Admiral Danish Fleet HQ, National Operation,
Maritime Environment

Project on sub-regional risk of spill of oil and hazardous substances in the Baltic Sea (BRISK)

Model report: Part 1 - Ship traffic

May 2012

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Approved CRJ

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1 Introduction

1.1 Background

The present data report is part of the Project on sub-regional risk of spill of oil and hazardous substances in the Baltic Sea (BRISK). BRISK work package 3 consists of the following work steps:

1 Method definition

2 Data collection

3 Model modification

<u>Part 1: Ship traffic</u> *(covered by the present report)*

Part 2: Transport of oil and hazardous substances

Part 3: Vulnerability areas and classification of vulnerability and damage

Part 4: Frequency and quantity of spill of oil and hazardous substances

Part 5: Spreading and containment of spilt oil and hazardous substances

4 Assessment of risk of pollution

5 Identification of need for adequate resources

6 Existing resources

7 Need for additional resources

1.2 Scope

Work step 3 (model modification)

Work step 3 (model modification) is based on the two preceding work steps 1 (method definition) and 2 (data collection). Its aim is to implement the chosen methodology, i.e. to process the collected data and to prepare the computational tools for the subsequent risk assessment in work step 4.

Work step 3 is named *model modification*, because it is based on a similar model that has earlier been applied to the Danish waters. Thus, the model is not created from scratch, but only modified, adapted and extended.

Sub-report on ship traffic

The present part 1 of the Model report deals with the ship traffic model. As decided in work step 1 (method definition), only ships of 300 gross tonnage and more are considered in the model. Apart from the limited spill potential of smaller ships, this decision is also linked to the availability of vessel traffic data via AIS (Automatic Identification System). AIS data are only sporadically available for smaller ships, which are not covered by SOLAS' requirement of carrying an AIS device on board.

The sub-report on ship traffic is divided into the following chapters:

Chapter 2: Ship traffic data

Chapter 3: AIS analysis

Chapter 4: Ice and ice-free seasons

Chapter 5: Flow of goods

Chapter 6: Prognosis

2 Ship traffic data

HELCOM AIS

HELCOM's AIS database is the primary data source for establishing the traffic model. This database stores AIS reports at six-minute intervals from all vessels in the HELCOM area equipped with AIS transceivers. In order to eliminate seasonal differences and in order to provide statistically significant amount of data we analyze AIS records for a 365-day long period of time. A period lasting from 1 July 2008 to 30 June 2009 is chosen as reference. This is mainly due to the duration of the ice season, which during winter 2008/2009 was close to an average winter.

Lloyd's Register

Lloyd's Register (LR) is a database containing information on a large number of vessel's parameters. Since every vessel has a unique IMO number, which is both used in LR and for AIS, it is possible to determine relevant vessel characteristics for the vessels recorded in the AIS database (type, size, geometry, single or double hull etc.).

3 AIS analysis

3.1 Basics

AIS data reports consist of position reports (POS) and static reports (STAT). Full description of the content of those reports can be found in the document:

RECOMMENDATION ITU-R M. 1371-1

published by *International Telecommunication Union (ITU)*. Here we give only short description of the AIS data focusing on information important for the project.

POS reports

POS reports contain information about dynamic properties of the vessel such as position, speed, course etc. together with a MMSI number as an identifier. AIS transceivers broadcast those data every 2 to 10 seconds depending on the vessels speed and every 3 minutes while the vessel is at anchor. Data such as position, speed and course are automatically generated.

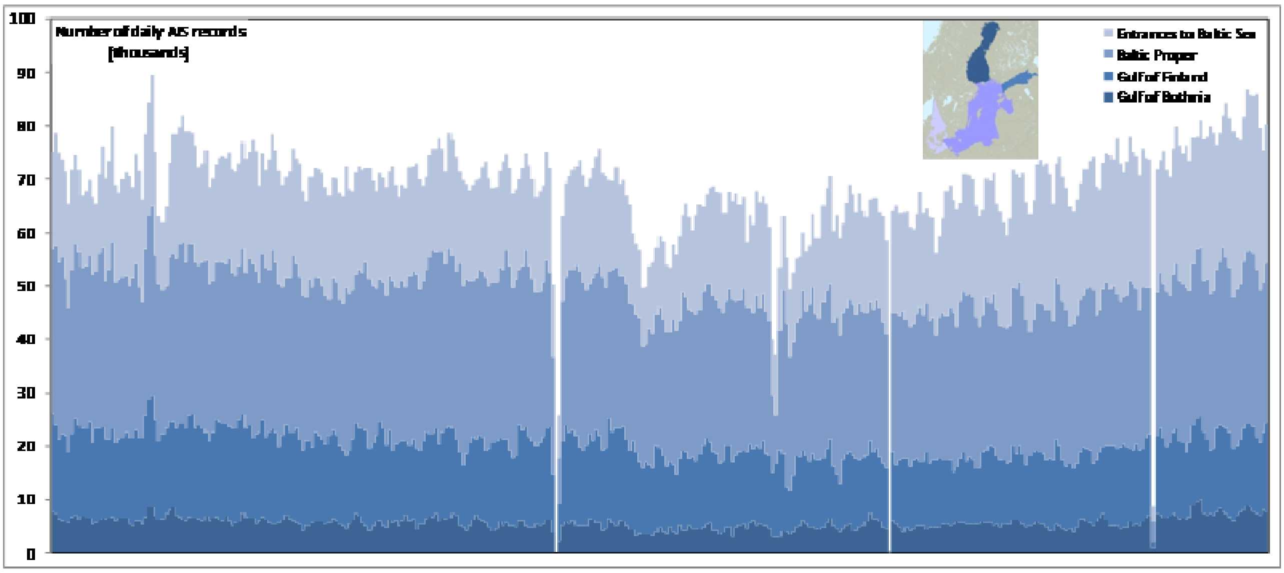
STAT reports

STAT reports contain information about the vessel itself, amongst others MMSI number, IMO number, vessel's name, radio call sign, size, actual draught, category of potentially hazardous cargo and position of AIS transmitter relative to the ship. Those data are broadcast every 6 minutes and they are continuously updated by the vessels crew, so it happens that they are not valid.

Analysis of the HELCOM-AIS data in this project has focused on the basic and most reliable part of AIS data -vessels position and identification. In some cases though, we had to use some information from the STAT records for better vessel identification.

3.2 Compression

AIS data have been delivered by Farvandsvæsenet (Danish Maritime Safety Administration) in a form of 12 text files (112.5 GB). We received data as a one dataset which means that POS reports have been compiled with STAT reports. In general the AIS records for a particular ship should be stored at 6 minutes intervals, which turned out not always to be the case. We received over 300 millions AIS records. By filtering out data from ships with class 2, not under operation, at interval shorter than 5 min etc. and reports from small pilot vessels without IMO number we reduced our dataset size to 36% of original size. Since in our traffic model we take into account only ships larger than 300 GT and sailing within analysis' area we reduced the number of records that went directly to the ship track analysis procedure to 27% of the original dataset. Daily variation of number of AIS reports in different regions of Baltic Sea are



