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BRISK II

Traffic analysis

Deliverable 2.3

HELCOM
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SWEDISH COAST GUARD
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GRÄNSBEVAKNINGSVÄSENDET
FINNISH BORDER GUARD
DANISH MINISTRY OF DEFENCE

This document is developed within the BRISK II project to analyse ship traffic in the Baltic Sea and submitted by the Core Project team on 30.9.2025.

BRISK II, Long-term risk analysis for oil and hazardous and noxious substances (HNS) pollution from shipping accidents to the marine environment in the Baltic Sea, is a project co-funded by the EU.

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1 Introduction

1.1 Background

This data report is part of the long-term risk analysis for oil and hazardous and noxious substances (HNS) pollution from shipping accidents to the marine environment in the Baltic Sea, in short BRISK II. The BRISK II project comprises the following deliverables on the analyses:

1. Deliverables under work package 1 include project management related reports (e.g. progress reports).

2. Work package 2: Basic analysis
   - 2.1 Method note
   - 2.2 Data collection note
   - 2.3 **Traffic analysis *(this report)***
   - 2.4 Cargo analysis
   - 2.5 Accident and spill model
   - 2.6 Probability of oil release

3. Work package 3: Future damage analysis
   - 3.1 Traffic scenarios
   - 3.2 Selection of risk reduction scenarios
   - 3.3 Impact mapping of spilt oil and HNS
   - 3.4 Mapping of environmental vulnerability
   - 3.5 Mapping of environmental damage due to oil
   - 3.6 Mapping of environmental damage due to HNS

1.2 Scope

This report presents the ship traffic model. The model is an idealised (i.e. simplified) representation of the actual traffic observed in 2024. Future traffic scenarios are described in a separate report called Traffic scenarios (deliverable 3.1). The traffic model is the main input for the accident and spill model (deliverable 2.5). Thus, the quality of the traffic analysis is key to the reliability of the project results.

As decided in the Method note (deliverable 2.1), 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 the 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 basics
Chapter 4: Combination and filtering of AIS data
Chapter 5: Traffic density mapping
Chapter 6: Ship traffic route net
Chapter 7: Calibration
Chapter 8: The resulting traffic model

2 Ship traffic data

2.1 HELCOM AIS

The HELCOM AIS server, fed by the Baltic Sea coastal states' national AIS databases, is the primary data source for establishing the traffic model (HELCOM, 2022). This server stores AIS reports with less than six-minute intervals from all vessels in the HELCOM area equipped with AIS transceivers. To capture seasonal variations and to provide a statistically significant amount of data the traffic modelling is based on a full year of AIS data covering the period from 1 January 2024 to 31 December 2024. Since 2024 was a leap year with 29 days in February this period covers in fact 366 days. The HELCOM data has been supplemented with data collected and made publicly available by the Danish Maritime Authority to cover the area North of Skagen that is not included in the HELCOM data. This was necessary to enable the traffic modelling and the underlying AIS data to cover the entire western coastline of Sweden.

2.2 Register Data on Ships

Though a large commercial industry has developed due to the availability of AIS data, the detailed information about the individual ships is still provided – directly or indirectly – by the ship registers overseeing the design and maintenance of the individual vessels. The vessel characteristics needed to supplement the limited information provided with the AIS data (type, size, geometry, single or double hull etc.) has been gathered from various sources (Lloyds Register, S&P's Sea-Web, IHS-Fairplay, etc.) which were either available from previous navigational studies, or acquired specifically to cover the vessels observed in the Baltic Sea during 2024.

BRISK II

3 AIS 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 Recommendation ITU-R M. 1371-5 (ITU, 2014) published by International Telecommunication Union (ITU). Here we give only short description of the AIS data focusing on information important for the project.

3.1 POS reports

POS reports contain information about dynamic properties of the vessel such as position, speed, course etc., as well as the MMSI number of the AIS device. The MMSI number is provided in all AIS reports and constitutes the main identifier of the vessel in the AIS broadcasts. The AIS device broadcast those data in a digital VHF transmission every 2 to 10 seconds depending on the vessels speed and every 3 minutes when the vessel is at anchor. Data such as position, speed and course over ground are automatically generated using the GPS positioning in the AIS device, whereas other POS data (heading, rate of turn) will require connection to the gyrocompass of the vessel.

3.2 STAT reports

STAT reports contain more elaborate information about the vessel itself and its intended journey: IMO number, vessel's name, radio call sign, size, actual draught, category of potentially hazardous cargo and position of AIS transmitter on the vessel. Those more extensive data packages are broadcast at 6 minutes interval. Since they require to be manually entered by the vessels crew this data is less reliable than the POS reports. To simplify collection, storage and delivery of AIS data, the information from POS and STAT broadcasts are typically combined, so every data record includes detailed data from both.

Analysis of the AIS data in this project has focused on the basic and most reliable part of AIS data – the vessel identification via the MMSI number of the AIS transponder and the position and speed. The information from the STAT records on the vessel have been used when necessary to enhance vessel identification.

4 Combination and filtering of AIS data

AIS data have been received from HELCOM for the part of the Baltic Sea up to the boundary of the HELCOM area as defined in the HELSINKI Convention Article 1: “the parallel of the Skaw in the Skagerrak at 57° 44.43'N”, which lands on the Swedish west coast on a point slightly north of Gothenburg. To cover the entire West coast of Sweden data from DMA (Danish Maritime Authority) has been included for the area north of the HELCOM area (see Figure 4-1). The data sources are very similar and are easily harmonized to allow direct combination in one data pool. The combined data constituted about 500 million records or 140 GB of data, which was mostly because of a very high time resolution in the supplementary DK data.

By excluding data from vessels with a gross tonnage less than 300 GRT, data from vessels that do not move, eliminating smaller vessels that clearly do not constitute an environmental hazard (e.g. pilot vessels), and considering only AIS records within the study area, and by ensuring that AIS records for each individual vessel are at least 5 minutes apart, the data set is reduced considerably to about 55 million records representing 17 GB of data.

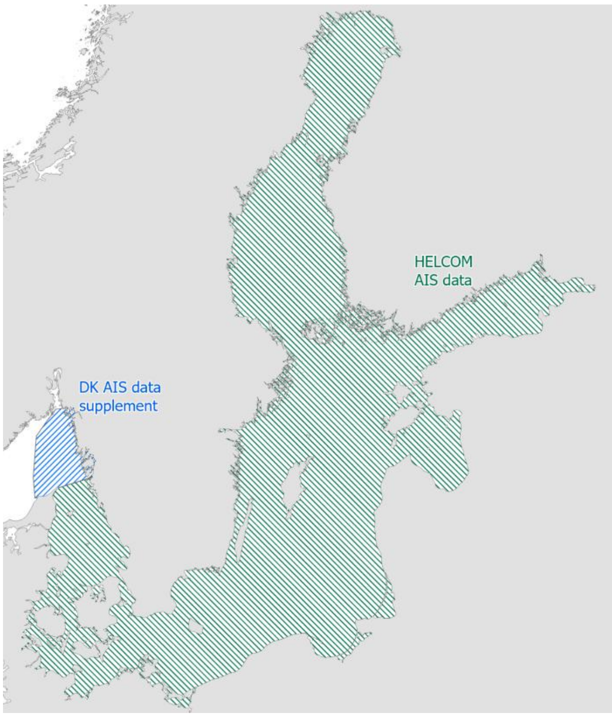

Figure 4-1 Areas of AIS data sources

The daily variation of number of AIS records during the one-year period is presented in Figure 4-2, showing a fairly constant rate of AIS-data with minor variations in a weekly pattern and a general drop around years end. Figure 4-2 also provides a breakdown of the data rate into contributions from the four main regions in the study areas – *Baltic Sea entrance*, *Baltic Proper*, *Gulf of Finland* and *Gulf of Bothnia*. The area called *Baltic Sea entrance* consists of Kattegat, the Belt Sea and small parts of the western Arkona basin (Figure 4-3). The overview displayed in Figure 4-1 shows that the contributions from *Baltic Proper* and *Baltic Sea entrance* dominates by far.

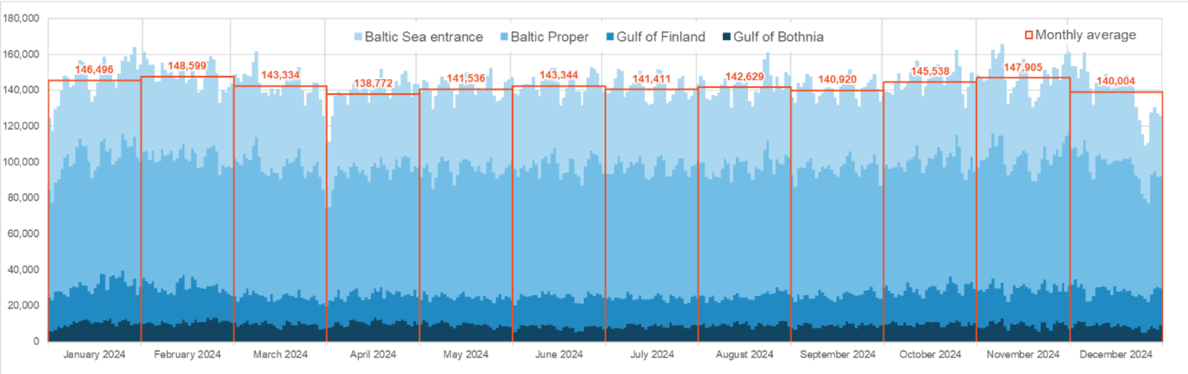

Figure 4-2 Variation of AIS-records per day, indicating contributions from the 4 main areas in the Baltic sea: Baltic Sea entrance (Kattegat, the Belt Sea and parts of the Arkona basin), Baltic Proper, Gulf of Finland and Gulf of Bothnia (See Figure 4-1), and the monthly average.

