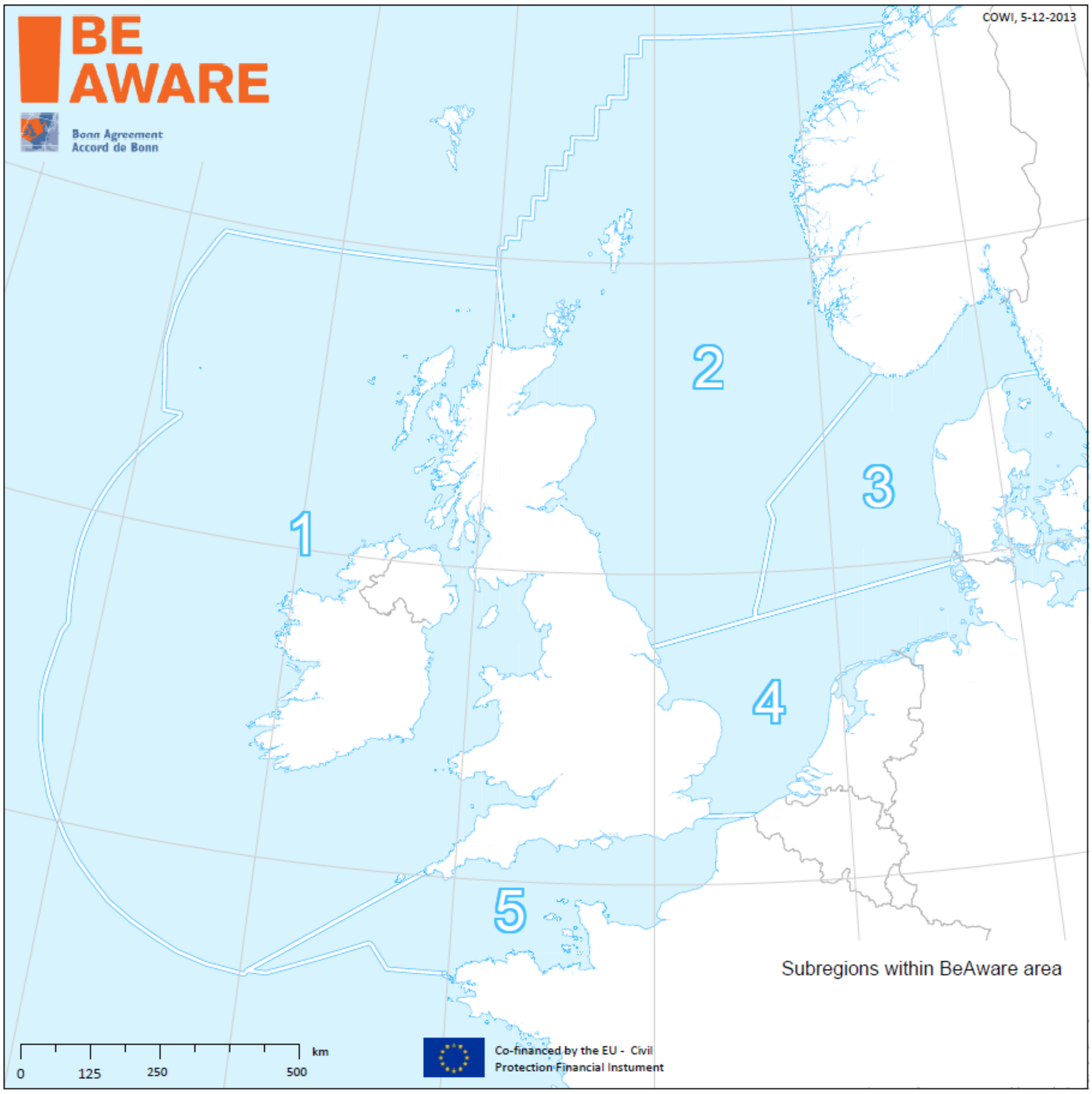


Figure 10-1 Regions within the Be-Aware area

10.1 Offshore Installations Oil Spill Risk Analysis

The main sources of oil pollution risk in the Bonn Agreement area involve accidents related to ships alone (ship-ship collisions or groundings) and related to offshore installations (oil and gas platforms, wind farms and other fixed objects), either due to being hit by vessels or from the installations themselves.

In considering spillage from accidents involving offshore installations, three possible scenarios were considered by BE-AWARE, as outlined in Technical Sub Report 7: Offshore Installations Oil Spill Risk Analysis.

- Spillage from the ship due to damage as a result of a collision/contact between a ship and an offshore installation. This could be a platform or wind turbine or other structure (ship – platform or ship - turbine);
- Spillage from the offshore installation due to damage as a result of a collision/contact between a ship and an offshore installation (platform or Floating Production, Storage and Offloading vessel (FPSO) spills by collision);
- Spillage from the offshore installation, due to events at the installation that lead to damage resulting in a spillage of oil (platform operation spills).

The computation of the spillage from a ship due to a collision or contact between a ship and an offshore installation was initiated with computation of the collision probability. This computation was made with the SAMSON model, using the traffic databases for 2011 and 2020, developed under BE-AWARE. A spillage would only occur when a cargo tank was penetrated; this depended on the collision energy. When a loaded fuel tank or cargo tank was penetrated, bunker oil or cargo oil was spilt. When an oil platform was hit by a ship the probability that this collision resulted in a spillage also depended on the kinetic energy. It was assumed in modelling that collisions of above 50 MJ energy would result in a spillage from the platform.

Finally, an assessment was made of the probability of a spill from accidents and blow-outs from oil installations. For blow-outs a distinction was made between oil and gas condensate wells, normal wells and high pressure and high temperature (HPHT) wells. For each operation the probability of a blow-out was specified together with the number of operations per year. For each country in the Bonn Agreement area, the number of platforms, FPSO's and wells was known, including the number of HPHT wells. Combining this information with the likely spill sizes for different incidents resulted in calculations modelling the amount of oil spilt from platforms during daily operations.

As with all risk analysis of this type some assumptions were made to simplify the calculations and allow a regional comparison to be undertaken within the restraints of the project. In the offshore analysis due to the high level of regulation in the North Sea area it was assumed that the risks of general operational accidents were similar in different North Sea Countries and these were applied uniformly to all installations, with the exception of HPHT installations. Also the uncertainty for the larger blow out events is higher as they happen so rarely. This was of course a simplification but was adequate for a regional comparison with other risk types.

The table below contains the resulting spill frequencies and the total tonnes spilt per year. The results are presented for 2011 and 2020, including the relative change from 2011 to 2020 in the last column. From 2011 to 2010 the spill frequencies and the total amount spilled increased, with a large contribution to this from the ship – wind turbine collisions.

The results of this element of work contributed to the overall analyses of the amount of oil spilled.

	2011		2020		2020/2011	
	Frequency of spill per year	Volume of spills in tonnes	Frequency of spill per year	Volume of spills in tonnes	Relative change in frequency of spill	Relative change in volume of spills
Ship-platform	0.0141	78	0.0180	99	1.27	1.27
platform spills by collision	0.0893	86	0.1290	127	1.44	1.49
FPSO spills by collision	0.0004	5	0.0003	4	0.69	0.78
spills directly from platforms	1.9112	3420	1.9112	3420	1.00	1.00
Ship-turbine	0.0064	26	0.0643	303	10.01	11.51
Grand Total	2.0215	3615	2.1228	3954	1.05	1.09

Table 10-1 Frequency and volume of spills for 2011 and 2020

The predicted 3420 tonnes of spills per year for spills directly from platforms was not in fact the amount of oil that is yearly spilt, but reflects infrequent events averaged over many years. Ninety percent of the amount predicted would be in fact delivered by spills from events that occur less than once in 70 or 145 years, e.g. infrequent blow-out events. The oil spilt in these types of events can be very large.

The results of this study have been used to compute the exceedance probability of a spill size. This result is shown in the figure 10-2.

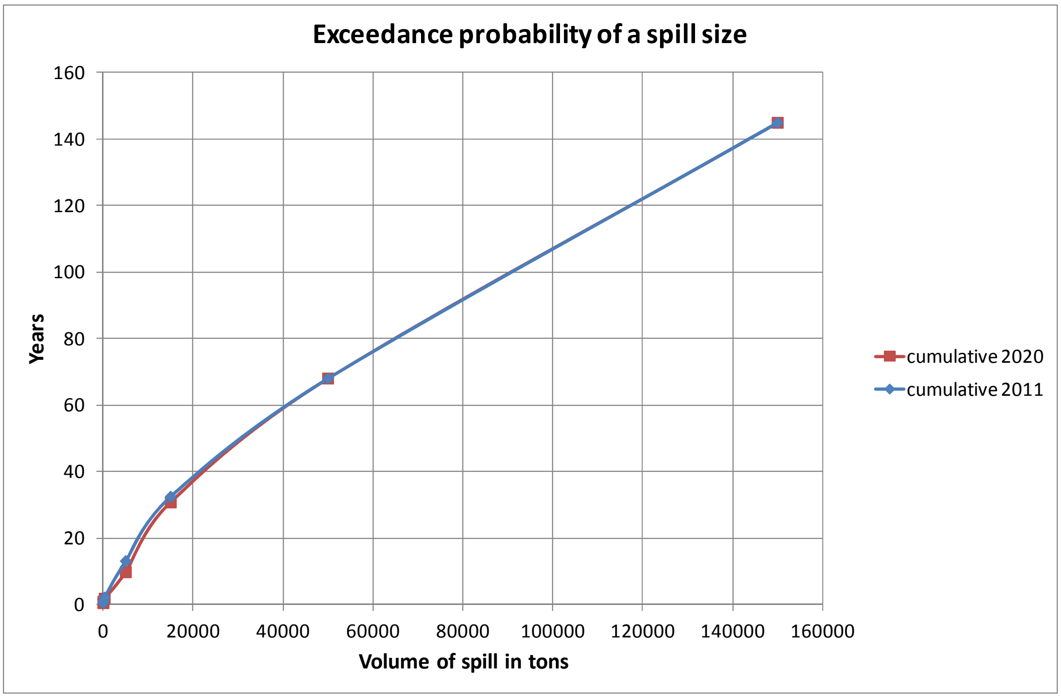


Figure 10-2 Exceedance probability of a spill with a certain size

This figure shows that once in 40 years a spill can be expected of approximately 22,000 tonnes. Once in 100 years the spill size is approximately 90,000 tonnes.

Mitigating measures

The BE-AWARE methodology took into consideration existing risk reducing measures, however possible future response measures would only be addressed in a second phase (BE-AWARE II) where the outflow of oil would be modelled. As a result recent advances in technology, particularly for blowout accidents, such as subsea capping and dispersant application equipment were not taken into consideration in this report.

10.2 Maritime Oil Spill Risk Analysis

The model that was used to undertake the Maritime Oil Spill Risk Analysis has earlier been applied to the Baltic waters (BRISK). Therefore, the model was not created from scratch, but modified, adapted and extended for the Greater North Sea and its approaches.

The relevant spill scenarios for the project were identified and discussed in the Method note (see Annex 1). They comprise the following events occurring in the open sea with vessels of a gross tonnage of 300 and above:

- Ship accidents (ship-ship collisions, groundings, fire, foundering etc.)
- STS operations and bunkering at sea
- Collisions with fixed objects (platforms and wind turbines)

Furthermore operational and accidental spills were treated for the following non-vessel related accidents

- Spills from offshore oil installations

The cause of an accident could be a number of issues including but not limited to e.g. defective equipment, bad weather, human error or alcohol. Regional differences could in principle give variations in the cause of accidents over the project area and this was taken into account through the applied accident statistics, as outlined in section 7, which were used as a basis for the risk calculation.

Technical Sub Report 8 outlines the basis for the calculation of the navigational oil spills (ship accidents, ship-to-ship transfers and bunkering at sea). However the results below include the results of both the navigational and offshore risk analysis and therefore show the results of all of the accidents.

Within each of the BE-AWARE sub regions the frequency of different accident types were calculated for both the existing situation and the future 2020 scenario. The frequency for individual spill sizes was also calculated.

In the results significant regional differences were seen in the results. Accidents caused by collisions were predicted to be most pronounced in areas with high intensity traffic in combination with narrow straits or areas with crossing traffic or complex traffic patterns. These significant regional differences are also shown in the risk of spills that is presented in figure 10-3, for 2011. In the northern part of the North Sea there was limited traffic over a very large area, hence reducing the probability of ship-ship collisions. However due to the presence of a substantial number of oil platforms the risks of spills from the platforms was the largest contributor in this area. In high traffic areas such as along the coast of the Netherlands, Belgium and Germany the ship-ship collision risks became much more pronounced and constitute the largest contribution to the overall picture.

Grounding accidents were based on the grounding statistics for the period 2002-2011. There were significant local differences in the statistical background data and this was apparent when looking at the results of the grounding accidents.

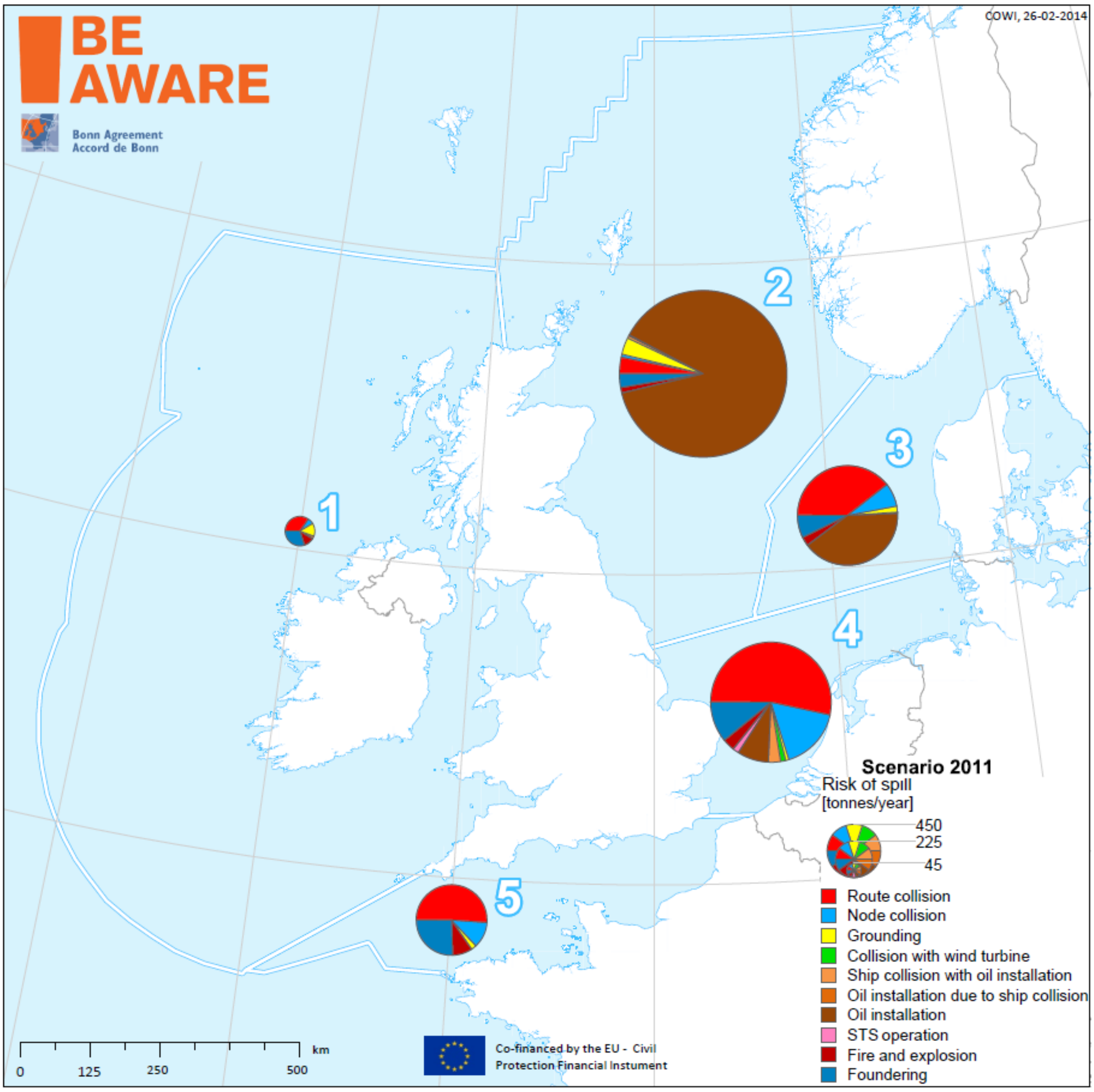


Figure 10-3: Relative risk of all spills, in tonnes per year, for the different BE-AWARE sub regions for the 2011 scenario.

When comparing the change in the in the regional risks between 2011 and 2020 (see Figure 10-4) the main differences were due to the increase in shipping intensity particularly in regions 3, 4 and 5. The risks of spills due to collisions with wind turbines will also increase in those regions due the development of new offshore wind farms to meet renewable targets. This was particularly noticeable in the southern North Sea region 4.

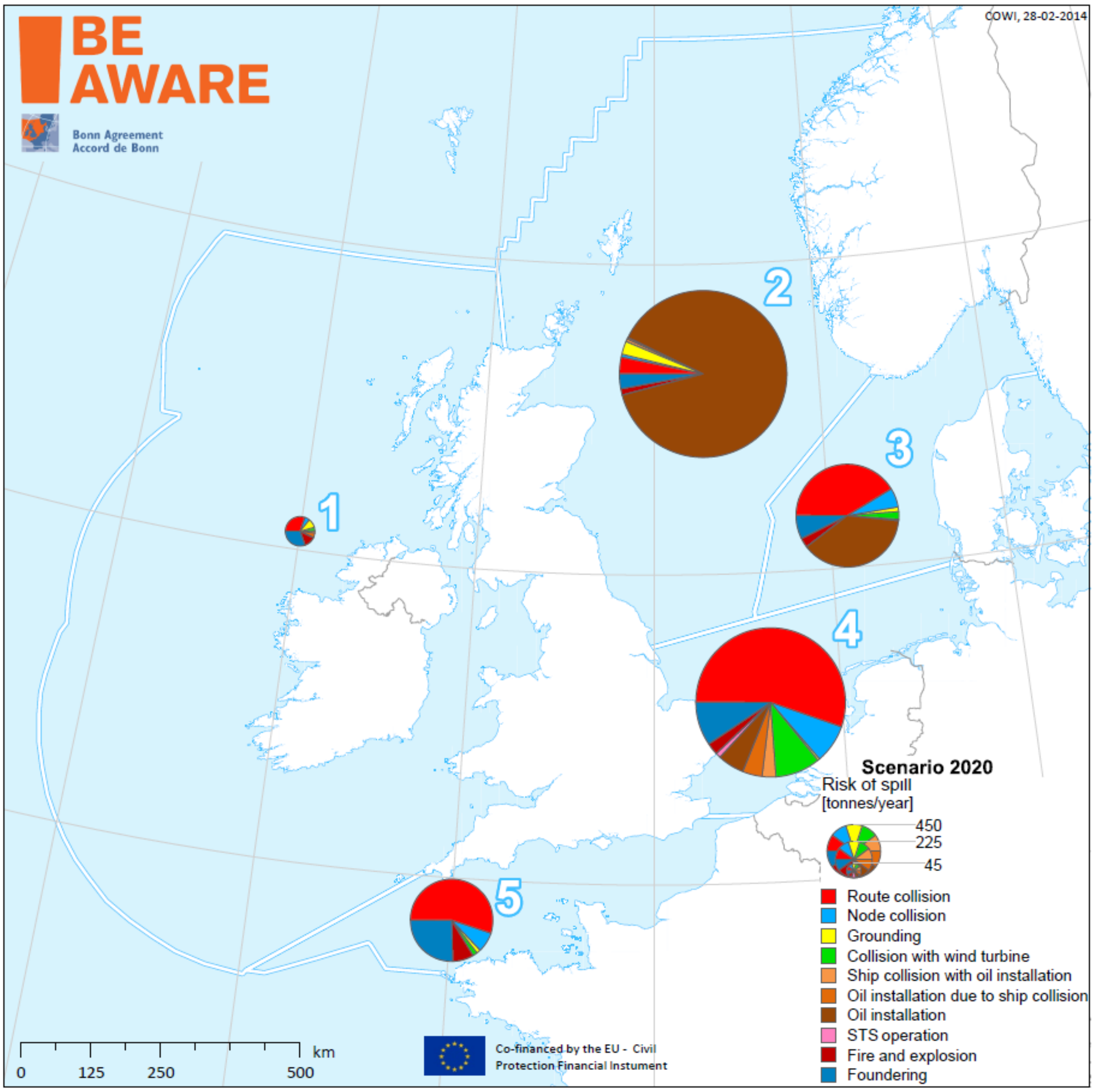


Figure 10-4: Relative risk of all spills, in tonnes per year, for the different BE-AWARE sub regions for the 2020 scenario

The figure 10-5 below clearly shows the differences in the relative contribution to the risk from the accident types in the sub regions for the scenario 2020. It highlights some interesting regional differences, for example in Region 1: The Atlantic where the traffic density is lower the proportion of risk of spills due to foundering or fire and explosion is higher and accounts for about 45% of the total. By contrast, in region 2: Northern North Sea the risk is dominated by oil installations and the increasing contribution of risk from wind farms can be seen in Region 4: Southern North Sea.

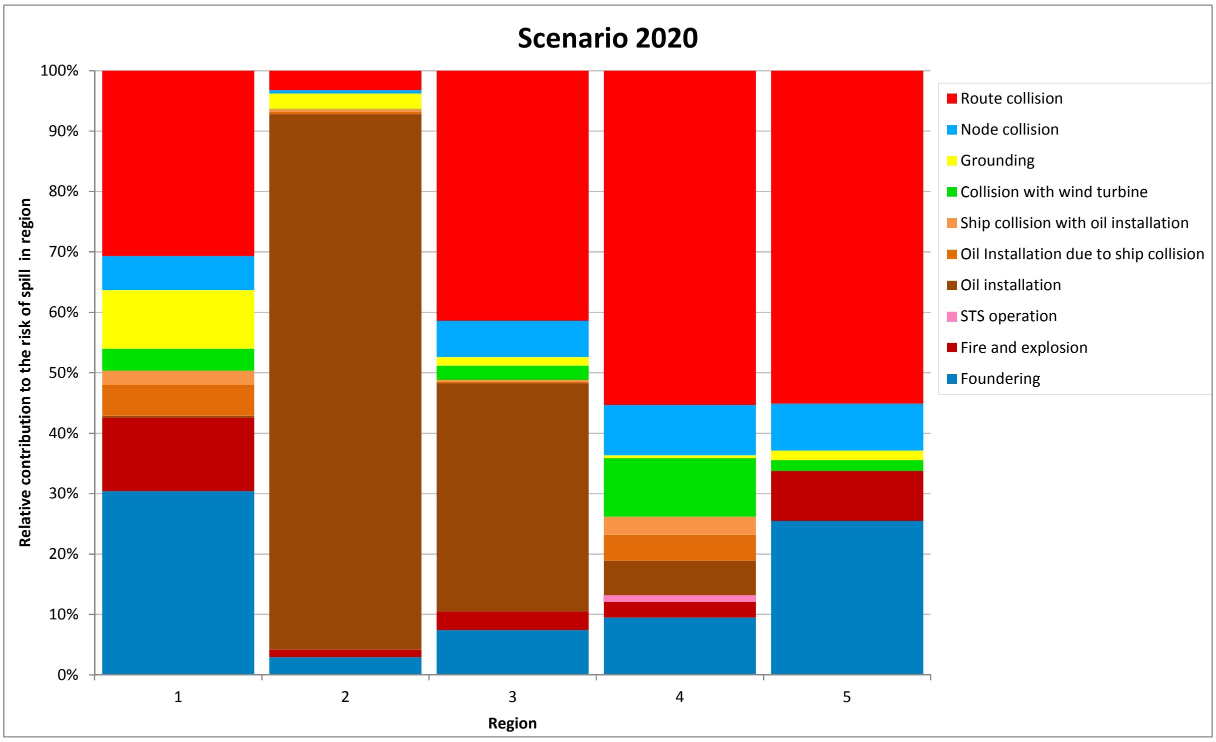


Figure 10-5: Percentage contribution of different risk types in the BE-AWARE sub regions for 2020

In the Bonn Agreement area the risks of extremely large spills were dominated by rare events such as blow-outs from offshore installations. Even though the return period of such an event is very long, the size of a single spill could lead to a large average annual spill figure in tonnes per year. While large spills can come from offshore installations, overall, the largest contributor to oil spills (in tonnes) was the outflow of liquid cargo as a result of collisions with large tankers.

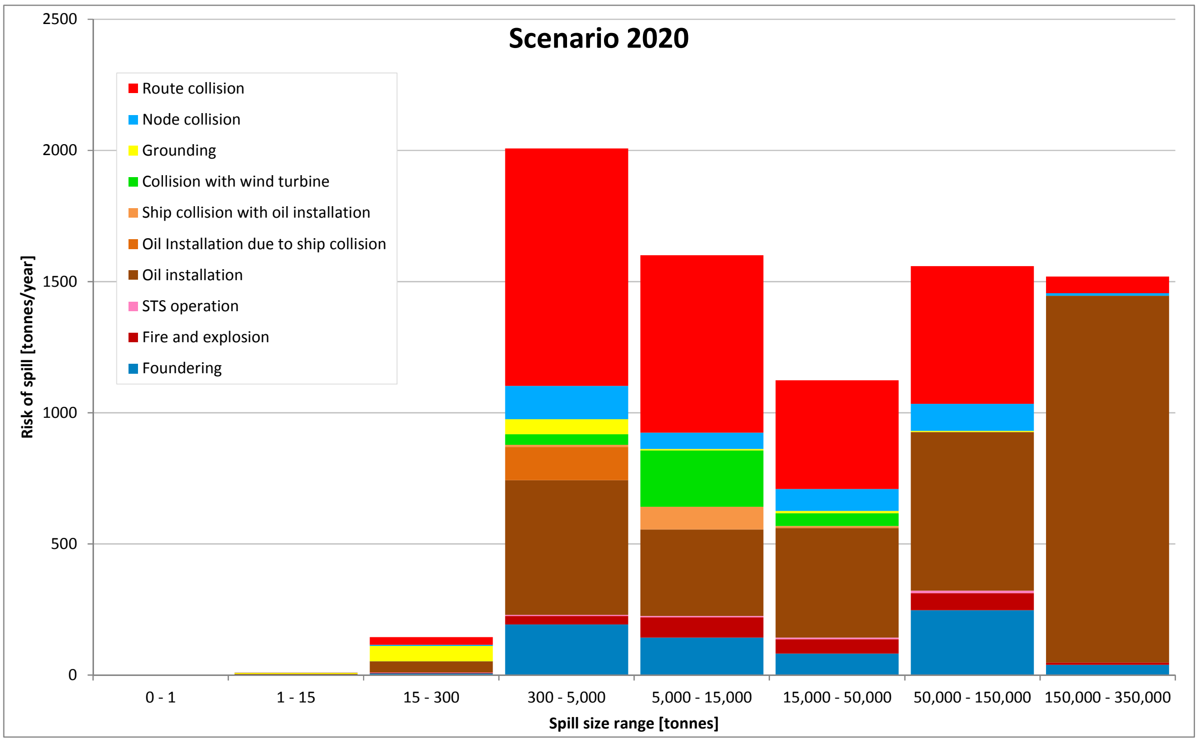


Figure 10-6: Overview of the risk of various spill sizes in tonnes per year, divided by accident type, for the 2020 scenario

Minor and medium sized spills were typically from accidents where the vessels had only sustained minor damage or leakage. Groundings mainly contributed to the overall risk of minor and medium sized spills.

