BE AWARE

Bonn Agreement
Accord de Bonn

METHODOLOGY NOTE

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Co-financed by the EU –
Civil Protection Financial Instrument

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COWI

MARIN

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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.

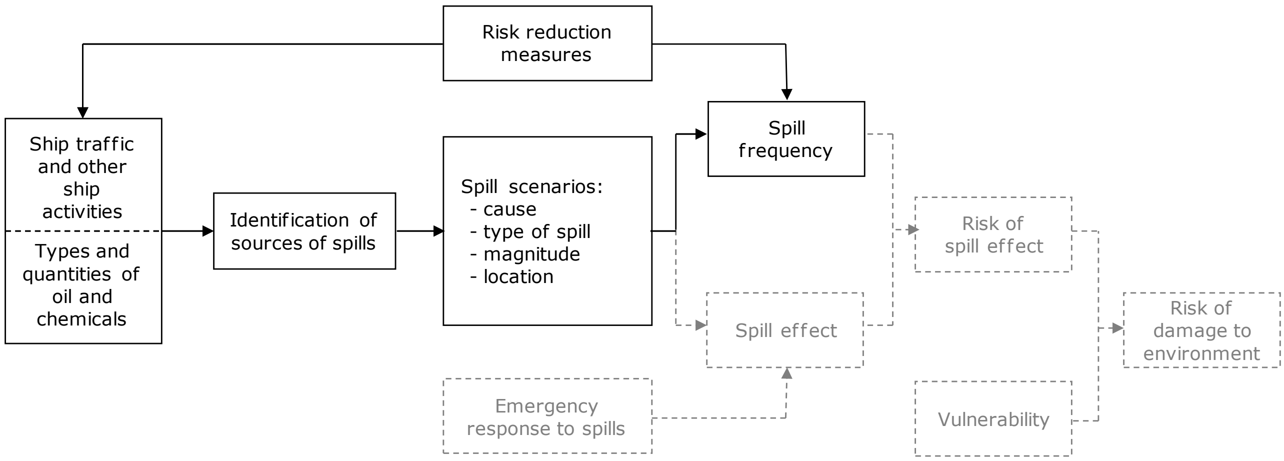


Figure 1-1 Data and calculation flow of the model (BE-AWARE work steps are indicated in solid black, work steps of the follow-up project phase are indicated in dashed gray)

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.

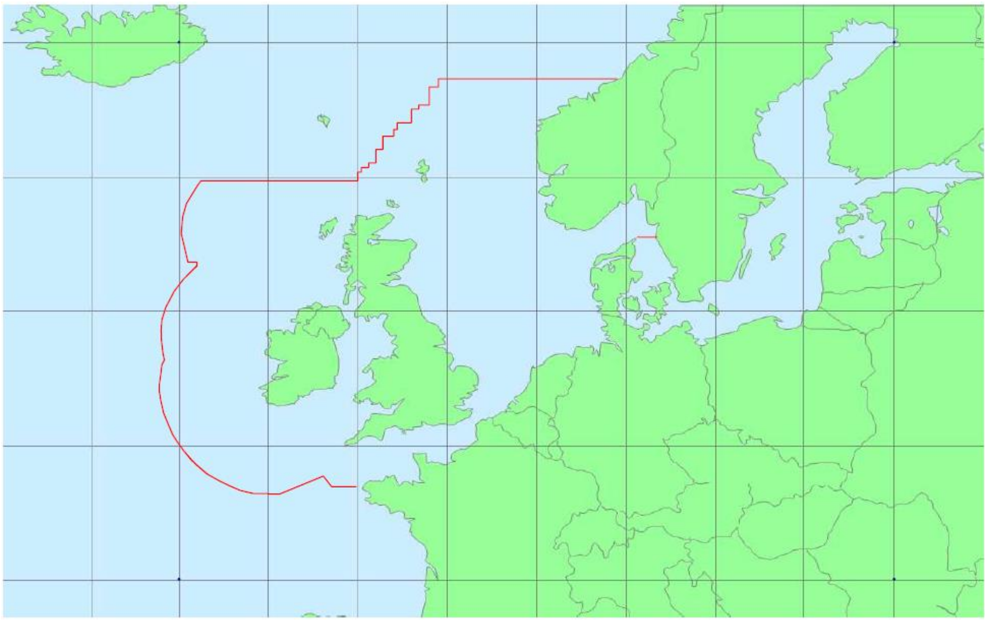


Figure 2-1 Project area for BE-AWARE. The area is also often referred to as the "Bonn Agreement Area"

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)

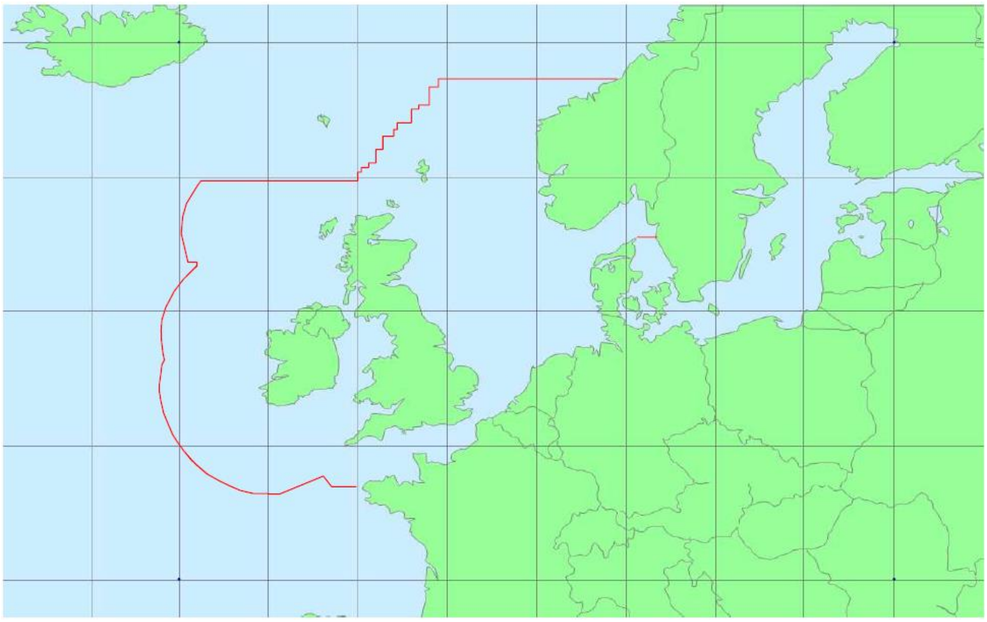


Figure 2-2 Project area for BE-AWARE

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.