However, since the contributions represent a product of the region size and the vessel traffic density within the region, the data rate must be adjusted for region area to provide indications of the traffic density within each region. Doing so shows the density to be largest in the *Baltic Sea entrance* followed by *Gulf of Finland*, *Baltic Proper* and the *Gulf of Bothnia* – see Table 44-1.

Figure 44-3 Areas of the Baltic Sea for the purposes of this assessment: Baltic Sea entrance (Kattegat, the Belt Sea and parts of the Arkona basin), Baltic Proper, Gulf of Bothnia and Gulf of Finland.

Table 44-1 Relative traffic intensity derived from AIS data rate and approximate areas.

Region	**Relative traffic intensity**
Baltic Sea entrance (Kattegat, Belt Sea and parts of the Arkona basin)	100%
Gulf of Finland	60%
Baltic Proper	35%
Gulf of Bothnia	10%

5 Traffic density mapping

In continuation of the discussion of traffic intensity above, the route-based modelling used in the study must reflect the actual ship traffic pattern, and this can in principle be established by mapping the AIS point intensity within the study area. However, the AIS records represent point positions on the vessel journeys through the area, and since the data points included in the analysis have been limited to no more than one point per 5 min from each vessel, the AIS points would be sparse – approximately 500 m apart for a typical vessel speed of 15 knots. Recognizing that the vessel is known to have passed between the sequence of consecutive AIS points, it is appropriate to approximate the vessel journey by the track obtained by connecting the AIS points with straight lines and determine the density of these tracks.

The traffic density mapping shown in Figure 5-1 illustrates the density of the approximated tracks, where the density has been calculated as the accumulated length of vessel tracks within each 250m×250m cell. The resulting high-resolution mapping provides an excellent illustration of the different levels of traffic intensity; from the focussed, large volume of vessels in transit utilizing the established main routes, over the less restricted regional traffic servicing local destinations, to the cris-crossing of local traffic, fishing vessels, dredgers and other service and work vessels operating locally.

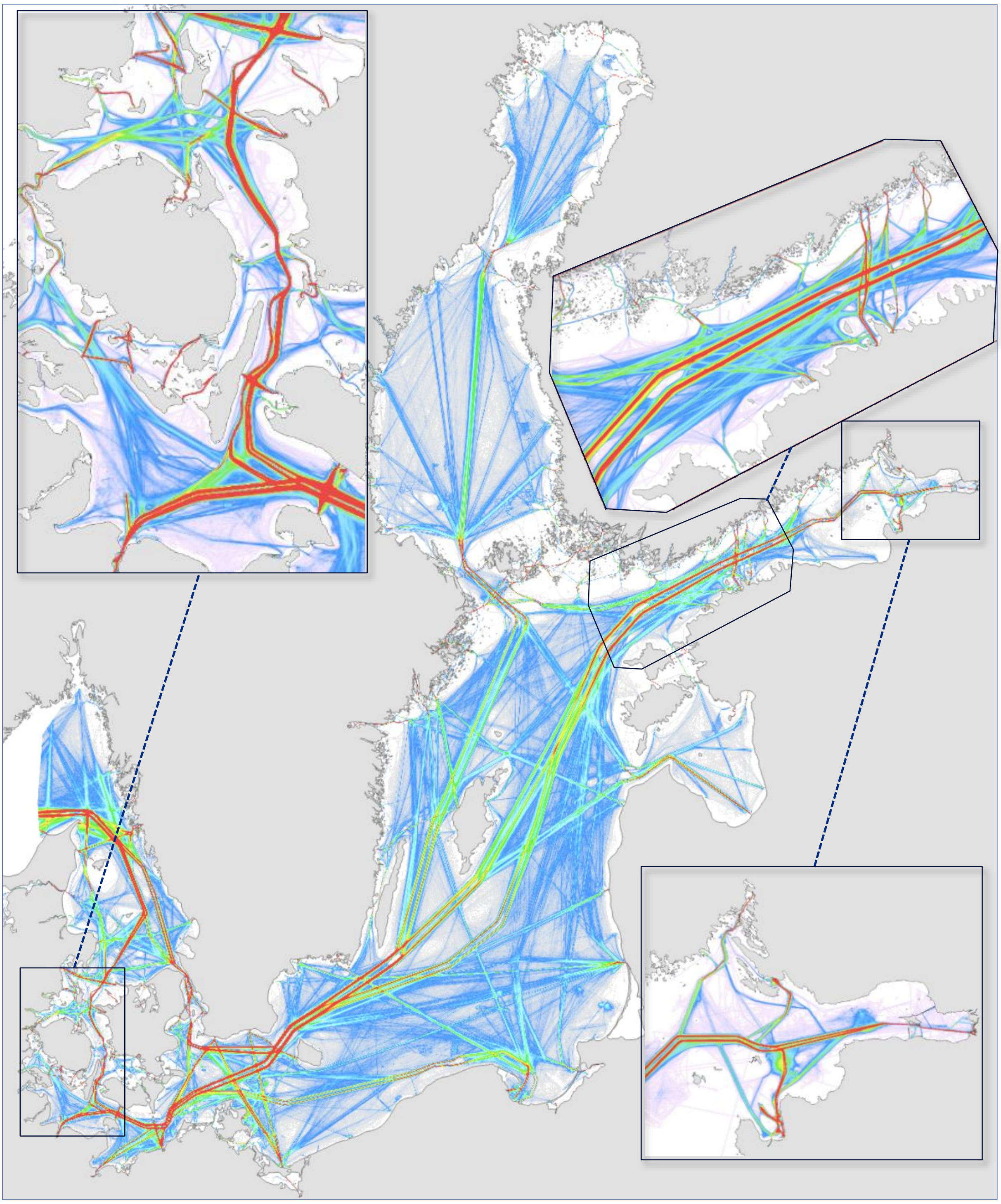

Figure 5-1 *Traffic density mapping based on AIS data for 2024 (warm colours = highest traffic intensity, cold colours = lowest traffic intensity, white = no traffic).*

In the following figures (Figure 5-2 through Figure 5-8) the established traffic density mapping is compared with the corresponding mapping of the traffic based on AIS data from 2008-2009 used as basis for the original BRISK project (BRISK, Part 1: Ship Traffic, 2012).

The overall picture of the traffic in Figure 5-2 is generally the same, but more close inspection reveals some local differences being the result of changes to the navigational arrangements.

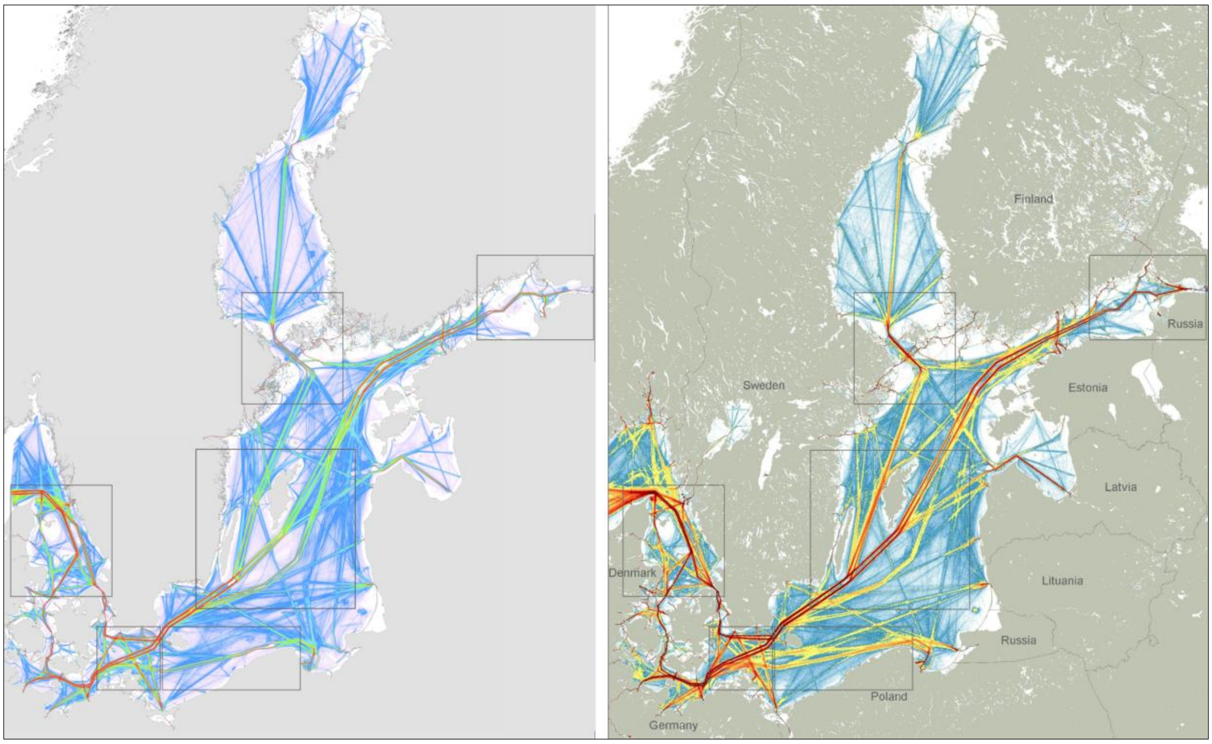

Figure 5-2 *Comparison of the AIS density mapping based on 2024 data used in the present study with the original mapping of the AIS data from 2008-2009 used in BRISK I (BRISK, Part 1: Ship Traffic, 2012). Colour scales are not directly comparable. The marked areas are presented in higher resolution for more detailed inspection in Figure 5-4 to Figure 5-8.*