The frequency of collision accidents were mainly spread along those areas of the North Sea with the highest amount of traffic. Groundings were more dependent on local weather phenomena and bathymetry; the grounding model was therefore based on representative points which created these risks. Foundering and accidents with fire and explosions were assumed to be distributed evenly in the area based on the distance sailed, thus only dependent on the level of traffic.

There were significant differences overall and on a regional level between the 2011 and the 2020 scenarios. This was caused by the changes in the levels of traffic, the development in ship size, the development in Risk Reducing Measures and an increase in new uses of maritime space, particularly the development of offshore wind farms which increased the risk of a collision with individual turbines. This was a significant change in the 2020 scenario, compared to the 2011 scenario.

11. Qualitative analysis of HNS spill risks

Another key pollution risk in the Greater North Sea is spills of hazardous and noxious substances (HNS) and therefore the project undertook an analysis of HNS risks for the Bonn Agreement area. Unlike the risk assessment for oil this analysis was a qualitative analysis. This was for several reasons:

- There was less information available on HNS shipments compared to oil shipments mainly because HNS is more complex to map or monitor/track;
- The environmental impact of a HNS spill at sea can be different for each type of substance transported and there was no methodology available that includes these effects in a large area-based risk assessment;
- Chemical tankers may carry several types of substances. No extensive mapping/statistics are available at this stage related to the transport of different HNS types by tankers in the EU area.

In addition to these reasons, obtaining data for HNS transport in the study area was very difficult due to perceived commercial confidentiality issues. The project was however able to obtain data for the ports of Rotterdam and Antwerp at the level of detail required for in-depth analysis. The information from the port of Rotterdam was limited to bulk goods (oil and HNS), whilst the information from the Port of Antwerp included bulk (no oil) and packed goods, i.e. information from containers.

The project was thus able to develop an insight in the amount, type and characteristics of HNS handled in the two ports. This was done by developing an overview of the three methods of classifying dangerous goods (HNS). An analysis of the data received from Rotterdam and Antwerp was carried out following the overview. This resulted in a list of the 100 most transported substances and a hazard classification of the substances handled in the ports. In a third stage the databases from Rotterdam and Antwerp were combined with the SAMSON accident database for the BE-AWARE area. Using these data, an estimate was made of the involvement of ships carrying HNS in collisions. The analyses were made for two methods of classification and also estimated was the involvement of chemical tankers in collisions was also estimated.

Comparison for bulk goods

Table 11-1 sets out the goods handled in bulk in Rotterdam and Antwerp. When the percentage substances classified by the International maritime Dangerous Goods code (IMDG) in categories 1-9 were compared for the two ports, the percentage for Rotterdam was slightly smaller than for Antwerp.

Goods transported in bulk	Rotterdam				Antwerp				Comparison
	Total [t]	Percentage [%]	Shipments [-]	Average amount [t]	Total [t]	Percentage [%]	Shipments [-]	Average amount [t]	Rotterdam/ Antwerp
Total (HNS + harmless substances)	14277473	100.00%	5487	2602	31683760	100.00%	12408	2553	45%
Total IMDG 1-9	10438155	73.11%	3566	2927	24900774	78.59%	10541	2362	42%
Total ACROPOL	562080	3.94%	275	2044	2107883	6.65%	257	8202	27%
Total GESAMP	2579	0.02%	18	143	1085	0.00%	7	155	238%

Table 11-1: Comparison of HNS transported in bulk to Rotterdam and Antwerp

In the last column the data for Rotterdam and Antwerp are compared. The amount of HNS handled in bulk in Antwerp was approximately a factor two (2.2) larger than in Rotterdam. When the percentage of the total amount that was classified as IMDG 1-9 was compared for the two ports, the percentage for Rotterdam (73%) was slightly smaller than for Antwerp (78%).

In Antwerp the spread in the IMDG classification of the substances was much larger than for Rotterdam. For Antwerp the substances were divided over 26 IMDG classes, while for Rotterdam only over 14 classes. However, many classes give a relatively small contribution to the total picture. The next figure shows a comparison between Antwerp and Rotterdam for those IMDG classes that contribute more than 1% to the total (Class 3 is flammable liquids).

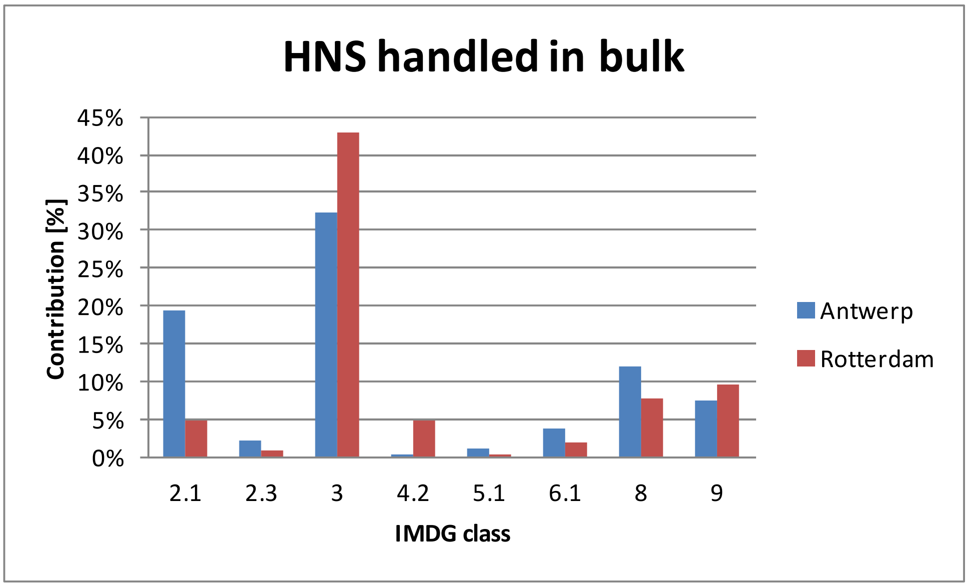


Figure 11-1: IMDG classification of bulk cargo for Rotterdam and Antwerp (contribution larger than 1%)[1]

Comparing the amounts handled from the Top 20 ARCOPOL (Atlantic Regions' Coastal Pollution Response) list of substances hazardous to human health one can conclude that Antwerp handles almost 5 times more Top 20 ARCOPOL classified substances in bulk compared to Rotterdam. For the top 100 most hazardous substances according to GESAMP (Joint Group of Experts on Scientific Aspects of Marine Pollution) it is the other way around: Rotterdam handles more. But it should be noted that the amounts are extremely small in both ports so it is unlikely that these comparisons are of key interest.

Comparison bulk and packed goods

Table 11.2 Comparison of HNS transported in bulk and packed to Antwerp

Antwerp	Packed				Bulk				Comparison
	Amount [t]	Amount [%]	Shipments [-]	Average amount [t]	Amount [t]	Amount [%]	Shipments [-]	Average amount [t]	Packed/Bulk
Total (HNS + harmless substances)	13198301	100.00%	167721	79	31683760	100.00%	12408	2553	42%
IMDG 1-9	13198301	100.00%	167721	79	24900774	78.59%	10541	2362	53%
Arcopol	770679	5.84%	3166	243.4	2107883	6.65%	257	8202	37%
GESAMP	6846	0.05%	416	16.5	1085	0.00%	7	155	631%

[1] The IMDG classes refered to in figure 11-1 are: 2.1: flammable gases; 2.3: toxic gases; 3: flammable liquids; 4.2: substances liable to spontaneous combustion 51: oxidizing substances; 6.1: toxic substances; 8: Corrosive substances; 9: Miscellaneous dangerous substances and articles

From table 11-2 it was concluded that in the port of Antwerp a considerable amount of HNS cargo was handled as packed goods, these being approximately equivalent to 50% of the total amount of bulk goods. This was a large amount of activity, certainly when is realised that the average amount per shipment was much smaller.

Comparing the IMDG classification for packed and bulk it was concluded that a larger variety of goods were transported as packed goods (32 IMDG classes) than in bulk (26 IMDG classes). For both bulk and parcels a number of classes contained very small amounts of cargo. The next figure gives an overview of those IMDG classes that contribute more than 1 per-cent to the total.

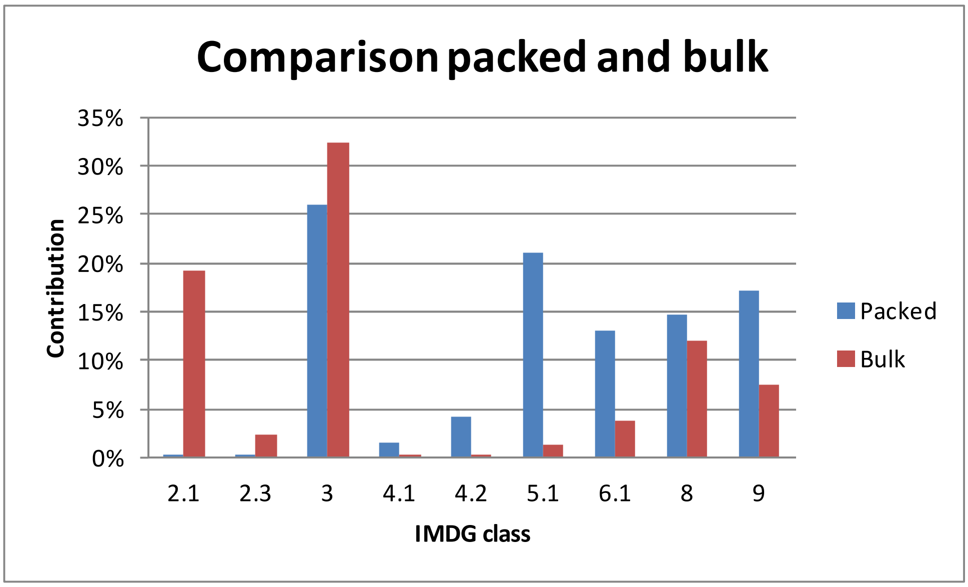


Figure 11-2 Comparison of the IMDG classification of cargo transported packed and as bulk (contribution larger than 1%)

The TOP 20 ARCOPOL substances were handled more often as bulk cargo. But approximately 6% of the HNS handled were from the TOP 20 ARCOPOL list, both for packed and bulk.

The results found for substances from the Top 100 GESAMP list was of special interest. The GESAMP list was set-up to rank HNS transported in bulk. So, when the Top 100 GESAMP list was used to analyse the most dangerous goods transported as packed goods, dangerous substances identified as marine pollutants under IMDG that are normally transported as packed goods were not fully included in the analysis. However, as most GESAMP substances in the port of Antwerp were handled as packed goods this can be seen as an indicator that probably the most dangerous substances were handled as packed goods, in containers.

11.1 Approximation of the probability that HNS is involved in collisions

For the Bonn Agreement area an analysis was been made on the probability that HNS is involved in a collision, extrapolated by modelling data on HNS cargoes from Antwerp and Rotterdam.

The result of this analysis is summarised in the next table.

Table 11.3 Modelled amount of HNS cargo involved in collisions

HNS transported in bulk			
On basis of Rotterdam data	Amount [t]	Shipments involved in collisions, per year	Vessels involved in collisions, Per year
HNS and harmless substances	2916	4.00	1.45
HNS (IMDG classes 1-9)	2213	3.39	*1.23*
Chemical tankers I and II	3940	0.78	*0.28*
Chemical tankers I and II, (IMDG classes 1-9)	2688	0.33	*0.12*
TOP 20 ARCOPOL	89	0.14	*0.05*
On basis of Antwerp data			
HNS and harmless substances	1994	0.60	0.36
HNS (IMDG classes 1-9)	1414	0.52	*0.32*
HNS transported as packed goods (based on Antwerp data)			
Packed goods in IMDG classes 1-9	844	4.15	0.82

This table presents for various cargo classifications the predicted amount of (HNS) cargo involved in a collision per year, the predicted number of shipments involved in a collision per year and an estimate of the number vessels involved in collisions per year. There can be more than one shipment of a vessel. These figures were very indicative approximations as these were based on the datasets for Rotterdam and Antwerp only. Furthermore these figures only gave a first, rough approximation of the number of incidents with no indication of the amount of substances spilt.

From the table the following was concluded (on basis of the data from Rotterdam):

- From the 10 collisions that occur every year in the Bonn Agreement area one collision would involve a vessel that carried substances classified as IMDG 1-9. Approximately 2200 tonnes of HNS would be involved in the collision.
- Approximately 0.3 collisions (once in 3 years) would include a chemical tanker of class I or II. Per year approximately 3000 tonnes of HNS would be involved in a collision.
- Approximately 0.1 collisions (once in 10 years) would include a vessel that carried substances from the Top 20 ARCOPOL list. Per year approximately 90 tonnes of ARCOPOL HNS would be involved.

For HNS transported as packed goods the following was concluded:

- It was estimated that there would be 0.8 collisions per year that involved a vessel with HNS on board;
- The total amount of HNS involved in a collision would be 843 tonnes per year which would include 4 different HNS shipments.

11.2 The geographical distribution of HNS involved in collisions

For both packed goods and bulk goods the geographical distribution of HNS in collisions was determined by modelling. For the geographical distribution the results as described in section 11.2 above were used. These results were based on the HNS data received from the ports of Antwerp and Rotterdam only. Results are presented below for a wide range of substances (IMDG 1-9) and more specific (harmful), Arcopol and IMDG 6.1.

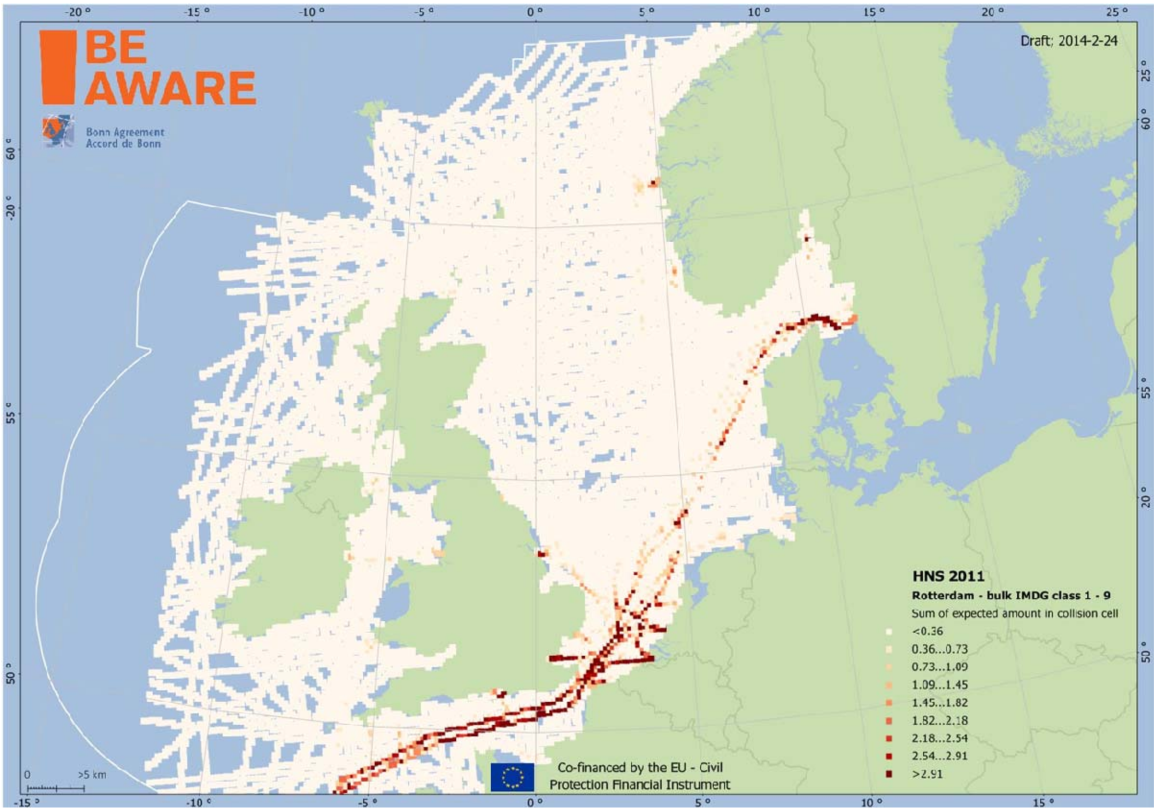


Figure 11-3: Modelled collisions involving bulk HNS cargo in IMDG 1-9 classes (based upon Rotterdam data)

It should be noted that, although based on data from Rotterdam, risk concentrations were also found at Antwerp, Hull, Mongstad, Oslo and Southampton. For packed goods, based on data from Antwerp, contributions were found at Rotterdam, Oslo, Southampton, London and Felixstowe.

As Rotterdam and Antwerp are among the biggest ports in Europe it is clear that a large share of the transported HNS in the North Sea at one point will be sailing in and out of one of these ports. However there are local trade patterns of HNS that were not captured by the analysis in this report; where ships carrying HNS sailed between local ports only, or where a ship sailed from a sea area outside the North Sea and directly to its destination i.e. without calling at Rotterdam or Antwerp. As a consequence, local risk areas were likely not to have been identified in the above risk maps. HNS substances used locally for specialized local industries could be a considerable risk locally, but their quantity could be small compared to the quantities handled in the two ports used for reference in this report. HNS substances transported to and from oil platforms could be an example of substances transported locally.

12. Case Study

As part of the BE AWARE project a benchmarking activity was done to examine the result of the BE-AWARE risk assessment against the SAMSON model for a high risk area. This would allow Contracting Parties that use SAMSON nationally to take these differences into consideration when comparing the BE-AWARE results against national studies. The comparison was done via a case study in the high intensity traffic area off the Belgian and Dutch coasts (see figure 12-1). The following comparisons were performed.

- Comparison of the BE-AWARE route structure with the SAMSON schematization.
- Assessment of the accident frequencies: ship – ship collisions and groundings.
- Assessment of the spill frequencies and sizes.

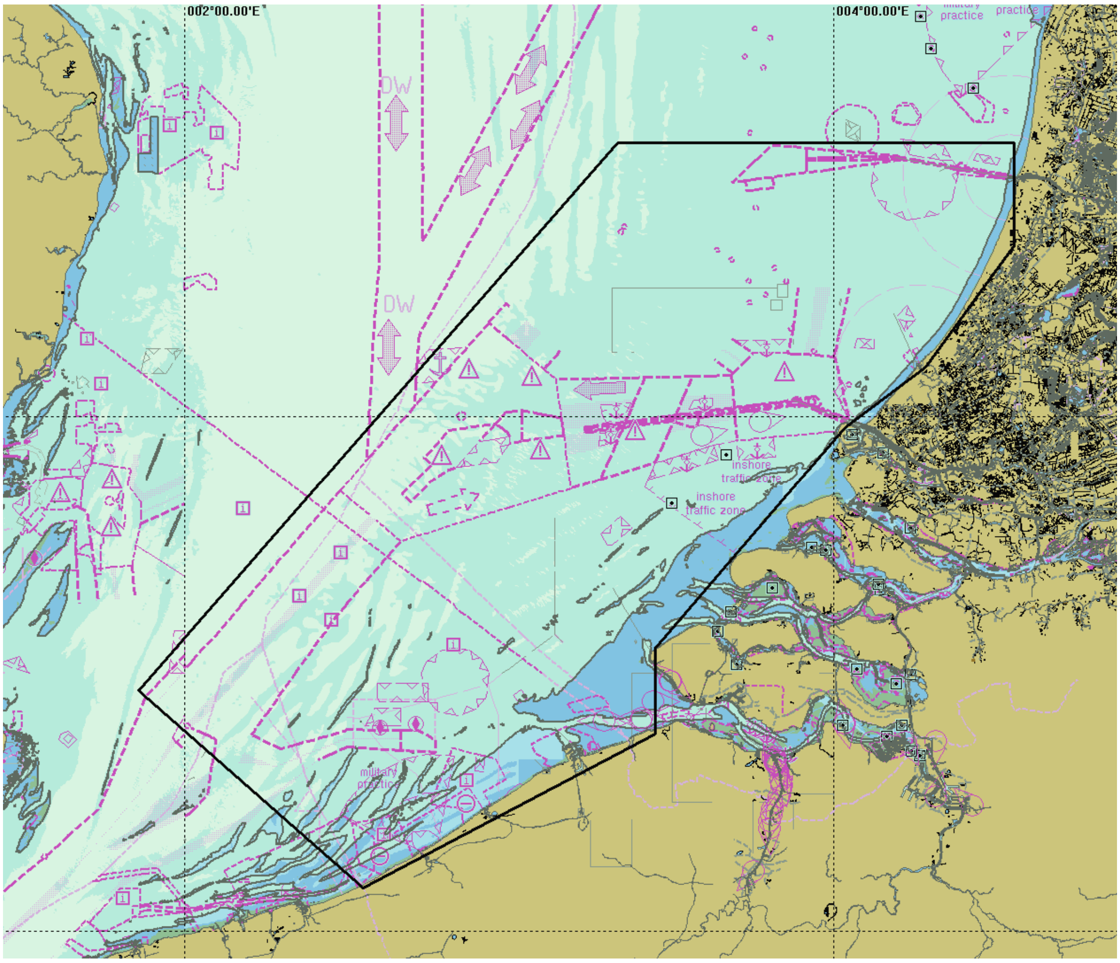


Figure 12-1: Case Study Area

The models for collision risk in BE-AWARE and SAMSON had the same basis. The number of encounters was calculated based on the traffic database consisting of links with number of ship movements. Each link had its own lateral distribution. SAMSON used a fixed domain around the ship that would be kept free of other ships and BE-AWARE a distance of 20 ship lengths. BE-AWARE used one causation factor for the transition from encounters to collisions. SAMSON used a ship type and size dependent casualty rate, because there is a difference in casualty sensitivity between ship type and ship size classes. The casualty rates were also different for the three types of encounters. The casualty rates of SAMSON were derived from the world wide casualty database with focus on the North Sea.

The models for grounding were also different. SAMSON had detailed accident data for the Dutch region and it used two models for the contact risk for an object or grounding: one model for a ramming risk, a grounding or contact with normal speed after a navigational error, and one model for a grounding by drifting or a contact after a technical failure. For BE-AWARE this data was not available for the whole Bonn Agreement region and therefore parameters derived from historical casualty data were used instead.

The table 12-1 contains the results of 3 cases used to compare the models that are described in more detail in Technical Sub Report 10. The same cases were used when comparing the grounding risk. It should be noted that the total amount of accidents in the case study area is roughly 25% of the incidents in the total BE-AWARE area. This is due to the very dense traffic flows in this area. The oil spilt in the Case Study area is about 30% of the total spills in the BE-AWARE area.

Case 1: The table contains the frequencies for collisions for the nodes and the route links that are located within the Case Study area and for groundings. For each incident also the frequency of a spill is given for bunker oil and a number of cargo substances carried in bulk. The frequencies of BE-AWARE for the routes that are partly located in the Case Study area were multiplied with the fraction that is within the Case Study area.

Case 2: The traffic database for 2011 of BE-AWARE was converted to a traffic database for SAMSON. Next the collision risk was calculated with the SAMSON collision risk and spill models.

Case 3: Is based upon the SAMSON database for 2008 converted to match the traffic situation for 2011 to allow a direct comparison with the BE-AWARE results.

	1	2	3
	Results of BE-AWARE, based on nodes and links in Case Study area	SAMSON with BE-AWARE database of 2011	SAMSON with SAMSON database updated to 2011 intensity
on route / head-on + overtaking	1.96	2.53	1.34
in nodes / crossings	0.51	2.89	2.53
total collisions	2.46	5.42	3.87
bunker spills	0.35	0.05	0.04
cargo oil spills	0.02	0.09	0.05
total spills	0.37	0.14	0.09
bunker oil spilt [t]	334.1	18.7	12.7
cargo oil spilt [t]	320.9	1464.7	803.9
total oil spilt [t]	654.9	1483.4	816.6
Average size bunker oil spill [t]	956	344	327
Average size cargo oil spill [t]	14495	16696	16617

Table 12-1 Predicted number of Ships involved in collisions and spill frequencies for 2011

The following statements can be made when different cases of **Error! Reference source not found.** are compared:

- **BE-AWARE model versus SAMSON model:** Case 1 and Case 2 contained results for the same traffic database of BE-AWARE for 2011 but calculated with respectively the BE-AWARE and SAMSON models. The total number of ships involved in collisions with the SAMSON model was 5.42 thus 2.2 times the 2.46 of BE-AWARE. The main difference was in the number of crossing collisions 2.89 for SAMSON and 0.51 for BE-AWARE. The latter might have been affected by the difference in definitions of both collisions. Further the predicted number of bunker spills by SAMSON is much lower.
- **BE-AWARE traffic database versus SAMSON traffic database:** Case 2 compared with Case 3 shows the difference between using the BE-AWARE traffic database and the SAMSON database. Using the SAMSON database the number of the head-on and overtaking collisions was 1.34 per year compared with 2.53 for the BE-AWARE database. The difference in crossing collisions of 2.89 per year for the BE-AWARE database and 2.53 per year for the SAMSON database was negligible.
- **BE-AWARE vs SAMSON:** However when you compare the two models in their entirety including the traffic databases and models the results were very similar with only minor differences in the number of crossing collisions and the volume of bunker oil spilt. The predicted spill frequency by the BE-AWARE models for bunker oil was higher and for cargo spills was lower than predicted by the SAMSON models. The average size of a cargo oil spill was nearly the same for both models. While the average spill of bunker oil was much larger 956 tonnes much larger than the 344 tonnes calculated by SAMSON the average size of the cargo spills at 14495 tonnes and 16696 tonnes respectively were very similar.

The purpose of risk models is that they describe what happens as effectively as possible in an objective way. Risk models are very useful in indicating differences between different scenarios or quantifying the effect of measures. Risk models are less accurate in predicting absolute values of certain occurrences. It can be seen from the comparison of the results of the BE-AWARE and the SAMSON model above that with respect to collisions and groundings in the Case Study area they delivered overall figures that were in the same order of magnitude. The largest difference was found to be for the probability and volume of bunker spills, although it should be emphasised that these volumes are much smaller than the cargo spill volumes. The probability and the volume of a bunker spill seemed to be high in the BE-AWARE model with respect to the number of ships involved in collisions and the fuel capacity of the ships. In general a closer fit between the models would have been more desirable but the differences shown were acceptable.

13.Conclusions

The aim of BE-AWARE was to identify the risk of accidents and the likely size of spills caused, quantitatively for oil pollution and qualitatively for HNS, for both 2011 and 2020. The long term aim is to identify the best measures to reduce these risks at a sub-regional level therefore the results have been presented in 5 sub regions: the Atlantic, the Northern North Sea, the Eastern North Sea, the Southern North Sea and the Channel.