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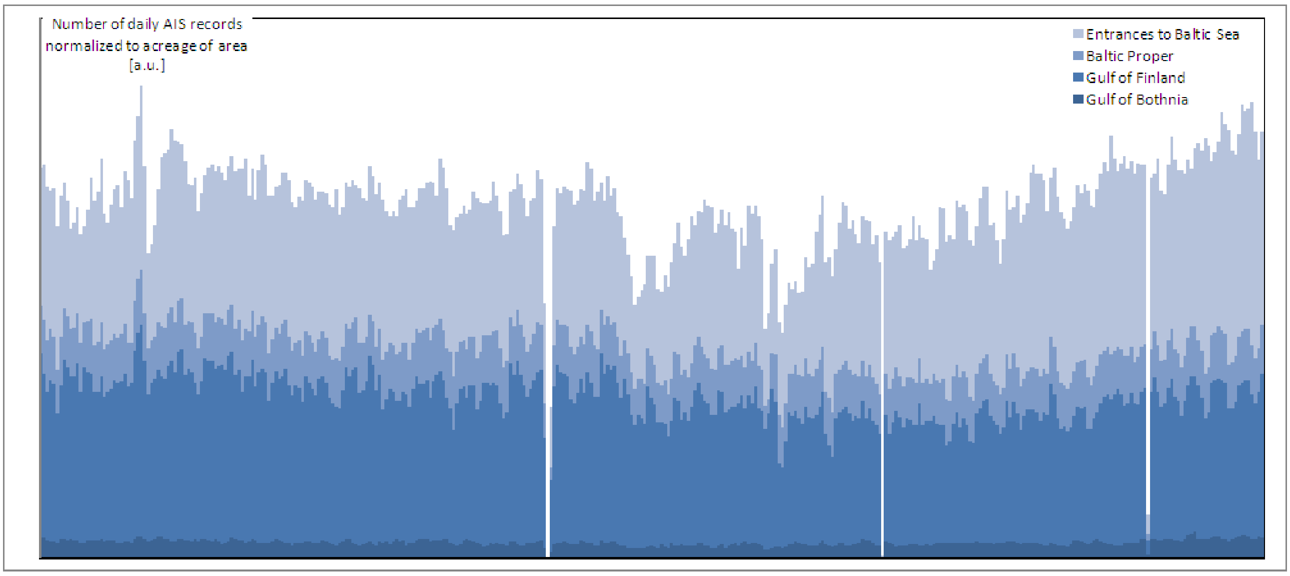

2009 normalized to the
he Baltic Sea.

presented in Figure 3.1. The same data as in Figure 3.1, but renormalized to the sizes of the different areas of the Baltic Sea are shown in Figure 3.2 (weighing parameters corresponding to the sizes of the areas: Bothnia : Finland : Proper : Entrances   12 : 3 : 19 : 4). In this manner we get simplified information about the density of the traffic in the areas. One easily can see that the densest traffic is in the Gulf of Finland and in the Entrances to the Baltic Sea. Therefore great care was taken for those two areas with densest traffic when the net of sea routes was created.

3.3 Traffic intensity

As a basis for the further analysis, it is necessary to determine the resulting traffic intensity for the entire Baltic Sea area. This intensity should – apart from confirming a correct data processing – be suitable as a decision basis for the generation of the routes and the following data analysis (Section 3.4).

The intensity is determined by following the trace of a specific vessel – longitude, latitude – 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 3.3)

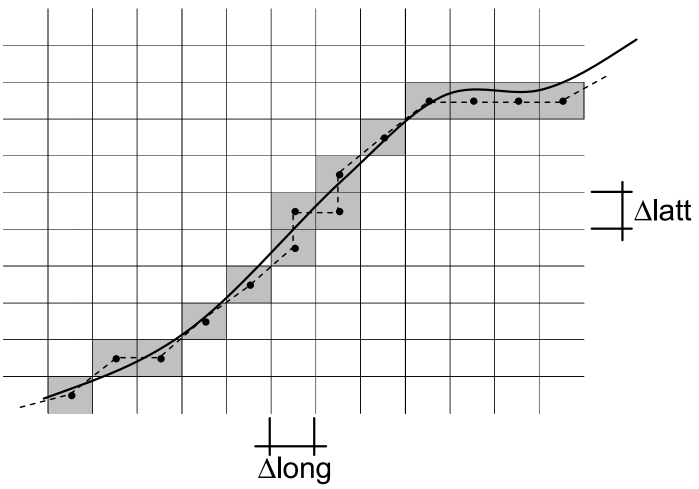

Figure 3.3 Digitalisation of a vessel's trace for determining the traffic intensity

Even if the trace should have more than one AIS report within a cell, only cell passages are counted. In this way, the additional weight given to very slow ships compared to fast ships in the calculation of intensity is reduced. Moreover, anchoring vessels and vessels in harbours are kept from distorting the intensity plot (our approach corresponds to those used in commercially available AIS data programme packages). Because our AIS reports are at intervals larger than 5 min and cell size is roughly 500m x 500m it means that in most cases the digitalised trace consists of cells that do not adhere (500m in 5 minutes corresponds to 3.1 knots which is significantly less than the normal vessel speed). That means that counts per cell cannot be straightforwardly translated into the number of vessels populating the route. It also means that faster vessels leave 'fewer footprints' and slower vessels leave 'more footprints'.

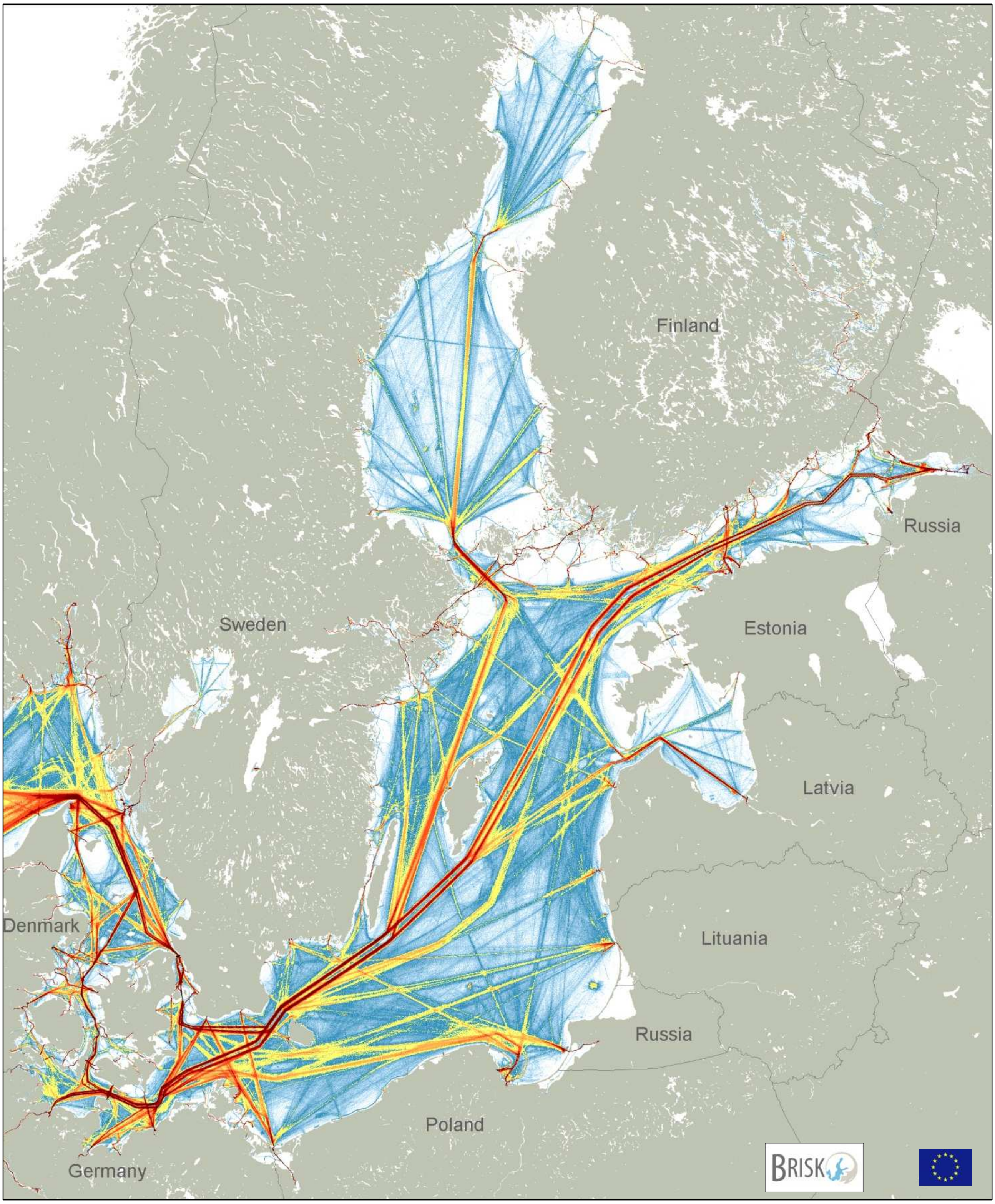

Figure 3.4 Map of traffic intensity based on counted passages per cell.