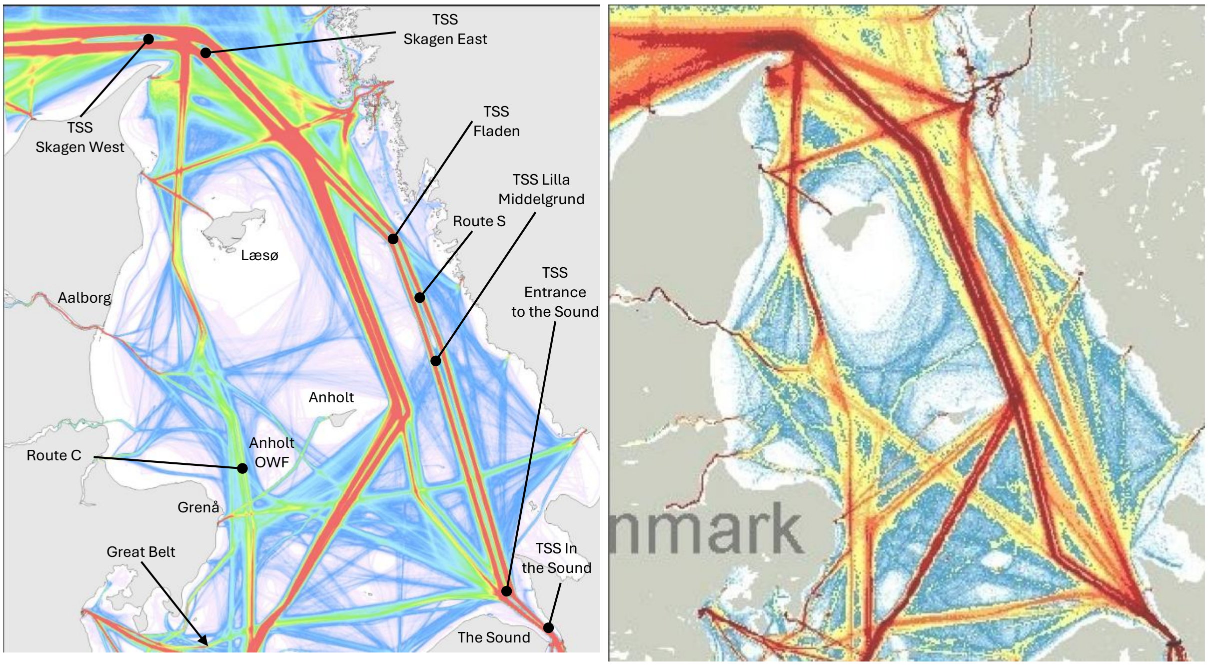

Figure 5-3 *Comparison of the AIS density mapping in Kattegat based on data from 2024 (left) used in the present study and data from 2008-2009 (right) used in BRISK I (BRISK, Part 1: Ship Traffic, 2012). (TSS: Traffic Separation Scheme, OWF: Offshore wind farm)*

In the Kattegat the traffic arrangement was changed significantly in 2020, by establishment of Route S subject to TSS along the Swedish coast whereby the traffic utilizing the Great Belt and the Sound remains separated until a junction just north of Læsø. This difference is clearly observable in Figure 5-3 and the continuation of the joint route north of Skagen also clearly reveals the two TSS's introduced there.

The straight route between the Sound and the entrance to the Limfjord and Aalborg has been shifted south to join Route C along the coast of Jutland just NE of Grenaa and thereby go south of the wind turbine farm located halfway between Grenaa and Anholt.

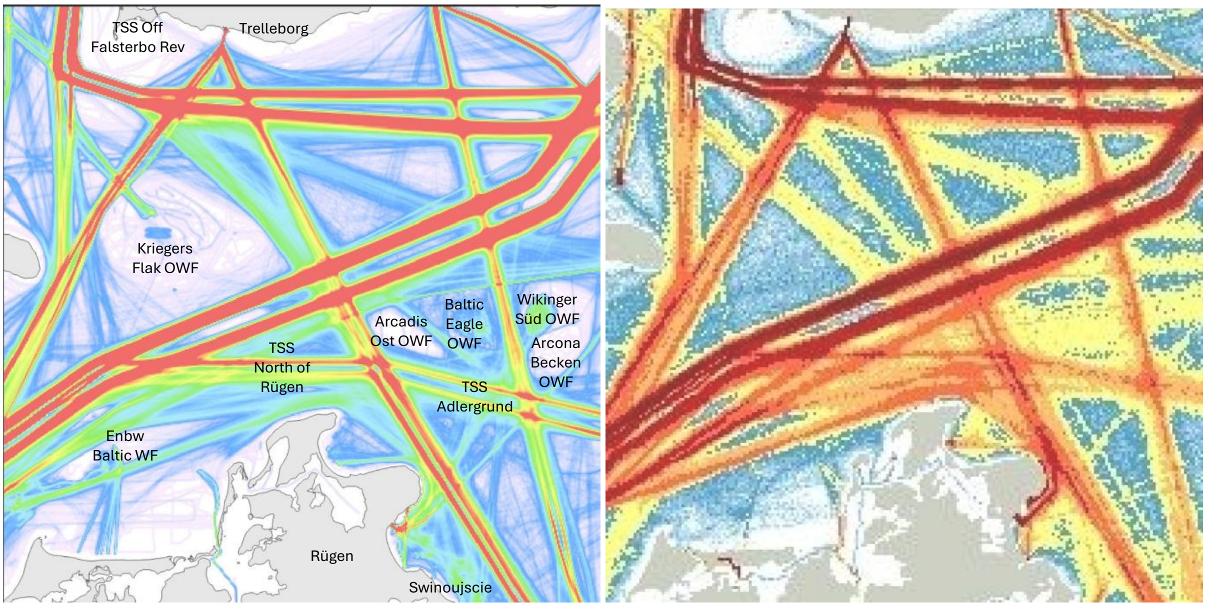

Figure 5-4 *Comparison of the AIS density mapping in the Arkona Basin based on data from 2024 (left) used in the present study and from 2008-2009 (right) used in BRISK I (BRISK, Part 1: Ship Traffic, 2012). (OWF: Offshore wind farm)*

The Arkona Basin between Rügen of Germany, Denmark and Sweden covered by Figure 5-4 is an ideal location for offshore wind turbine farms. As these are also heavily trafficked waters the routeing in the area has been rearranged to provide the necessary clearance of ship traffic around the relevant locations of the offshore wind farms (OWFs) – Kriegers Flak and Adlergrund. The establishment of Kriegers Flak OWF in the years between 2008-2009 and 2024 has only led to a slight shift of the Trelleborg-Lübeck ferry line route, whereas the more congested traffic across and around Adlergrund has required more firm arrangements with the introduction of TSS North of Rügen and TSS Adlergrund. This has also caused a consistent separation of the north- and south-going lanes on the route to Swinoujscie that intersects the TSS arrangements.