In order to undertake the analysis a significant amount of data was required as input to the models including: AIS data for the traffic model, accident statistics for all countries, existing and planned risk reducing measures and detailed cargo information for all major ports. This data collection was a major challenge for the project as, for example, the AIS coverage was not uniform across the whole region, due to the range of VHF, and therefore an algorithm was used to connect broken tracks. In future project projects, if available, satellite AIS should be used to get better coverage. It was difficult to get access to detailed cargo information from the ports due to confidentiality issues, although the project was grateful to those that did provide data. In a future analysis it would be desirable to obtain detailed information from more ports and also it is a wish that information on transported substances is registered in the same terminology. In the end however the data received in this project was sufficient to be able to undertake the analysis and have confidence in the results.

Whilst the method used for BE-AWARE was based upon established models used in previous oil pollution risk studies they still required modification to adapt them to the specific characteristics in the Greater North Sea and its Wider Approaches. Such modification entailed the inclusion of the risk from the offshore oil and gas industry and the expected increase in offshore wind farms. The importance of including these risks in the modelling is clearly demonstrated when the regional risk of spills for 2020 is examined. For the Northern North Sea, where the traffic is relatively less dense but the majority of the offshore oil installations are found, the risk picture was dominated by spills from those installations. Also in the Southern North Sea there was a clear increase in the risk from wind farms from 2011 to 2020 due to the expected development over this period.

Taking into account the above conclusions, it was nevertheless clear that overall the main risk for oil pollution was due to collisions involving loaded ships and overall the largest contributor was the outflow of cargo as a result of collisions with large tankers, even if the risk frequency for this type of event was very low. Minor and medium sized spills were typically from accidents where the vessels had only sustained minor damage. Groundings also generally only contributed to the risk of minor and medium sized spills. The frequency of collision accidents was mainly spread along the areas of the North Sea with the highest amount of traffic, i.e. regions 3, 4 and 5.

For the qualitative risk of HNS it was only possible to undertake the analysis on the data from Rotterdam and Antwerp, which provided the most detailed information on goods transport to and from their ports. Due to the less detailed information being available, the environmental impact of a HNS spill at sea being different for every type of substance transported and the fact that chemical tankers may carry several types of substances it was not possible to undertake a quantitative risk analysis. Therefore the analysis focused on categorising the different hazards posed by the substances in terms of how they react when released in an accident, their risk to public health and their risk to the environment. To the extent possible the likelihood that HNS cargo on-board a ship would be involved in an accident was also modelled using the SAMSON model using the Rotterdam and Antwerp data. It was recognised that there were shortcomings with the approach, particularly that more local trade patterns of HNS were not captured by the analysis. However it did highlight that the main risks again existed in the regions with the highest shipping density.

The risk assessment undertaken in the BE-AWARE project was not planned to be the end of the regional risk evaluation in the Bonn Agreement Area. The aim is to understand the impact of the predicted spills in 2020 and how they are affected by different potential risk reducing and response measures. Therefore it is essential to be able to undertake a region wide analysis of the environmental and socioeconomic sensitivity of the area to oil pollution to combine this with modelling of the outflow of oil from the spills identified in BE-AWARE. Therefore during the project a discrete task was undertaken to develop a methodology for such an analysis. The methodology used in the Baltic by the BRISK project was identified as best practice, and adapted for North Sea conditions and expanded to include a greater consideration of the socioeconomic issues, with input from Bonn Agreement Contracting Party experts.

BE-AWARE II

In order to undertake this future analysis the Bonn Agreement has again been successful in securing funding from the EU Civil Protection Financial Instrument to undertake a second phase of the project. BE-AWARE II aims to identify the most effective future risk reduction and response measures, at a sub-regional scale, to address the risk of spills identified in BE-AWARE for the 2020 scenario. It aims to achieve the following main objectives:

- To identify alternative future (2020) scenarios for risk reduction measures and response capacities;
- To model the fate and weathering of oil for the potential spills identified in BE-AWARE for each of the scenarios;
- To identify the socioeconomic and environmental vulnerability of the coastline and offshore areas using the methodology developed in BE-AWARE;
- To identify the impacts of oil in the environment, taking into consideration the vulnerability of the coastline and offshore areas, for each of the selected scenarios;
- To develop risk management conclusions for Bonn Agreement sub-regions based on the most efficient and cost effective scenarios identified;
- To promote a common understanding of risk assessment practices and cross border risk management.

The project started in December 2013 and will finish in November 2015 and more information can be found at beaware.bonnagreement.org.

Annex 1

Method note as agreed at the Risk Assessment Seminar

BE AWARE

Bonn Agreement
Accord de Bonn

METHODOLOGY NOTE

Bonn Agreement
Accord de Bonn

Co-financed by the EU –
Civil Protection Financial Instrument

Photo: Maritime and Coastguard Agency (UK) Graphic design: Ungermeyer, Berlin

BE AWARE

Bonn Agreement
Accord de Bonn

DOCUMENT TITLE:	Methodology Note
TASK:	D
AUTHOR:	Albrecht Lentz (COWI)
PUBLISHED ON:	2013-02-07
VERSION:	2.0

COWI

MARIN

Bonn Agreement
Accord de Bonn
Co-financed by the EU –
Civil Protection Financial Instrument

The Greater North Sea and its wider approaches is one of the busiest and most highly used maritime areas in the world. With the ever-increasing competition for space comes an increased risk of accidents that could result in marine pollution.

Currently the area has no overall risk assessment for marine pollution; risk is mapped with a variety of national risk assessments which are undertaken with differing methodologies; thus reducing comparability.

The BE-AWARE project is therefore undertaking the first area-wide risk assessment of marine pollution using a common methodology that allows the risk to be mapped and compared under different scenarios.

The project outcomes will improve disaster prevention by allowing North Sea States to better focus their resources on areas of high risk.

The project is a two year initiative (2012-2014), co-financed by the European Union, with participation and support from the Bonn Agreement Secretariat, Belgium, Denmark and the Netherlands, with co-financing from Norway.

Contents

1. Introduction

1.1 BE-AWARE project setup

The project was initiated as a consequence of the (Dublin Declaration, 2010), where it was stated that a Bonn Agreement Area wide risk assessment should be prepared and "apply methodologies and experience gained from the BRISK project in the Baltic Sea". The BRISK project included an integrated risk assessment study for the Baltic Sea partly funded by the EU (BRISK method, 2012).

The present methodology note describes the applied methodology commonly agreed by partner countries participating in the BE-AWARE project group including the external consultants. The methodology principles are taken from the methodology of the BRISK project (BRISK method, 2012) and adjusted to the specific condition of the North Sea area.

The modifications include amongst others the absence of ice conditions, additional refinement of the grounding model and on the model for accidental spills from platforms.

1.2 Background

The present Methodology Note is part of the BE-AWARE project dealing with the risk of spill of oil and HNS in the Bonn Agreement area. BE-AWARE consists of the following work steps:

- A Project management and communication
- B Kick-off meeting
- C Regional resource database
- D Methodology
- E Area-wide traffic study
- F Sensitivity analysis
- G Risk assessment workshop
- H Bonn Agreement area-wide risk assessment
- I Case study
- J Project conference

1.3 Scope

Work step D, which is documented by the present Methodology Note, prepares the grounds for the project execution (Work step E and H). Thus, it has the following objectives:

- Basic definition of key issues, such as the substances and scenarios to be dealt with
- Basic principles of how ship traffic, goods transport, accidents and spills are represented in the model

The data and calculation flow of the model is illustrated in Figure 1-1.

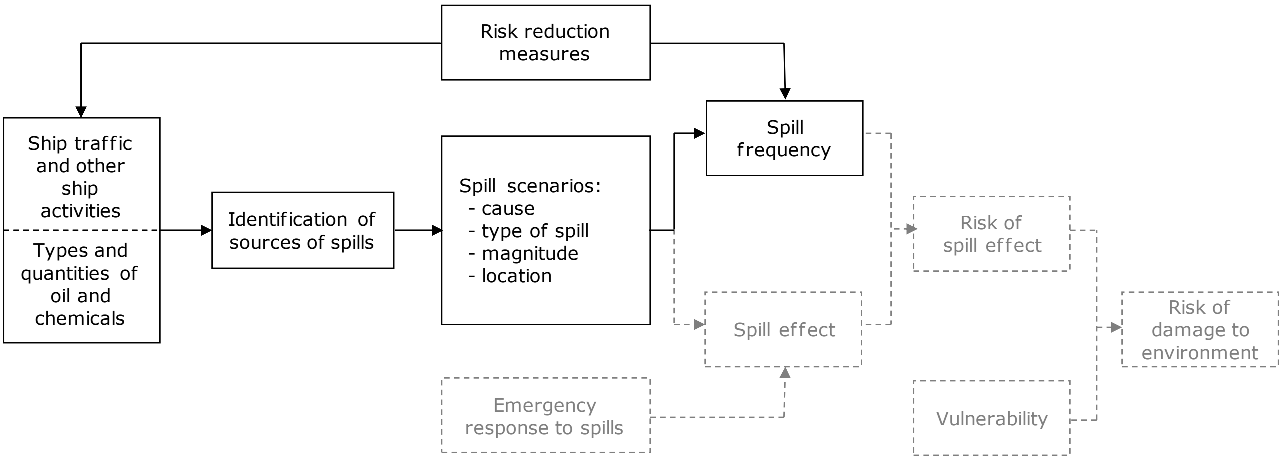


Figure 1-1 Data and calculation flow of the model (BE-AWARE work steps are indicated in solid black, work steps of the follow-up project phase are indicated in dashed gray)

Correspondingly, the present Methodology Note is divided into the following chapters:

Table 1-1 Methodology note chapters and corresponding BE-AWARE tasks

Chapter	Title	Corresponding BE-AWARE task	Responsible consultant
2	Hazard identification and selection of scenarios	*None (definition of general principles)*	COWI
3	Ship traffic	Task H1.1	COWI
4	Classification of oil	*None (definition of general principles)*	COWI
5	Oil transport model	Task E3	MARIN
6	Traffic prognosis	Task E4	MARIN
7	Frequency and quantity of oil spills	Task H1.3	COWI
8	Oil spills related to offshore installations	Task E5	MARIN
9	Qualitative analysis of HNS risks	Task H7	MARIN

2. Hazard identification and selection of scenarios

2.1 Introduction

The purpose of the present chapter is to serve as a paradigm for the hazard identification and scenario selection for the entire BE-AWARE area, here defined as in Figure 2-1.

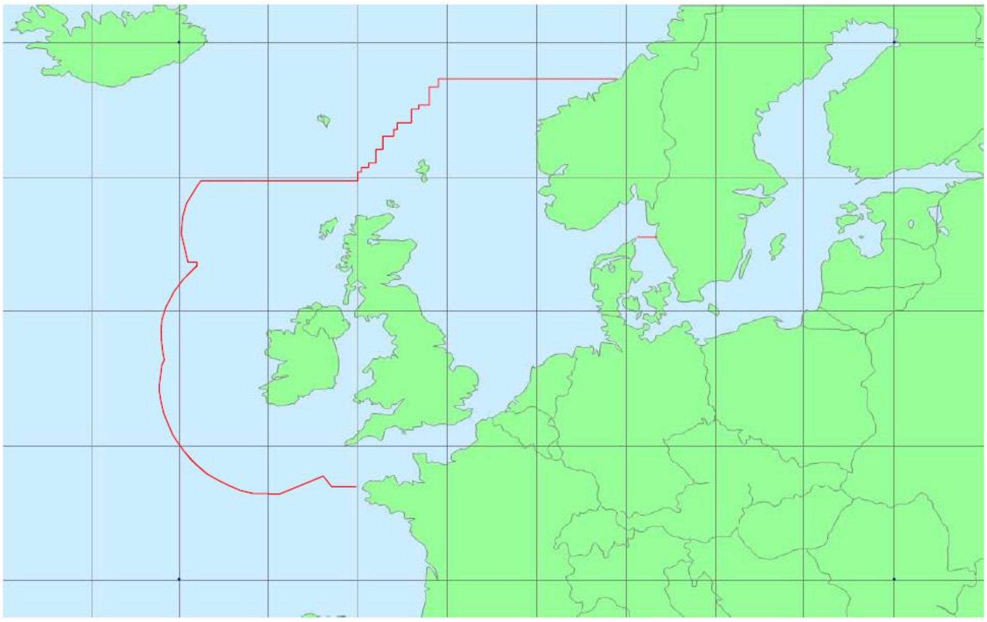


Figure 2-1 Project area for BE-AWARE. The area is also often referred to as the "Bonn Agreement Area"

The risk analysis includes incidents with spills of oil in the present situation (year 2011) and in a future situation (year 2020). Spill of hazardous substances are not included in this study, but described in more qualitative terms in other parts of the project.

A risk analysis considers the likelihood as well as the consequences of oil in the project area as basis for the next stages in the project. The aim of the analysis is to provide a common description of the risk. This will be of paramount importance for future development of the emergency preparedness with respect to combat of oil and hazardous substance spills in the project area.

The first part of the risk analysis is a systematic identification of sources of unwanted spills of oil to the marine environment. For each source of spill the overall risk to the marine environment is assessed and the sources are grouped as follows:

- Sources included in the risk analysis.
- Sources not included in the risk analysis, because combat of the corresponding spills are considered to be outside the scope of the project. This applies essentially to land-based activities and activities inside harbours and lagoons (compare Section 2.4).
- Sources not included in the risk analysis, because the risk is judged to be insignificant.

The risk analysis does not consider continuous and permitted releases even if such may cause harm to the marine environment. This is because the emergency preparedness is not required to combat the effects of such spills. Examples would be a continuous release of hazardous and noxious substances (HNS) in waste water from on-shore sewer systems.

Sabotage, terror and acts of war are not covered by the risk analysis. Sabotage and terror events are difficult to assess in a risk analysis as the likelihood is impossible to set. An emergency preparedness able to combat likely events threatening the marine environment would in most cases also be able to act effectively against acts of sabotage and terror. Acts of war shall not be the basis for the design and sizing of the emergency preparedness.

Identification and assessment of sources are reported in Section 2.2.

For the sources to be included in the risk analysis scenarios for spills of oil are defined. The scenarios include the elapse of the incident until the spill takes place. For spills of oil with potential of damaging the marine environment a span of consequences is modelled. These are, however, not described here, but would be the subject of a possible second project phase.

The scenarios to be modelled are described in Section 2.3.

2.2 Identification of sources of spill to be modelled

The risk analysis models a number of scenarios for spills of oil and HNS in the Bonn Agreement area. In this section all possible types of spill are identified and it is assessed if the risk due to these spills is large enough to have an impact on the planned sub-regional emergency preparedness. Only spills that are large, harmful and frequent enough are modelled.

2.2.1 Global hazard identification

The following main sources of spill to the sea able to cause damage to the marine environment have been identified:

- Ships
- Land based activities (outside the scope of the risk analysis)
- Offshore oil and gas extraction
- Other offshore activities
- Air traffic, satellites etc.
- Subsea dumping sites
- Nature

These main sources of spill are considered in the following sections.

2.2.2 Ships – overview

The main topic of the risk analysis is pollution of the marine environment caused by ships.

Considering the large variety of ships and ship activities the following subdivision has been applied:

1. Cause of spill to the sea
2. Type of ship
3. Size of ship
4. The ship's activity at the time of spill to the sea.

2.2.3 Cause of spills at sea

Distinction is made between the following spill causes:

- Accidents at sea. Accidents where the ship is damaged e.g. collisions and groundings leading to spill of oil or HNS to the marine environment.
- Deliberate spills. Actions including illegal discharge of large amounts of polluting material in order to gain a benefit. The action is, however, not performed to cause deliberate damage to the marine environment. Typical actions of this nature would be flushing of tanks and emptying of waste oil tanks.
- Inadvertent spills. Such spills include spills due to faulty operation etc. without causing damage to the ship itself. Such spills will typically be minor spills e.g. a fault in the cooling water system causing large amounts of lubricants to be spilled to the sea. Goods damage. Spills due to mechanical damage to containers or their fastening without damage to the ship. Whole containers or their contents are lost overboard.

Accidents at sea

The risk analysis focuses on accidents at sea. These accidents may give rise to large spills having a huge impact on the marine environment. These large spills define the design loads for the emergency preparedness and disaster response. The sections below on ship type and ship activity are arranged mainly focusing on accidents at sea. Scenarios modelling accidents at sea causing spill of oil or HNS are set up.

Deliberate and inadvertent spills

Both deliberate and inadvertent oil spills are expected to be considerably smaller than spills after an accident. Thus such spills are not likely to cause extensive damage to the marine environment. The contribution to the total risk to the marine environment due to deliberate and inadvertent discharge/spills of oil is not modelled.

Damage to cargo, no damage to ship

Damage to or loss of cargo not caused by a sea accident is only likely to occur from container ships and general cargo ships carrying deck cargo. A typical scenario would include that the deck load is damaged or washed overboard in a storm.

Loss of drums or containers or damage to these in Danish waters causing spills is a rare event. In the case of Denmark, only one such incident has been recorded back in the 1980ies /Oil spill DK, 2007. This situation is regarded as representative for the entire project area.

Considering that the amount of oil products in a single container or a drum is likely to be small it is found that the risk of oil pollution of the project area due to loss of or damage to containers or drums is negligible compared to other modes of spill in the case of oil. Thus this contribution to the risk is not modelled.

As far as containers and drums containing HNS are concerned, it is less easy to determine whether the corresponding risk is relevant or not. This requires at least a qualitative investigation.

2.2.4 Type of ship

Analysing accidents at sea the following types of potentially harmful ship are considered:

- Ships with a cargo of oil or HNS harmful to the environment if spilled
- Ships not transporting oil or HNS, but carrying oil or harmful HNS for use on the ship

Ships with a cargo of oil or HNS

The harmful cargo may be in bulk or in containers packed as dangerous goods. Packed dangerous goods also include loads on road tankers or in bulk in lorries on board ferries. Thus the following types exist:

- Ships carrying a cargo of oil in bulk:
    - Tank vessels (including ships able to carry both oil and other HNS in their tanks). This is the main topic for the risk analysis. Scenarios for accidents at sea are set up in Section 2.3.2.
    - Spills due to tank flushing are not modelled.
- Ships carrying oil products packaged as dangerous goods:
    - Ferries (Ro-Ro) transporting railway carriages and road tankers with oil products. Due to the small amounts in each container or tank the risk to the marine environment is small and modelling of this type of spill during an accident at sea is not required.
    - Container ships. In principle oil products may be transported by container ships packaged in smaller containers. This is, however, considered only to occur rarely as the amount of products in the individual container would be limited. As above the risk is small and spills of this type during an accident at sea is not modelled.
    - Ships carrying general cargo. Same as indicated for container ships
    - Offshore supply vessels. Same as indicated for container ships.
- Ships carrying HNS in bulk:
    - Tankers and bulk carriers (including ships able to carry various types of product in their tanks). Spills of HNS from these ships due to accidents at sea is only modelled qualitatively, because the transported quantities and the corresponding environmental risk are small compared to the transported quantities and risk of oil, Section 2.3.2.
- Ships carrying HNS as packaged goods:
    - Ferries (Ro-Ro) transferring railway cars or trucks carrying dangerous goods
    - Container ships
    - General cargo ships
    - Offshore supply vessels.

  The amounts of HNS transported in these vessels are by far smaller than the amounts transported in bulk. Nevertheless, the risk due to spills of HNS from ships carrying packaged goods needs to be modelled at least qualitatively.
- Ships carrying radioactive substances and other extremely dangerous substances

  Radioactive substances and other extremely dangerous substances (e.g. dioxine) are not part of the analysis, because
    - These substances are packaged after special principles, which mean that an accident at sea will typically not cause any spill, because the container remains intact.
    - It is very difficult to obtain reliable data on the transport of such substances. We can only presume that the quantities are small and that transports of this type are rare.

Ships without a cargo of oil or HNS

In principle all types of ship will carry oils and HNS for their own use. However, the amounts will be limited.

The following compounds have been identified as potentially harmful:

- Bunker fuel, i.e. oil required for the propulsion and operation of the ship. Fuel for the ship's engine including the main engines and emergency generators etc.
- Various types of oil e.g. lubricant oils and hydraulic oils.
- HNS. Such may be:
    - HNS required for waste treatment, cooling plants, cleaning, rat control etc.
    - Paint, some include HNS to prevent fouling.

  The amounts of these HNS are likely to be small. The most harmful are assessed to be HNS for cooling plants (ammonia, HFC, freon at older ships) and paint. HNS for cooling plants are stored in smaller pressure bottles. Paint is kept in pots and the amount stored would at most be some 30 pots each containing 20 litres (Petersen, 2006), (Høyer, 2006).

The risk due to spills from ships only carrying oil and HNS for their own use are analysed in the following way:

- Scenarios describing spills of bunker fuel due to accidents at sea are set up, Section 2.3.3. In these scenarios also spills from tanks holding lubricants are included in case these tanks are more exposed to damage than the fuel tanks (during grounding).
- Deliberate and inadvertent discharge/spills of all types of oil are not modelled.
- Because the amounts of HNS for the ships own use are rather limited, the containers are small and because the likelihood of spill is small, modelling of these spills due to accidents at sea is not required.

2.2.5 Size of ship

The risk analysis does not consider ships of a size below 300 GT. The reason for this is partly that these ships are so small that they do not carry a cargo of oil or HNS and they may only cause relatively little harm due to spills of bunker fuel, partly that these ships have no obligation to transmit AIS-signals which are the main source for mapping the ship traffic (compare Chapter 3).

In (COWI, 2007) the spills registered from ships smaller than 300 GT were considered, and it was found, that they are of insignificant importance.

2.2.6 Vessel activity at the time of spill

Distinction is made between the following activities:

- Navigation at sea (outside harbours)
- Transfer of oil at sea
- Special activities at sea
- Activities in harbours

Navigation and anchoring at sea

Scenarios are set up describing spills of oil and HNS from ships due to accidents at sea, see Sections 2.3.2 and 2.3.3. Deliberate and inadvertent discharge/spills are not treated.

Transfer of oil at sea

Transfer of oil at sea may be:

- Transfer of a cargo from ship to ship (STS). Individual scenarios for this activity covering both accidents at sea and inadvertent spills (errors during operation etc.) are set up, see Section 2.3.6.
- Transfer of oil cargo from offshore production facility to ship.
- Transfer of oil cargo between a ship and a buoy with a pipe connection to shore.
- Transfer of bunker fuel from bunker ship to another ship passing through the project area. Individual scenarios are set up covering both accidents at sea and inadvertent spills (errors during operation etc.), see Section 2.3.7. The scenarios cover all types of transfer of oil to be used on the ship, see Section 2.2.4.

Transfer of HNS at sea

The following has been identified:

- Transfer between supply vessels and offshore installations. These activities are *not* modelled. This decision is in line with the decision to model chemical spills during navigation at sea only qualitatively. The risk posed by HNS transfers at sea is considered to be even lower.

Special activities at sea

Special activities at sea include:

- Cargo ships:
    - Transfer of provisions, persons etc.
    - Anchoring while waiting for a weather change
    - Hove-to while waiting for a weather change
    - Anchoring while waiting for a new task.

- Vessels performing special activities e.g.:
    - Diving ship supporting divers
    - Cable-laying vessel at work
    - Dredging, deepening and extraction of materials at sea.

- Fishing ships at work

For these activities no scenarios are set up. However, accidents at sea can occur during these activities and they are included in the statistical basis for modelling ships navigating at sea.

Special activities in general have a rather small frequency compared to ship traffic in general. Possibly fishing may not be small, however, only very few fishing vessels are of a size large enough to contribute significantly to the hazard of oil or chemical spills causing harm to the marine environment.

Activities in harbours

Activities in harbours are outside the scope of the risk analysis.

Mooring systems do exist at locations not protected by outer jetties. These systems without outer jetties are equally considered as harbours.

2.2.7 Land-based activities

Spills of oil and HNS from shore-based activities may occur after incidents at the plants and during transportation on road or rail. Further spill in connection with agricultural activities may occur.

Incidents at plants

During an incident on a shore-based plant spills of oil and HNS may reach the marine environment in several ways:

- By sewer systems possibly taking the spill to an area at some distance from shore
- By streams to the sea
- Directly to the sea in case the plant is located close to the sea.

Such incidents are outside the scope of the risk analysis.

Spills during transport

In case of spill events during transport oil and HNS may reach the marine environment:

- By sewer systems
- By streams to the sea
- Directly to the sea from a road along the coast
- Directly to the sea from a bridge across an area of sea.

Such incidents are outside the scope of the risk analysis.

Spills from agricultural incidents

Spills from agricultural incidents would be able to reach the marine environment by the following routes:

- By sewer systems possibly taking the spill to an area at some distance from shore
- By streams to the sea
- Directly to the sea in case the activity is located close to the sea.

Such incidents are outside the scope of the risk analysis.

2.2.8 Offshore oil and gas activities

Spills from oil and gas activities may occur in the following ways:

- Release directly from the reservoir (blowout) during prospection and exploration. During these activities a drilling rig may be working at a location not housing a permanent offshore facility
- Release directly from the reservoir (blowout) from a permanent offshore facility. This may occur during drilling of a production well, drilling of wells for injection of water or gas, during production or during work-over
- Spills from equipment on a permanent platform

- Spills from pipelines for transport of oil or gas
- Spills from the reservoir (blowout) from wells that are closed
- Spills during transfer of cargo between supply vessels and platforms or drilling rigs
- Spills from ships that collide with platforms or drilling rigs
- Spills from supply vessels that calling at platforms or drilling rigs

The BE-AWARE project partners have decided that the hazards due to the following incidents *are to be included* in the scenarios:

- Spills of 1 tonne and above from platforms and drilling rigs (including equipment) due to vessel impact. Both dedicated and passing vessels are considered.
- Spills of 1 tonne and above from platforms and drilling rigs (including equipment) independent of any vessel activities (e.g. due to blow-outs).
- Spills from ships after collision with a platform or a drilling rig. Both dedicated and passing vessels are considered.
- General spills from ships calling at platforms and drilling rigs. The risk of spill from this type of traffic is modelled as part of the general risk of spill from all navigating ships, Section 2.3.2 and 2.3.3.

The risk of releases from closed wells and closed test drills was also investigated in (COWI, 2007), where it was found that modelling of this risk is not required. This is assumed to apply equally to the Bonn Agreement area as a whole.

2.2.9 Other offshore activities

Other offshore activities e.g.:

- Subsea oil pipelines are *not* part of the model scope.
- Possible subsea HNS pipelines are not considered to be within the scope of the analysis. This decision is consistent with the decision not to model HNS releases from ships quantitatively. It is also in accordance with the assumptions in the BRISK project (BRISK method, 2012). .
- Releases from subsea gas pipelines are not considered a primary environmental threat and cannot be combated either.
- Construction and operation of sea-based wind turbines.

  Some incidents at this type of installation may result in spills causing pollution of the marine environment. However, the potential of harm is judged to be small and thus this type of spill is not investigated further. Reference is made to (COWI, 2007).

  Spills from ships calling at the installations are treated within the general model of spills from navigating ships, Section 2.3.2 and 2.3.3. The risk due to this type of navigation is not specifically modelled.

  Spills from ships colliding with the installations will be modelled in the present project due to a number of recent large wind farm projects.

- Construction and operation of bridges and tunnels above and below the sea.

Incidents at these structures may cause spills polluting the marine environment. The risk of pollution is judged to be small and the subject is not considered further.

Spills from vessels participating in the construction or operation of such structures are included in the general modelling of navigating ships, Section 2.3.2 and 2.3.3. Thus the risk of this type of activity is not modelled in detail.