Figure 3.4 shows the map of traffic intensity for the whole Baltic Sea area based on counted passages trough the cells of size approx. 500m x 500m. The colour scale is not linear and therefore not only most trafficked routes are visible. One can easily notice that the traffic has a tendency to concentrate along routes. It is especially well distinguishable in narrow navigation channels such as sounds (ex. The Sound or The Great Belt) or in areas with existing traffic separation schemes (ex. TSS "Off Gotland Island" or TSS "Off Hankoniemi Peninsula"). 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. One can also notice areas where the traffic intensity seems to diminish which can be caused by the large distance to the shore and hence some of the transmitted radio AIS reports are missing or not correctly recorded (ex. Bothnia Sea).

3.4 Route generation and analysis

The envisaged method for modelling ship collision risk requires that the ship traffic is modelled in a reasonable manner. Traffic tendency to concentrate along routes indicates that populated route net could be representative approximation of the sea traffic. Even the fact that the traffic on some routes is spread loosely to both sides of the route axis does not cause any conceptual problems (compare ship collision model in part 4 of the Model Report)

Route generation and analysis means:

- definition of a geographic route net, which can represent the vessel's movements in the Baltic Sea with good precision
- mathematical analysis of the route net, i.e. to determine the shortest possible paths through the net between any two locations
- mapping of the AIS trace, i.e. to associate each AIS point with a route net segment
- determination of 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 manually by creating a route net on a background map consisting of an intensity plot and a sea chart. This work is performed in a GIS programme (MapInfo 10). Once the route net has been defined, its geometry is exported to Excel for further analysis and in order to check its consistency (all route ends meeting at one node shall have the same coordinates).

Final route net used in our analysis is shown in Figure 3.5. Our route net consists of two types of elements:

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

Figure 3.5 Defined route net used in analysis of AIS records Blue line is the analysis boundary.

Route net goes beyond the geographical boundary (dashed, blue line in Figure 3.5) of our analysis and this fact enables beginning of mapping of the AIS traces a bit outside analysis area. In this way we should avoid boundary problems with mapping of AIS traces inside analysis area. Hence our mapping should be more reliable. In general, the route net is more detailed in areas with heavy traffic than in other areas. The Bothnian Bay is an exception to this rule. Here, extra detail was necessary in order to represent traffic in the ice and ice-free season on a single route net (see Chapter 4)

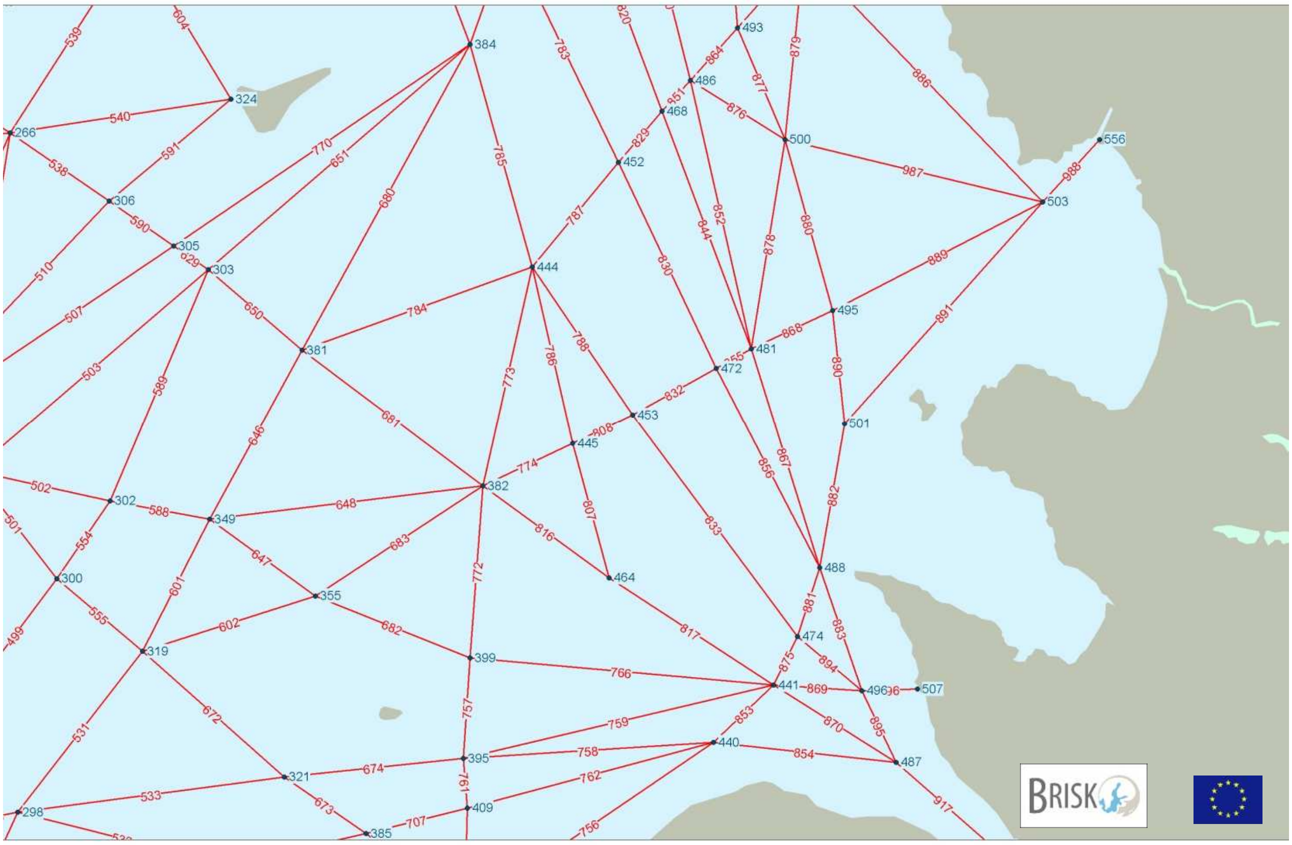

Figure 3.6 Example of enumerated route segments and nodes

Analysis of the route net

The route net defines different possible ways to travel 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 based on Markov network logic. The results are deposited in two separate matrixes which are created for the particular route net. The two matrixes are:

- *NN(i,j)*
  matrix describes that the shortest way from node *i* to node *j* starts by going from node *i* to *NN(i,j)*

- *ML(i,j)*
  matrix contains the length of the shortest way from node *i* to node *j*

Data structure of route traffic

Representation of the vessel's passage through the route net consists a list of used route segments. Therefore representation can be stored as a table with the sequence of route segments:

TrackNo	IMO	Time	RouteNo
…	…	…	…
1184064	8318128	2008-08-06 12:30:57	-545
1184064	8318128	2008-08-06 13:20:17	546
1184064	8318128	2008-08-06 13:32:37	594
1184064	8318128	2008-08-06 13:50:54	635
1184064	8318128	2008-08-06 14:28:27	663
1184064	8318128	2008-08-06 15:23:35	-698
…	…	…	…

Adding a sign in front of the route segment is a simple way of marking the passage direction.