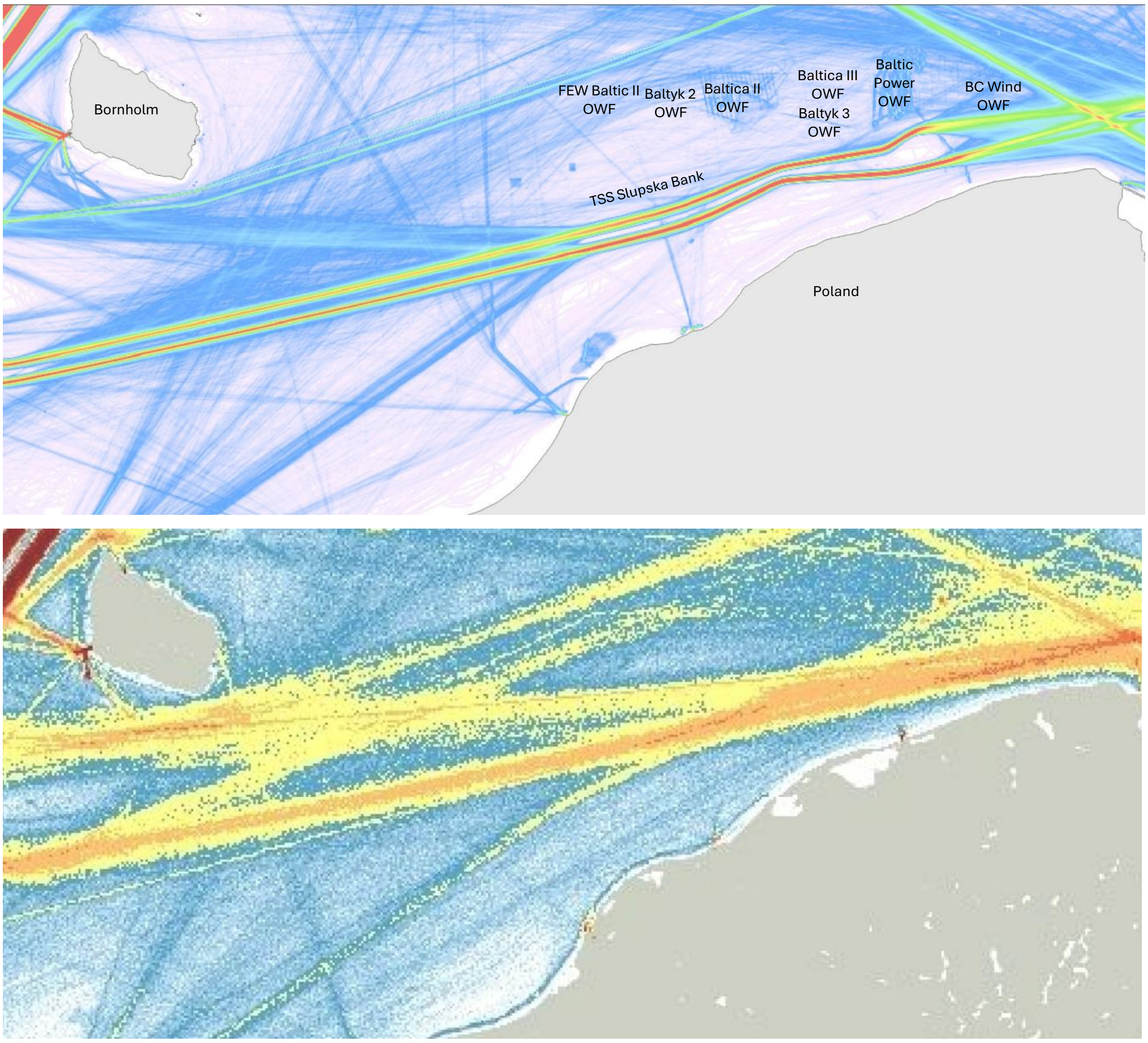

Figure 5-5 *Comparison of the AIS density mapping at Slupska Bank based on data from 2024 (top) used in the present study and from 2008-2009 (bottom) used in BRISK I (BRISK, Part 1: Ship Traffic, 2012). (TSS: Traffic Separation Scheme, OWF: Offshore wind farm)*

Attractive locations for offshore wind farms are also found on the Slupska Bank east of Bornholm and north of the coast of Poland and a TSS has been introduced close to the Polish coast to relocate the ship traffic off these areas – see Figure 5-5. The TSS is passing a shoal south of the Baltic Power wind farm, and to provide sufficient clearance between the two lanes of the TSS requires the west-going lane to pass north of the shoal, and the east-going lane south of the shoal, causing the wavey routeing around the shoal clearly noticed on the traffic density from 2024. The traffic density from 2008-2009 suggests that all traffic was passing south of the shoal prior to the introduction of the separation scheme. The lanes of the TSS Slupska Bank remain separated until reaching the TSS Adlergrund (see Figure 5-2) thus consistently keeping the two traffic directions separated when entering the more congested navigational arrangement in the Arkona Basin.

The comparison of the traffic densities in Figure 5-6 clearly shows the effect of several new TSS's. A TSS between Öland and Gotland cause the lane separation to be maintained all the way to the entrance to the Bothnian Sea shifts the route slightly west ensuring a larger clearance at the passage of Gotland. The shifted route alignment also increases the triangular area between the traffic lanes south-west of southern Gotland in which offshore wind farms are in consideration/development.

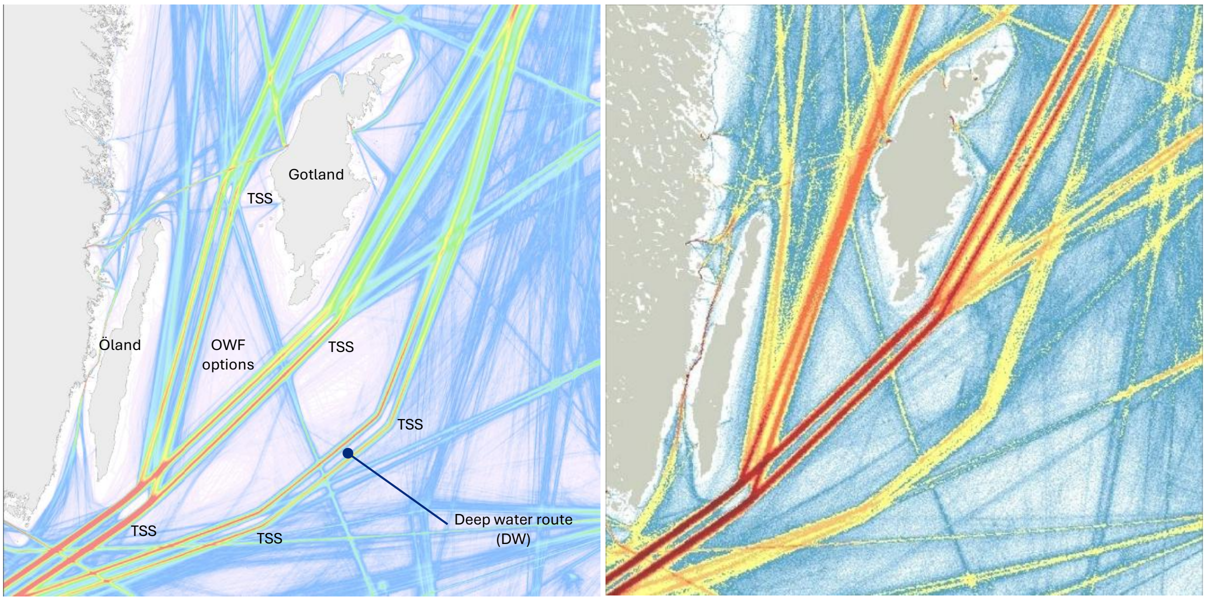

Figure 5-6 *Comparison of the AIS density mapping around Gotland based on data from 2024 (left) used in the present study and from 2008-2009 (right) used in BRISK I (BRISK, Part 1: Ship Traffic, 2012). (TSS: Traffic separation scheme, OWF: Offshore wind farms)*

While the effect of the existing TSS on the route passing closely south of Gotland is observed on both density maps, a significant change is noticed on the traffic using the deep-water (DW) route further south-east due to a new TSS introduced on this route. Although the colour coding of the traffic intensity on the maps does not enable direct comparison, it is also noted that the firmer arrangements with the TSS on the DW route appears to have attracted more traffic such that the two parallel TSS regulated routes to the Gulf of Finland now share the traffic more evenly.

The effect of introducing a TSS in the entrance to the Gulf of Bothnia is clearly recognized in the density maps in Figure 5-7, both on the traffic within the TSS regulated entrance, on the TSS regulated traffic on the eastern route that crosses the TSS, and to some extent on the traffic connecting from south.

Finally, Figure 5-8 provides a close-up comparison of the traffic density in the Russian end of the Gulf of Finland where the Russian Baltic Sea oil terminals are located. The navigational arrangement has not changed significantly, with a slightly larger lane distance of the TSS section in the far-left part of the figure as the main change visible when comparing the two maps. With reservations on direct comparison of the intensity colour coding in the two maps, it is considered evident that the traffic to and from Ust-Luga has increased significantly (as predicted during BRISK I) while the traffic to and from Vysotsk has decreased. Direct traffic in and out of Primorsk appears unchanged whereas the traffic between St. Petersburg and Primorsk and Vysotsk revealed by the 2008-2009 AIS data is no longer recognized in 2024.

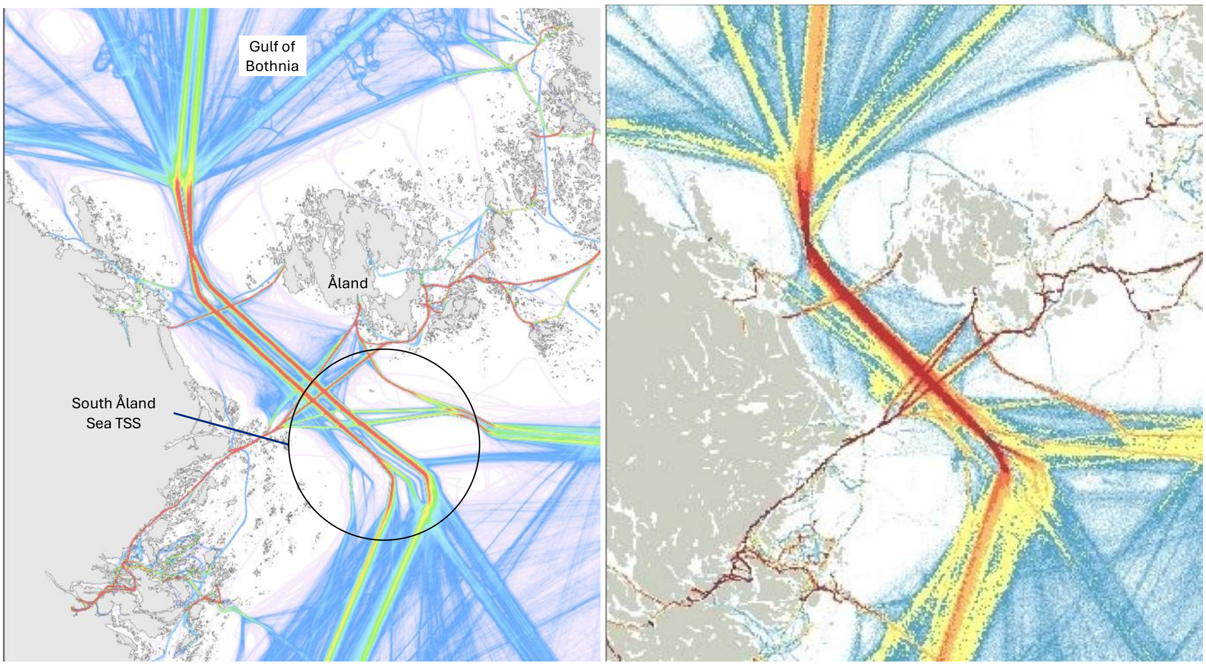

Figure 5-7 *Comparison of the AIS density mapping at the entrance to the Gulf of Bothnia based on data from 2024 (left) used in the present study and from 2008-2009 (right) used in BRISK I (BRISK, Part 1: Ship Traffic, 2012).*