- Operation of large buoys.

  The risk of pollution due to collisions with large buoys can be expected to be rather small compared to other potential spill causes. Therefore, it has been decided not to model this risk.

2.2.10 Aircraft, satellites etc.

The project area may be polluted by flying objects falling off the sky and from spills when the objects are damaged at the impact.

Objects falling from the sky

Aeroplanes may spill jet fuel in amounts up to what the largest planes may hold. Further air freighters may drop containers holding dangerous goods.

Jet fuel is a rather light oil product with a density of about 0.81 (Irving, 2006). In case of a spill after a crash the jet fuel will evaporate within short. The maximum amount spilled would be small. A Boeing 747-400 (jumbo jet) has a tank capacity of 217 m3 (Boeing, 2006) i.e. some 180 tonnes. However, the likelihood of a plane crash in the country's EEZ is considerably smaller than the likelihood of spills of oil due to accidents at sea (COWI, 2007): The frequency of crash of a large airplane in Danish waters may be estimated at 0.03 per year based on 189,000 flying hours in Danish airspace during 2005 (CAA-DK, 2006) and a probability of fatal accidents per flying hour for route and charter flight of 1.6 × 10-7 in the USA during 2005 (NTSB, 2006). For the smaller airplanes the likelihood is larger, but these planes carry very small amounts of fuel.

The risk of pollution from other types of flying objects falling of the sky including satellites, air ships and air balloons is without further judged to be negligible.

In conclusion modelling of the risk to the marine environment due to flying objects falling off the sky is not required as the risk is insignificant.

Spills from flying objects

During emergencies aeroplanes may dump fuel in the air before landing. The fuel will be finely dispersed in air (Puckgaard, 2006) and the fuel will not reach the sea in a way observed as pollution of the marine environment. It is found that modelling of the risk to the marine environment from this type of spill is not required.

2.2.11 Subsea dumping sites

In the project area, there possibly exist subsea dumping sites for mines, containers holding mustard gas etc. from World War II. Releases from these sites e.g. due to fishing activities may harm the environment.

The nature of these hazards and the corresponding emergency response is quite different from the preparedness to combat spills of oil and HNS in general.

Thus, the risk of releases from subsea dumping sites is not covered by the present study.

2.2.12 Nature

This source of pollution is considered for completeness.

A possible scenario would be:

- Release from an oil reservoir not occurring due to human activities for extraction of oil (these releases/spills are covered by the activities described in Section 2.2.8). Such a scenario is not likely to occur in the Bonn Agreement area. However, it is noted that releases from an abandoned oil well may be considered as a “release from nature”, if it is not possible to point out an owner or operator of the well.

It is found that it is not required to model such releases.

Additional sources of pollution relevant for the emergency preparedness in the BE-AWARE project area have not been identified.

2.3 Spill scenarios

2.3.1 General

Based on the identification in Section 2.2 scenarios for the following incidents are set up:

- Accidents at sea and spill of cargo in bulk from navigating ships, see Section 2.3.2
- Accidents at sea and spill of bunker fuel from navigating ships, see Section 2.3.3
- Spill as a consequence of a collision with a fixed structure:
    - Collision with an offshore installation or drilling rig, see Section 2.3.4
    - Collision with a wind farm, see Section 2.3.5
- Spill occurring during STS operations, see Section 2.3.6
- Spill during bunkering at sea, see Section 2.3.7
- Spills from offshore installations other than those caused by ship collisions to the offshore structures, see Section 2.3.8

Deliberate or inadvertent discharge/spill of oil from navigating ships, see Section 2.2.3, is NOT modelled.

2.3.2 Accidents at sea and spill of cargo from navigating ships

Accident types

The following types of accident are considered:

1. Grounding
2. Collision with other ship
    - Collision between two navigating ships
    - Collision between a navigating and an anchoring ship
3. Collision with fixed structure. This is described in sections 2.3.4 and 2.3.5.
4. Fire and explosion

5. Other types of sea accident leading to a loss of the ship as this may result in spills

Rare or very complex scenarios are not modelled. Such may e.g. be:

- Collision with a sunken ship. An example is several collisions with the Norwegian car carrier Tricolor that sunk in the English Channel on 14 December 2002 (Scotsman, 2003).
- Accidents caused by sea ice.
- Aeroplane crashing and hitting a ship. No accidents of this type are found.

These rare and complex scenarios will only contribute insignificantly to the overall risk of pollution due to oil and chemical spills in the Bonn Agreement area. In case such events have occurred in the Bonn Agreement area they will be included in the data base of sea accidents and consequently they will be part of the basis for the risk analysis.

Ship and material spilled

For all of the accidents described above the following combinations of ship type and type of spill are considered:

- Tank vessel and spill of oil cargo
- Tank vessel and spill of HNS either as gas or liquid: Only modelled qualitatively
- Other ships carrying HNS as packaged goods: Only modelled qualitatively
- Bulk carrier and spill of solid HNS: NOT modelled

Tank vessel and spill of oil cargo

The types of oil indicated below are modelled (compare Chapter 4). For each type density, solubility in water as well as possible "red" classifications considering fire hazard, health hazard and environmental hazard are indicated:

- Petrol, floats, “red” fire hazard, “red” health hazard
- Diesel, floats
- Crude oil, floats
- Fuel oil is modelled by IFO 380, may float just below the surface and a probability is indicated

The magnitude of spill:

- 0.3 t (0 - 1t)
- 4 t (1 - 15 t)
- 67t (15 - 300 t)
- 1,200 t (300 – 5,000 t)
- 8,700 t (5,000 – 15,000 t)
- 27,000 t (15,000 – 50,000 t)
- 87,000 t (50,000 - 150,000 t)

- 230,000 t (150,000 - 350,000 t)

The spill is assumed to occur instantaneously.

Time of spill compared to the time of accident:

- Immediately as the accident occurs
- Late compared to the time of accident.

It may be considered to model a delayed time of spill for a situation when a ship is grounded. In that case a spill may occur after some time as the ship may first be damaged later. However, it was found that groundings only give a small contribution to the risk compared to collisions, see (COWI, 2007) and (BRISK results, 2012). Thus, in order to simplify the calculations this effect was omitted.

Container ships, general cargo ships, ferries (Ro-Ro), offshore supply vessels, nuclear transports and spills of oil and HNS transported in containers

The risk to the marine environment due to accidents at sea leading to spills of oil transported as packaged dangerous goods is not modelled as the contribution to the overall risk for the marine environment is small, see Section 2.2.4.

2.3.3 Accidents at sea and spill of bunker fuel

Accident types

The same types of accident as described in Section 2.3.2 would also be relevant here.

Ship and material

All types of ship defined in Section 2.2.4 are relevant.

The following types of bunker fuel are considered:

- Diesel, floats
- IFO 380, may float just below the surface and a probability is indicated.

Magnitude of spill:

- 0.3 t (0 - 1t)
- 4 t (1 - 15 t)
- 67 t (15 - 300 t)
- 1,200 t (300 – 5,000 t)
- 8,700 t (5,000 – 15,000 t)
- 27,000 t (15,000 – 50,000 t)
- 87,000 t (50,000 – 150,000 t)
- 230,000 t (150,000 - 350,000 t)

The spill is assumed to occur instantaneously.

Time of spill compared to the time of accident:

- Immediately as the accident occurs
- Late compared to the time of accident.

This issue is handled in the same manner as indicated for tank vessels and spill of oil cargo see Section 2.3.2, i.e. only immediate spills are considered for accidents at sea.

2.3.4 Collision with offshore platforms and drilling rigs

The following sub-scenarios are considered:

- Spill from platforms and drilling rigs (including equipment) due to vessel impact. Both dedicated and passing vessels are considered. Only spills of 1 tonne and above are considered (see Section 2.2.8).
- Spill from ships after collision with a platform or a drilling rig. Both dedicated and passing vessels are considered. The two types of ship are, however, modelled separately using different models.

In principle, the scenarios can involve powered as well as drifting vessels.

In addition to the spill risk due to ship collisions, spills from platforms independent of any vessel activities are also modelled, see Section 2.3.8. The modelling principles are described in Chapter 8.

2.3.5 Collision with a wind farm

Collisions of passing ships with wind farms resemble collisions with other fixed objects such as platforms and are modelled accordingly.

Wind farms can in principle also be hit by dedicated vessels, as it is the case with platforms. However, visits of dedicated vessels are very rare compared to an oil platform. Given the low probability of a violent collision involving a leakage per visit, it is decided not to model the contribution from dedicated vessels.

The modelling principles are described in Chapter 8.

2.3.6 Spill during transfer of oil cargo at sea (STS operations)

Two scenarios are considered:

- Spill of oil from the loading system i.e. from hoses, valves etc. as well as overflow. This is modelled based on information retrieved from OILOPS (Danish case) and comparable national databases and a general experience with and analyses of transfer of liquids at sea, see Section 7.4.
- Spill of oil cargo (or bunker fuel) from tank(s) due to accidents at sea occurring in connection with the transfer. These incidents are considered in the same way as other accidents at sea, see Section 7.4.

2.3.7 Spill during bunkering at sea

Two scenarios are considered in the same way as described above for STS operations, see Section 7.4.

2.3.8 Spills from offshore installations due to other causes than ship collision

Spills from offshore installations due to other causes than ship collision are modelled. The modelling principles are described in Chapter 8.

2.4 Geographical scope

The geographical scope is limited to the Bonn Agreement area. In the context of BE-AWARE, the project area is defined as the sea area as indicated in Figure 2-2 (which is identical to Figure 2-1, but repeated here for illustration reason)

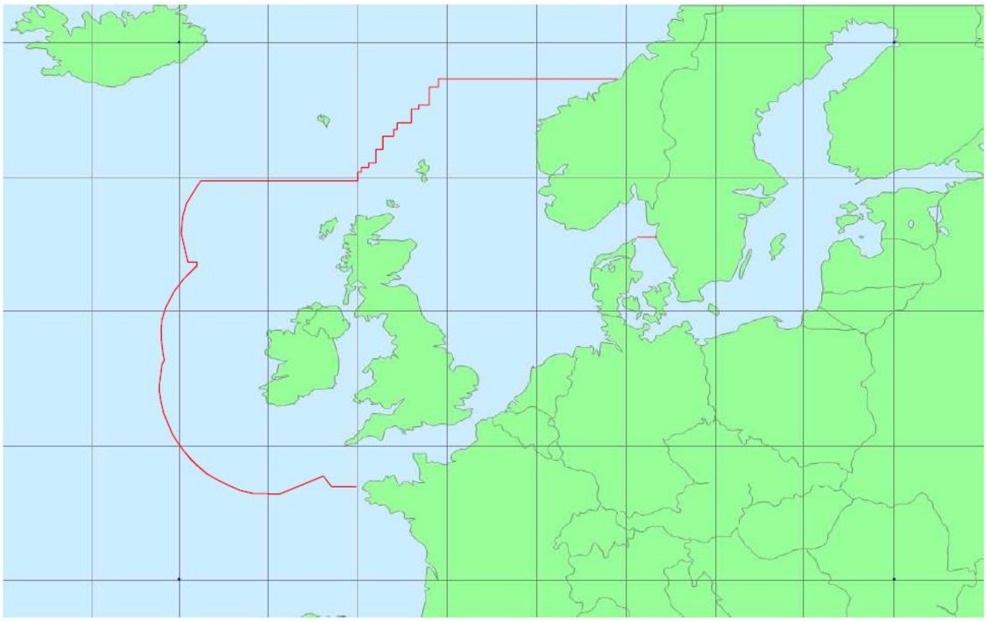


Figure 2-2 Project area for BE-AWARE

Inland waterways adjacent to the project area are not part of the scope. Inland waterways are understood as areas, which are only connected to the sea by a minor outlet (e.g. lagoons).

In the case of estuaries and fjords, the boundary of the project area is less obvious. The final project boundary will be defined by the project partners at a later stage, i.e. as soon as the first draft results of the risk analysis are available.

3. Ship traffic

The work outlined in this chapter corresponds to:	*Task H1.1*
Responsible consultant:	*COWI*

3.1 Introduction

Modelling the ship traffic in an appropriate way is one of the corner stones of the risk analysis. As in the earlier BRISK project covering the Baltic Sea (BRISK method, 2012), it is based on AIS ship traffic data. AIS (Automatic Identification System) consists of position messages broadcast by each single vessel, with information on identity, position, speed over ground, course over ground etc. AIS has been introduced as part of IMO's International Convention for Safety of Life at Sea (SOLAS) and is compulsory for all cargo vessels with a gross tonnage of 300 tons or more as well as all passenger vessels regardless of size. The intention is to increase the safety of vessels operating close to each other. In addition to this primary purpose, it is possible to collect AIS data by means of coast stations, which can be used to establish a comprehensive ship traffic database. The methodology described in this note requires the availability of such a database.

It is in the nature of such a database that it is very extensive and that its raw content cannot be applied directly in any ship accident risk model. This discrepancy is solved by generating a discrete route net covering the whole sea area and associating the individual AIS traces with the nearest net segments. The resulting route-based traffic description provides an unmatched basis for the following ship accident risk analysis.

The present chapter describes

- the applied/required data sources (Section 3.2)
- the AIS data analysis (including the generation of the discrete route net) and calibration (Section 3.3)

3.2 Ship traffic data

AIS data

The AIS data base operated by the Danish Maritime Authority (DMA) is the primary data source for establishing the traffic model. It records AIS messages of all AIS-equipped vessels in the Bonn Agreement area in six-minute intervals. Data are required for a 365-day period in order to eliminate seasonal differences and in order to provide statistically significant amount of data. A period lasting from 1 January to 31 December 2011 is chosen as reference period, since 2011 was the latest complete calendar year at the time the BE-AWARE project was initiated (early 2012).

IHS Fairplay data

The World Shipping Encyclopedia (WSE) issued by IHS Fairplay is a database containing information on a large number of parameters. Since every vessel has a unique IMO number, which is both used in WSE and for AIS, it is possible to determine relevant vessel characteristics for the vessels recorded in the AIS data base (type, size, geometry, single or double hull etc.).

The WSE has earlier been known as Lloyd's Register, i.e. prior to its purchase by IHS Fairplay.

3.3 AIS analysis

3.3.1 Basics

The AIS messages sent by the vessels consist of position reports (POS) and static reports (STAT), as described in Recommendation ITU-T M. 1371-1 issued by the International Telecommunication Union (ITU).

POS reports

POS reports are sent approx. every two seconds and contain information on vessel position, course, speed etc. In this reports, the ship is identified by its MMSI number.

STAT reports

STAT reports are sent every six minutes and contain information about the ship itself, amongst others MMSI and IMO number, name, call sign, size, actual draught, category of potentially hazardous cargo and position of the AIS transmitter relative to the ship.

Since the database records AIS messages at six minute intervals, it contains approximately an equal number of POS and STAT reports.

It has generally been observed that AIS reports, where vessels are supposed to enter data themselves are not always reliable. Information that needs to be updated by the crew (cargo, actual draught, destination etc.) are therefore not necessarily valid, whereas automatically updated information (position, course, speed) can be expected to be more reliable.

3.3.2 Compression

With a frequency of six minutes, the POS reports represent position data at a distance of 1-2 nautical miles (2-4 km) and additional compression is not advantageous. However, it is not necessary to keep a correspondingly large number of STAT reports. As a consequence, the data volume can be reduced by 50 %, considering that most STAT reports are redundant.

3.3.3 Compilation

Compiling the data for the further analysis means to link POS and STAT tables together, such that matching POS and STAT reports are identified. STAT reports contain information about the IMO number of a vessel (unique ID of the ship), which makes it possible to fetch further vessel characteristics from the World Shipping Encyclopedia (WSE). This data structure is illustrated in Figure 3-1.

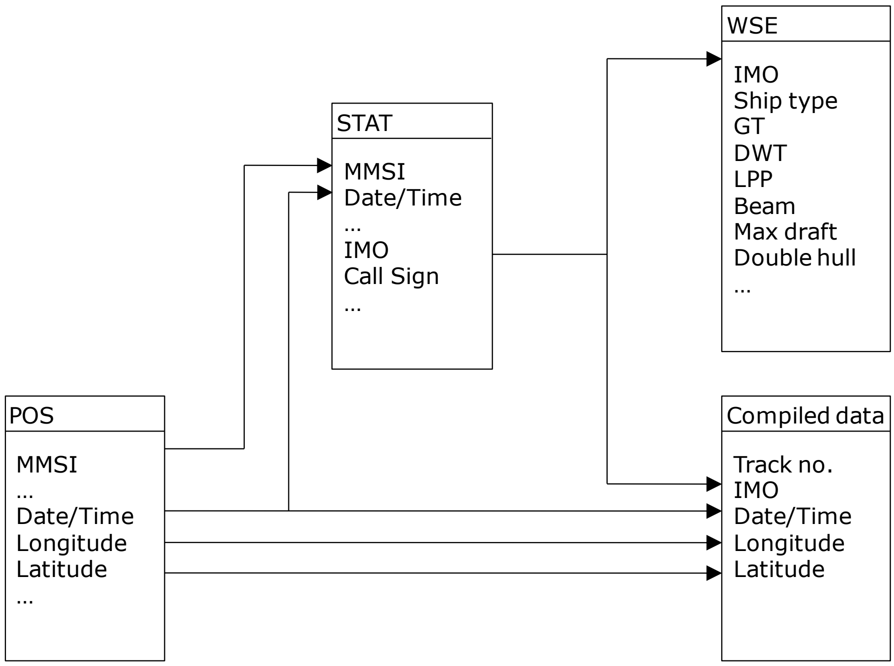


Figure 3-1 Data processing from raw AIS data (left) to the final basis of the analysis (right)

3.3.4 Traffic intensity

As a basis for the further analysis, it is necessary to determine the resulting traffic density for the entire Bonn Agreement area. This density should – apart from confirming a correct data processing – be suitable as decision basis for the generation of routes and the following data analysis (Section 3.3.5).

The density is determined by following the trace of a specific vessel – long, latt – and registering its path across a predefined quadratic grid. This approach is implemented by simply rounding the trace coordinates to the nearest multiples of the cell length (Δlong and Δlatt) in the grid net (see Figure 3-2).

Even if the trace should have more than one POS report within each cell, only cell passages are counted. In this way, it is avoided to attribute more weight to slow ships than to fast ships in the density calculation. Moreover, anchoring vessels and vessels in harbours are kept from distorting the density plot (the approach corresponds to that used in commercially available AIS data programme packages).

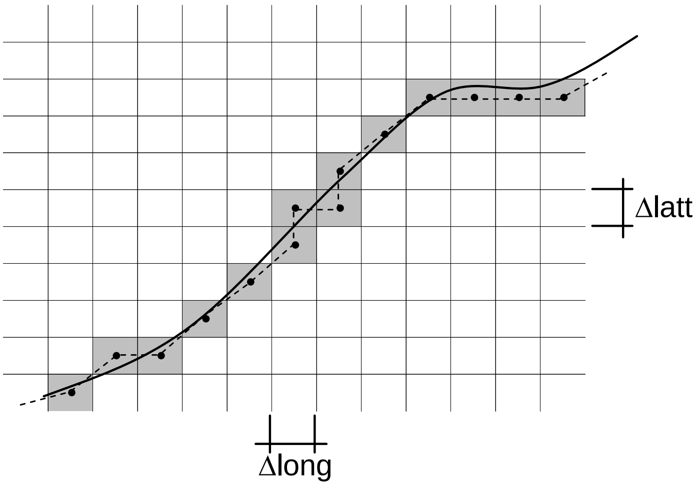


Figure 3-2 Digitalisation of a vessel track in order to determine the traffic density

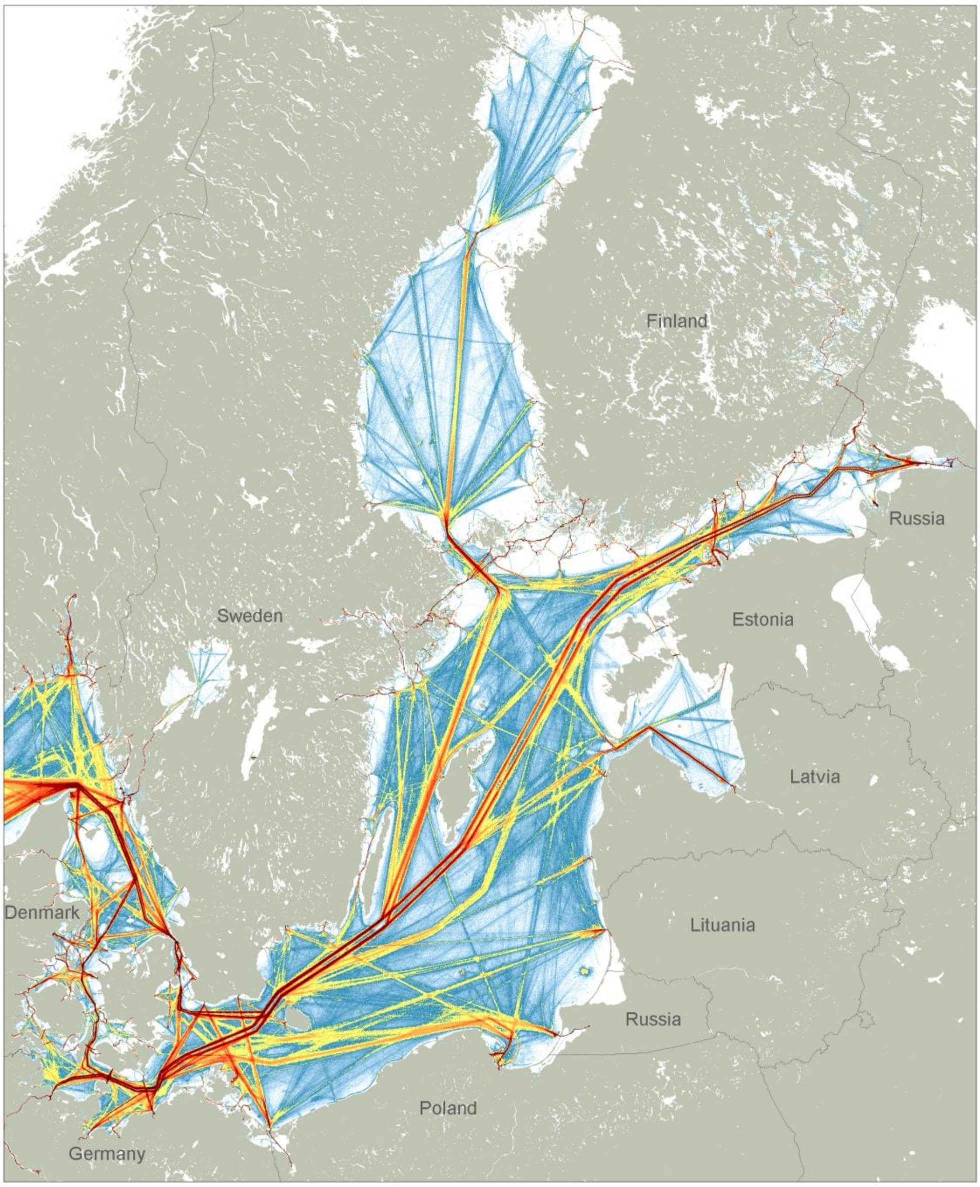


Figure 3-3 Example of a traffic density plot for the Baltic Sea based on the recorded traffic (BRISK traffic, 2012)

A simple density analysis of the recorded vessel passages yields a density plot as the one in Figure 3-3, where the traffic situation in the Baltic Sea is presented. The density was determined for a 500 metre grid.

3.3.5 Route generation and analysis

Ship traffic density tends to concentrate along more or less clearly defined routes. In the Baltic Sea example case in Figure 3-3, this tendency is especially evident, which partly is due to the narrow navigation channels and/or the presence of traffic separation schemes (TSS). However, the tendency of following clearly distinguishable routes is general, since vessels always follow the most direct possible route between two destinations and since the number of relevant destinations is limited. This tendency can be clearly seen in the right edge of Figure 3-3. On some routes traffic can be spread loosely to both sides of the route axis, but this does not cause any conceptual problems (compare ship collision model in Chapter 6.2.1).

Based on these considerations and considering the analysis-related advantages of a route-based traffic model, this modelling principle appears to be an obvious choice.

Route generation and analysis means:

- to define a geographic route net, which can represent the vessel movements in the Bonn Agreement area with good precision
- to analyse the route net mathematically, i.e. to determine the shortest possible paths through the net between two locations
- to map the AIS trace, i.e. to associate each AIS point with a route net segment.
- to determine various relevant statistics for each route segment, e.g. the distribution of the vessels' deviation from the route segment axis.

Definition of the route net

This work is done by manually creating a route net on a background map consisting of a density plot and a sea chart. This work is performed in a GIS programme (MapInfo). Once the route net has been defined, its geometry is exported to Excel (combined with Visual Basic for Applications) for further analysis and in order to check its consistency (all route ends meeting in one node shall have the same coordinates).

Figure 3-4 shows the route net that was used for BRISK (BRISK traffic, 2012). In general, a route net consists of two types of elements:

- nodes (defined by their longitude and latitude)
- route segments connecting the nodes

Analysis of the route net

The route net defines different possible ways through the sea area and the concept of "the shortest way" between two nodes in the route net is a useful support function for associating the AIS points to route segments.

The shortest way between two nodes is determined by means of a simple iterative algorithm. The results are deposited in two separate matrices. One of them contains the shortest way from node *i* to node *j*. The other contains the length of the shortest way from node *i* to node *j*.