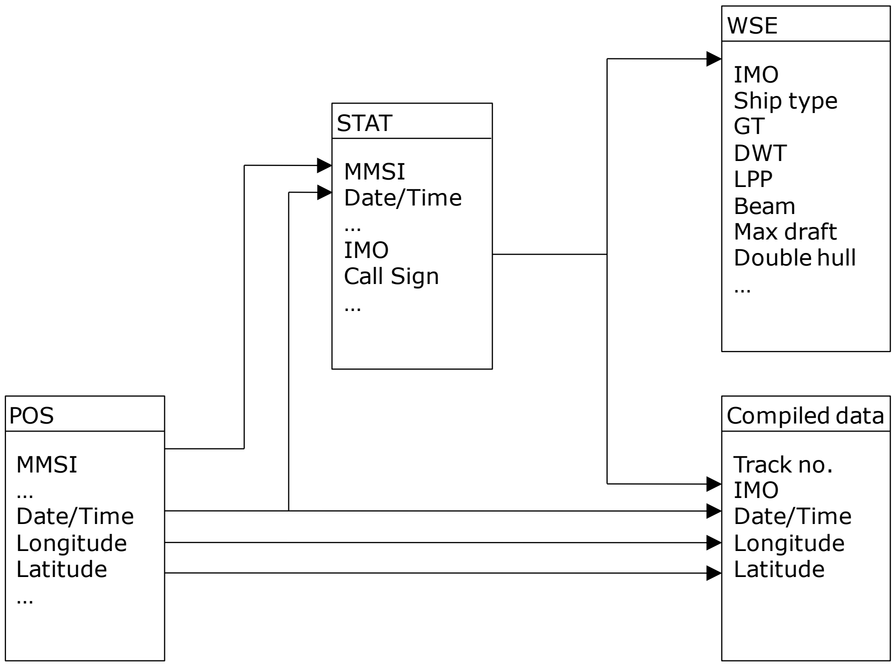


Figure 3-1 Data processing from raw AIS data (left) to the final basis of the analysis (right)

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).

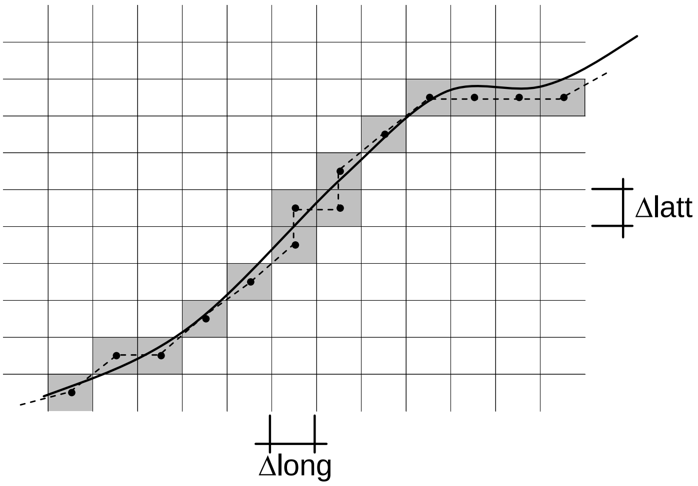


Figure 3-2 Digitalisation of a vessel track in order to determine the traffic density

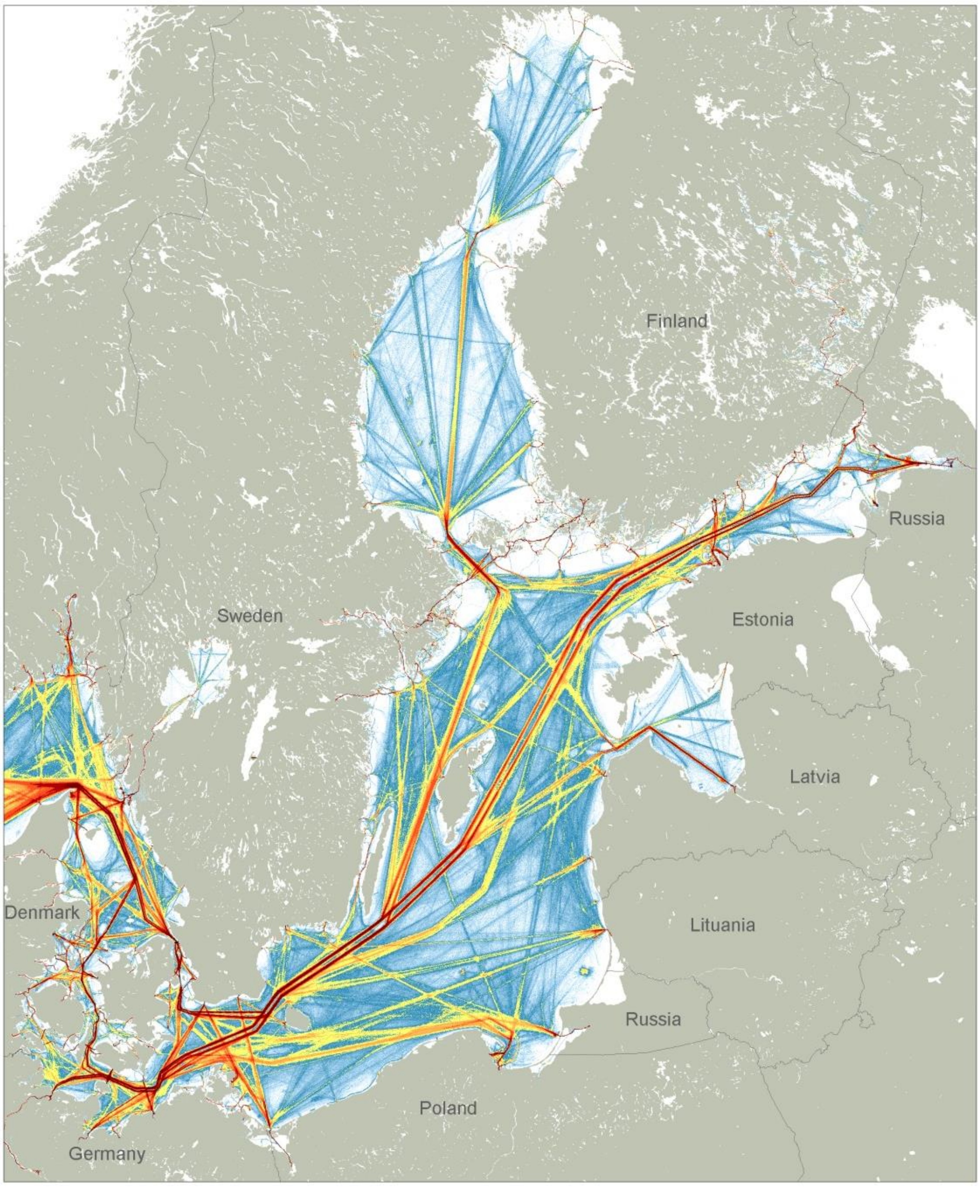


Figure 3-3 Example of a traffic density plot for the Baltic Sea based on the recorded traffic (BRISK traffic, 2012)

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*.