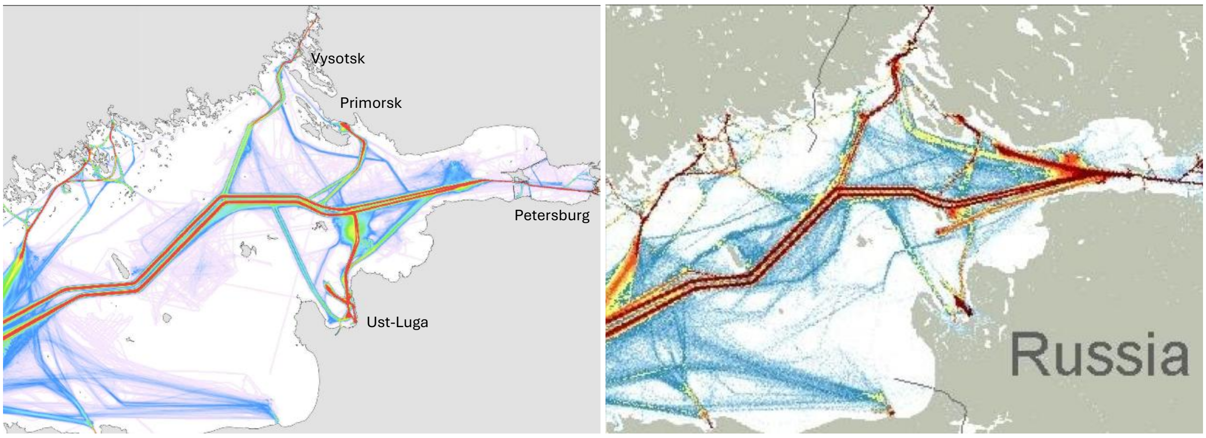

Figure 5-8 *Comparison of the AIS density mapping in the eastern end of Gulf of Finland based on data from 2024 (left) used in the present study and from 2008-2009 (right) used in BRISK I (BRISK, Part 1: Ship Traffic, 2012).*

6 Ship traffic route net

Even though the traffic density plots provide a very clear and detailed picture of where the ship traffic is located it does not provide a representation that can form a basis for a predictive modelling of ship accidents. This requires a more well-defined framework, and since the traffic density clearly illustrates the traffic to use either specifically marked routes or the most direct routes possible between origin and destination, a route network will provide an obvious and effective framework for the representation and modelling of the observed ship traffic.

6.1 Route net definition

The route net is established manually in a Geographic Information System (GIS) with the traffic density mapping and relevant navigational charts as background and using the route network established in BRISK I (BRISK, Part 1: Ship Traffic, 2012) as a starting point. The basic topology of the route net is described by *route nodes* defining the locations where routes connect or end, and the linear, two-point *route segments* that defines traffic connections between these nodes.

The actual changes to the navigational arrangement in the Baltic Sea have generally required a more refined routeing to be implemented in the route net, and the more detailed mapping of the AIS density in the present study – see Figure 5-2 – have revealed details that are relevant to capture by the route net. Consequently, the route net has been amended to include 2,444 nodes and 5,001 route segments, where the route net in BRISK I included 1,760 nodes and 3,371 route segments.

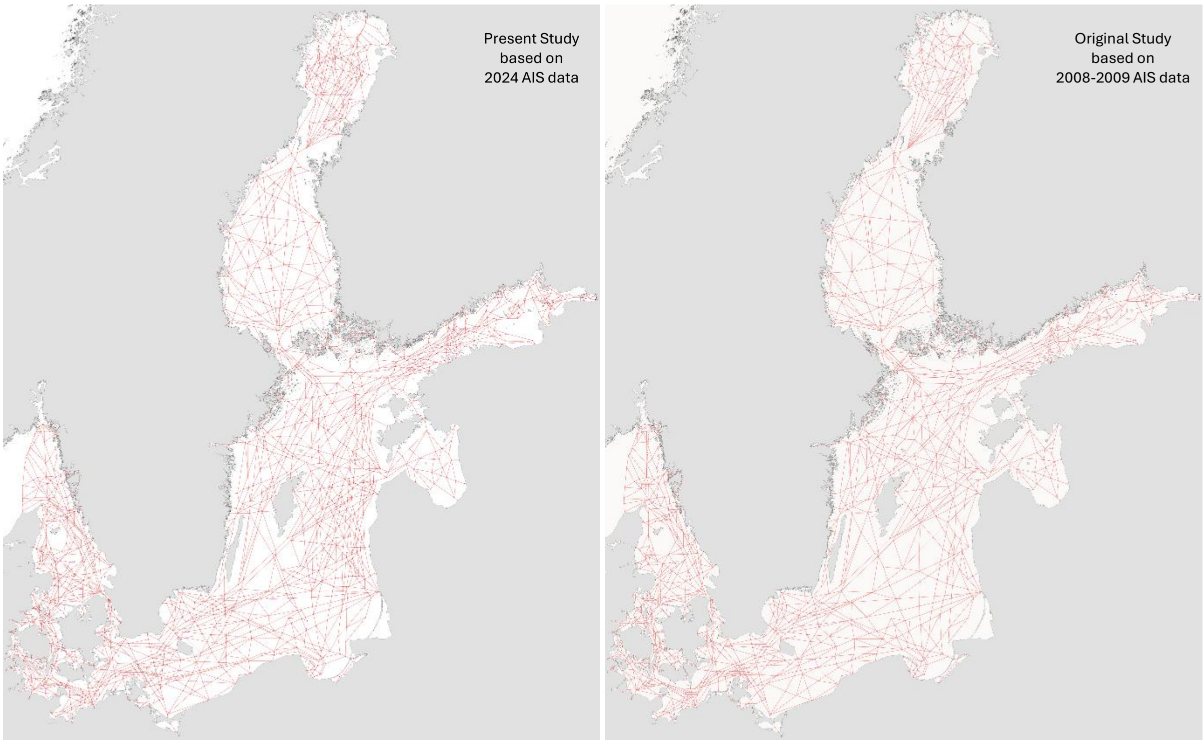

Figure 6-1 *Comparison of the route net determined on basis of 2024 AIS data used in the present study (left) with the route net based on the AIS data from 2008-2009 used in BRISK I (BRISK, Part 1: Ship Traffic, 2012) (right).*

Though the two route nets show in Figure 6-1 are very similar, refinements are particularly noticeable in the Bothnian Bay, in the middle of the Gulf of Finland, in the areas east and south-east of Gotland and in the Baltic Sea entrance.

6.2 Ice and ice-free seasons

Development of ice cover on the sea during winter limits the opportunities of sea transport and significantly alters the way under which navigation will be conducted. In ice-covered seas, ships will essentially be confined to channels established and maintained by ice breakers and by other traffic, and depending on the severity, the traffic can become more organized and conducted as convoys lead by an ice breaker.

Ice conditions in the target year 2024 prevailed during much of January, February and March. AIS data from the two of these months, January and February, have been inspected for changes in the navigational pattern captured by AIS density mapping for these two months compared to the remainder of the year. Notable differences are observed in the Bothnian Bay as shown in Figure 6-2 with the traffic in the winter months being less spread and not following the tight routes that are used in the remainder of the year.