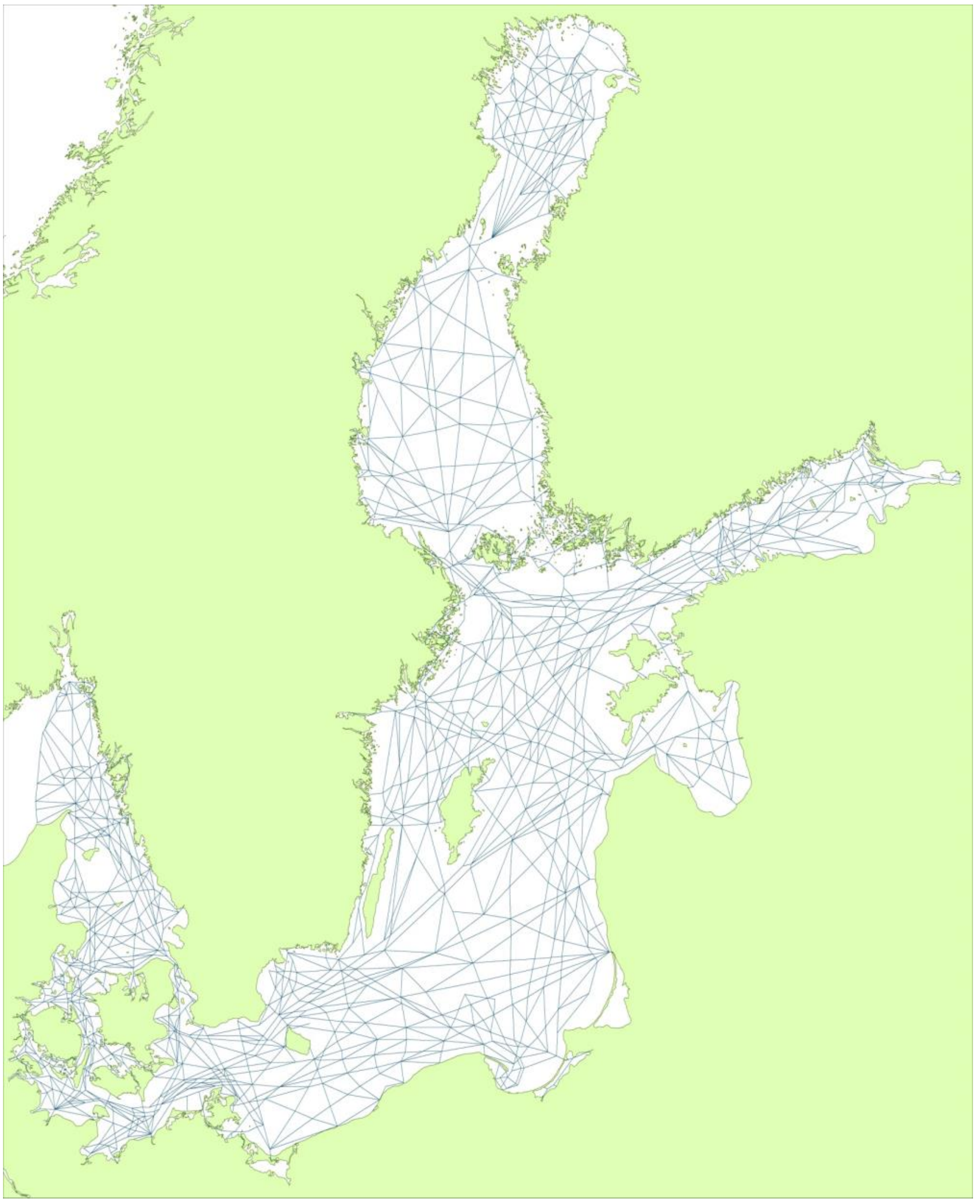


Figure 3-4 The route net used for BRISK (BRISK traffic, 2012)

Systematic mapping of the AIS traces

With the above-described basis it is possible to map the individual AIS traces systematically. As a first step, it needs to be defined, when a trace – i.e. a sequence of AIS points – can be concluded to represent a coherent journey. This definition needs to take the possibility of data transmission interruptions into account (see Figure 3-5). It would simplify the mapping procedure significantly to neglect missing sequences. However, this would result in a systematic underestimation of the traffic in certain area, if e.g. one local coast station has been out of order during a certain period of time. Furthermore, information about the total journey and its origin and destination would get lost.

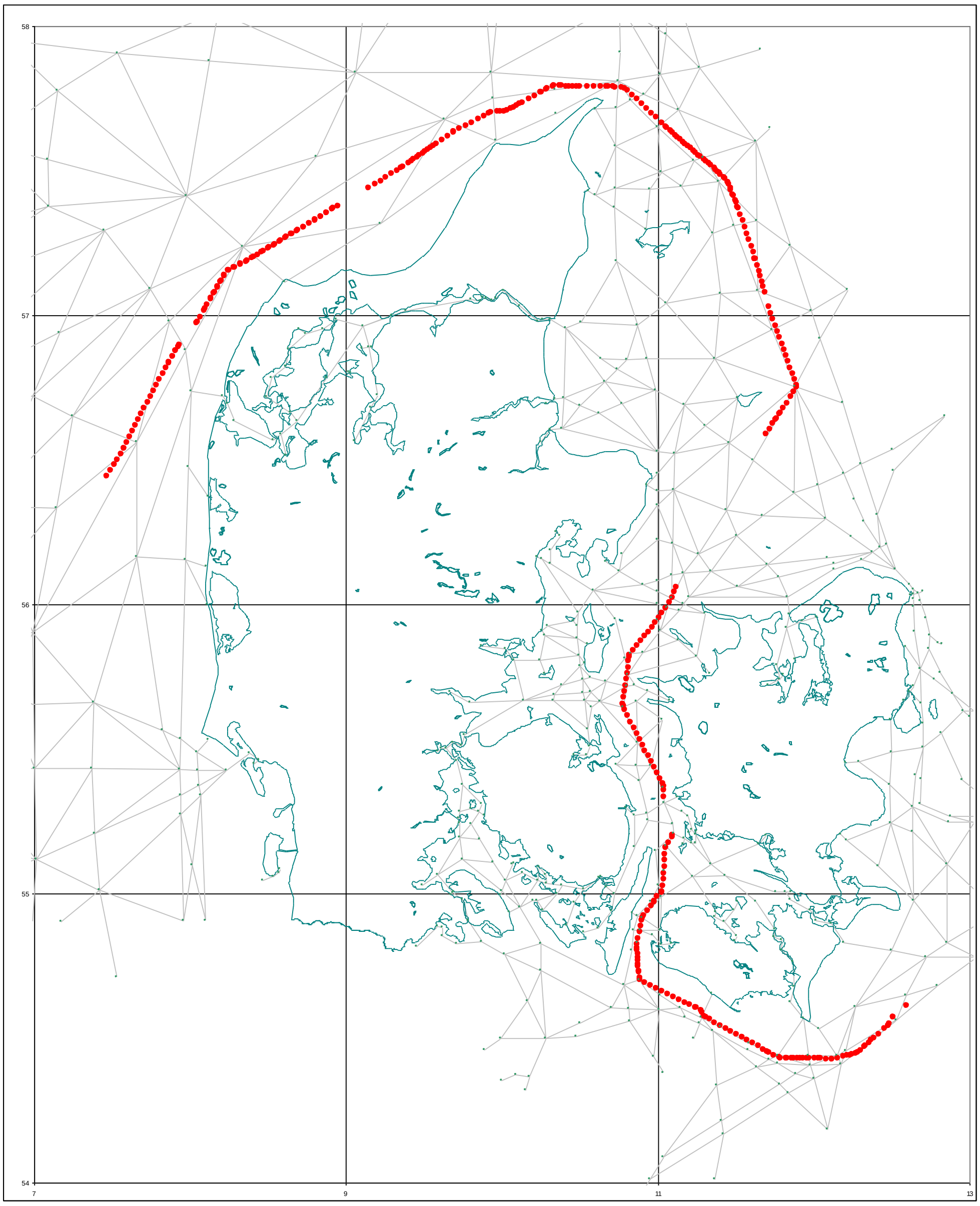


Figure 3-5 Example of AIS points of an identified trace with pronounced transmission interruptions

Therefore, the mapping procedure is refined in order to handle interrupted traces and to interpolate the missing sections. When an individual trace is identified, the following conditions are applied:

- The time difference between two successive AIS points must not exceed 4 hours
- An approximate vessel speed v_{appr} is calculated as the distance between two points divided by the time difference between the two messages. The two points are considered as part of the same trace if
  - $v_{appr} > 0$ knots (the ship does not stand still)
  - v_{appr} is finite (i.e. not very large, which would indicate an unrealistic jump and therefore an error)
  - $v_{appr} > 0.6 \times v_{avg}$, where v_{avg} is the average speed that has been observed earlier on the trace

With these conditions, the most significant errors are filtered away and the trace is not interrupted, if the vessel stops. The latter is chosen in order to obtain two separate traces in case a vessel is lying at a port.

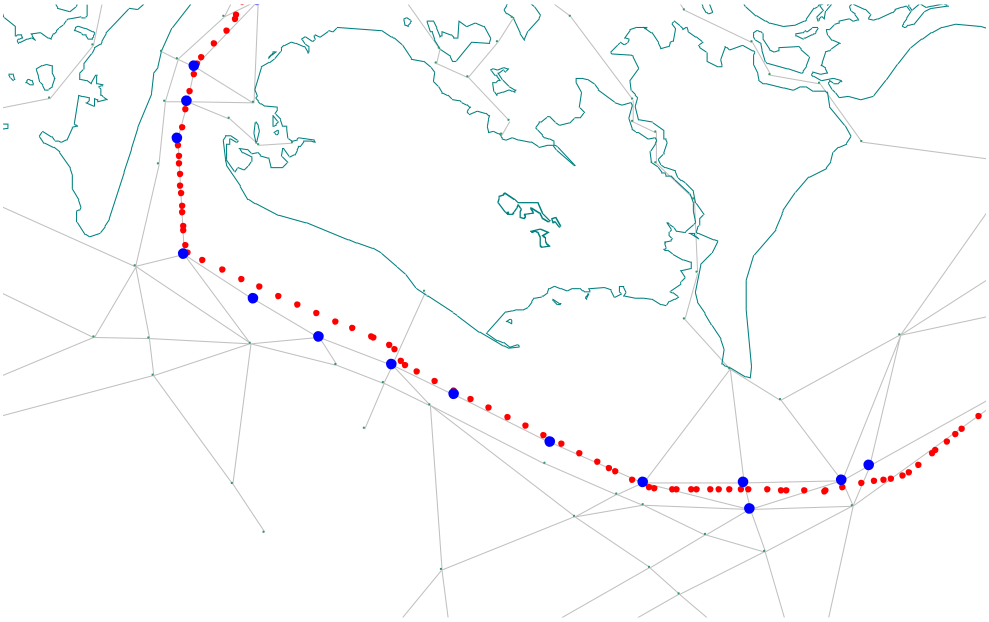


Figure 3-6 Determination of which nodes in the route net are close to the AIS trace

When a sequence of AIS points has been recognised as a continuous trace (as shown in Figure 3-5), an algorithm regards the point sequence and it is determines, which nodes are passed at the closest distance (see Figure 3-6).

Once the sequence of nodes in the route net has been determined, another algorithm removes unrealistic outcomes caused by the mathematical logics in the first algorithm (see Figure 3-7). Another typical misinterpretation are vessels that seem two sail into a “dead end”, i.e. by following a route segment first in one direction and then into the opposite direction before continuing. This error is equally removed.

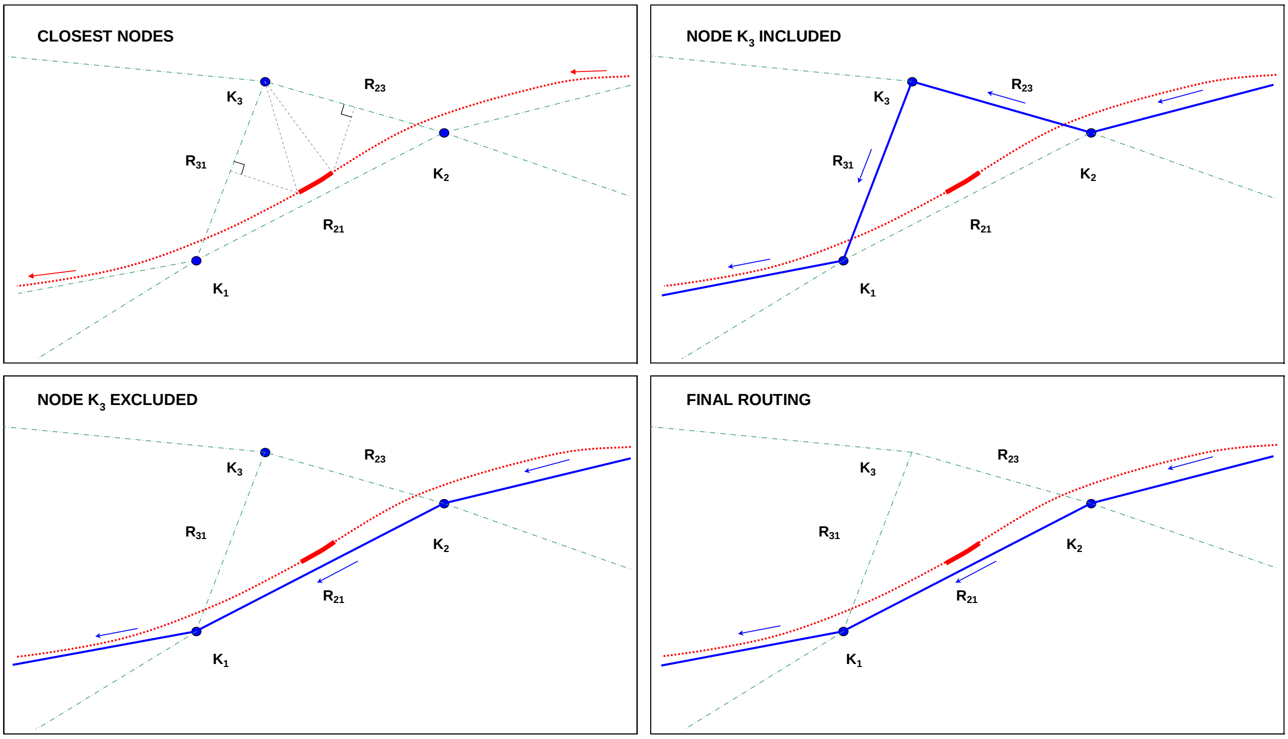


Figure 3-7 An example showing how the closest node (K_3) can mislead the mapping algorithm

Statistics During the route mapping procedure it is determined, which AIS points can be associated with which route segment passages. This information is subsequently used for determining the mean value and spreading of the average geometrical distance between the points and the ideal line in the route net. These statistics are required for the calculation of the collision frequency of vessels sailing along the same route segment (compare Section 7.3.2).

The obtained mean value and spreading estimates from a section of the Kattegat are illustrated in Figure 3-8 together with a plot of the traffic density. It can be seen that there is a good consistence between the mean value/spreading estimates and the shape of the routes in the density plot. One essential observation is that the statistics describe the traffic correctly even there, where a (manually defined) route segment does is not match the route in the density plot precisely. This shows that the traffic model is not overly sensitive with respect to the precise definition of the route segments.

It can equally be seen that heavily frequented routes tend to use very narrow corridors with very little spreading. Conversely, routes with very low traffic density and very weakly distinguished traffic corridors are characterised by a large spreading.

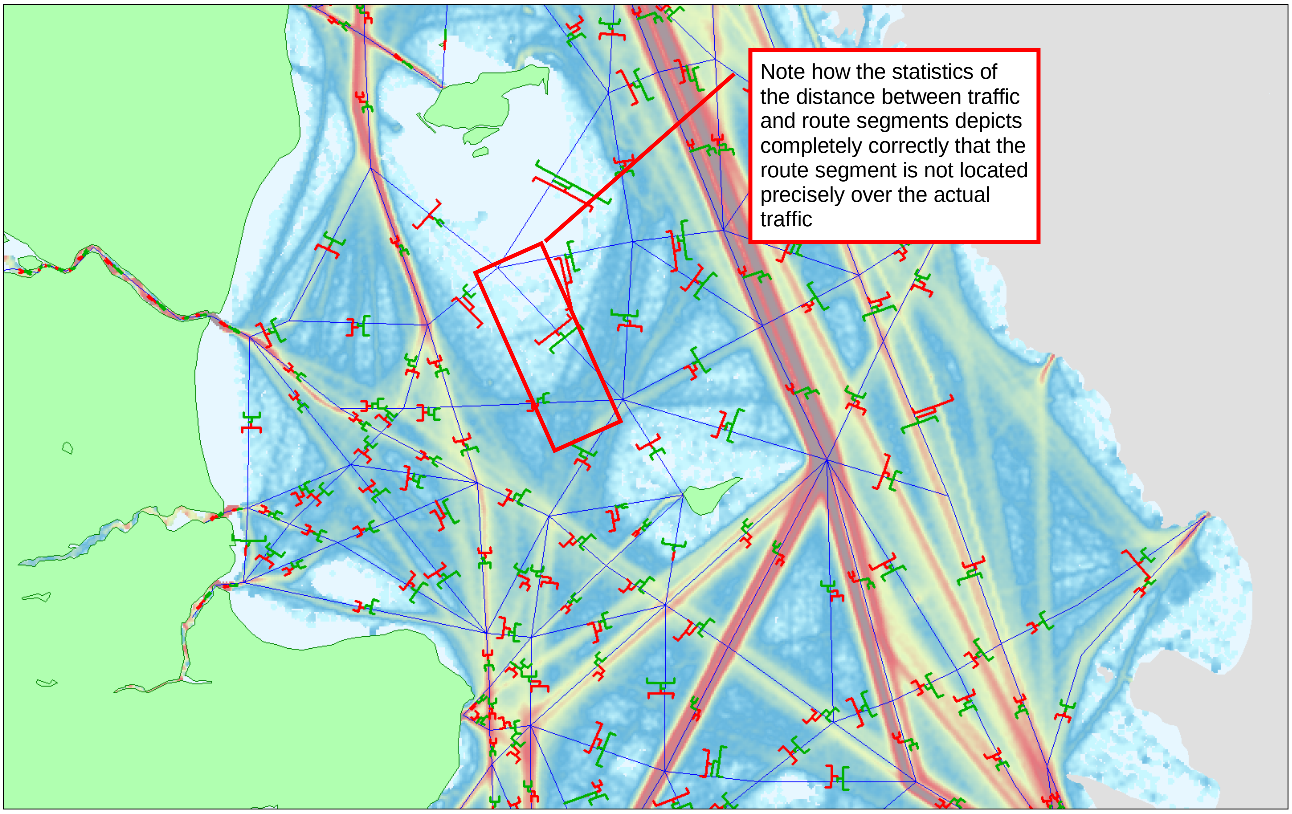


Figure 3-8 Graphic illustration of the mean value and spreading of the distance between vessels and route segment axes. For each route segment and each direction (red/green), an interval covering the average and ± ½ the spreading is shown (COWI, 2007)

3.3.6 Calibration

The relatively complex analytical procedure will inevitably lead to loss of traffic information. The reasons for this can amongst others be:

- periods, during which AIS point data (POS reports) are missing or incomplete
- vessels that do not send correct AIS information (STAT reports) and that cannot be identified therefore
- rejection of AIS points that do not yield qualified traces and cannot be mapped
- rejection during route analysis, because it is not possible to account for all data errors or for traces that are very inconsistent with the route net.

The traffic that has been mapped on the route net will give sensible traffic patterns and distributions, whereas the absolute numbers – e.g. the yearly traffic volume on specific routes – will underestimate the actual situation. Since it can be expected that the error sources affect the entire traffic picture in the same way – both with respect to geography and ship types – these lost data can be compensated by resizing the entire mapped traffic volume up accordingly.

AIS outages

In order to identify AIS outages, the number of POS reports per day is plotted as a function. In this way, outages become evident very quickly and can be compensated by means of a calibration factor f1.

For the current project, the factor needs to be determined anew. It can be a good idea to plot a separate POS function for each major geographic area. In this way it can be avoided to dilute local outages beyond recognisability.

Route definition and analysis

The reduction of the mapped AIS reports – and therefore of the traffic volume – that follows from the elimination of traffic data where

- the vessel cannot be identified or
- it is not possible to define a qualified trace or
- the route analysis cannot be performed, because the AIS data and the route net are not sufficiently compatible

is examined by comparing the traffic volume with passage statistics based directly on raw AIS data. These passage statistics are obtained by counting how many observations can be made, where two successive AIS points from one vessel are located each on one side of a virtual passage line.

The total calibration factor for both effects is obtained as

$$F = f_1 \times f_2$$

It is introduced separately for each single route passage (i.e. each single vessel movement on a route):

IMO	TrackNo	Time	RuteSegment	F
…	…	…	…	…
9274616	186144	12/16/05 10:01	-88	1,195
9274616	186144	12/16/05 10:07	-87	1,195
9274616	186144	12/16/05 10:24	61	1,195
9274616	186144	12/16/05 10:55	1079	1,195
9274616	186144	12/16/05 11:13	1080	1,195
9274616	186144	12/16/05 11:32	27	1,195
…	…	…	…	…

This approach has the advantage that other factors, such as prognoses of the future traffic development can easily be implemented (compare Section 6).

In order to verify the calibration, the corrected traffic volume can be compared to the records of a VTS centre or a specific port. In (COWI, 2007), this was done with data from VTS Great Belt. The difference between the corrected traffic volume and the VTS observations amounted to only 1.5 % for vessels above 1,000 DWT which shows that the applied calibration is sufficiently effective. For vessels below 1,000 DWT, the divergence was greater (note that cargo vessels under 300 DWT are not required to carry an AIS device at all).

3.3.7 The resulting traffic model

The resulting traffic model is essentially described as a database table containing all identified route passages (events, where a vessel passes a route segment) combined with information about passage direction and vessel characteristics from the World Shipping Encyclopedia (WSE) and a corresponding table containing the calibration factor F. Using this detailed model has the following advantages:

- traffic surveys can be performed very flexibly based on the detailed ship characteristics from the WSE
- the actual journeys of the respective vessels are contained in the description, since sequences of route passages are tied together by a common track number and the date information

- conditional traffic patterns – e.g. an overview of the routes used by ships travelling between the North and the Baltic Sea (via the Skagerrak or via the Kiel Canal) – are relatively easy to provide
- the passage of the vessels through the respective nodes in the route net – i.e. on which route segment does a vessel arrive at a node and on which route segment does it continue – are contained in the description and can be used in the ship collision model

The database provides traffic data for the calculation of accident and spill frequencies, which are directly dependent upon the traffic, its volume and composition.

In order to display the content of the traffic model, different tables can be extracted – the aggregated transport activity (sailed nautical miles) and the distribution of the traffic on specific routes to different ship types and sizes.

Classification of ships

The information on the identified vessels that can be found in the World Shipping Encyclopedia is more detailed than what is meaningful in the context of the risk analysis. This broad classification is reduced to 24 different types as shown in

Table 3-1. Type 25 “unknown” is not used in the final traffic model, but is used in order to classify the remaining group that cannot be indentified during the model establishment.

The ship groups introduced in

Table 3-2 are used for preparing statistics and results.

Table 3-1 Ship types used in the model

Type ID	Type description
1	Work vessel
2	Car transport
3	Bulk
4	Bulk/Oil
5	Container
6	Fishing vessel
7	Ferry
8	Ferry/Ro-Ro
9	Cruise ship
10	Reefer
11	Nuclear fuel
12	Offshore
13	Ro-Ro
14	Tug
15	General cargo
16	Navy
17	Tanker, food
18	Tanker, gas
19	Tanker, chemical/products
20	Tanker, chemical
21	Tanker, product
22	Tanker, crude oil
23	Tanker, others
24	Others
25	Unknown

Table 3-2 General groups of types used for preparing statistics and results

Vessel group	Type description
Tankers	Bulk/oil
	Tanker, food
	Tanker, gas
	Tanker, chemical/prod.
	Tanker, chemical
	Tanker, product
	Tanker, crude oil
	Tanker, others
Bulk carriers	Bulk
General cargo	General cargo
Packed cargo	Car transport
	Container
	Reefer
	Nuclear fuel
	Offshore
	Ro-Ro
Ferry and passenger traffic	Ferry
	Ferry/Ro-Ro
	Cruise ship
Others	Work vessel
	Fishing vessel
	Tug
	Navy
	Others
	Unknown

3.4 Geographical sub-divisions

The Bonn Agreement area is divided into sub-areas that are defined in order to provide sea areas that are relatively homogeneous conditions, e.g. with regards to hydrography, ship traffic intensity, and environment. If a strait with dense traffic is located between two open sea areas, the situation could be represented by three areas. When establishing the sub-areas, both, all mapping and analysis refer hereto, e.g. sea charts and AIS ship traffic density plots.

4. Classification of oil

The work outlined in this chapter does not correspond to any of the BE-AWARE project tasks, but serves as a basis for task E3 (Chapter 5).

4.1 Definition of oils

The definitions of "oils" given below are used throughout the study.

4.1.1 Oils

An oil is defined as:

- Any form of mineral oil or mixtures of oil including crude oil, condensates from natural gas, oil sludge and oil waste as well as fuel oil and other refined products, except petro chemicals which are defined as HNS. This definition is in accordance with the definition of oil in MARPOL Annex I (IMO, 1987a), in which it is said that petro chemicals come under MARPOL Annex II (IMO, 1987b). An amendment to MARPOL Annex II entered into force 1 January 2007. Changes are in the number system and in the requirement that vegetable oil is to be carried in chemical tankers.
- Any form of animal or vegetable oil.

4.2 Oil compounds selected for modelling

4.2.1 Oil cargos

Modelling of tank vessels is done combining goods transport information from and the IHS Fairplay WSE. IMO number, type and size of ship are attributed to the goods transport registrations. Routes of transportation are then obtained by combining this information with the AIS-based traffic database.

The information retrieved comprises:

- Type of cargo
- For each type of cargo the number of tank vessels and the typical size of cargo in tonnes

The cargo is grouped into the representative types indicated in the table below. Information is an example valid for Danish waters only.

Table 4-1 Cargo types for tank vessels

Group	Fraction of tank vessels	Typical size of cargo
Crude oil including condensate	25-35% in the Great Belt	90,000 t
Fuel oil including bunker fuel	25-30% in the Great Belt and 15% in The Sound	50,000 t
Diesel, jet fuel and heating oil	25-30% in the Great Belt and 40% in The Sound	30,000 t
Petrol and naphtha	10% of the Great Belt	30,000 t
LPG and propane	25-30% in The Sound	-

Oil products	5% in the Great Belt	-
Vegetable oil	2%	-

4.2.2 Oil carried for the use of the ship

Oil for the use of propulsion is stored in the ship's fuel tanks. The capacity of these tanks is typically in the range of between 2,000-10,000 t. For container vessels the tanks may be as large as 15,000 tons. The tanks constitute a potential source of oil pollution.

Fuel is available in a number of grades with a rather large difference in price. Typically larger ships would use heavy (residual) oil which is less costly than refined products (diesel), used by smaller ships. The following distribution on fuel types was used (O.W. Bunker, 2006):

- IFO 380: 75%
- IFO 180: 10%
- Refined products: 15%

4.2.3 Modelling of oil

Based on the information about the amounts transported and the physical behaviour in case of a spill to the sea the following substances are selected to be modelled representing oil:

- Crude oil and fuel oil (always considered to be liquid)
- Diesel
- Petrol
- IFO 380 (and a probability of sub surface floating).

IFO 380 is representing both IFO 180 and IFO 380. The probability of sub surface floating is set considering this.

5. Oil transport model

The work outlined in this chapter corresponds to: *Task E3*

Responsible consultant: *MARIN*

5.1 General framework

Information about the vessel cargo are of vital importance for predicting, which substances can be released into the maritime environment in case of an accident at sea. Traffic information contained in the recorded AIS data (STAT messages) can comprise information about the classification of the cargo of a vessel, but the data are not sufficiently detailed and reliable in order to be applied in the risk analysis. Thus, the vessel cargo needs to be investigated in more detail based on other databases, such as port data.

Only substances and cargo types that are supposed to have a significant impact upon the environment are included in the model. The choice of these substances is described in Chapter 4, where a number of cargo groups are defined in order to represent the cargo aboard bulk carrying vessels. The cargo groups are identified by a number and a representative substance, see Table 5-1.

Type 0 (bunker oil incl. lubricants) is not a cargo type but represents the oil products used for propulsion and maintenance on all vessels. This means that this type of substance can be released from any vessel in case of an accident at sea. Categorising these substances alongside with those substances that can be transported as actual cargo leads to an advantageous data structure with regard to the further spill analysis process.

Table 5-1 List of substances used in the modelling of vessel cargo and bunker oil

Type	Representative substance
0	Bunker oil, lubricants
19	Crude oil
20	Fuel oil
21	Gasoil, diesel, petroleum, jet fuel and light fuel oil
22	Gasoline

The developed method for tying cargo types to the ship traffic describes the probability of encountering a given cargo type depending on:

- the route (defined as the connection between two terminal points, i.e. ports or platforms)
- the ship type and size

Based on the distribution of cargo and on ship traffic information the total transported amount of the respective compounds is estimated. Results are validated against information on the total amounts transported.