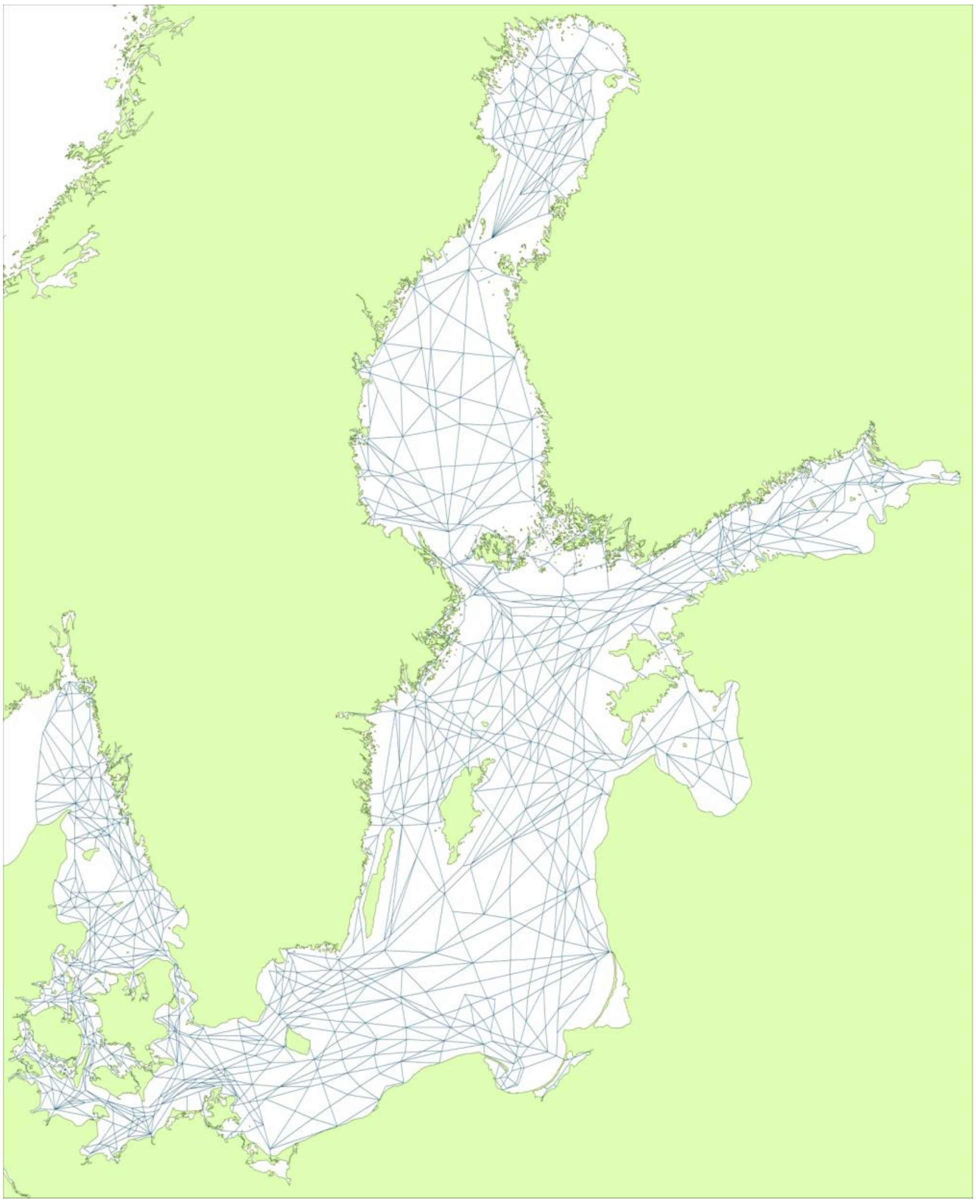


Figure 3-4 The route net used for BRISK (BRISK traffic, 2012)

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.