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 3.7). It would simplify the mapping procedure significantly to neglect missing sequences. However, this would result in a systematic underestimation of the traffic in certain areas, 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.

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 7 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)

With these conditions, the most significant errors are filtered away and the trace is interrupted, if the vessel stops. The latter is chosen in order to obtain two separate traces in case of a vessel lying in a port or at anchor.

When a sequence of AIS points has been recognized as a continuous trace (as shown in Figure 3.7), an algorithm regards the point sequence and determines, which nodes are passed at the closest distance (see Figure 3.8).

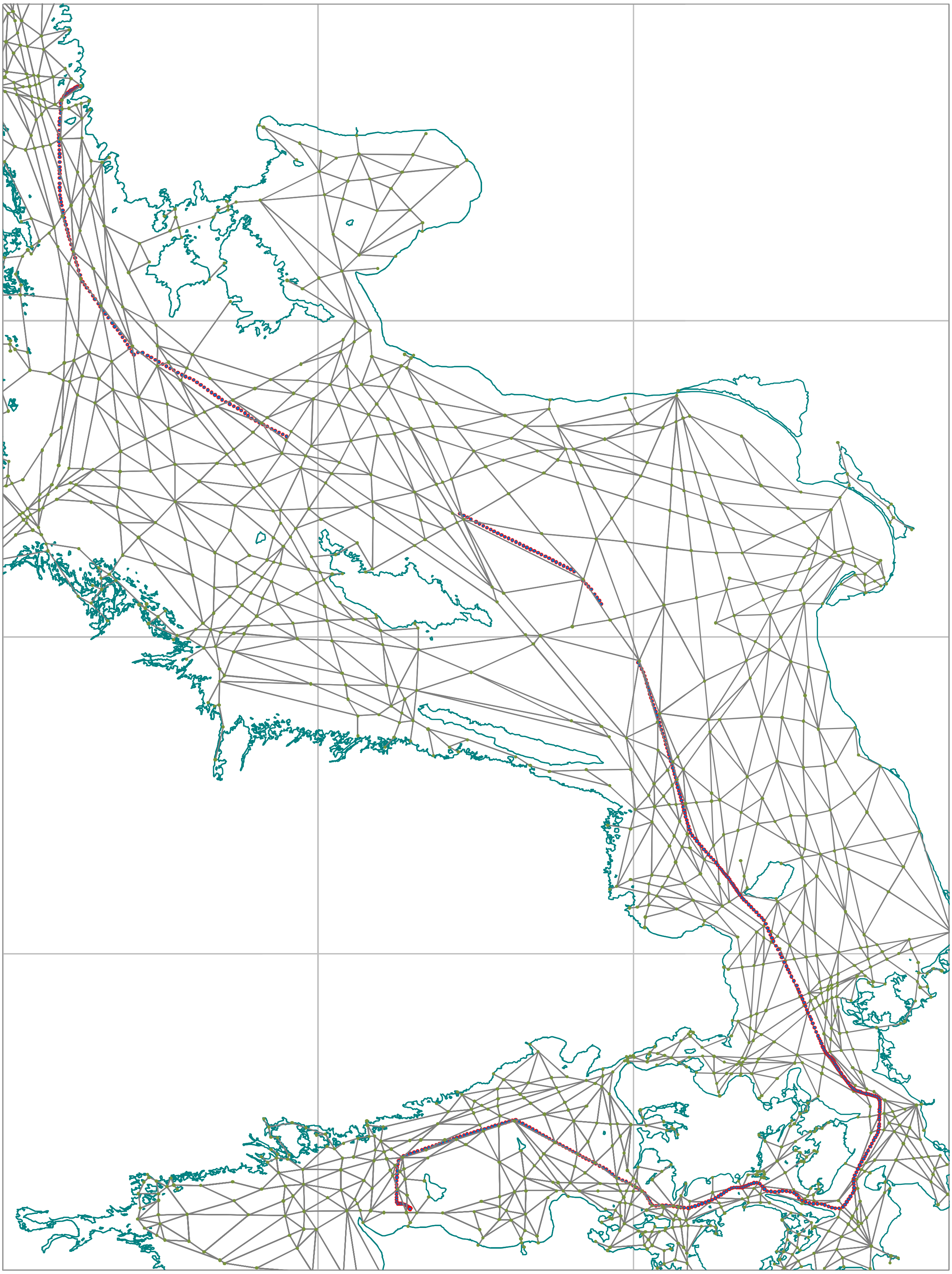

Figure 3.7 Example ot the AIS points for identified track with cleardropout of AIS reports.

To limit the number of analysis iterations it has been necessary to simplify and optimize this determination of the closest nodes to the trace. It is done by, among others determination of the closest node once for a number of points evenly distributed (additional grid) in the area of analysis and storing the results in the table. So in the analysis of AIS points we determine first the closest grid nodes and via above mentioned reference table we find directly the closest route net nodes. This additional, discrete grid used in this approximation method has sufficiently good resolution (500m in both directions) to assure that no major errors happen while determining the node closest to the AIS track.

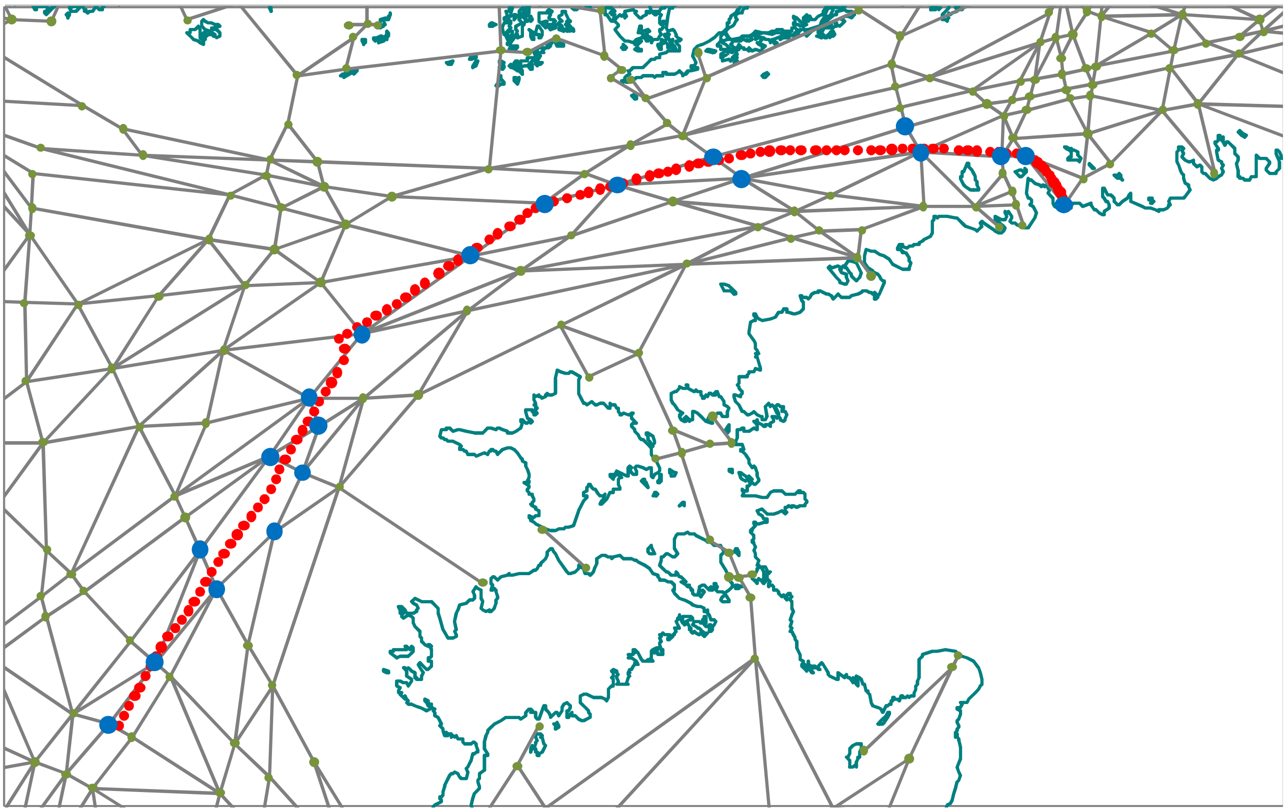

Figure 3.8 Determination of which nodes are closet to the AIS track.