5.2 Specific approach

5.2.1 Objective

The proposed methodology is in line with earlier research that has been performed by MARIN in order to analyse the flows of oil transport on the North Sea. This method is mainly based on two main assumptions:

1. The probability on an oil spill at a certain location, given an accident with a tanker, is a function of:
   - The probability of damage to a cargo tank of an oil tanker at that location;
   - The probability that the oil tanker is loaded with oil.
2. The size of the oil spill is related to the amount of oil that is carried by the damaged ship

This means that, in order to calculate the probability of an oil spill of a certain spill size, it is necessary to know, apart from the probability that a tanker gets damaged, two properties:

- The probability that a tanker of a certain type and size at that location is loaded with oil
- The expected amount of cargo oil that is on board, in case the tanker is loaded

To determine these two properties is the objective of Task E3. COWI's work with Task H1.3 will result in the probability of damage at a certain location (see Chapter 6.2.1).

The data for HNS will also be gathered and processed by MARIN, but as this is not part of the deliverable to COWI, the method for HNS is not part of this method note.

5.2.2 Scope

Transport routes

The two properties that need to be derived vary for different locations. Therefore they will be derived for different typical transport routes (in both directions) as well as for ships which cannot be attributed to any of these typical routes.

Two types of transport routes can be distinguished:

- Oil transports to and from ports in the Bonn Agreement area
- Oil transports between other ports outside the Bonn Agreement area; thus only transit in the Bonn Agreement area

In order to evaluate the characteristics of oil transports on both of these two types of routes, the traffic network that will be obtained during Task H1.1 by AIS analysis will be used.

The two properties will be derived for different oil classes.

Oil types

Four groups will be distinguished (based on Section 5.1): Crude oil, fuel oil, diesel and petrol. The different substances will be attributed to these four groups either by the name or UN number of the substance.

5.2.3 Methodology

General

The following steps can be distinguished:

1. Research the transport routes in the Bonn Agreement area
   - Transport to/from/between destinations in the Bonn Agreement area;
   - Oil transports that only transit the Bonn Agreement area but do not call at a destination in this area.

   → Definition of the main transport routes in the area.

2. Data analysis for each of the transport routes, determine:
   - The probability that an oil tanker at that location is loaded with oil;
   - The expected amount and type of cargo oil that is on board, in case the tanker is loaded.

3. Extrapolation of derived properties towards ship traffic outside the main transport routes.

Research on oil transport routes

To/from ports in the Bonn Agreement area

Each ship that carries dangerous goods, such as oil, has to report these goods when it enters or leaves a port region at the port authorities. These *dangerous goods reports* contain the identity of the vessel, the UN code, description and quantity of the dangerous cargo as well as the previous and next port of call. Therefore, these reports are a reliable data source when it comes to establishing the transports to and from the ports within the Bonn Agreement area.

It is not required to collect data from all the ports in the area, as few ports account for the majority of the oil transports in the area. The results from these main ports are considered to be representative for all ports in the area, i.e. with respect to estimating the load state and cargo type on board the individual vessels. Based on the total GT of oil tankers that called at ports in the Bonn Agreement area in 2008, a list was made of the ports that together account for 70 % of the oil tankers' GT in this year. The list is displayed below in Table 5-2.

Table 5-2 Representative oil ports in the Bonn Agreement area

Port	Country
Antwerp	Belgium
Le Havre	France
Wilhelmshaven	Germany
Cork	Ireland
Rotterdam	The Netherlands
Mongstad	Norway
Sture	Norway
Gothenburg	Sweden
Falmouth	United Kingdom
Fawley	United Kingdom
Hound Point	United Kingdom

Port	Country
Immingham	United Kingdom
Milford Haven	United Kingdom
Tees	United Kingdom

As it is also regarded relevant to also include data from Ireland, which has no major oil port, the port of Cork was added to this list.

As far as available, also reports are obtained from the major oil platforms in the Bonn Agreement area.

Each of the shipments needs to be linked to the traffic database from Task H1.1 such that a total overview of all transports to and from the Bonn Agreement area can be generated. The traffic database is a set of voyages that is extracted from AIS over the year 2011, as provided by COWI. For each voyage the following is available:

- Ship identity
- Start and end location: a port, platform or the border of the Bonn Agreement area (or the border of AIS coverage)
- The start and end date and time of the voyage

With this data available, it can be analyzed where cargo was transported from and to. By also analyzing import/export statistics from the ports and oil platforms in the area, an overview can be created of the main oil transport routes within the Bonn Agreement area.

Transiting transports
The traffic database from Task H1.1 will also contain all voyages that only transited the area. Using these results, all movements of oil tankers on such a route can be obtained. Using this overview in combination with literature on oil transport, the most relevant transit routes can be evaluated. These routes will be grouped in different categories. A first suggestion for the grouping of routes is:

- USA ↔ Baltic
- Northern Russia/ Norway ↔ Mediterranean/ Africa/ Asia
- Baltic ↔ Mediterranean/ Africa/ Asia

The main transit routes will be selected based on the highest number of ship movements that is determined for each of the routes.

It is underlined that these are only the most important routes and that not all shipping movements will be included in the remainder of the analysis. The reason is that there is not sufficient information available to research this type of traffic in more detail. Again, the concept is that the main routes are representative for the overall situation, i.e. with respect to estimating the load state and cargo type on board the individual vessels.

Data analysis per transport route

The preceding steps have resulted in an overview of the main oil transport routes. This is presented in an overview of the oil transports to and from the major oil ports and platforms in the area. Furthermore, the main oil transport routes that only pass the area have been derived. The following steps, will determine for each of the main oil transportation routes, the probability that an oil tanker is loaded and the expected amount and type of oil on board.

To/from ports in the Bonn Agreement area

For all the ports listed on the previous page, the number of ship calls is known from the traffic database from Task H1.1 and the type and amount of oil carried by those ships is known from the dangerous goods reports. This information can directly be linked to the traffic database from Task H1.1.

For each main oil transportation route, the probability that a ship carried oil will be determined per ship type and size class. The average and maximum amount of cargo that was carried by each of those ships will also be determined. These factors can be applied for the future traffic prognosis, for the transiting routes and for ships outside the main routes. This will be described in the following sections.

The following categorization of ship size classes, based on Gross Tonnage (GT), is standard applied by MARIN:

Table 5-3 Size classes

Size class	GT
1	100-1,000
2	1,000-1,600
3	1,600-5,000
4	5,000-10,000
5	10,000-30,000
6	30,000-60,000
7	60,000-100,000
8	>100,000

With regard to the ship types, the same division is used as in the BRISK project:

Table 5-4 Ship types

Tanker type	Ship type Lloyds
Bulk/Oil Carrier	Bulk/Oil Carrier
	Ore/Oil Carrier
Chem./Product Tanker	Chemical/Oil Products Tanker
Chemical Tanker	Chemical Tanker
	Molasses Tanker
	Alcohol Tanker
	Caprolactam Tanker
	Inland Waterways Chemical Tanker
Crude Oil Tanker	Crude Oil Tanker
	Bitumen Tanker
	Coal/Oil Mixture Tanker
	FPSO (Floating, Production, Storage, Offloading)
	FSO (Floating, Storage, Offloading)
Product Tanker	Oil Products Tanker
	Bunkering Tanker
	Inland Waterways Oil Tanker
Tanker, others	Latex Tanker
	Inland Waterways Other Liquids Tanker

Transiting transports

For the main oil routes that only transit the Bonn Agreement Area, there is no information available from the ports concerning the amount and types of cargo. Therefore, for these routes the numbers need to be derived in an alternative way. This will be done by extrapolation of the results for the transport routes as described in the previous section.

First of all, the number of oil tankers that sailed along each route is known from the traffic database from Task H1.1. Literature research possibly can give an indication of the amounts of oil that are trans-shipped along each route. This gives some indication about the average volumes carried by ships.

Furthermore, the typical transit routes will be compared to the typical routes with a destination in the Bonn Agreement area, with regard to ship types and sizes and typical import/export characteristics. The objective is to find routes that are similar with respect to the ship traffic and types of cargo. For instance, it is likely that ship traffic of oil tankers between the USA and north-west Europe (for which the characteristics are known), is similar to the ship traffic of oil tankers between the USA and the Baltic area. As it is fair to assume that all routes either start or end in Europe, considering the positioning of the Bonn Agreement area, it is regarded feasible to find comparable routes. The analysis will be backed by literature reviews for as far as available.

Based on the comparison of routes, it will be decided which route within the Bonn Agreement area is the most representative for each of the transiting routes. From these routes the probability that a tanker of a specific type and size carries oil as well as the expected amount of oil will be copied from that route.

It should be realized that the outcome of the analysis is not an exact description of the amount of oil that is transported along each route, but an estimation of the probability that a tanker is loaded and the expected amount and type of cargo oil that is on board given that a tanker is loaded.

Ship traffic outside the main transport routes

A small portion of the total traffic of oil tankers cannot be attributed to the main transport routes. For these cases an estimation has to be made of the probability that they are loaded and the expected amount of oil that is on board, based on the results for the oil tankers on the main transport routes. Depending on the results for the main routes, some kind of weighted average will be used for these ships.

5.2.4 Used data

For this analysis the following data sources are used:

- Dangerous goods reports identified ports 2011
- Import/export data 2011 of ports and oil platforms in the area
- The traffic database as extracted from AIS 2011 by COWI during Task H1.1

5.2.5 Deliverables

The deliverables will consist of two parts:

- For each of the main transiting routes (including the direction) the probability that a tanker of a specific type and size carries oil and also the expected quantity, for each class of oil.
- The same properties for tankers that could not be attributed to a main route.

The main routes cover both the main routes to/from ports in the Bonn Agreement area and the main transiting routes. Both parts of the deliverables will be brought together into one single database.

6. Traffic prognosis

The work outlined in this chapter corresponds to: *Task E4*

Responsible consultant: *MARIN*

In addition to analysing the present traffic situation, the future development needs to be taken into account in order to provide a sound basis for sustainable decision-making.

Therefore, the situation in 2020 is modelled as a scenario in addition to the present-day scenario. This requires a realistic prognosis of the traffic development in the mean time.

6.1 General framework

6.1.1 Definition of ship types

The ship types described in

Table 3-1 need to be reflected in the prognosis. However, the available prognoses envisage transport volumes within certain market segments rather than for certain ship types. Therefore, the 25 ship types are attributed to 13 marked segments, as shown in Table 6-1.

Table 6-1 Division of ships into market segments for the analysis

Main group for prognosis	Market segment	Vessel type (as in Table 3-1)
Cargo transport	Cars	Car transport
	Containers	Container
	Ro-Ro	Ro-Ro
	Bulk cargo	Bulk
	Liquefied natural gas (LNG)	Gas tanker
	Chemicals	Chemical tanker, other tanker
	Oil transport	Chemical/product tanker, product tanker, crude oil tanker, bulk/oil
	General cargo	General cargo
	Food tanker	Food tanker
	Reefer	Reefer
	Others	Offshore, work vessel, fishing vessel, tug, navy, nuclear fuel, others, unknown
Passenger transport	Route passenger transport	Ferry, ferry/Ro-Ro
	Cruise	Cruise ship

6.1.2 General approach

When goods and passenger transport volumes at sea are rising, this does not necessarily imply that the number of ship movements is increasing. In fact, it can be observed that the number of ships tend to remain somewhat constant, whereas the average ship size is steadily increasing (BRISK traffic, 2012). Therefore, both the volume of transported goods and passengers *and* the fleet development need to be taken into account.

Fleet development

In a first step, the development of the global fleet is analysed. In (BRISK traffic, 2012), the development of the average ship size during 1995-2000 and during 2000-2005 was regarded for each vessel type based on Clarkson Register and WSE. The same reference period is used for the present project.

Next, the global development is transferred to the regional situation in the Bonn Agreement area. This work step consists of the following consecutive tasks:

- Definition of a few main inter-regional traffic streams

- Analysis of size restrictions on each of these traffic streams (draught and length restriction at the entrances to the Bonn Agreement area, port characteristics etc.)
- Estimation of the future development of average ship sizes based on global trends in the past, local restrictions (draught etc.) and expert judgement

Cargo transport

The prognosis of future cargo transport is modelled in eight steps:

1. The basic import and export data for 2008 and 2011 are obtained (the data situation is investigated during work step C, Regional resource database). Data are provided for 20 different types of cargo.
2. A prognosis of the development up to 2020 is obtained (the data situation is investigated during work step C, Regional resource database). Data are provided for 20 different types of cargo.
3. The 20 cargo types are attributed to three main cargo groups (dry bulk/liquid bulk/other)
4. Based on step 1 to 3 the annual growth of transported tonnage is estimated for each main cargo group
5. In addition to the analysis in step 4, there is the possibility of performing supplementary analyses for the most important shipping segments
6. The main cargo groups are attributed to the vessel types in

7. Table 3-1
8. The corresponding increase in ship movements is corrected by the effect of growing average ship sizes (see Fleet development above). Furthermore, the prognosis is corrected for imbalances between import and export: If import is larger than export for a given product at a given port, additional export will not lead to additional ship movements. Instead, the partly-loaded outbound ships will have a higher loading percentage.
9. The prognosis is performed based on the information in step 1 to 7.

Passenger transport

Based on available ShipPax reports, the present situation is obtained. Future development is performed for each major ferry and Ro-Ro route separately, based on historical trends as well as on considerations about future changes in the infrastructure.

In the case of cruise traffic, separate estimates are performed based on observed annual growth rates both on a global and a Bonn Agreement area level.

6.1.3 Implementation in the model

In the model, the expected future traffic increase is implemented by modifying the factor *F* that has been introduced in Section 3.3.6.

6.2 Specific approach

6.2.1 Objective

The objective of Task E4 is to make a prognosis for the shipping traffic in 2020, based on the expected fleet and cargo transport developments. The prognosis will be based on the available literature and the prognoses of ports and countries on cargo transport and ship calls.

6.2.2 Scope

The analysis will focus both on “moving” ships and on the filling rate of anchorage areas.

6.2.3 Methodology

Three questions are to be answered in this task in order to arrive at the prognosis for each of the main transport routes:

1. Which are the main transport routes in the Bonn Agreement area?
2. What increase of cargo is expected on each of those routes?
3. How does the cargo increase relate to the number of vessels per ship type and size on each of the routes?

Identification of the main transport routes

By combining available literature and the historical data of ports (which will be provided by the member states), an overview will be created of the main transport routes per commodity. This will be done based on the transported cargo volumes and the number of vessels. The main groups for commodities correspond to those in Table 6-1.

A special issue with respect to the main transport routes on the North Sea are the transit routes that do not call at any of the ports in the Bonn Agreement area. In order to get an accurate overview of the number of ships of certain ship types and sizes, the traffic database from Task H1.1 that will be based on 2011 AIS data will be analyzed. In this database separate voyages are identified, which can be linked to ports in the Bonn Agreement area. Voyages which cannot be attributed to any of the ports, can be considered transiting voyages. By evaluating at which position the ship entered and left the area, an overview is created of each of the main transiting routes per ship type and size:

- Atlantic – Baltic
- Atlantic – English Channel
- English Channel – Baltic

By combining the number of ships of the different types with available literature of worldwide transport routes, it can be concluded which worldwide routes and transport trends are relevant for the transiting routes in this area.

Cargo prognosis 2020

In this part of the analysis the focus is on cargo developments only, as this is the standard way in which expected growth of ports and market segments is expressed. For each of the commodities transported to and from ports in the Bonn Agreement area an overview will be given of the historical developments in the area, based on literature and the information that is provided by each of the Bonn Agreement member states. The historical overview of cargo transport will serve as a reference for the future prognosis.

The prognosis will be based on available prognoses from ports and countries for each of the routes in the Bonn Agreement area. For each of these routes and for each of the commodities an estimate will be made based on the expected volumes in 2020. By making this estimate, the main developments in the area regarding port extensions will be taken into account. The data analysis will be backed by literature, for as far as available.

Also for the worldwide trends that are relevant for the transiting routes, an overview will be given on the historical developments. As no data from ports is available on this topic, this analysis will be based on literature and trends on other routes. Also the future prognosis will rely on literature and trends on other routes.

Ship traffic prognosis 2020

The final step is to relate the cargo commodities to the different ship types and sizes. It will be assumed that cargo commodities can be related to specific ship types. The relations defined in Table 6-1 will be used.

In the past decennia the ship size has increased and it is expected that this development will continue in the near future. For this reason, the number of ship movements is not directly related to the cargo volume developments. Therefore, additional research is required with regard to the future ship sizes. The result of this step is a factor for each commodity expressing the cargo volume per ship movement that will be applied for the entire area. A distinction will be made for the different ship sizes. It will be assumed that the filling rate of ships of a specific size will not change towards 2020.

Finally for each ship type – ship size combination on each of the main transport routes a factor F can be calculated, expressing the expected increase of ship movements in 2020 compared to 2011.

For minor routes and ships which could not be attributed to any of the main routes, factors will be derived from the main routes, based on similarities between the main and minor routes.

Anchorage areas

In this part of the analysis a factor will be derived for the development of the filling rate of anchorage areas. The filling rate of an anchorage area is defined as the average number of ships that is present in the anchorage area.

Anchorage areas in the North Sea area are typically used as waiting places before or after a port visit. The filling rate of anchorage areas is therefore related to the number of ship visits to the nearest port.

Based on the analysis of the number of ship movements on each of the main transport routes, the factors for each of the ship type – ship size combination for each of the relevant ports are available. It will be assumed that the filling rate is directly related to the number of ship movements.

6.2.4 Used data

For this analysis the following data sources are used:

- Historical data on goods/passenger transports to the ports of each member country
- Import/export statistics from ports for 2011
- Forecasts of ports for different types of cargo/ ship movements / passenger transport
- Relevant future port development plans from each member country
- Literature on cargo transport in Europe and worldwide
- Literature on fleet development

6.2.5 Deliverables

The deliverables consist of:

- Factors per ship type /size combination for each of the main transport routes in the Bonn Agreement area (per direction), comparing the number of ship movements for the 2011 / 2020 situation
- Factors per ship type /size combination for the minor transport routes in the Bonn Agreement area (per direction), comparing the number of ship movements for the 2011 / 2020 situation
- Factors per ship type / size combination for each of the anchorage areas in the Bonn Agreement area, comparing the filling rate for the 2011/2020 situation

7. Frequency and quantity of oil spills

The work outlined in this chapter corresponds to: *Task H1.3*

Responsible consultant: *COWI*

Spills related to offshore installations are analysed separately as part of Task E5, see Chapter 8.

7.1 Ship accidents in the Baltic Sea

In a first step, it needs to be clarified, which types of ship accidents are to be modelled. In the BRISK project covering the Baltic Sea (BRISK spill, 2012), the accident statistics over a period of five years was used as a basis. From this data set a number of entries were dropped:

- All accidents involving vessels of less than 300 GT (compare Chapter 2)
- Accidents in harbours (compare Chapter 2)

Table 7-1 reflects the situation in the Baltic Sea, which borders to the Bonn Agreement area. It served as a point of reference at the BE-AWARE method meeting, where it was decided to use the same groups of accident types for the BE-AWARE model. The same type of statistical overview as in Table 7-1 will be performed for the entire Bonn Agreement area during work step H (Bonn Agreement area-wide risk assessment).

Table 7-1 Total number of sea accidents in the Baltic Sea 2004-2008 (HELCOM database plus national corrections, only relevant accident types, without port accidents) (BRISK spill, 2012)

Accident type	Number of accidents	Relative contribution
Grounding	230	70.3 %
Collision with vessel	31	9.5 %
Collisions with object	23	7.0 %
Fire	34	10.4 %
Physical damage	1	0.3 %
Pollution	6	1.8 %
Foundering	2	0.6 %
Total	*327*	*100 %*

7.2 General modelling

7.2.1 Fujii's model

In the present context, a model is understood to be a calculation method permitting to estimate the occurrence of sea accidents based on basic data. The present section describes how accident frequencies are calculated by means of the established models. Observed data (such as traffic statistics) are used as input in the calculation.

A generally acknowledged method for estimating the frequency of accidents where ships run into some sort of obstacle – another ship, a ground, any other obstacle – was developed by the Japanese physicist Yahei Fujii /Fujii, 1984/ and can be expressed in the following way:

$$F = N \times P_g \times P_c \times P_s$$

where

- F … the accident frequency, i.e. number of accidents per year
- N … the number of ship passages per year
- P_g … the geometrical probability, i.e. the probability that a ship is on collision course with a nearby obstacle (within 20 ship lengths)
- P_c … the causation probability, i.e. the probability that a ship on collision course does not undertake (successful) evasive action. This probability includes both human and technical failure.
- P_s … the probability that the damage exceeds a certain limit, e.g. that the impact is violent enough to cause leakage

The modelling consists in calculating the above equation by calculation the respective factors for each area and accident type. The aim is to describe the factors such that they describe the actual situation as good as possible. It is in the nature of such a calculation that it will always be an uncertain approximation. However, experience shows that it can be useful, especially if the calculation is a good approximation that describes the occurrence of a phenomenon in a significant way for a given area.

Since Fujii's model gives a clear image of the influence of some of the most significant effects at question, choosing this model is a reasonable basis for establishing a more detailed model, as described in the following.

In the present risk analysis, the model is supposed to reflect the effect of risk-reducing measures (RRMs), which can be added by introducing an additional factor

- P_e … Effect factor, which takes the effect of RRMs upon the causation factor into account (e.g. due to increased surveillance)

and by adjusting the parameters of the traffic model in accordance with the expected effects of the RRMs (e.g. the fraction of ships using a maritime pilot, usage of ECDIS). The latter adjustment will influence Fujii's N parameter (e.g. by means of altered traffic distributions).

Fujii's model is used in order to calculate the occurrence of sea accidents where ships run into an "obstacle" and is therefore linear dependent upon the traffic intensity N. In the case of collision between two ships, the collision frequency depends therefore upon the traffic intensity in both sailing directions. In order to be able to handle these accidents, Fujii's model is adjusted in such a way that the linear dependency on N is replaced by a function of the two colliding traffic intensities N_1 and N_2:

$$h(N_i) = \begin{cases} h(N) & \text{...for collision with fixed objects} \\ h(N_1; N_2) & \text{...for collision between ships} \end{cases}$$

Other parameters such as vessel speed, angles and lengths etc. are equally part of the calculation of the collision frequency (see Section 7.3 for a general overview).

The risk analysis of oil and hazardous chemical spill requires calculating the occurrence of the different incidents involving spillage depending on several conditions:

- Sea areas
- Substance groups for oil and hazardous substances, respectively
- Spill sizes
- Time-dependent scenarios (today, 2020)

Therefore, Fujii's model needs to be generalised and expressed in such a way that the spills are assumed to occur at a series of representative locations:

F(location, substance group, spill size, scenario) = $h(N_i) \times P_g \times P_c \times P_s \times P_e$

7.2.2 General risk analysis model

With regard to the analysis of the different pollution events it is sensible to re-formulate Fujii's model such that

F{spill size} =

F{sea accident} ×

P{hull damage with possibility for spillage | sea accident} ×

P{spill size | hull damage with possibility for spillage} ×

Effect factor{Risk reducing measures}

where

F{spill size} is the spill frequency (occurrences per year). This quantity corresponds to *F* in Fujii's model.

F{sea accident} is the frequency that a sea accident that can cause spillage occurs. This quantity includes the effect of the traffic intensity (*N, N1* and N_2 in Fujii's generalised model), geometrical conditions with respect to route, vessel, speed etc. (P_g in Fujii's model) as well as navigational conditions (P_c in Fujii's model).

P{hull damage with possibility for spillage | sea accident} is the probability of a sea accident entailing a damage that breaks the containment of oil or hazardous substances and therefore can lead to an accident. Thus, it includes aspects of Fujii's factor P_S. However this differentiation is necessary, since the risk analysis shall be capable of handling the size of the spills.

P{spill size | hull damage with possibility for spillage} is the probability of a given spill size given hull damage and can therefore be seen as being part of Fujii's factor P_S.

Effect factor{Risk reducing measures} is the reduction factor for the spill frequency that is estimated on the basis of the risk reducing measures

F{spill size} is then calculated for the same parameters as mentions above, i.e.

- Sea areas
- Substance groups for oil and hazardous substances, respectively
- Spill sizes
- Time-dependent scenarios (today, 2020)

which can be expressed as

F{spillage | location, substance group, spill size, scenario}

It is emphasized that the above description is general so that variation will occur for the respective accident types – depending on the complexity of the respective problem. It can e.g. be necessary to calculate

P{hull damage with possibility for spillage | sea accident}

and

P{spill size | hull damage with possibility for spillage}

as random distributions instead of probabilities. Details are not described here. In this way it becomes e.g. possible to handle the fact that a given spill size can consist of contributions both from minor spills from ships with a lot of cargo and from large spills from ships with less cargo.

7.2.3 Calculation procedure

As a consequence, the calculation of the spill frequencies are calculated on the basis of a traffic model that reflects the distribution of the ships with respect to

- vessel type
- vessel size
- hull configuration (single/double)
- load state (loaded/in ballast)
- draught
- operational vessel speed
- risk-reducing measures (RRMs)

The traffic model is prepared for traffic corresponding to the traffic today and in 2020.

The models for the frequency of sea accidents include the effect of following RRMs:

- Pilotage
- VTS centres
- Increased surveillance
- Double hull at the cargo tank (implemented as part of the consequence model)
- Double hull at the bunker (implemented as part of the consequence model)
- Electronic Chart Display and Information System (ECDIS)
- Bridge Navigational Watch Alarm System (BNWAS)
- Traffic separation schemes (TSS)
- Escort towing in narrow shipping lanes
- Emergency towing of damaged ships

Other effects may in fact *increase* the risk of accidents. They can be considered in the same way as RRMs. However, while RRMs are modelled by a factor ranging between 0 and 1, risk-increasing measures or circumstances are modelled by a factor exceeding 1. In the earlier BRISK project, this applied e.g. to ships sailing as part of an icebreaker convoy, which entails an increased risk of bow-to-stern collisions within the convoy (BRISK spill, 2012). For the BE-AWARE project, no such phenomena are currently included.

7.2.4 Distribution of leakage of oil and hazardous substances between substance groups

Once the calculated spill frequencies have been obtained, the spill frequencies per substance group are calculated based on the relative distribution of the transported cargo (compare Chapter 5).

7.3 Modelling of accidents at sea

7.3.1 Grounding

Frequency of powered grounding

The approach for calculating the frequency of powered grounding is simple and based upon the available data and statistics.

1. The Bonn Agreement area is divided into several sub-areas (Section 3.4).
2. For each sub-area, the powered grounding frequency is calculated, based on historical accident data and divided with the number of nautical miles sailed per year. The result is a powered grounding frequency per sailed nautical mile. Each waterway section has a different frequency.
3. The powered grounding frequency is corrected for the effect of pilotage, such that a pilot-free frequency is obtained.
4. Present and future powered grounding frequency on an annual basis is calculated by multiplying the distance sailed by different ships with the grounding rate per nautical mile. This step is performed separately for piloted and non-piloted ships. In the former case, the result is multiplied with a risk reduction factor for having a pilot on board.