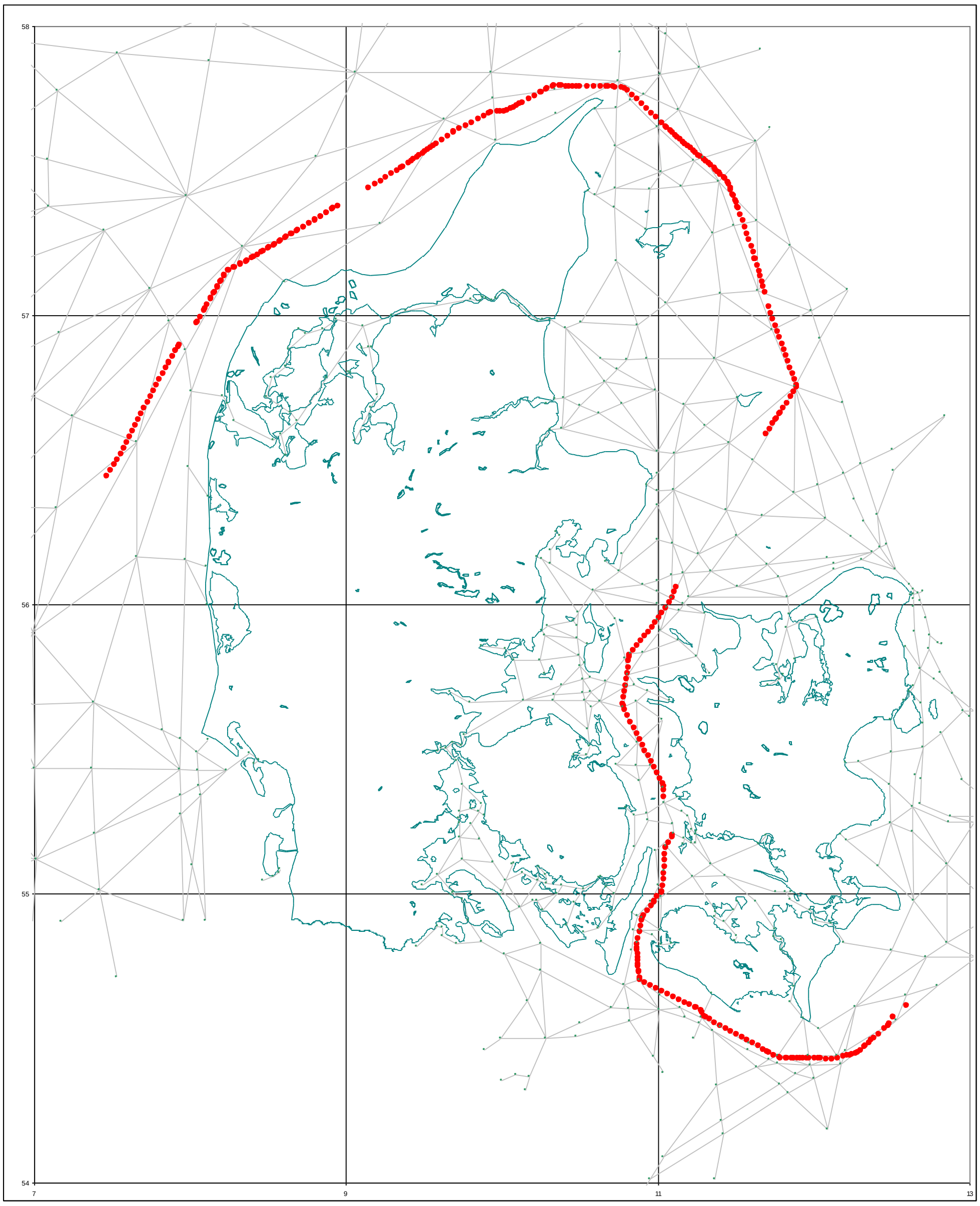


Figure 3-5 Example of AIS points of an identified trace with pronounced transmission interruptions

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.

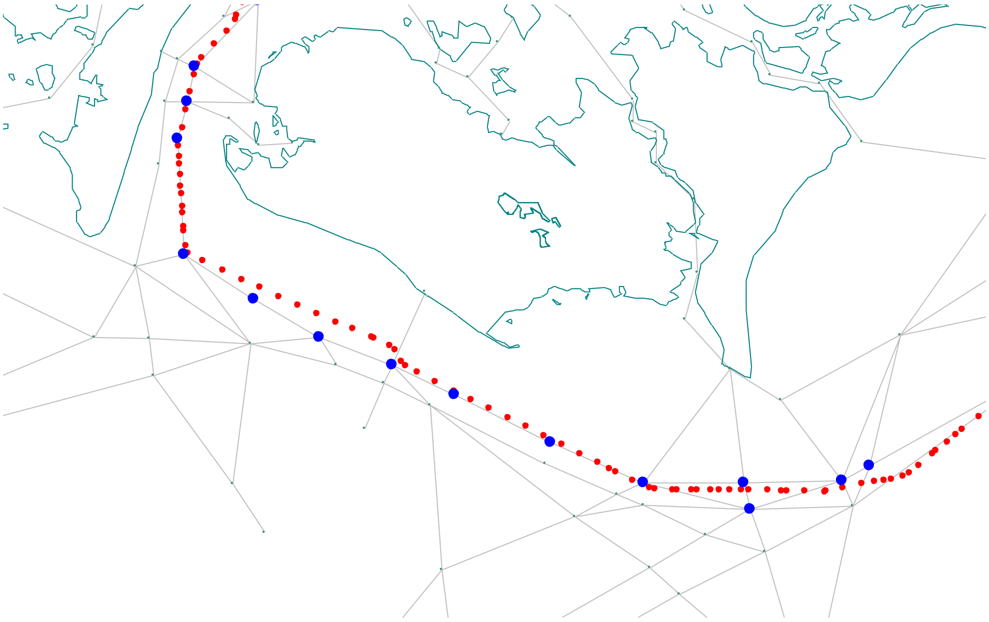


Figure 3-6 Determination of which nodes in the route net are close to the AIS trace

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.

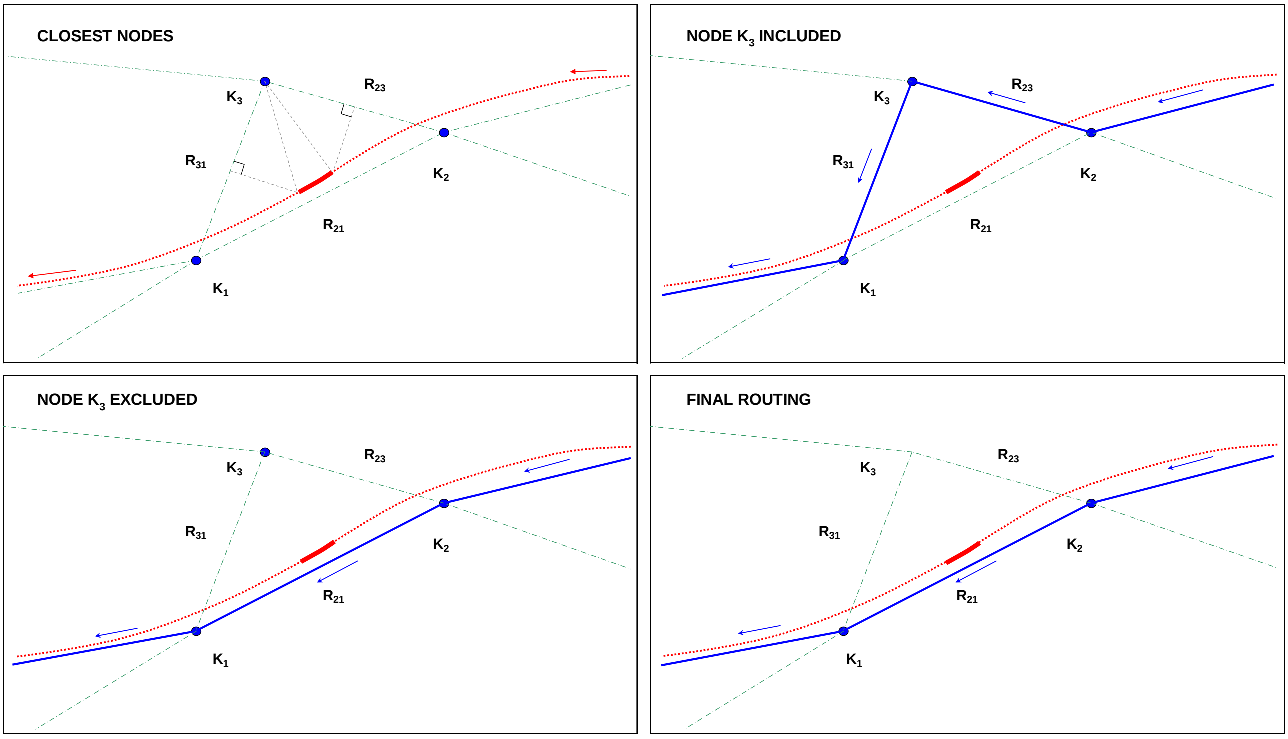


Figure 3-7 An example showing how the closest node (K_3) can mislead the mapping algorithm

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.