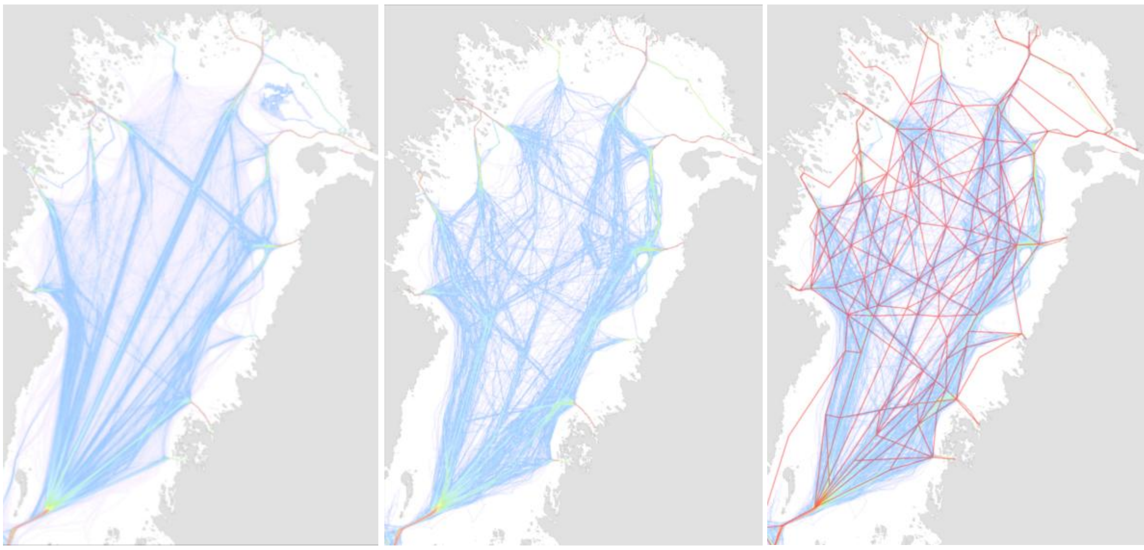

Figure 6-2 *Ship traffic density in the Bothnian Bay based on the entire year (left), during the winter months Jan/Feb (middle), and during the winter months with the established route net (right).*

Recognizing that the traffic model by concept can provide the ship traffic in any specific period of 2024 that may be considered necessary to analyse differently in the accident modelling, a separate detailed analysis is not considered relevant in relation to the preparation of the traffic model. But it must be secured that the established route net is able to capture the traffic pattern during the winter months, and the illustrations in Figure 6-2 and Figure 6-3 shows this to be the case.

The shorter distances between ships when navigating in ice-breaker convoys could in principle be captured in the analysis of the AIS data, but since the effect is modelled explicitly in the accident model (deliverable 2.5), this has not been attempted.

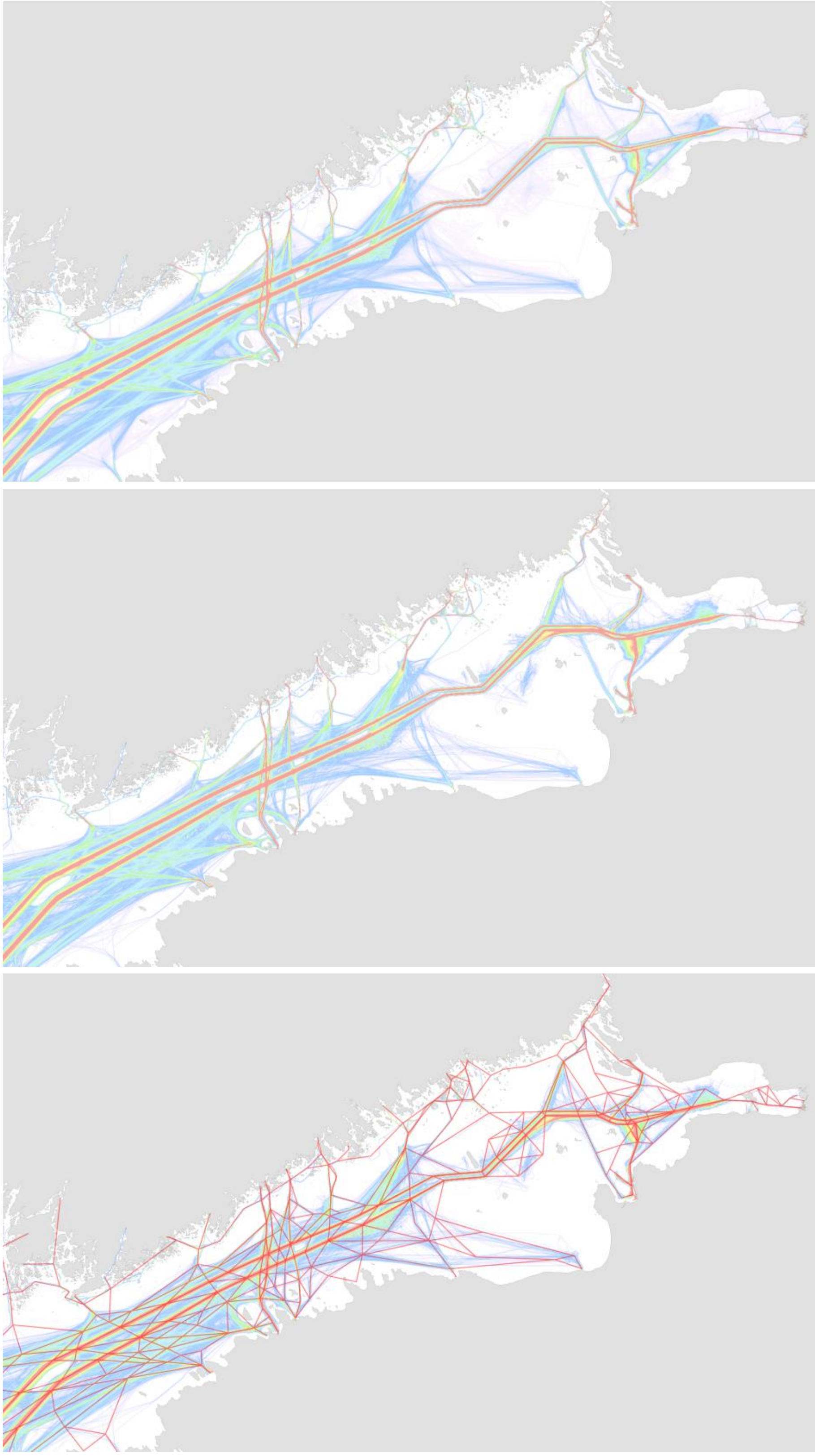

Figure 6-3 *Ship traffic density in the Gulf of Finland based on the entire year (top), the traffic during the winter months Jan/Feb (middle), and during the winter months with the established route net (bottom).*

6.3 Route net analysis

The automated association of the AIS data to the route network is a detailed and time-consuming process that can be greatly supported by pre-processing the route network in two ways. The first being a simple pre-analysis of the area covered to establish approximate proximity matrices that returns the closest node and route segment for a given point in the area. The proximity assessment of the route network is thereby done once instead for each of the millions of AIS points included in the data basis.

The second pre-processing step provides an efficient connectivity description throughout the network, that provides the shortest length of a journey between two nodes, and a Markov-based description of how that journey is broken down into a succession of consecutive route segments. This description greatly supports the decision process involved in associating the sequence of AIS points from the recorded passage of a vessel through the Baltic to equivalent passages on the route segments on the route network. As it does occur that the sequence of AIS records from a vessel journey can be interrupted, the description can fill out the gap by suggesting the shortest path through the route network while the AIS data stream is interrupted.

6.4 AIS point association to the route net

The large amount of AIS data to be associated with the route net makes it imperative for the processing to be as simple as possible while still being effective and sufficiently accurate. The succession of AIS points for a vessel journey forms a track that inspires to be associated with route segments in the route net – see Figure 6-4. But the algebra involved in checking the proximity and direction of a local selection of track of points with the neighbouring route segments ends up being too time consuming for the large volume of data that needs to be processed.

A simpler and computationally more effective approach is to determine the nodes in the route network that are closest to the sequence of AIS points (step 1 in Figure 6-4). This can be done effectively utilizing the pre-processing of the route net to provide an approximate proximity mapping of the nodes. Secondly, that sequence of nodes is inspected using the pre-processed topological framework of the route net to find the nodes and associated route segments that provide the best consistency between the length of the AIS track and the length of the equivalent sequence of route segments (step 2 in Figure 6-4).

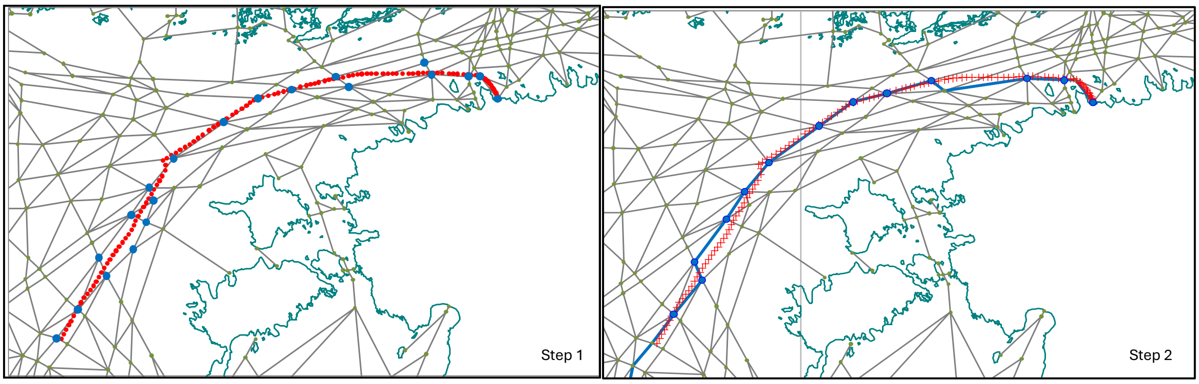

Figure 6-4 *Association of the AIS points with the route net.*
Step 1 (left): identify the nodes in the route networks that are closest to the sequence of AIS points.
Step 2 (right): Select the nodes and thus the route segments that are most consistent with the aggregated distance in the track based on the sequence of AIS points.