Once the sequence of route net nodes has been determined, another recursive algorithm determines which nodes are essential to achieve best possible track representation. Algorithm starts with first and last track nodes and finds node that lies closest to the centre of the track between those start and end nodes. Here, sequence of nodes is split into two, and each of the two sequences is treated with this recursive method. Quality of the track mapping onto route net including this centre node is checked after each new subdivision of node sequences. If quality improves or stays unchanged, the centre node is taken into account. If quality deteriorates, it means that including the new node gives inconsistence in tracks global way and logic of the route net. Evaluation of track representation quality is carried out by comparison of the route track length with the real track length (calculated via numerical integration). This quality check is robust and fast method to apply in the main algorithm.

This additional procedure is necessary, because systematic determination of sequences of the closest nodes often give nodes that are leading mapping algorithm astray (see Figure 3.9).

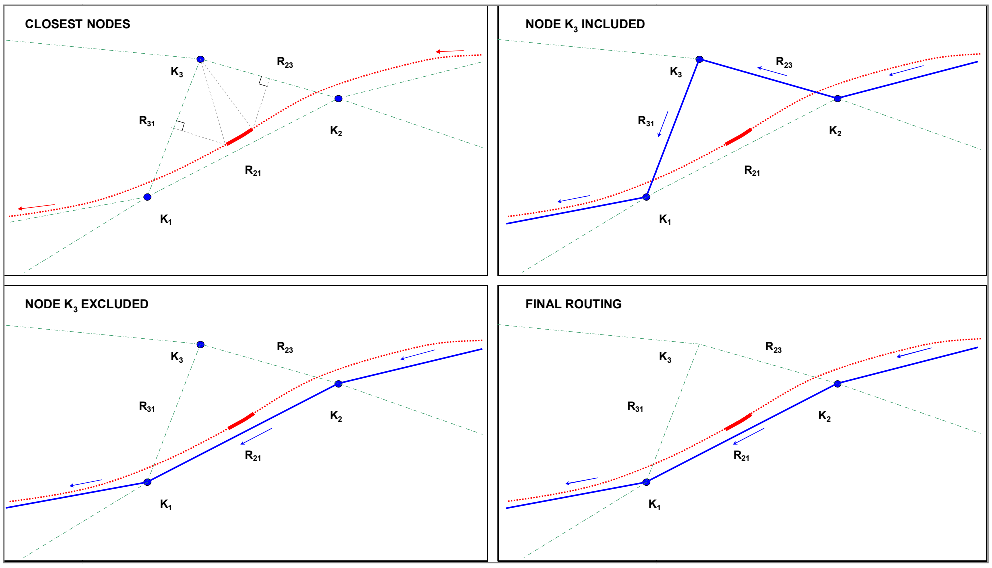

Figure 3.9 An example showing how the closest node (K_3) can mislead the mapping algorithm

Example shows identified nodes closest to the track as nodes $\mathbf{K_1}$, $\mathbf{K_2}$ and $\mathbf{K_3}$. While taking into account centre node $\mathbf{K_3}$ makes route length too large ($\mathbf{R_{23}}$+$\mathbf{R_{31}}$) in comparison with the actual track length, omitting node $\mathbf{K_3}$ gives good approximation ($\mathbf{R_{21}}$) of the track length. Situation would be even worse if route segment $\mathbf{R_{21}}$ did not exist - see Figure 3.10. In such a case including node $\mathbf{K_3}$ leads to "dead end" and even large increase of route length. Applying quality check algorithm removes those types of errors.

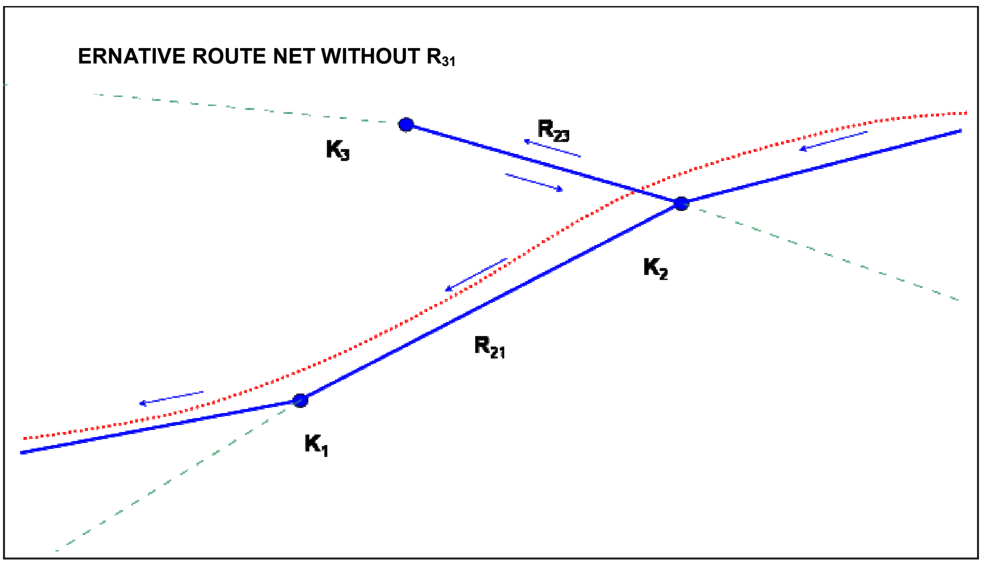

Figure 3.10 Example of misleading track mapping.