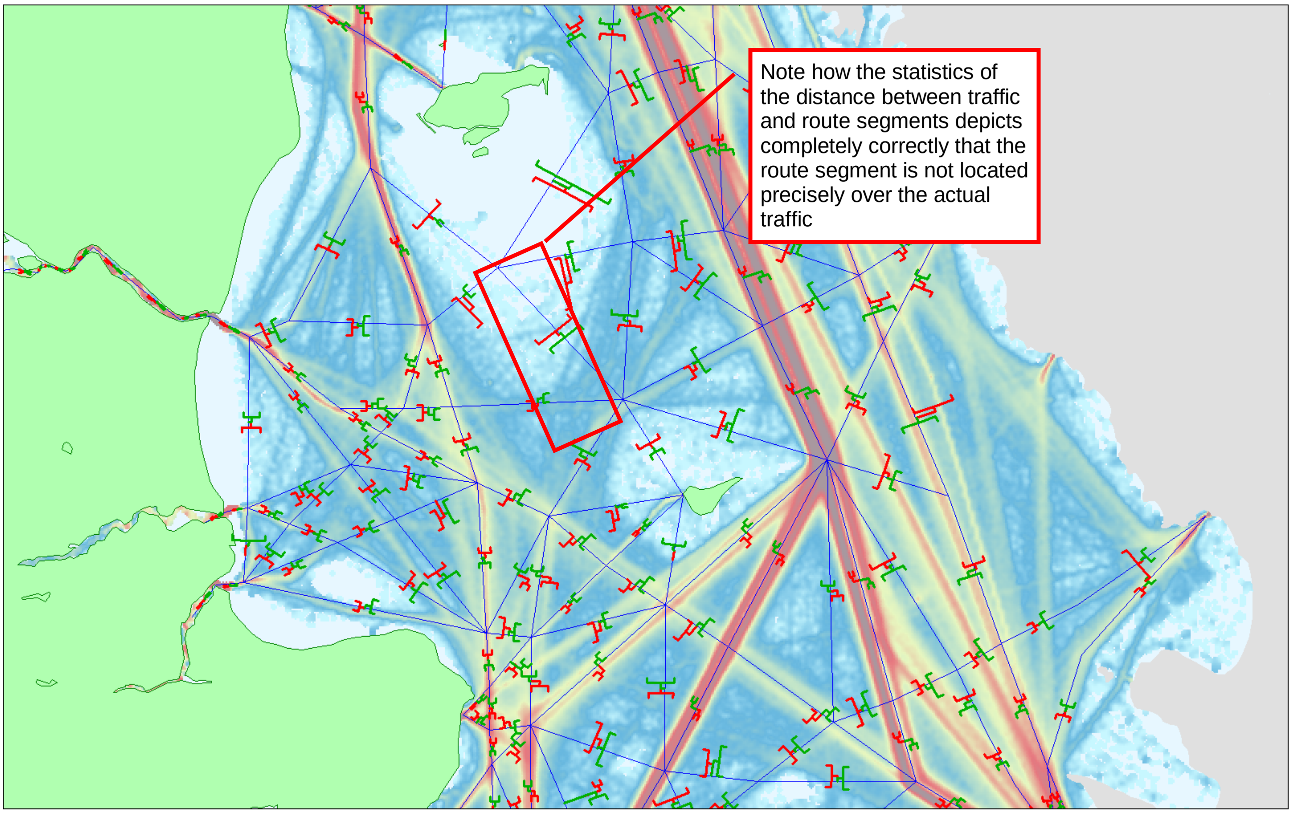


Figure 3-8 Graphic illustration of the mean value and spreading of the distance between vessels and route segment axes. For each route segment and each direction (red/green), an interval covering the average and ± ½ the spreading is shown (COWI, 2007)

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).

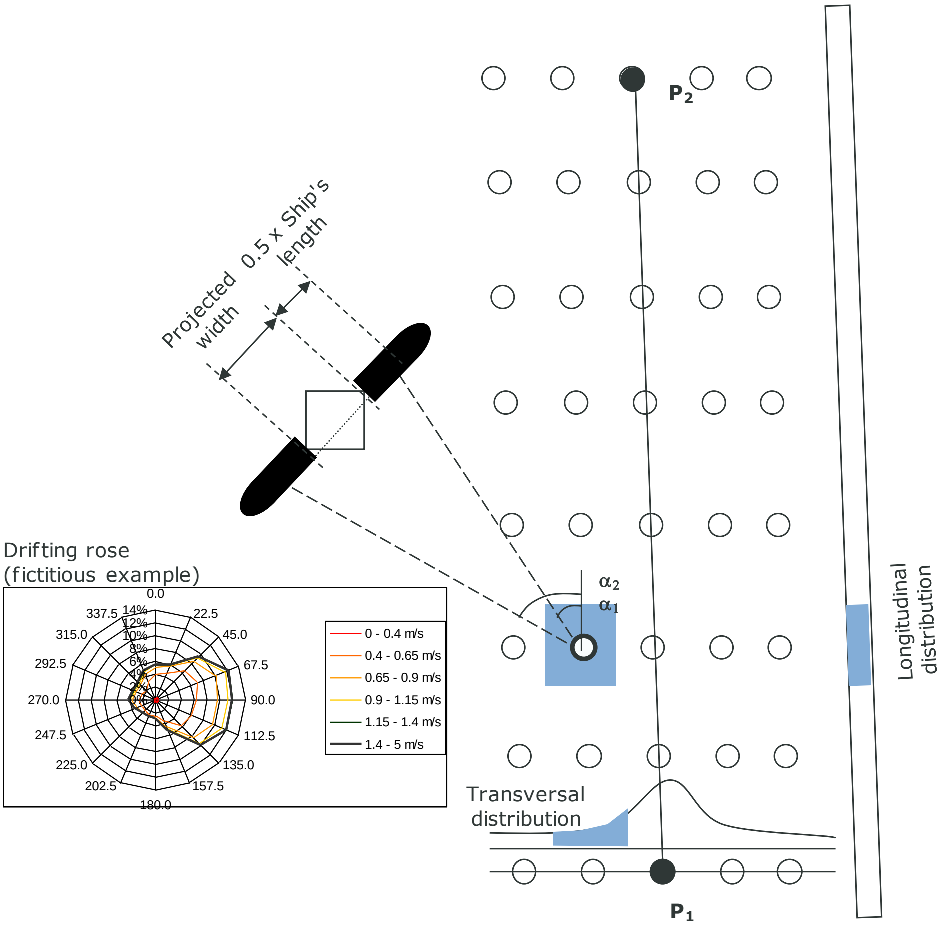


Figure 7-1 Geometric evaluation of the collision frequency for drifting collisions