Using the route net topology to support the AIS point association also provides an effective way of managing temporary disruption of the AIS data during the journey of a vessel – see Figure 6-5. In case the AIS data coverage resumes at a later stage of the vessel journey, the route network topology provides a suggestion for the shortest way through the route network that connects the parts of the journey covered by AIS data.

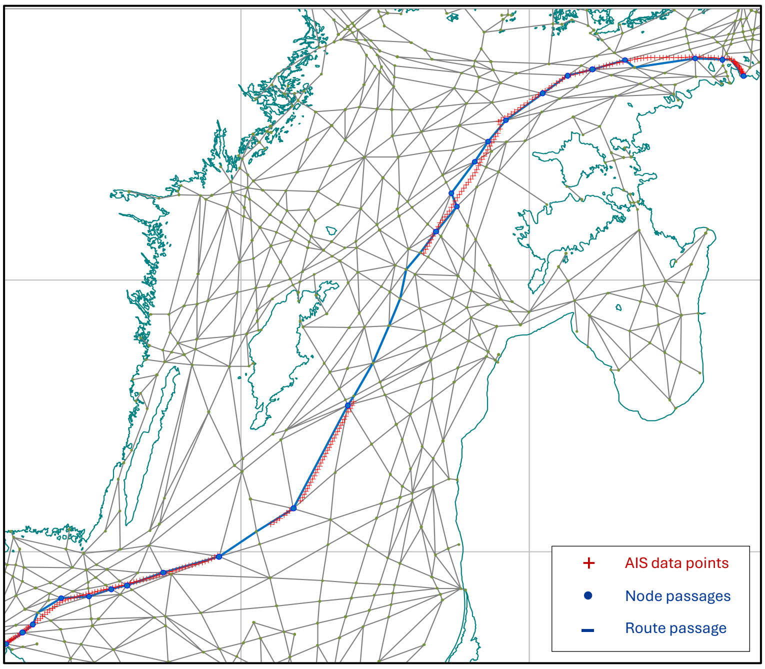

Figure 6-5 Drop out of AIS data during a vessel journey and the suggested completion of the journey along the route network.

With the established approach the route net association of the 55 million AIS point records consumes about 150 PC hours or 6.3 PC days. The result of the route association is 7 million records of route passages that each identify:

- **Vessel identity**
  MMSI and IMO number which provides access to all available information about the vessel.

- **Track**
  A unique number identifying the specific journey by the specific vessel across the route network that the route segment passage is part of.

- **Date and time**
  Date and time of the route passage which enables establishment of aggregated traffic descriptions for a specific period.

- **Route segment**
  The number of the route segment, which describes the vessel movement geographically.

- **Passage direction**
  The direction in which the route segment has been passed.

This description enables the traffic to be separated based on vessel type and size, on geographic location of the route segment, on origin and/or destination of the journey, on time of the day and day of the year, and permits a direct factorial adjustment of each vessel movement to account for changes in the traffic pattern and volume, it constitutes a versatile traffic modelling for the risk analysis forming the core of the study.

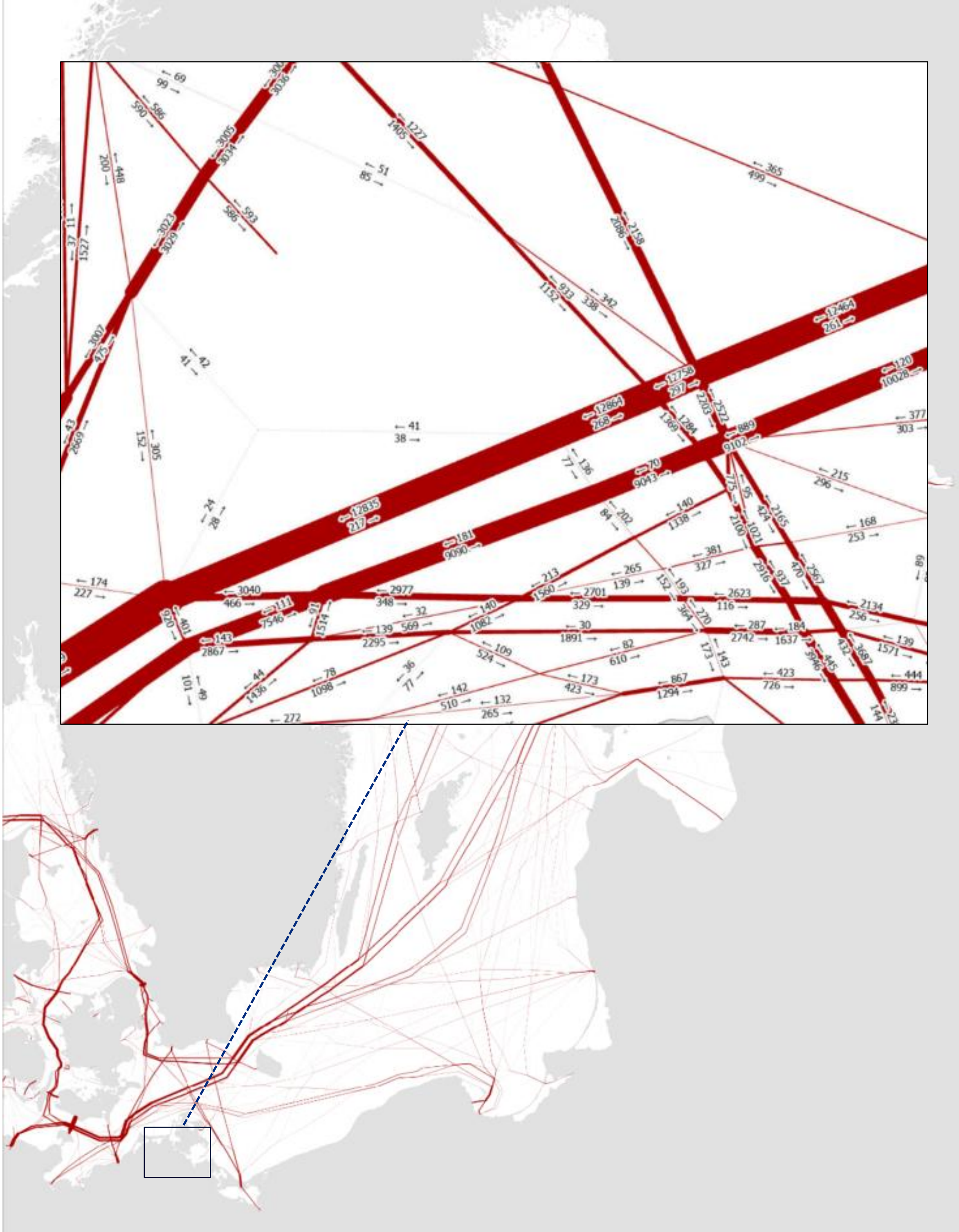

Figure 6-6 *Plot of the aggregated traffic on the route network. The widths of the route segments are proportional with the combined traffic volume from both directions.*

6.5 Statistics of route deviations

The preceding analysis that transforms the AIS point data to journeys along the route network provides the main description of the ship traffic in the model. Once this analysis has concluded the best route net approximation for the AIS points from a vessels journey in the area, the individual AIS points are associated with the resulting specific route net segments, and this provides data for a more detailed assessment of the deviation of the actual track given by the AIS point from the idealized journey along the route network – see Figure 6-7.

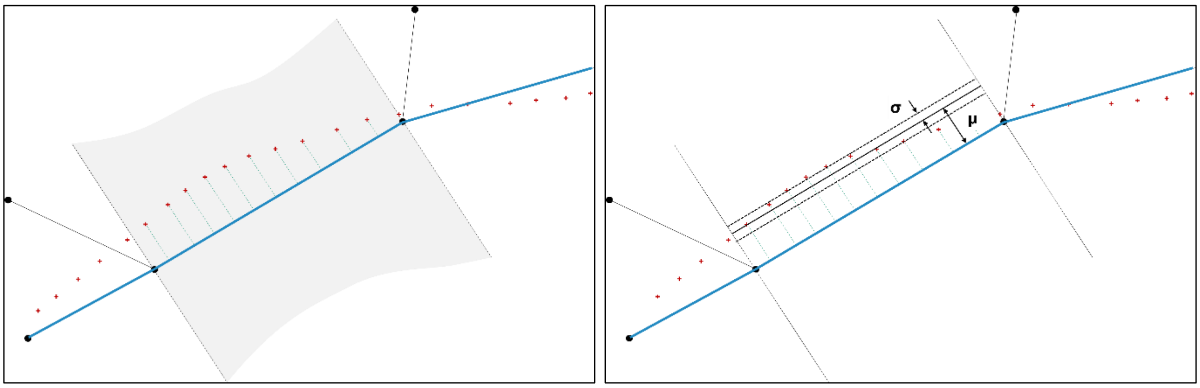

Figure 6-7 *AIS offsets from route segment. Only the distances to the AIS points within the perpendicular grey area are included in the point statistics for route segment.*