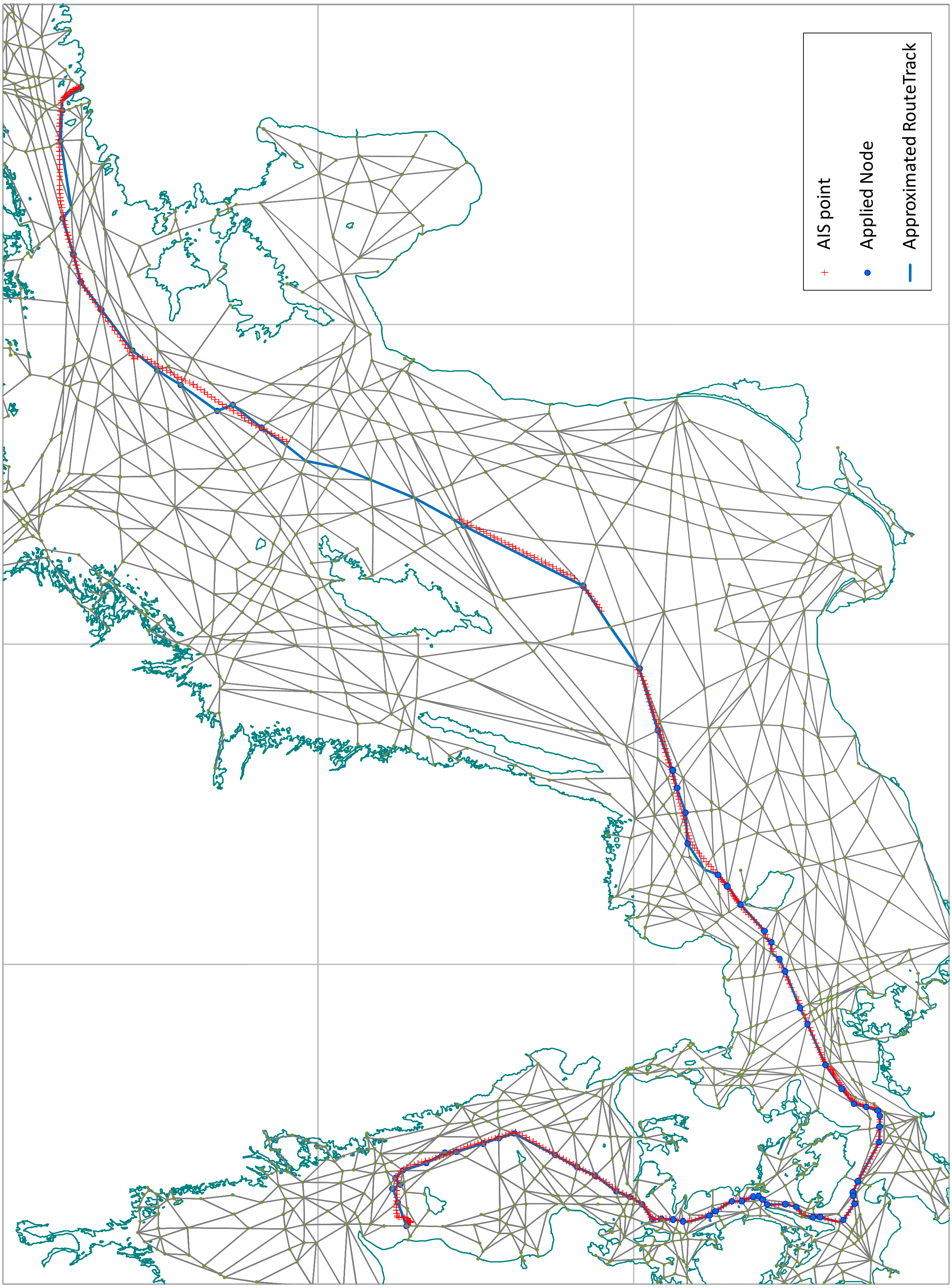

Figure 3.11 Example of the mapping of the AIS track with clear AIS report's dropout.

Described procedures enable reliable route mapping even for tracks with AIS reports' dropout. Results of algorithm calculations are presented in *Figure 3.11*.

After the track has been determined, it is noted which AIS points have actively contributed to the track mapping and which route segments are included in this track.

Key results for track mapping usage of AIS reports

Total number of AIS reports.. 319,477,926

In the process we filtered out AIS reports where:

Target class equals 2... 14,613,026

Time interval smaller than 5min 125,406,749

Reports from small pilot vessels.. 14,664,316

Position not changed... 50,313,049

Number of records per vessel smaller than 5.............................. 11,487

Position outside of the analysis area 2,095,261

Result

AIS reports in the analysis area 112,374,038

AIS reports from ships large enough to qualify to the track tracing process 85,596,822

AIS reports with identified track 67,535,206

AIS reports that got assigned route track............................. 41,558,821

Identified route passages 7,752,935

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 Part 4 of the Model Report).

3.5 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 reports are missing or incomplete
- vessels that do not send correct AIS information and therefore cannot be identified
- 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 AIS reports per day is plotted as a function of time (Figure 3.1). In this way, outages become evident very quickly and can be compensated by means of a calibration factor f_1. There are 2 days without any AIS reports and there are 3 other day where the number of records per day is significantly smaller than for other days of the year. Our estimate of the calibration factor is found to be:

$$f_1 = 1.0082$$

It means that the whole traffic volume has to be resized by 0.82 %.

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

can be examined by comparing the traffic volume with passage statistics based directly on raw AIS data. These passage statistics can be 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. That will result in calibration factor f_2.

The total calibration factor for both effects can be obtained as

$$F = f_1 \times f_2$$

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

In order to verify the calibration, the corrected traffic volume could be compared to the records of a VTS centre, for example Great Belt VTS.

3.6 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 Lloyd's Register 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 Lloyd's Register
- 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 all traffic in the entire Baltic Sea sailing to or from the Kiel Channel – 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 Lloyd's Register 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 identified during the model establishment.

Table 3.1 Ship types used in the model (left) and general groups of types used for preparing statistics and results (right)

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

With GIS system, traffic can be illustrated graphically for individual traffic segments. Examples of this kind of data presentation are in Figure 3.12 and in Figure 3.13.

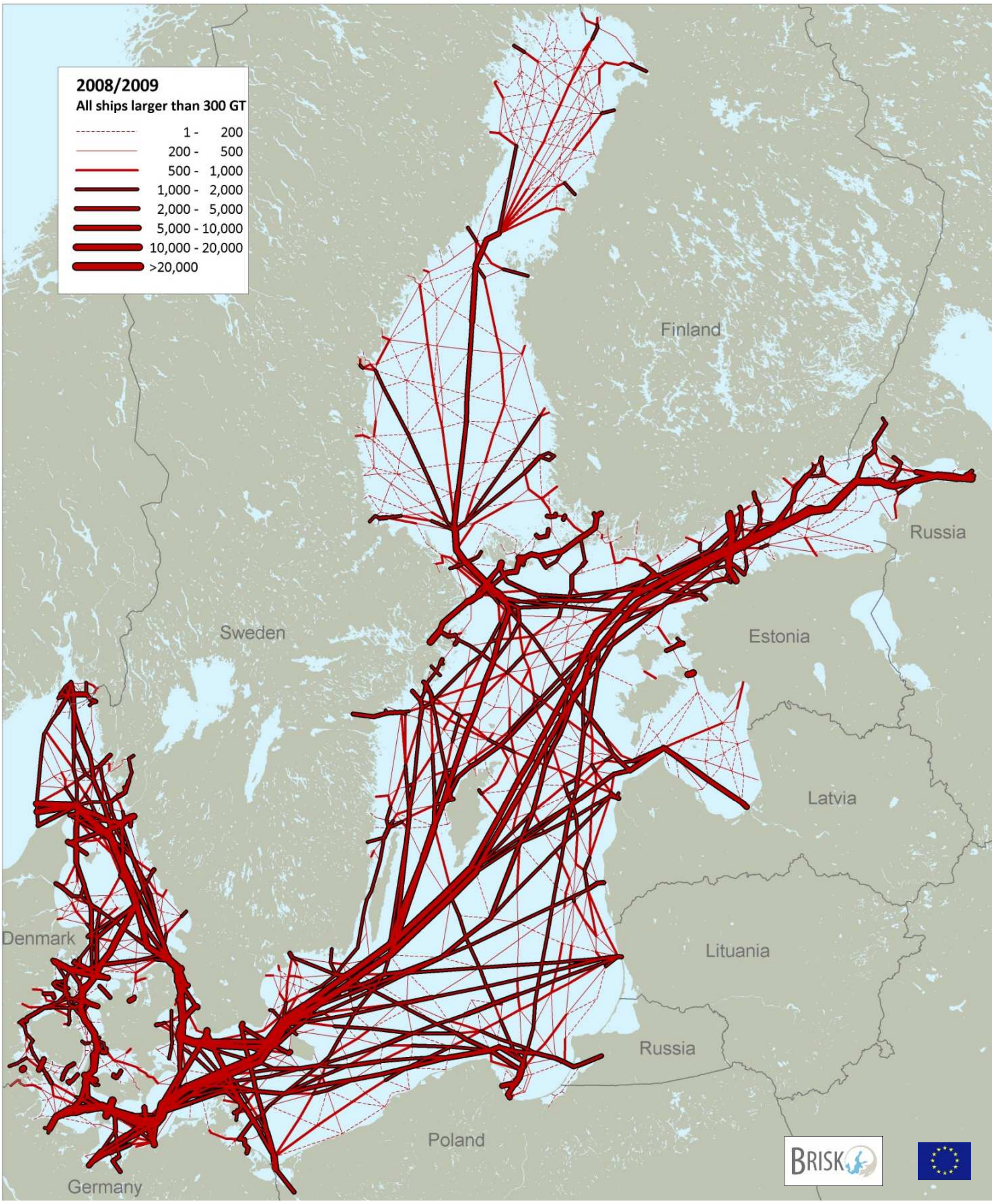

Figure 3.12 Map of the total traffic intensity on route segments of all ships bigger than 300GT in the period from 1July 2008 to 30 June 2009