Frequency of drift grounding

The approach for drift grounding is based on

- The outage frequency (loss of propulsion and/or steering)
- The time elapsed before re-establishing full machinery and steering capability (repair time)
- The probability of non-successful emergency anchoring
- The distance and position of the ship relative to the ground
- The drifting speed and direction
- A calibration factor adjusting the overall results to the statistically observable number of events

The outage frequency and the distribution function of the repair time are estimated based on research results from Technical University of Denmark (Friis-Hansen, 2008). The probability of non-successful emergency anchoring in based on estimates adopted by the German Ministry of Transport for wind mill projects (BMVBW, 2005)

The distance to the ground depends on the outage location, which is randomly distributed both along the route leg (longitudinally) and transversally (Figure 7-2). The longitudinal distribution is uniform, whereas the transversal distribution is based on the AIS-based distribution function included in the traffic model (Task H1.1).

The drifting speed and direction are modelled as a function of the original sailing direction (prior to the outage), the wind rose (speed and direction) and the current rose (speed and direction). These parameters are aggregated into a drifting rose as the one in Figure 7-2. The principle used for establishing the drifting rose are based on (ICS & OCIMF, 1998).

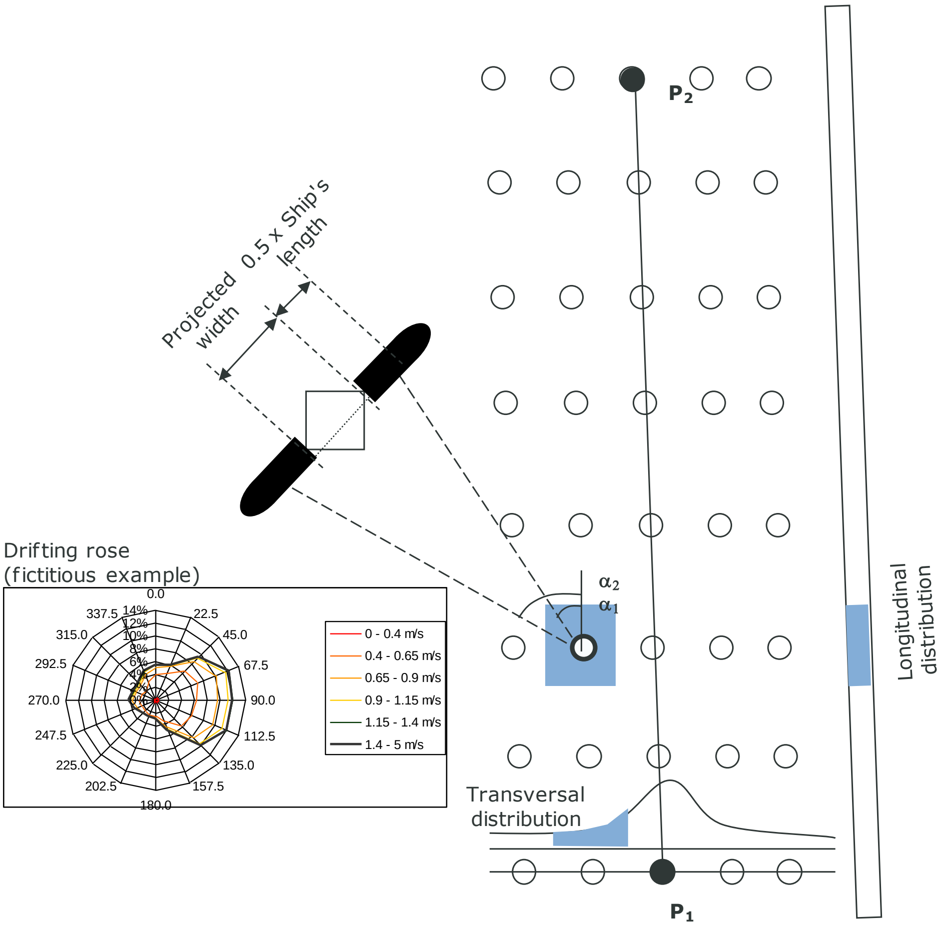


Figure 7-1 Geometric evaluation of the collision frequency for drifting collisions

Probability of spill given grounding

The probability and quantity of spill in case of grounding is derived from the results in (Rømer, 1996), (DNV, 2003) and (Ylitalo, 2010) in accordance with the approach used for BRISK (BRISK spill, 2012).

Separate models are indicated for cargo and bunker spillage, respectively.

7.3.2 Ship-ship collision

The collision modelling is based on the route-based traffic analysis described in Chapter 3.

Frequency of route collisions

Collision frequencies for route collisions are modelled for two situations (Figure 7-2):

- head-on collisions between ships sailing in opposite directions
- overtaking collision between ships sailing in the same direction

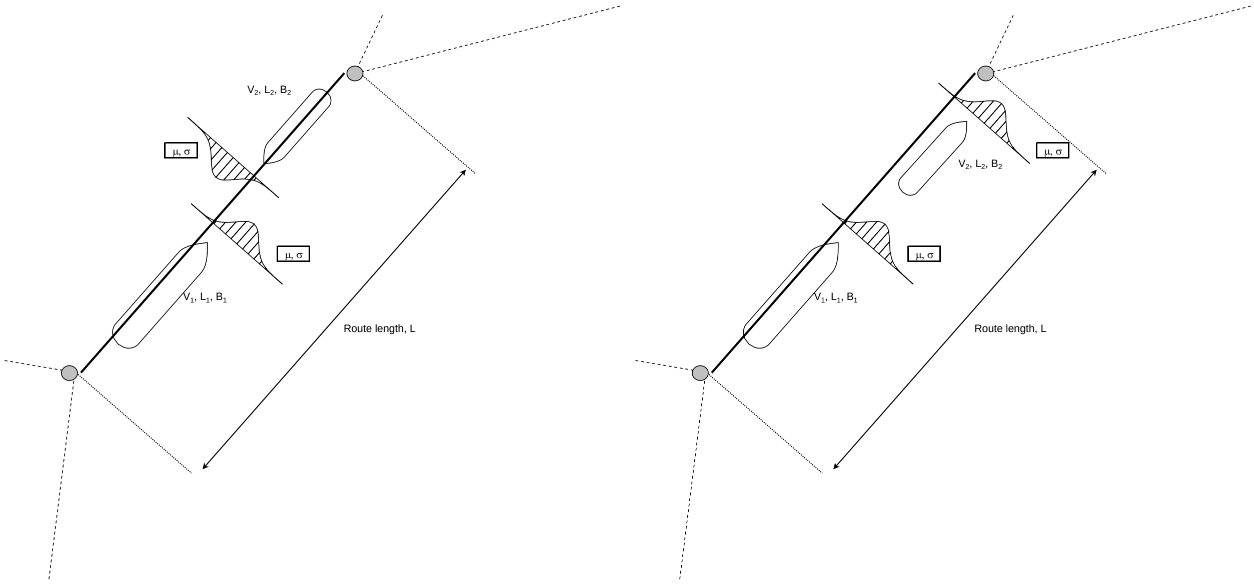


Figure 7-2 Head-on and overtaking collisions

The collision frequencies depend on:

- the length of the route segment
- the traffic intensity in each direction
- the length, breadth and speed of the ships
- the deviation of the ships from the route axis
- the causation probability Pc

With the detailed route and traffic description described in Chapter 3 it is possible to calculate the collision frequencies for the respective route segments.

Frequency of node collisions

The frequencies of node collisions are modelled for a number of relative manoeuvres between the crossing ships.

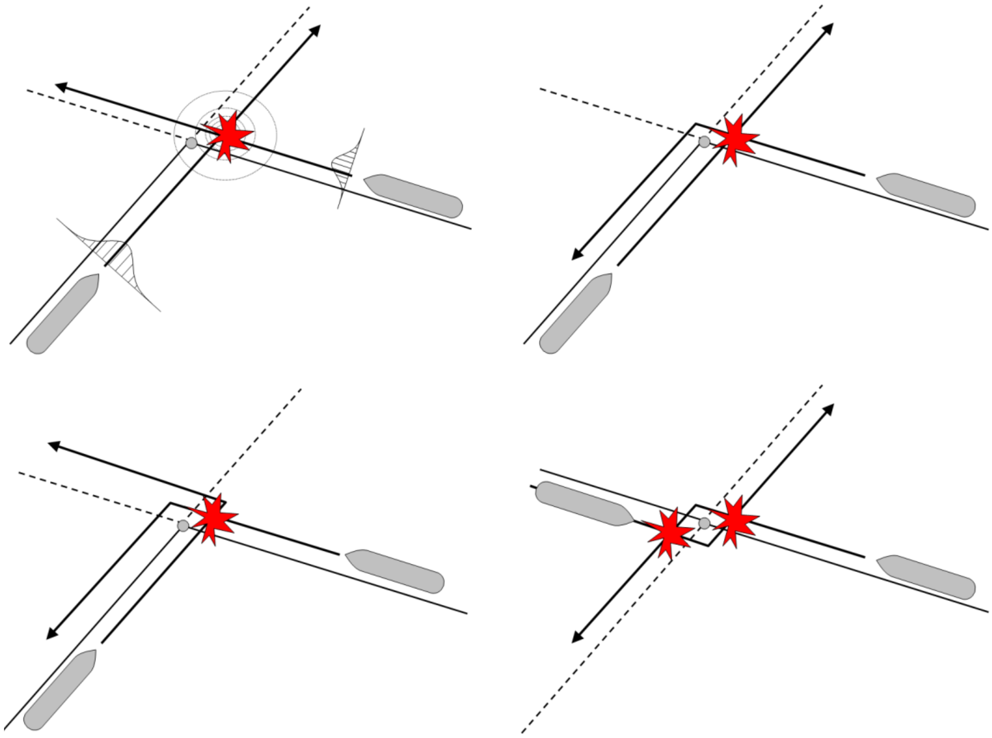


Figure 7-3 shows four important crossing manoeuvres.

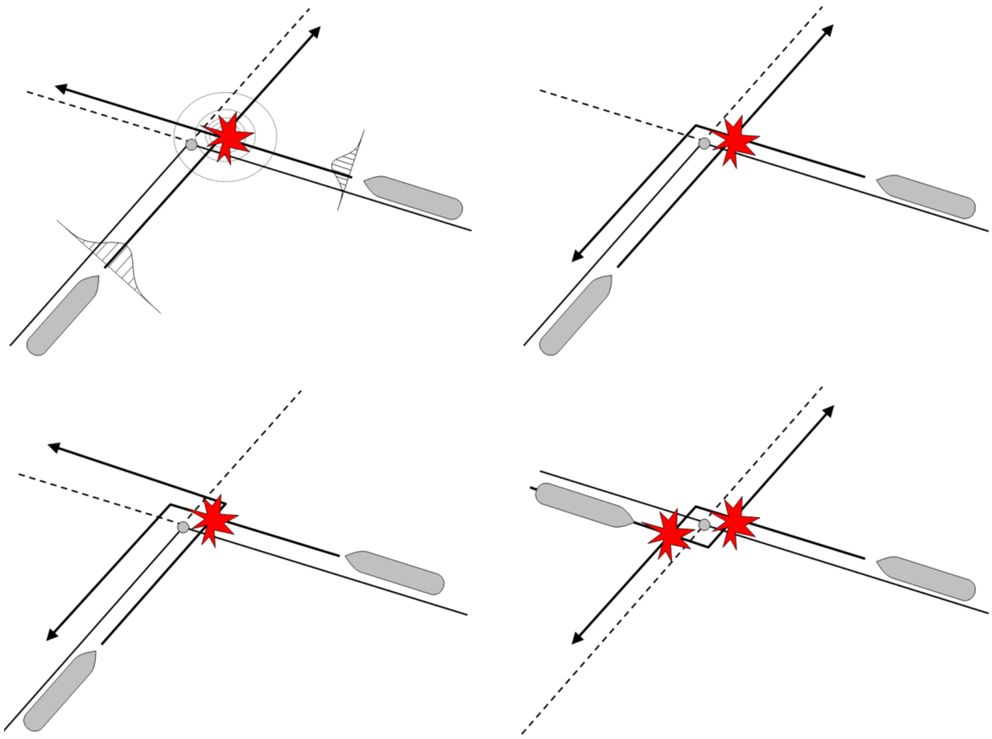


Figure 7-3 Regular crossing collisions and bending/crossing collisions

The collision frequencies depend on

- the traffic intensity in each direction

- the length, breadth and speed of the ships
- the crossing angle
- the causation probability Pc

Based on the detailed traffic description described in Chapter 3 it is possible to calculate the collision frequencies for the respective nodes in the route net.

Hull damage in case of collision

In order to assess the consequences of ship-ship collisions, a series of idealised ship designs have been developed. The damage size in case of a collision is described in accordance with work performed by Erik Sonne Ravn and Peter Friis-Hansen at Technical University of Denmark, who elaborated routines simulating large numbers of representative collision scenarios. A neural network is applied in order to

- determine the penetration at the hit vessel (both for bulb-shaped and conventional ship bows)
- the damage length at the hit vessel
- the damage height at the hit vessel
- the vertical position of the damage

These results are calculated based on data about the colliding ships:

- vessel speeds
- collision angle and draught
- bow shape (bulb or conventional)

The results from these simulations are used in order to estimate the possible spill in case of collision.

Spill in case of hull damage

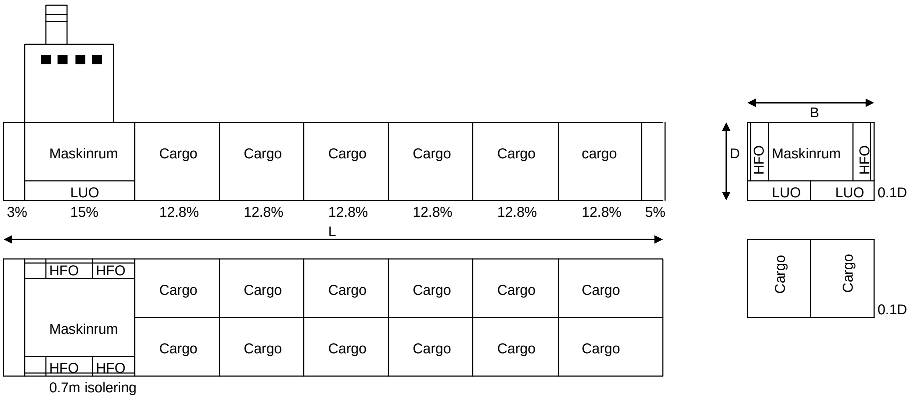
A number of assumptions need to be made in order to determine the amount of bunker oil and eventual cargo emerging in case of hull damage:

- The ships are categorised into seven ship types
    - tankers with single and double hull
    - chemical tankers
    - bulk carriers
    - container ships
    - general cargo ships / packed goods
    - Ro-Ro ships
    - Ro-Pax ferries
- Size of the bunker tank
- Division into cargo compartments of equal size

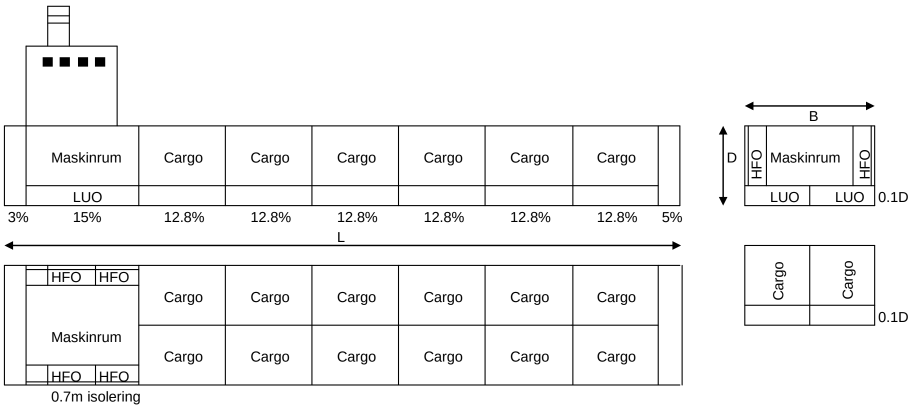
- Triangular distribution of the collision speed from 0 to vmax with 2/3 vmax as the most probable case
- Collision angles in the interval 30 to 150°

- Ship types are represented by rectangular boxes with rectangular cargo compartments, i.e. as idealised vessels (Figure 7-4 illustrates the case of tank ships):

Single hull



Single hull with double bottom



Double hull

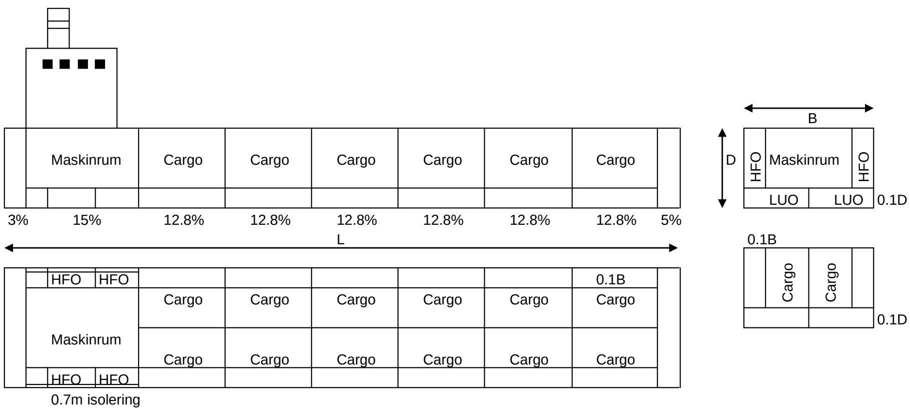


Figure 7-4 Idealised tankers used for determining the spill in case of hull damage

- the spill size depends on the position of the damage relative to the water line:

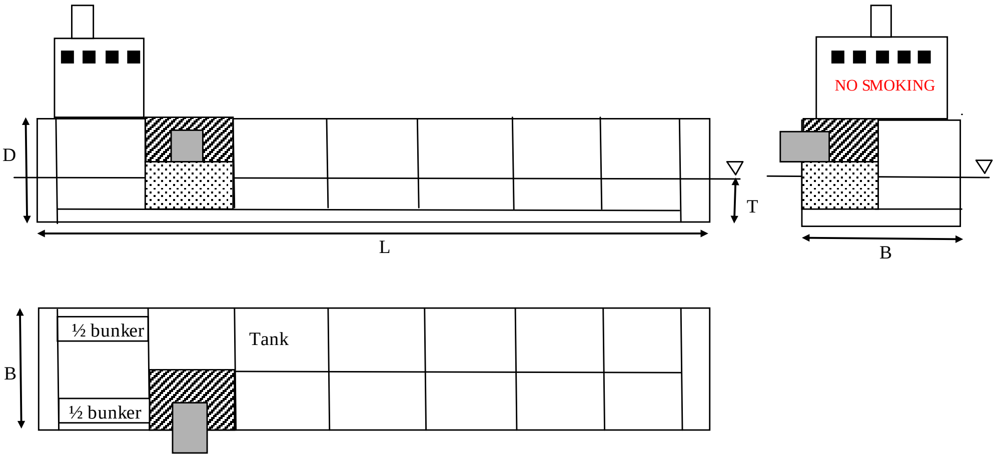


Figure 7-5: Example of a penetration above the water line. The shaded part is leaked. The dotted part remains in the tank.

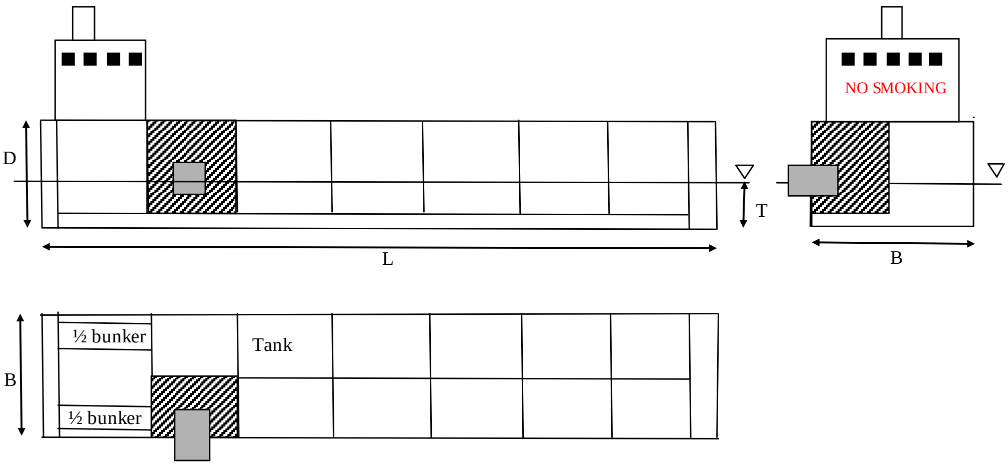


Figure 7-6: Example of a penetration below the water line. The entire shaded part is leaked.

For each collision, 250 simulations with varying angles, collision point relative to the ship length and speed are performed.

The spills are calculated for a number of different scenarios, where

- the impacting ship is
  - loaded/not loaded
  - hitting diagonally from the front/back
- the hit ship is
  - loaded/not loaded
  - double-hulled/single-hulled
  - bunker-protected (double hull at bunker)/not bunker-protected

In addition, all combinations between representative ship-types that are used in the simulations are analysed. This yields a very large number of combinations (>100,000). The results are stored in a database table.

7.3.3 Fire and explosion

The probability of fire and explosion is estimated as an occurrence rate per sailed sea mile based on an investigation by DNV (DNV, 2003).

The probability of spill given fire/explosion and the relative probability of a specific spill size are estimated in accordance with BRISK (BRISK spill, 2012).

7.3.4 Damage and foundering due to other causes

The probability of damage and foundering due to other causes – such as hard weather, structural fatigue, load instability etc. – is estimated as an occurrence rate per sailed sea mile based on accident statistics for the Bonn Agreement area.

7.4 STS operations, bunkering at sea and ships at anchor

7.4.1 Introduction

STS operations (ship-to-ship transfer) and bunkering at sea resemble each other in most aspects: One vessel is anchored, another vessel arrives, berths, a hose connection is established and oil is transferred from one vessel to the other.

Bunkering in harbours is not part of the scope (compare Chapter 2).

In Section 2.3.6 and 2.3.7, two main scenarios have been identified:

- Accidents during transfer, e.g. hose failure, over-bunkering etc.
- Collisions during approach, i.e. the arriving vessel hits the anchored vessel, leading to hull penetration and spillage

In the case of ships at anchor, the probability of a spontaneous spill is less relevant. However, ships at anchor are equally subject to ship collisions caused by passing vessels.

7.4.2 STS operations

Identification of locations

The first step consists in identifying the main STS transfer location, which tend to be concentrated in geographically confined areas.

Number of operations

Next, the number of STS operations is estimated based on historical data. In order to estimate the future situation, a yearly growth rate is estimated in accordance with the traffic prognosis described in Section 6 and interviews with STS operators.

Probability of spill during transfer

In case of spill during transfer the following oil volumes will be released:

- The content of one transfer hose (there are usually two hoses), which is typically 1 ton, compare (BRISK spill, 2012).
- The volume that is being pumped from the beginning of the spill (e.g. over-bunkering, hose leakage) until the pump is stopped. The pumping rate has been determined as maximum of 4,000 m3/hour in (COWI, 2007). This number is used as a default value. With this information, it is

possible to determine the time before pump stop that is needed in order to reach the different spill sizes used in the analysis.

If the spill cause is overloading, a certain volume will remain on the receiving ship. All further oil will flow down on both sides of the receiving ship.

If the spill cause is hose rupture, the oil will be immediately released into the sea.

The probability of an oil spill during transfer is estimated from that observed in the Norwegian and Scottish part of the North Sea.

The relative probability of a certain spill size is estimated

- from oil spill statistics
- from logistic considerations based on the expected time between beginning of the spill and pump stop

Combining the spill probability with the number of STS operations yields the yearly spill frequency and quantity.

Probability of collisions during approach

During STS operations, the (smaller) feeder ship is manoeuvred towards the (larger) mother ship with the help of tugs. Therefore, the probability of a collision leading to hull damage and spill is comparatively low. Based on Norwegian experience, it was estimated to be 1/30,000 in (BRISK spill, 2012). Combining this number with the yearly number of STS operations at a location yields the corresponding spill probability.

Probability of passing vessel impact

The probability of the feeder or mother ship being hit by a passing vessel during the STS operation with oil spill as consequence is calculated in the same way as for passing vessels hitting vessels during bunkering in Section 7.4.3. In (COWI, 2007), the probability turned out to be lower than the conservatively estimated probability of oil spill due to feeder ship impact in the case of the Danish EEZ. Therefore, the probability of spill due to passing vessel impact is assumed to be included in the numbers for feeder ship impact.

7.4.3 Bunkering at sea

Identification oflocations

The first step consists in identifying the main bunkering-at-sea locations. In general it is estimated that there are several locations for bunkering at sea in each Bonn Agreement member country's EEZ.

Number of operations

Next, the number of bunkering-at-sea operations is estimated based on historical data. In order to estimate the future situation, a yearly growth rate is estimated in accordance with the traffic prognosis described in Section 6 and interviews with bunkering companies.

Probability of spill during transfer

In case of spill during transfer the following oil volumes will be released:

- The content of the transfer hose, which has been determined as typically 600 kg in case of fuel oil transfer and 150 kg in case of transfer of refined products in (COWI, 2007). These numbers serve as default values.
- The volume that is being pumped from the beginning of the spill (e.g. over-bunkering, hose leakage) until the pump is stopped. The pumping rate has been determined as maximum of 400 m3/hour in (COWI, 2007). These numbers serve as default values. With this information, it is possible to determine the time before pump stop that is needed in order to reach the different spill sizes used in the analysis.

If the spill cause is over-bunkering, a certain volume will remain on the receiving ship. All further oil will flow down on both sides of the receiving ship.

If the spill cause is hose rupture, the oil will be immediately released into the sea. However, all oil will flow into the gap between the two ships. From Denmark, it is known that it is common practise to place a floating barrier between the two ship sterns. It is presumed that this assumption applies to other Bonn Agreement countries as well. Considering that the orientation of anchored ships follows the current, the oil is bound to drift into the barrier and further spreading of the oil is avoided.

The probability of an oil spill during transfer is estimated by combining oil spill and bunkering statistics.

The relative probability of a certain spill size is estimated

- from oil spill statistics
- from logistic considerations based on the expected time between beginning of the spill and pump stop

Combining the spill probability with the number of bunkering operations yields the yearly spill frequency and quantity.

Probability of collisions during approach

The probability of a collision during approach of the bunker ship and subsequent oil spill during transfer is estimated by combining oil spill and bunkering statistics. Multiplying this probability with the yearly number of bunker operations yields the corresponding spill frequency. In the case of Denmark, the yearly frequency was found to be negligibly low compared to other spill sources (COWI, 2007).

Probability of passing vessel impact

The probability of a given passing vessel hitting the bunker ship and/or the receiving ship can be determined by modifying the general model from Section 7.2:

$P = P_g \times P_c \times P_b$

where

P_g … the geometrical probability, i.e. the probability that a ship is on collision course with the bunker ship/receiving ship (within 20 ship lengths). This probability is calculated based on the AIS traffic data for the area around the bunkering location

P_c … the causation probability, i.e. the probability that a ship on collision course does not undertake (successful) evasive action. This probability includes both human and technical failure.