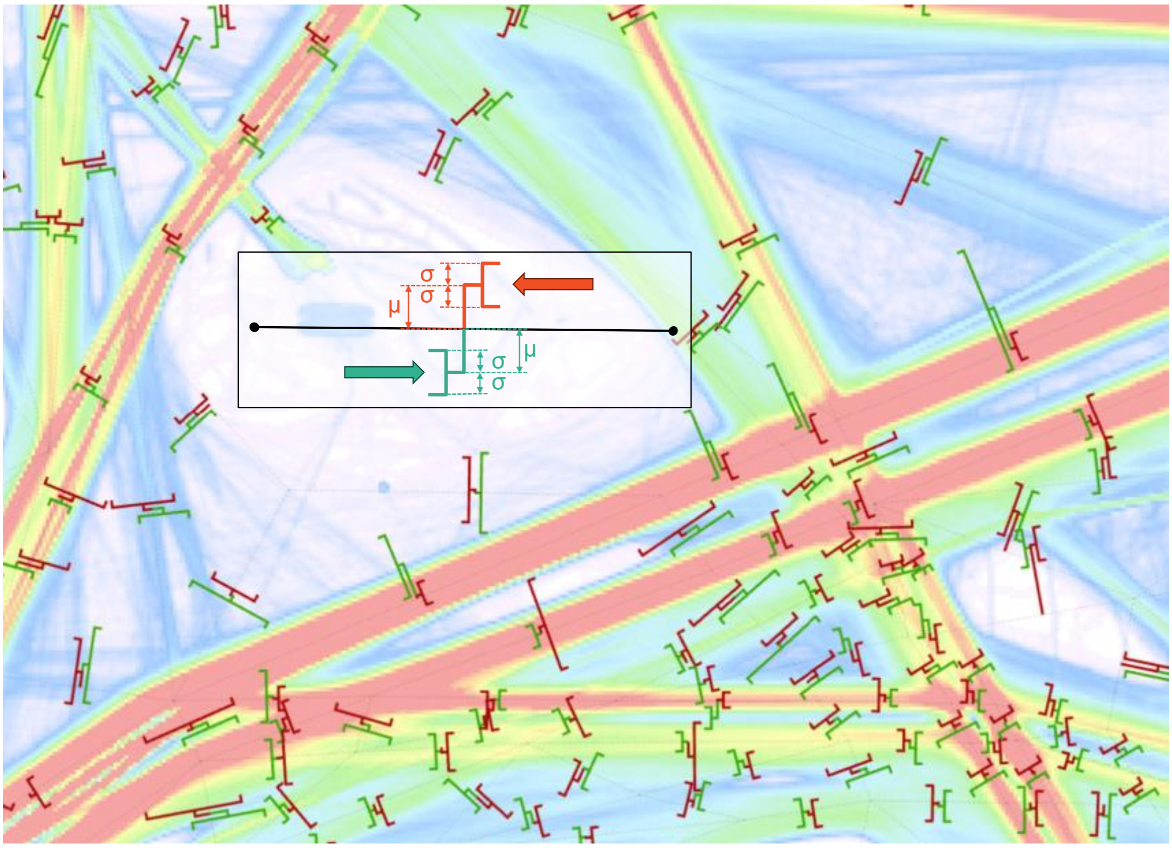

Figure 6-8 *Graphic indicators for the statistics (average and standard deviation) for each direction of the traffic on the route segments within the excerpt enlarged in Figure 6-6. The vignette in the centre indicates the interpretation of the indicators: they initiate at the middle point of the route segment, direction of traffic is "into the cup", and the green traffic directions is arranged to always be upwards.*

Only the AIS points between the perpendiculars through the route segment endpoints are included as basis for the statistics: the average offset **μ** along the route segment, and the standard deviation **σ** of the points around this average. When the traffic on the route net is aggregated for a subset of or all the traffic, the statistics from each individual vessel passage along each route segment can be combined to provide the average offset and the standard deviation for the selected traffic.

Figure 6-8 illustrates the resulting statistics for all traffic on the routes within the enlarged area in Figure 6-6. The indicators confirm – or are confirmed by – the traffic density mapping underneath by supporting that:

- On single two-way routes the vessels in the two directions are shifted to the right (to starboard) when facing the direction that the vessel travels along the route. This reflects the general precaution that opposing vessels preferably pass each other to the right.

- In a traffic separation arrangement, where opposing traffic is separated on two routes, the mean value plus/minus a standard deviation for the traffic in the intended direction of the route is centred on and narrowly bounding the traffic density shown in the background. The traffic in the opposite direction – which usually is only a small fraction of the traffic in the intended direction – is generally much more spread, which suggests that the opposing traffic cautiously stays far away from the larger and more focussed traffic navigating the route as intended.

In combination the detailed route-based traffic description and the associated statistics of the offset and deviation of the actual vessel trajectories provides imperative input for the models used to assess the risk of navigational hazards that can cause unwanted spills to the sea, i.e. the Accident and spill model described in deliverable 2.5.

7 Calibration

7.1 General 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.

No complete dropouts are observed when inspecting the variation of the daily rate of AIS data in Figure 4-2, and the general reduction of the AIS data rates early in January and in the end of December 2024 are not considered sufficiently large and well defined to be corrected for.

The detailed registrations received from Great Belt VTS for 2024 have made a comparison possible on the traffic going through the Great Belt Bridge. This have indicated the route traffic passing through the East Bridge in the Traffic Model is about 10% less than the registrations made by VTS Storebælt. This loss of traffic volume, which is a consequence of the demanding data processing algorithm, is corrected by a corresponding calibration factor.

Further reference data may become available during the processing of ship traffic and goods data directly from harbours and terminals as part of the Cargo Analysis (deliverable 2.4) – and this could be used to support further regional or general calibration of the traffic model.

7.2 Shadow fleet and data disturbances

Ships figuring on the EU sanction list – the so-called shadow fleet (Caprile & Leclrec, 2024) – have been investigated with respect to AIS compliance. This was done by

- comparing the number of passages observed by Great Belt VTS to the locally received AIS signals
- checking whether the ships observed in the Great Belt send a continuous trace of signals all the way to their port of arrival or departure in the Baltic Sea

Neither of the checks revealed any obvious anomaly, i.e. the shadow fleet vessels showed generally good AIS compliance, especially in the Great Belt area. This means that is has not been necessary to introduce a specific correction factor to the traffic model. Any other properties of the shadow fleet in terms of potentially increased accident-proneness are covered in the Accident and spill model (deliverable 2.5).

Slightly over 22,800 vessel passages were made through the Great Belt in 2024. Of these passages, 444 were related to the shadow fleet, corresponding to 2% of the total number. However, many of the shadow fleet vessels are relatively large ships. Thus, the proportion of the shadow fleet is higher when only looking at ships over a certain size. The shadow fleet activities are linked to the Russian harbours in the Gulf of Finland, which are part of a major export route for Russian crude oil and refined oil products (Caprile & Leclrec 2024). As already anticipated during BRISK I, the maritime traffic situation has changed in the Gulf of Finland during the past decade. The Baltic pipeline System 2 now reaches the Ust Luga harbour, increasing the capacity of this harbour. Today the harbour also allows for larger ships to enter due to deepening of the fairway leading into the harbour.

It is important to note, that disturbances of the global navigation satellite system occur almost daily in the Gulf of Finland. AIS spoofing and jamming as well as switching off the AIS transmitter before entering Russian waters is also observed daily in the Gulf of Finland (TRAFICOM 2024 and 2025; HELCOM IC EG AIS 4-2025; observations of the Finnish Border Guard). The ensuing irregularities in AIS data distort the local real-time picture of the ship traffic in the area. However, as initially mentioned this does not affect the traffic model, which includes mechanisms to mend holes in the AIS coverage, as described in Figure 6-5.

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8 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 Sea-web ship 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 Sea-web
- 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. 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.

9 Abbreviations

AIS	Automatic Identification System
BRISK	Also referred to as “BRISK I”: Project on sub-regional risk of spill of oil and hazardous substances in the Baltic Sea, 2009-2011
BRISK II	Long-term risk analysis for oil and hazardous and noxious substances (HNS) pollution from shipping accidents to the marine environment in the Baltic Sea, 2025–2026
HELCOM	Baltic Marine Environment Protection Commission (also: Helsinki Commission)
IMO	International Maritime Organisation
MMSI	Maritime Mobile Service Identity
SOLAS	International Convention for Safety of Life at Sea
TSS	Traffic Separation Scheme
VTS	Vessel traffic service

10 References

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Caprile, Anna and Leclrec, Gabija, 2024	Russia's 'shadow fleet': Bringing the threat to light. Briefing of the European Parliament Members' Research Service, PE 766.242, November 2024, 12 pp.
HELCOM, 2022	HELCOM Recommendation 33/1-Rev.2 on Unified interpretation in relation to access to and use of HELCOM AIS data.
HELCOM IC EG AIS, 4-2025	Memo of the fourth informal consultation session of the Expert Group for Mutual Exchange and Deliveries of AIS & Data (IC EG AIS 4-2025), May 2025.
ITU, 2014	International Telecommunication Union (ITU), Recommendation ITU-R M.1371-5, 2014.
TRAFICOM, 2024	Satellite navigation service interferences in Finland. Finnish Transport and Communications Agency, published 30.9.2024.
TRAFICOM, 2025	Finland and Estonia warn vessels in the Gulf of Finland of an increase in GNSS disruptions. Finnish Transport and Communications Agency, published 13.6.2025.

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