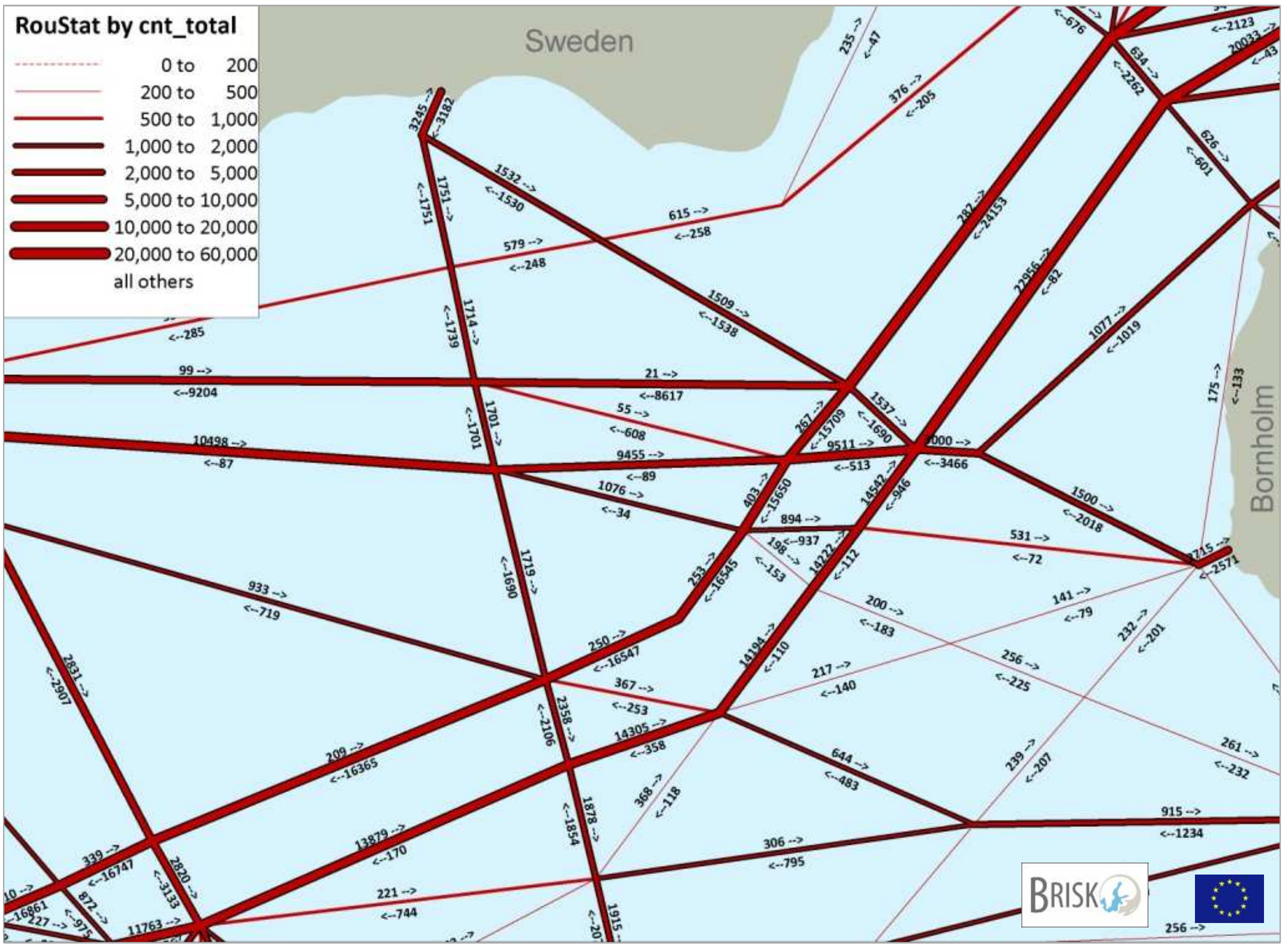

Figure 3.13 Map of the total traffic intensity on route segments of all ships bigger than 300GT - close up of the north-east part of Arkona Sea in the period from 1 July 2009 to 30 June 2009.

4 Ice and ice-free seasons

Effects of sea ice upon ship traffic

Sea ice during winter is a major issue when regarding the Baltic Sea as a whole. Ice channel navigation has a number of effects upon traffic patterns:

- In ice-covered sea areas, ships are essentially bound to use routes with ice channels, i.e. many summer routes will not have any traffic. In general, traffic intensity per route and time unit is different than during the ice-free season.
- Total traffic intensity differs between ice and ice-free season because many journeys are postponed until the end of the ice-season.
- Traffic spreading relative to the route axis is affected both by the shape of the ice channel and the usage of ice-breaker convoys.
- The distance between ships following the same direction is affected by the usage of ice breaker convoys.

All of these effects have an influence upon the accident frequency and thus the frequency of spills (see Part 4 of the Model Report). In order to take them into account, the procedure described in the following section is used.

Route pattern

The approach described in Section 3.4 models the traffic as a discrete route net (Figure 3.5) which is established based on the observed traffic intensities (Figure 3.4). The effect of ice channel navigation in the route layout was implemented by

- creating an traffic intensity plot for the ice-free part of the year,
- creating an traffic intensity plot for a period of time, where it is known that the part of the sea was in fact covered by ice
- based on these two plots, establishing *one* route net that is able to reflect both conditions (for methodological reasons, establishing two separate route nets would be very unpractical)

Intensity and spreading along routes

Each route is analysed with respect to traffic intensity (number, type and size of ships) as well as straying relative to the route axis (see Section 3.4). We performed a separate analysis for the ice seasons and the ice-free season each. Separate traffic statistics for the ice season and the ice-free season for the data collection year were established. Of all winters since the introduction of HELCOM AIS, winter 2008/2009 comes closest to the average duration of ice season definition (see Data Report). In analyzed period of time the ice season corresponded roughly to February and March 2009.

In the Gulf of Finland, ice appears first in the east and spreads westwards afterwards. In the less heavily navigated Gulf of Bothnia ice spreads from the north to the south. Therefore, there is no precise “beginning” and “end” of the ice season. Nevertheless, it is proposed to pretend as though this was the case for reasons of methodological simplicity.

In the affected areas, ice affected traffic patterns to a certain degree. It could be observed that ships use fewer routes under ice conditions than under normal conditions. Nevertheless, the routes are the same, i.e. there are just some additional routes during the ice-free season.

The only exception to this observation is the traffic in the Bothnian Bay, i.e. the northernmost part of the Gulf of Bothnia - *Figure 4.1*. Here, traffic patterns during ice season and ice-free season are independent of each other to a high degree.