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

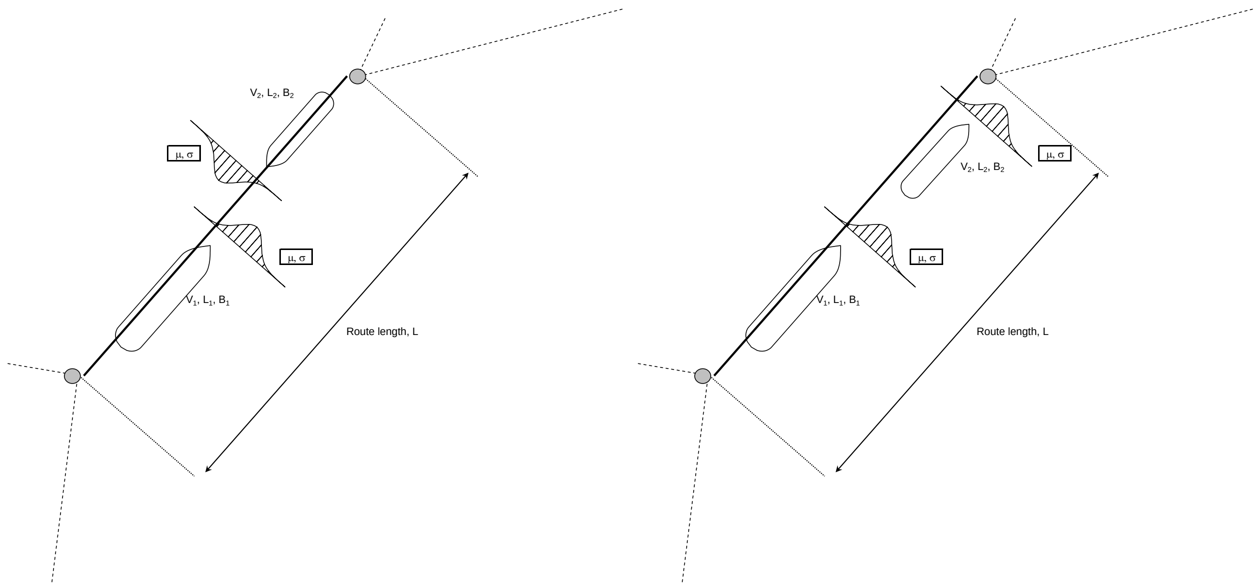


Figure 7-2 Head-on and overtaking collisions

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.

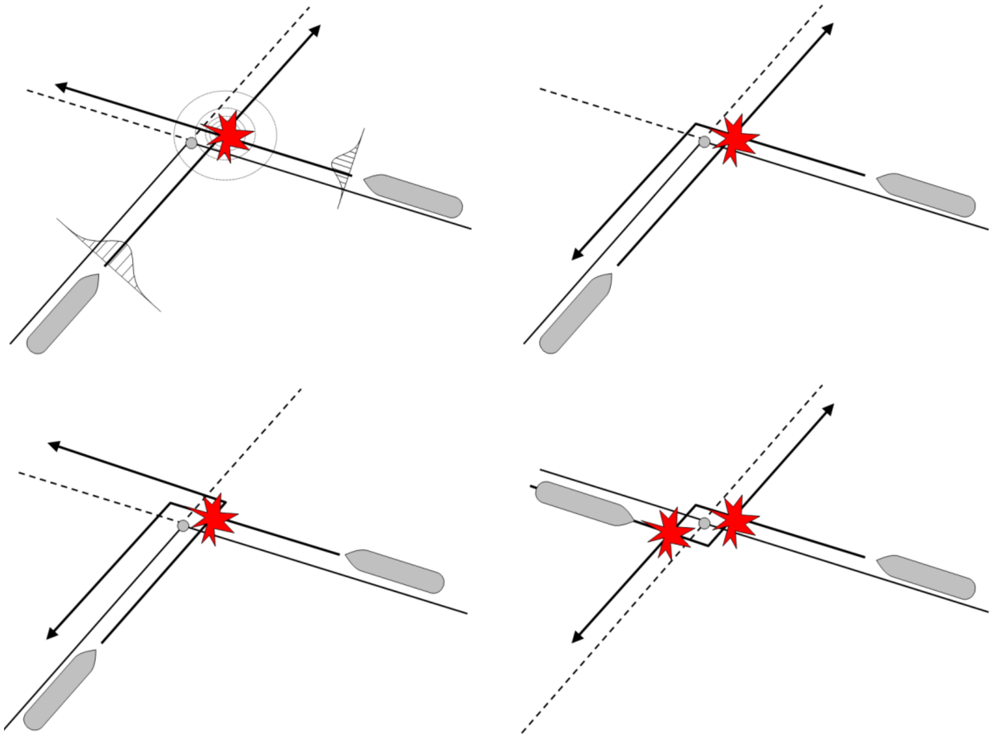


Figure 7-3 shows four important crossing manoeuvres.