P_b ... the probability that the bunker and receiving ship are present at the bunkering location

The probability of spill in case of such a collision is calculated in the same way as for other ship-ship collisions (see Section 7.3.2). This is possible, because bunker and receiving ships are not permanently present. Therefore, the AIS data can be expected to contain ship movements at the bunkering location, as opposed to the location of fixed objects or grounds.

Multiplying this probability with the yearly number of bunker operations yields the corresponding spill frequency. In the case of Denmark, the yearly spill frequency was found to be negligibly low compared to other spill sources (COWI, 2007). This conclusion can first be verified for the other parts of the Baltic Sea once the data collection phase has been completed.

7.4.4 Ships at anchor

The present section deals with ships lying at anchor for other reasons than those discussed above (i.e. STS transfers and bunkering at sea).

Ships at anchor are exposed to the risk of passing vessel impact. In the case of STS operations and bunkering at sea, it was concluded that this risk is negligibly small compared to other relevant risks. However, the number of ships lying at anchor for general purposes is significantly higher than that of ships involved in STS transfers and bunkering at sea. Therefore, it cannot be stated beforehand that the risk of should be negligible.

The frequency of passing vessel impact is estimated as described above in Section 7.4.3. The consequences are modelled in the same way as for other ship-ship collisions, see Section 7.3.2.

Ships anchoring inside ports or at a immediately adjacent to the port are considered to be outside the scope of the analysis.

8. Oil spills related to offshore installations

The work outlined in this chapter corresponds to:	*Task E5*
Responsible consultant:	*MARIN*

8.1 Objective

Analysis of oil spill frequencies per spill size from offshore installations.

8.2 Scope

Offshore installations include:

- Offshore platforms (including rigs)
- Offshore wind farms
- Other offshore structures, if considered relevant

As for offshore platforms (including rigs), the following scenarios are included:

- Spills of 1 tonne and above from platforms and drilling rigs (including equipment) due to vessel impact. Both dedicated and passing vessels are considered.
- Spills from ships after collision with a platform or a drilling rig. Both dedicated and passing vessels are considered.
- Spills of 1 tonne and above from platforms and drilling rigs (including equipment) independent of any vessel activities.

Oil spills as a consequence of damage to wind turbines (caused by ship collisions or in a different way) is not regarded a relevant risk. This is therefore not taken into account.

Contacts with piers near port entrances are not included in this analysis. Collisions with ships at anchor are dealt with in Task H1.3.

8.3 Methodology to calculate oil spills from ships after a collision with an offshore platform or wind farm

8.3.1 General description of spill calculation

The calculation of a possible spill follows the process described below.

1. Determine the number of exposures. (An exposure can be explained as a certain elementary “traffic situation” which is representative for a certain type of collision.)
2. Calculate the probability of a collision by multiplying the number of exposures with their respective casualty rate. (The casualty rate is the probability that the exposure leads to a real collision with a platform or wind turbine.)

$$p_{collision} = n_{exposures}\ Casrat$$

3. Determine the probability that a collision results in an outflow due to the penetration of a cargo or bunker tank.
4. Determine the probability of an outflow of a certain substance, by multiplying the probability of penetration of a cargo or bunker tank with the probability that this tank contains the specific substance.

$$p_{spill} = n_{exposures}\ Casrat\ p_{penetration}\ p_{substance}$$

5. Determine the spill size based on the tank size and the penetration location.

$$V_{spill} = n_{exposures}\ Casrat\ p_{penetration}\ p_{substance}\ V_{tank}$$

All these values will be totalized per platform or wind turbine.

8.3.2 Traffic modelling

The standard way of modeling traffic in MARIN's navigational risk analysis program SAMSON is to use a combination of waypoints, connections between those waypoints (called links), the number of ship movements along each link per ship type and ship size, and a lateral distribution per link. In order to use the same basis for these calculations as will be used for the other frequency calculations within BE-AWARE, such as ship-ship collisions and groundings, the calculations will not be based on the standard MARIN traffic database, derived from the LLI voyage database, but directly on AIS data.

In this study the AIS data are modeled in such a way that SAMSON can be applied to individual ship movements. For each AIS message in the data a separate link is created. The starting waypoint of this link corresponds to the position in the AIS message; based on the position, course over ground and speed at the time the AIS message was sent the expected path of the vessel is projected for the time until the next message is available. The expected position after the time period is the end waypoint of the link. Each of these "links" (the projected path of the ship) is treated as a link by SAMSON.

As AIS is an actual representation of traffic, traffic is modeled much more accurately then when based on a traffic database. However a drawback is that coverage is not guaranteed. It is possible that there exist gaps in the data. For this reason also calculations will be done for a "standard" traffic database. This database will be directly based on the traffic database that COWI extracts from the AIS data as part of Task H1.1. As the traffic database corrects the AIS data for data gaps, this provides an accurate overview of the total traffic image.

The risk caused by vessels which visit the platform, such as supply ships and shuttle tankers will be reported separately. The same will be done for fishing vessels, as far as they are included in the traffic database.

8.3.3 Collision frequencies

In order to be able to calculate the expected spill frequencies from ships as a consequence of collisions with offshore platforms and wind turbines, it is required to calculate the probability that a platform or turbine is collided against by a ship of a specific type and size sailing with a specific speed. The calculations will be performed by using the ship-contact model within safety assessment model SAMSON. This model is described below.

The platforms are modelled either as rectangles or circular shapes, depending on the actual shape of the platform, defined by a position, length, width and orientation. Wind turbines are modelled in a similar way: each wind turbine is a separate "platform" with a circular shape and a diameter as specified per wind farm.

As the calculations are time consuming, the calculations will not be done for each wind turbine separately. Instead, the calculations are done for each of the corner turbines for each wind farm and one or more turbines in the centre of the wind farm. By calculating a weighted average probability of each turbine, depending on its position in the wind farm, and multiplying this probability for the number of turbines in the wind farm, the total probability is obtained.

Two causes of contact between a ship and an object are distinguished during accident analyses:

- A ramming contact as a result of a navigational error;
- A drifting contact as a result of a mechanical failure of the engine or steering engine.

The first type is due to a human failure in the vicinity of an object that cannot be recovered or is first recovered after the point of no return. The second type is the result of a power failure near an object.

The relevant exposures (elementary "traffic situations" which are representative for a certain type of collision) for contact between a ship and an object are:

- Ramming opportunity for a ramming contact;
- Danger miles for a drifting contact.

Contact with an object as a result of a navigational error (ramming)

In Figure 8-1 a vessel is shown at a distance x from the last waypoint. The vessel proceeds to the next waypoint where the vessel has to change course. For a given position of the vessel 3 lines are drawn on either side of the vessel track with an interval of 10˚. These lines indicate possible paths of the vessel after a navigational error has occurred. The object near the vessel is defined as a selection of straight lines between different points. These straight lines are characterized by two geographic positions. In the figure they are denoted as 1 and 2. Whether or not the object will be hit by the vessel depends on the following matters:

- The position at which the error happens;
- The direction of the ship after the error has occurred;
- The possibility that the error is recovered in time; depending on the distance between the ship and the object, as well as the sailing speed.

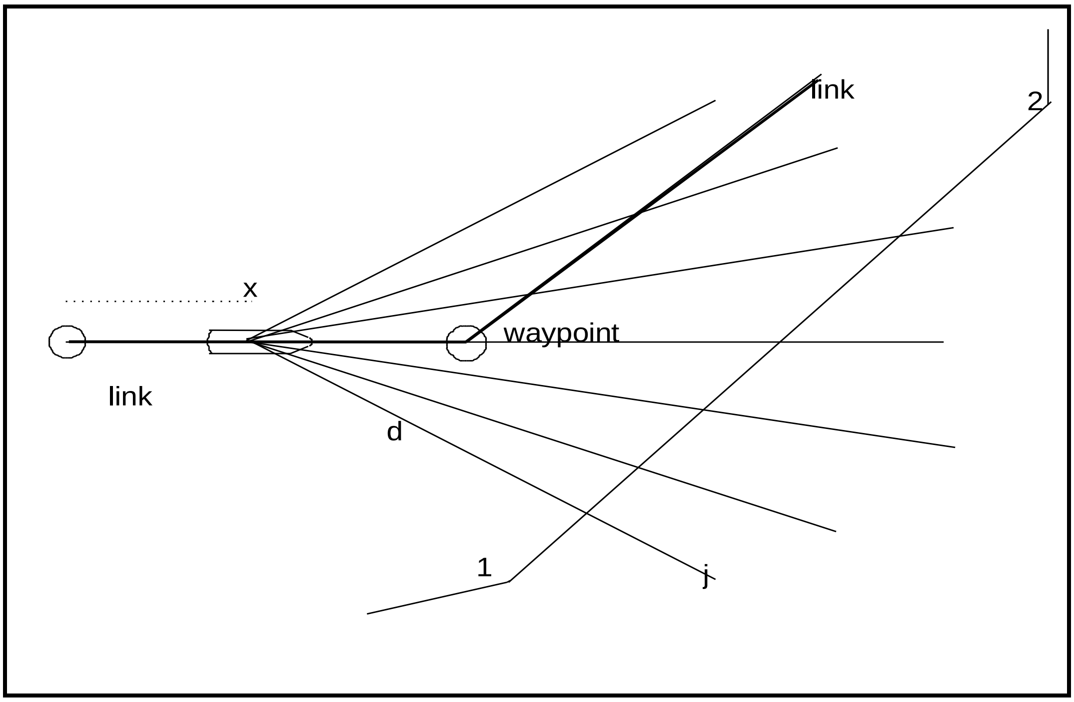


Figure 8-1 Definition of ramming opportunity

A ramming contact with the object due to a navigational error can start at each position on the link. The speed at which the navigational error occurs, is assumed to be equal to the service speed. The distance to the object which is expressed by the number of ship lengths, is determined both for the initial course line and for the six new lines. The distribution over the possible directions after the error occurred is as follows: 0.05, 0.1, 0.2, 0.3, 0.2, 0.1, 0.05 for the respective directions -30˚, -20˚, -10˚, 0˚, 10˚, 20˚ and 30˚.

The number of ship lengths that are available in each direction towards the object indicate the available time for the navigator to mitigate the consequences in case of a navigational error. The probability of a ramming contact with an object given a navigational error is related to the distance and ship length as follows:

$$p_{nav} = \int_{x_1}^{x_2} e^{-a\frac{d_\psi(x)}{L_i}} dx \qquad (8\text{-}1)$$

with

a ... Danger measure (dimensionless parameter with a standard value of 0.1)

d_ψ ... Distance of the vessel on the link to the object in direction ψ

L_i ... Ship length of class *i*

x ... Position of the vessel on a link

p_{nav} .. Probability of a ramming contact with an object given a navigational error

The number of ramming opportunities given a navigational error is now given by the following expression.

$$RO_k = \sum_{\psi} \sum_{i} p_{\psi} N_{ij} \int_{x_1}^{x_2} e^{-a\frac{d_{\psi}(x)}{L_i}} dx \qquad (8\text{-}2)$$

with

N_{ij}	…	Number of vessels using link j of vessel class *i*
p_{ψ}	…	Probability of a course in direction ψ
RO_k	…	Ramming opportunity for an object on link k

As in this study links are created for each AIS message separately, the number of ships per link (N_{ij}) is equal to 1.

The number of contacts can be calculated by multiplying the number of ramming opportunities with the probability of a navigational error:

$$\#contacts_{NE} = CASRAT_{RO} \sum_{k} RO_k \qquad (8\text{-}3)$$

with

NE	…	navigational error
$CASRAT_{RO}$	…	matrix with the probability of a navigational error

The CASRAT parameter calibrates the ramming model with the actual observed accidents. Several studies have been performed in order to derive the relationship between the probability on a navigational error and the probability on a contact as a result of such an error, specific for the North Sea area, see (Van der Tak, 1995) and (Koldenhof, 2004). By taking into account the developments in ship sizes and the composition of the world fleet and using the derived relationship, the casualty rates are annually updated based on the worldwide and regional casualty statistics.

Contact as a result of an engine failure (drifting)

The danger miles are that part of the link between x_1 and x_2 at which a loss of propulsion of a ship poses a potential threat to the object. The vessel will drift in a direction indicated by the environmental conditions. To determine if a ship will actually drift against the object, it is necessary to know the time needed to drift from the link to the object. To calculate this so-called drifting time, first the distance between the point on the link where the engine failure occurs and the object has to be calculated. If the drifting time is larger than the time to repair the engine, the ship can drift against the object.

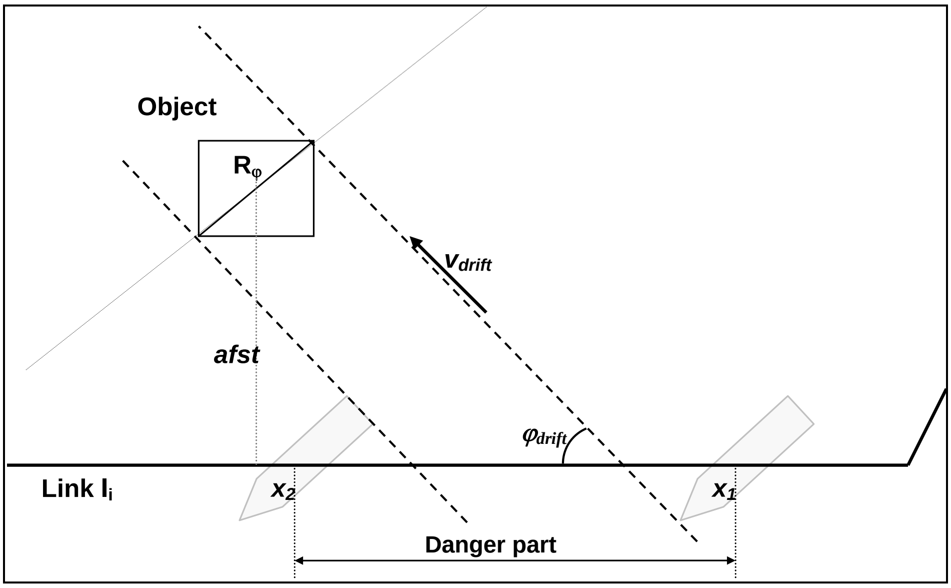


Figure 8-2 Definition of a drifting contact

If a ship is at point x on the link, the distance to the object is given by r(x) and the drifting time by:

$$t_s = \frac{r(x)}{v_{dbin}} \qquad (8\text{-}4)$$

with

t_s … Drifting time (hr)

$r(x)$ … Distance of a point x on a link to the object

v_{dbin} … Resulting drifting speed of ship *i* in loading condition *n* at Beaufort scale number **b**

In this model the drifting speed is assumed to depend on the Beaufort class. Given that an engine failure occurs, the probability that the duration of engine failure is larger than the drifting time to the object is given as follows:

$$P_{EF}(t > t_s) = 1 \quad \text{for } t<0.25\text{hr} \qquad (8\text{-}5)$$
$$P_{EF}(t > t_s) = \frac{1}{1.5(t_s - 0.25) + 1} \quad \text{for } t\geq 0.25\text{hr}$$

Based on these parameters, the *danger miles* can be determined for each link. The danger miles describe the number of nautical miles on each link where, if an engine failure occurs on board a specific vessel, the object could be hit by the vessel. This distance is shown in Figure 8-2 as the "danger part". Wind conditions, current conditions, ship characteristics and the geometry of the object are taken into account.

The number of contacts is determined by multiplying the summation of the danger miles for all links with the engine failure rate $CASRAT_{EF}$ as follows:

$$\#contacts_{EF} = CASRAT_{EF0-7} \sum_k \sum_{b=0}^{7} p_b DM_{bk} + CASRAT_{EF8up} \sum_k \sum_{b=8}^{11} p_b DM_{bk} \qquad (8\text{-}6)$$

$CASRAT_{EF0-7}$ … Engine failure rate for 0-7 Beaufort

$CASRAT_{EF8up}$ … Engine failure rate for 8-11 Beaufort

p_b ... Probability of Beaufort class *b*

DM_{bk} ... Number of danger miles per link

As for the ramming model, the CASRAT parameters serve as calibration parameters for the drifting model and represents the probability that an engine failure in the danger part actually leads to an accident.

8.3.4 Calculating spill sizes and spill frequencies based on calculated contacts

Determine number of collisions resulting in an outflow

The outflow model follows the chain of events between the contact to a possible outflow. An outflow occurs only when:

1. The damage takes place in the cargo or bunker part of the ship. A damage in front of the collision bulkhead or in the aft part of the ship will not result in an outflow. Of course the structural damage can be severe, but there will be no direct threat to the environment.
2. The cargo or bunker tank is penetrated. In case of a single hull ship the wing tank is penetrated when the ship hull is penetrated. In case of a double hull tanker more energy is required to penetrate the inner hull, being the hull of the cargo or bunker tank.
3. The penetrated cargo or bunker tank is loaded. The cargo or bunker tank that is penetrated can be a ballast tank or empty.

The amount of outflow depends on the location of the hole and the size of the penetrated tank.

There are no publications available on the damage to ships as a consequence of a contact with a platform or wind turbine. Therefore, the outflow models are not based on measured data but on assumptions based on collisions between ships for which publications are available.

For a drifting contact, it is assumed that the ship drifts sideways against a platform with a speed below 3 knots. It is assumed that a damage occurs to one or two of the outside tanks.

In case of a ramming contact, it is assumed that the ship hits the platform with full speed. The assumed damage model is that of a collided ship in case of a collision between two ships. This damage model is based on studies carried out for IMO (IMO, 1992) and is implemented in SAMSON.

For the collision of a tanker, the information of task E3 about the probability that a tanker of a certain type and size at that location is loaded with oil and the expected amount of cargo oil that is on board for the main transportation routes will be used.

Determine probability of outflow of a certain substance

The probability that a certain substance will flow out of penetrated tank follows from the probability that the damaged tank contains the specific substance.

The probability that a specific cargo tank contains a substance of a specific type of cargo depends on the probability that the tanker is loaded, its filling rate, the tank lay-out of the vessel and its loading state. The first two properties are derived in task E3. For the remaining two properties assumptions need to be made. These assumptions are the same as used in the ship-ship collision study. See Task H1.3.

Also for the bunker tanks, the assumptions related to the filling rate of the different tanks will be the same as used by COWI in the ship-ship collision study, see Task H1.3.

Determine spill size

The spill size depends on the height of the penetration with respect to the waterline. For a penetration above the waterline, it is assumed that amount of oil above the underside of the hole will flow out. For a penetration under the waterline it is assumed that total volume of the tank will flow out, which is a worst case scenario. This will not happen due to hydrostatic pressure, but over time, oil and water can interchange position.

8.3.5 Correction for future changes in wind farms and platforms

Like ship traffic, also the number of wind farms and offshore platforms and rigs will be different in 2020 than in 2011, because of the construction of new objects and the decommissioning of rigs and platforms. In order to correct for these changes, the calculated spill frequencies for 2011 need to be scaled towards 2020. This will be done based on predictions on changes in the number of platforms to be constructed and decommissioned, as well as for wind farms to be constructed. For as far as possible this will be done on a regional scale; this means that for different regions different scaling factors will be used to correct for the number of spills.

8.4 Methodology to estimate oil spills from platforms

There is generally very little information regarding this type of oil spills. In Task E6 part of the analysis is to collect data on these types of spills. If this type of information can be obtained, it is possible to calculate an average “spill-factor” for platforms. If this information cannot be obtained, the risk will be quantified by making some very simplified assumptions.

The following general approach will be followed:

1. A small number of platform groups will be defined (max. 10 different groups) based on similarities (construction type, exposure to wind and waves, flow rate etc.)
2. For each platform group, a number of spill scenarios will be defined. The scenarios will primarily differ with respect to their respective spill size.

In the risk assessment reports, it will be stressed that the platform spill analysis only serves to provide an order of magnitude and a means of comparison with the ship-related spill risk. In case the platform contribution should turn out to be significant, the risk assessment reports will have to stress the necessity of additional, more detailed investigations (which, however, would not be part of Be-Aware project in its presently defined form).

The project partners have decided that only spills of 1 tonne and above shall be considered (see Section 2.2.8).

8.5 Used data

- AIS data 2011
- Extracted traffic database as provided by COWI (Task H1.1)
- Platforms: position, dimension and orientation from BE-AWARE user database
- Wind farms: position (polygon), number of turbines and dimensions of turbines from BE-AWARE user database

- The probability that a certain ship has a certain amount and type of cargo oil on board, as derived in task E3
- The probability that a certain ship has a certain amount of bunker oil on board as provided by COWI
- Division of the amount of cargo/bunker oil over the tanks, taking the regulations into account

8.6 Deliverables

- Probability of a spill from a ship per location (platform or wind farm) and spill size class for:
    - Spills as a consequence of a collision between a passing vessel and the platform or wind turbine;
    - Spills as a consequence of a collision between an attendant vessel and the offshore platform;
    - Spills from an offshore platform as a consequence of non-ship related incidents.

For the wind farms the total spill frequency will be summed for all of the wind turbines in the wind farm.

9. Qualitative analysis of HNS risks

The work outlined in this chapter corresponds to: *Task H7*

Responsible consultant: *MARIN*

9.1 Objective

At this stage it is chosen not to calculate the risks of HNS transport in the Bonn Agreement area as accurately as for oil, because of the following reasons:

- There is much less detailed information available on the shipments of HNS compared to oil;
- The environmental impact of a spill at sea is different for every type and there is currently no methodology available to include these effects in a risk assessment in a detailed way;
- Chemical tankers can carry several types of substances. No extensive research is available at this stage related to the transport of different HNS types by tankers in the EU area.

Because of the above mentioned reasons and taking into account the fact that the spill frequencies of HNS are very low compared to oil spill frequencies, this study does not include a quantitative HNS spill risk assessment. Task H7 has the following objectives:

- Assessment of hot-spot areas with respect to the risk caused by ships carrying HNS by qualitative analysis;
- Identify possible methodologies for future quantitative risk assessments;
- Identify areas requiring further research.

The analysis will focus on HNS transported in bulk.
However, HNS as packed goods will also be taken into account. We have to see how much data will be available on transported HNS, but for some types the environmental impact can be large even for a very small amount of HNS (i.e. one or two containers, as in the case of the Sherbro, http://www.cedre.fr/en/spill/sherbro/sherbro.php).

9.2 Methodology

The approach that is chosen is to set up a quantitative assessment for as far as possible at this stage, without performing the actual accident frequencies. As not all information and knowledge is available yet, it will become clear which data and knowledge gaps exist and a possible direction for solutions of these problems will be explored. Using this approach establishing a qualitative risk assessment and setting up a methodology for a future quantitative assessment go hand in hand.

As a first step, accident statistics related to HNS spills will be analyzed. For this part of the work the results of task E6 can be used as well as worldwide accident data (IHS Fairplay). The statistics will be used to give an overview of the frequency of HNS spills.

A second step is make an inventory of all HNS types which are transported in the Bonn Agreement waters and to bring all these types into a small amount of groups. Classification of HNS could be based on either the damage to the environment or based on the ability to clean up the substances. This depends on the consequence analysis of the risk assessment. Therefore, the main ideas behind the classification should be made in cooperation with an expert on this topic, within the BE-AWARE project. There is a significant amount of literature (see for instance (Neupart, 2011), (ARCOPOL,

2011) and (RESPIL, 2007)) available on the characteristics of different types of HNS when spilled into seawater and how these could be incorporated group wise in a maritime risk assessment. Therefore, an important task is to analyze all available literature. The findings will be used to identify the groups of HNS which are relevant for the BE-AWARE project.

Research is required related to the ship types and sizes which transport the different groups of HNS, the probability that these ships are loaded and the filling rate. This will be done by analyzing data on HNS transports from ports and linking this information to ship movements. This is done in a similar way as is done in task E3 for oil transports. A difference is that for HNS only restricted data will be available. Therefore, the result will rather be a rough estimate than a detailed description of transports.

It is not required to collect data from all the ports in the area, as few ports account for the majority of HNS transports in the area. The results from these main ports are considered to be representative for all ports in the area, i.e. with respect to estimating the load state and cargo type on board the individual vessels. Based on the total GT of oil tankers that called at ports in the Bonn Agreement area in 2008, a list was made of the ports that together account for 70% of the chemical tankers' GT in this year. The list is displayed below.

Table 9-1 Representative ports in the BE-AWARE area used for HNS transport modelling

Rotterdam	NLD
Antwerp	BEL
Amsterdam	NLD
Milford Haven	GBR
Hamburg	DEU
Le Havre	FRA
Fawley	GBR
Gothenburg	SWE
Immingham	GBR
Dunkirk	FRA
Tees	GBR
London	GBR
Mongstad	NOR
Brofjorden	SWE
Falmouth	GBR
Wilhelmshaven	DEU
Coryton	GBR
Zeebrugge	BEL

Based on the analysis of HNS transports an overview can be given of the main transport routes for the different groups of HNS. This, in combination with shipping accident frequencies as identified in Task H1.3, will be used for the qualitative assessment to identify hot spot areas.

The frequency calculations will not actually be performed. A description will be given of how this could be done in a later stage.

9.3 Used data:

- Data on HNS transports in 2011 from ports in the Bonn Agreement area
- Extracted traffic database 2011 as provided by COWI as part of Task H1.1
- Results of tasks E3 and E6
- Available literature
- If provided: EMSA statistics

9.4 Deliverables:

- Hot spot areas with regard to HNS spills
- Description of suggested approach for a quantitative analysis of a maritime HNS risk assessment, similar to the oil risk assessment in BE-AWARE
- Overview of data and knowledge gaps for a full quantitative risk analysis of HNS spills
- Recommendations for the facilitation of future quantitative risk assessments

10. Abbreviations

AIS	Automatic Identification System
BNWAS	Bridge Navigational Watch Alarm System
BRISK	Project on sub-regional risk of spill of oil and hazardous substances in the Baltic Sea
ECDIS	Electronic Chart Display and Information System
EEZ	Exclusive economic zone
HELCOM	Baltic Marine Environment Protection Commission (also: Helsinki Commission)
HNS	Hazardous and noxious substances
IMO	International Maritime Organisation
RRM	Risk-reducing measure
SOLAS	International Convention for Safety of Life at Sea
STS	Ship-to-ship transfer
TSS	Traffic separation scheme
VTS	Vessel traffic service
WSE	The IHS Fairplay World Shipping Encyclopedia

11. Literature

ARCOPOL, 2011 — The Atlantic Regions' Coastal Pollution Response (ARCOPOL), *Risk Priorisation Methodology for Hazardous & Noxious Substances for Public Health*, 2011

BMVBW, 2005 — Bundesministerium für Verkehr, Bau- und Wohnungswesen, *Genehmigungs-relevante Richtwerte für Offshore-Windparks*. Bericht einer Arbeitsgruppe, Main document and Appendix 2 (both in German), 14 March 2005

BRISK method, 2012 — *Project on sub-regional risk of spill of oil and hazardous substances in the Baltic Sea (BRISK): Risk Method note*. COWI for Admiral Danish Fleet HQ, report no. 70618-3.1.1, rev. 3.0, April 2012

BRISK results, 2012 — Project on sub-regional risk of spill of oil and hazardous substances in the Baltic Sea (BRISK): Risk model results. COWI for Admiral Danish Fleet HQ, report no. 70618-3.2.2, rev. 1.0, April 2012

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