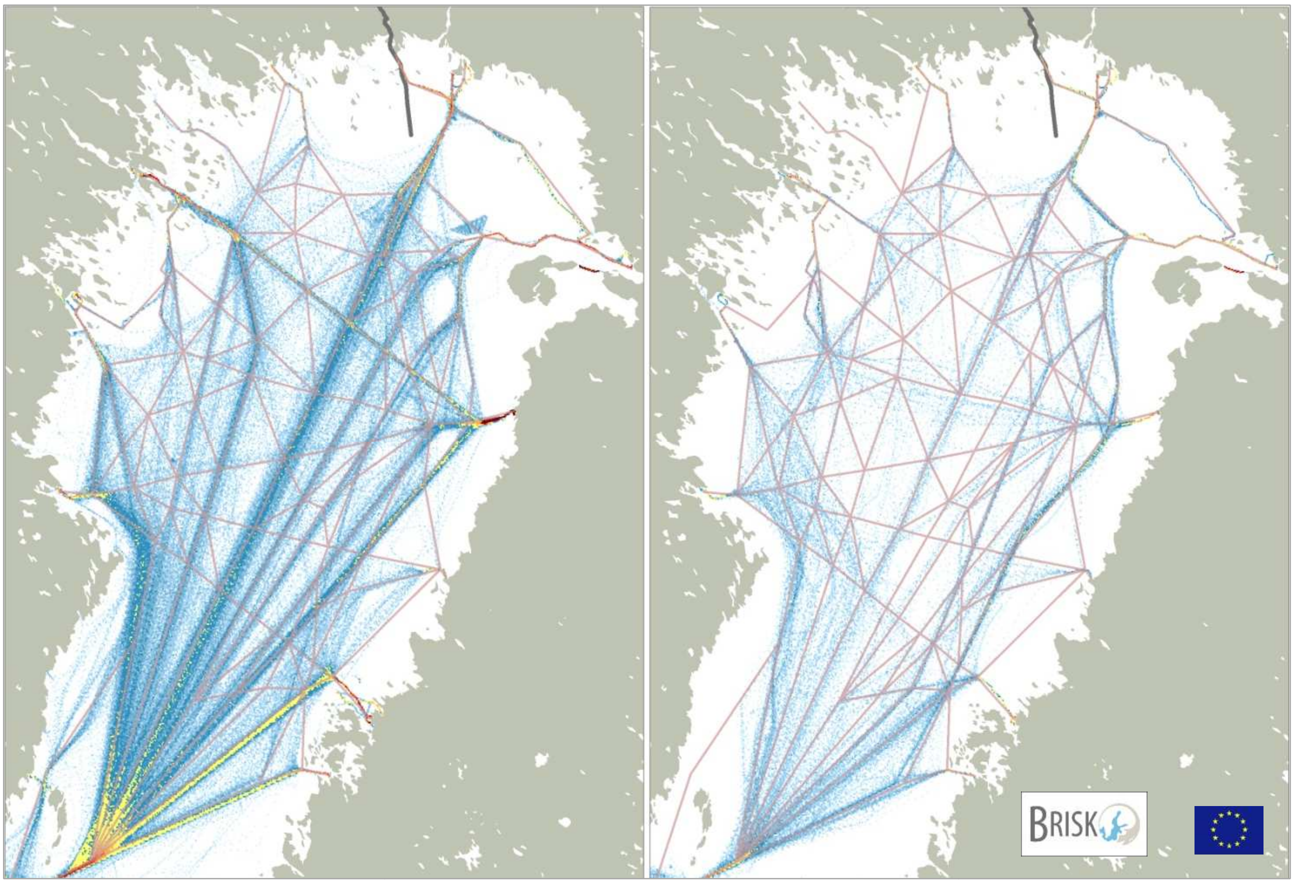

Figure 4.1 Ship traffic density in the Bothnian Bay during ice season (left)and during ice-free season (right)

Note that the traffic intensity in *Figure 4.1* is automatically higher during the ice-free season than during the ice season, because the former lasted 10 months and the latter lasted 2 months in 2008/2009.

The effect of short distances between ships in ice-breaker convoys is modelled directly in the accident model, see Part 4 of the Model Report

5 Flow of goods

Information about the cargo on board the respective ships are of vital importance for predicting, which substances can be released into the maritime environment in case of an accident. Traffic information contained in the recorded AIS data (STAT messages) can in the best case comprise information about the classification of the cargo of a vessel, but those data are not sufficiently detailed and reliable in order to be applied in the risk analysis. Therefore, the transported cargo is investigated in a more detailed way based on data from other sources. The corresponding model is referred to as transport model and is described in Part 2 of Model Report.

6 Prognosis

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 will be modelled as a scenario in addition to the present-day scenario. This requires a realistic prognosis of the traffic development in the mean time.

Data

The prognosis is based on the following sources of information:

- National data on historical transport development and/or prognoses
- The Baltic Marine Outlook 2006, containing a traffic forecast reaching until 2020
- AIS-based traffic data (compare Section3)
- Clarkson Register
- Lloyd's Register

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 market segments, as shown in Table 6.1.

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 tends to remain somewhat constant, whereas the average ship size is steadily increasing /Oil spill DK, 2007/. Therefore, both the volume of transported goods and passengers *and* the fleet development need to be taken into account.

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

Fleet development

In a first step, the development of the global fleet is analysed. The development of the average ship size during 1995-2000 and during 2000-2005 is regarded for each vessel type based on Clarkson Register and Lloyd's Register.

Next, the global development is transferred to the regional situation in the Baltic Sea. 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 Baltic Sea, 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

A detailed description is given in Appendix 1.

Cargo transport

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

1 The basic import and export data for 2003 are obtained from the obtained national data supported by Baltic Maritime Outlook 2006. 20 different types of cargo are considered.

2 A prognosis of the development up to 2020 is obtained from the obtained national data as well as Baltic Maritime Outlook 2006.

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 Table 3.1

7 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 to/from the Baltic Sea for a given type of ship, it is the increase in import that is governing the prognosis.

8 The prognosis is performed based on the information in step 1 to 7.

The prognosis is carried out on the basis of that in /Oil spill DK, 2007/ with two major modifications:

- Due to the global financial crisis, ship traffic is assumed to be constant during the years from 2008 to 2012 (note that this assumption does not affect the fleet development, as ships are assumed to be replaced by larger ships as they reach the end of their service life independently of the development of cargo volumes).
- A number of assumptions on the redistribution of traffic due to the construction of the new Russian port at Ust-Luga are made.

A detailed description is given in Appendix 1.

Passenger transport

Based on the ShipPax report from 2009 or a more recent report (if available), 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 (e.g. construction of the Fehmarn Belt fixed link).

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

A detailed description is given in Appendix 2.

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 3.5 for each ship type, ship size, sea area and sailing direction.

The details of the implementation are described in Appendix 1 and 2 for cargo and passenger ships, respectively.

7 Abbreviations

AIS	Automatic Identification System
BRISK	Project on sub-regional risk of spill of oil and hazardous substances in the Baltic Sea
HELCOM	Baltic Marine Environment Protection Commission (also: Helsinki Commission)
IMO	International Maritime Organisation
LR	Lloyd's Register
MMSI	Maritime Mobile Service Identity
SOLAS	International Convention for Safety of Life at Sea
TSS	Traffic Separation Scheme
VTS	Vessel traffic service

8 References

/Oil spill DK, 2007/ *Risikoanalyse: Olie- og kemikalieforurening i danske farvande (Risk analysis: Oil and chemicals pollution in Danish waters)*, prepared for Danish Ministry of Defence by COWI, COWI report 63743-1-01, October 2007

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Appendix 1: Goods transport prognosis

Appendix 2: Passenger transport prognosis