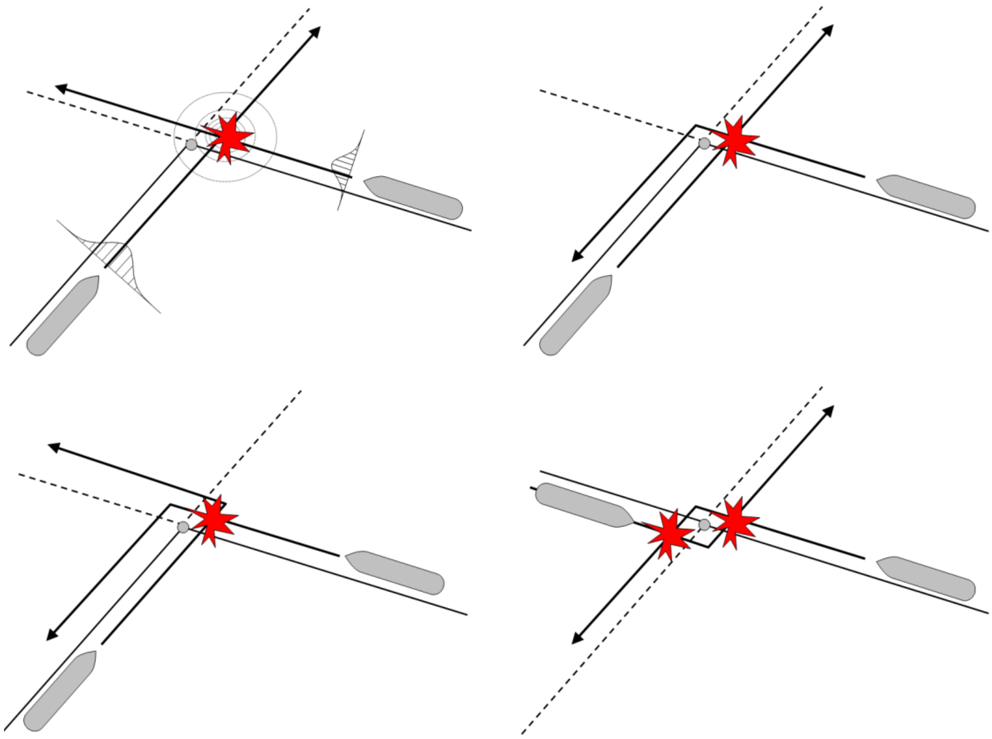


Figure 7-3 Regular crossing collisions and bending/crossing collisions

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

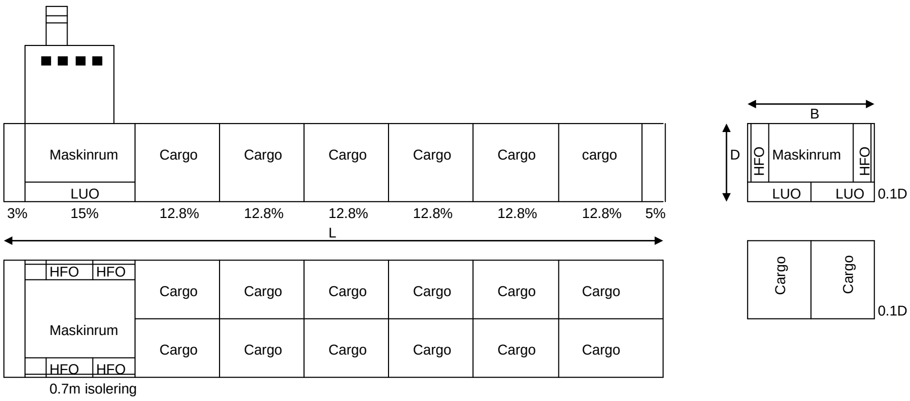
A number of assumptions need to be made in order to determine the amount of bunker oil and eventual cargo emerging in case of hull damage:

- 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

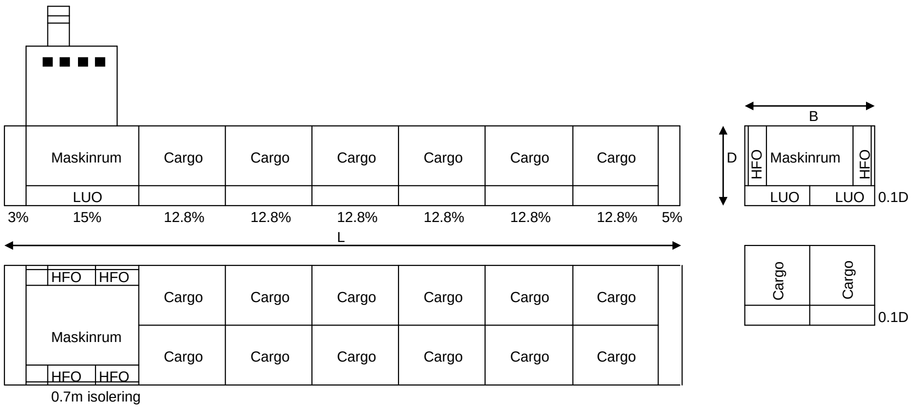
- Triangular distribution of the collision speed from 0 to vmax with 2/3 vmax as the most probable case
- Collision angles in the interval 30 to 150°

- 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

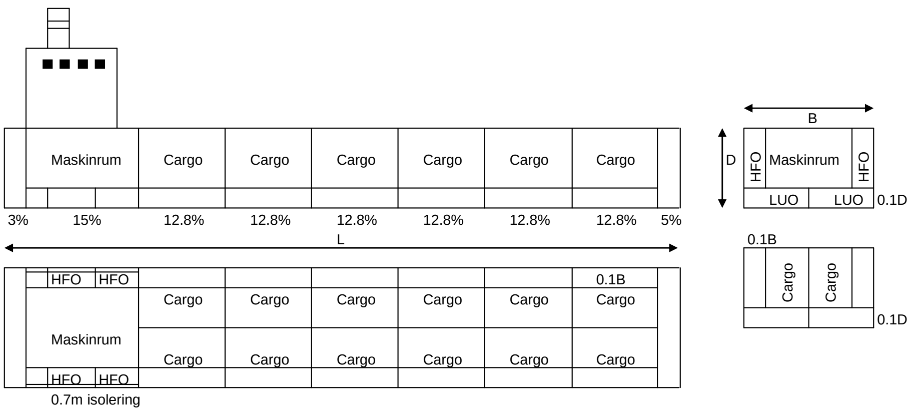


Figure 7-4 Idealised tankers used for determining the spill in case of hull damage

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

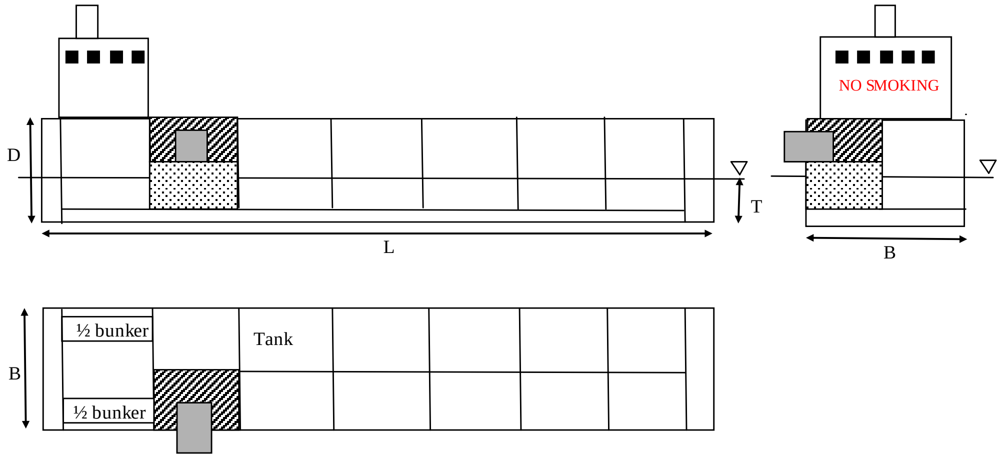


Figure 7-5: Example of a penetration above the water line. The shaded part is leaked. The dotted part remains in the tank.

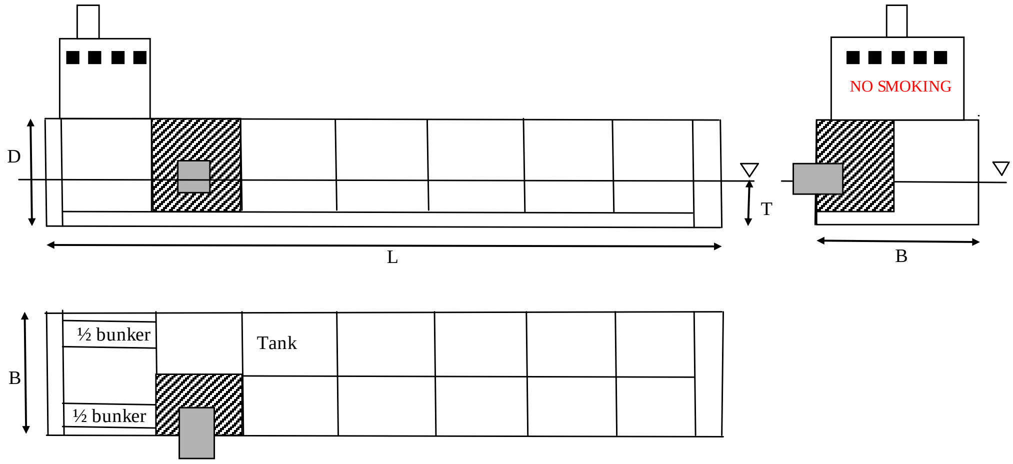


Figure 7-6: Example of a penetration below the water line. The entire shaded part is leaked.

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.

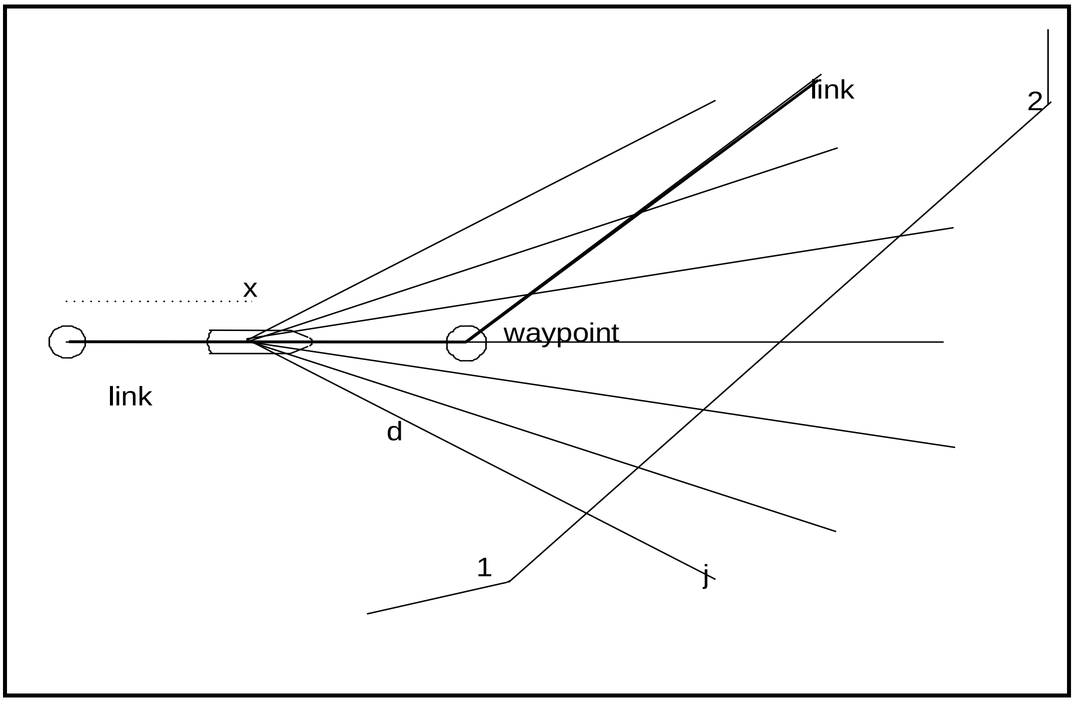


Figure 8-1 Definition of ramming opportunity

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.

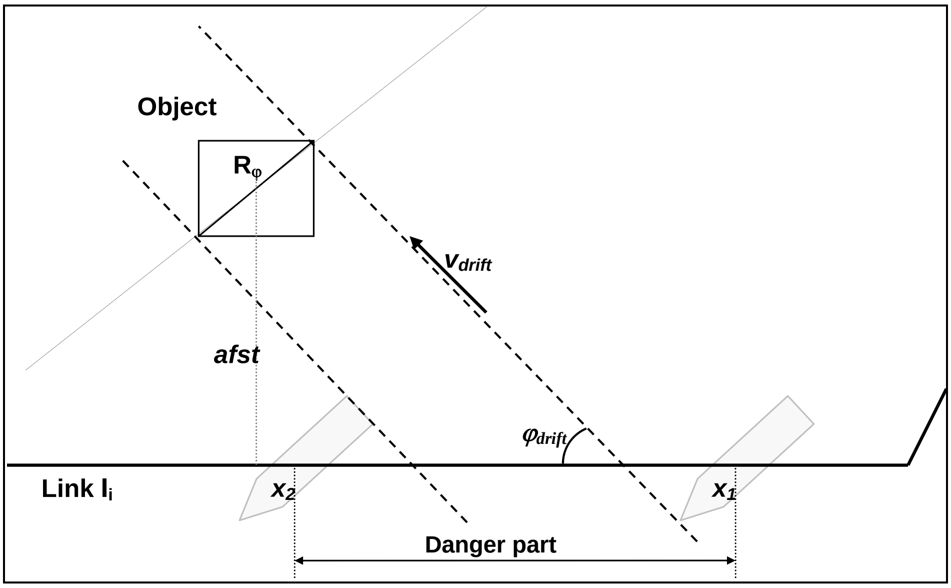


Figure 8-2 Definition of a drifting contact

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:

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

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:

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

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:

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

$CASRAT_{EF0-7}$ … 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

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