FORMAL SAFETY ASSESSMENT ROUTING BALTIC

Analysis of search areas for future windfarms on the North Sea

Report No.	**:**	**32774-1-MO-rev.1.0**
Date	**:**	**29 October 2021**
Version	**:**	**1.0**
		Final Report

FORMAL SAFETY ASSESSMENT ROUTING BALTIC

Analysis of search areas for future windfarms on the North Sea

Ordered by : Ministry of Infrastructure and Water Management
To Joris Brouwers, MSc
Rijnstraat 8
2515 XP The Hague

Reported by : H. Huisman, Y. Koldenhof

Signature Management :

Version	Date	Version description	Checked by
0.1	14 December 2020	First Draft	
0.2	22 April 2021	Draft incl SAMSON-results	H.L.J. Ammerlaan
1.0	29 October 2021	FINAL (after review client)	H.L.J. Ammerlaan

CONTENTS **PAGE**

1 INTRODUCTION

Marine Spatial Planning (MSP) is becoming more and more important and instrument to deal with conflicts between different uses. With the global exponential increasing interest for offshore renewable energy and the historic usage by shipping from the available sea space, two of the main conflicting interests are identified. Furthermore, especially by North Sea countries, a tendency has been identified for exploration and development of offshore renewable energy sites closer to the borders. In this study, MARIN will focus on opportunities, challenges and impossibilities when combining shipping and offshore renewable energy in the Northeastern area of the Dutch continental shelf, directly located near the Dutch-German maritime boundary..

1.1 Motivation

The Netherlands Ministry of I&W with its directorates DGLM and RWS ZD have common ideas, in consultation with the governments of Germany, Denmark and Belgium, to create an integrated routeing system from Dover Strait through the southern North Sea to the Skagerrak in the northern North Sea. Consensus about the future need for international routeing has been reached during various international meetings related to this topic. The Netherlands' government is investigating possibilities to optimize parts of its sea areas situated in the shipping routes towards the Baltic Sea, using the first concepts of marine spatial plans of Germany, Denmark and the Netherlands as basis. The latest marine spatial plans of all three coastal states indicate that a formalisation of international shipping routes is required in order to allow for continuous and safe shipping in the area. This concerns the connection between the shipping routes already established in the EEZ's of the Netherlands, Germany and Denmark. The main part and focus is the connection of the Off Friesland TSS via German shipping routes to Skagerrak. The need for routeing measures is caused by marine spatial plans indicating offshore wind energy development areas in those EEZ border areas.

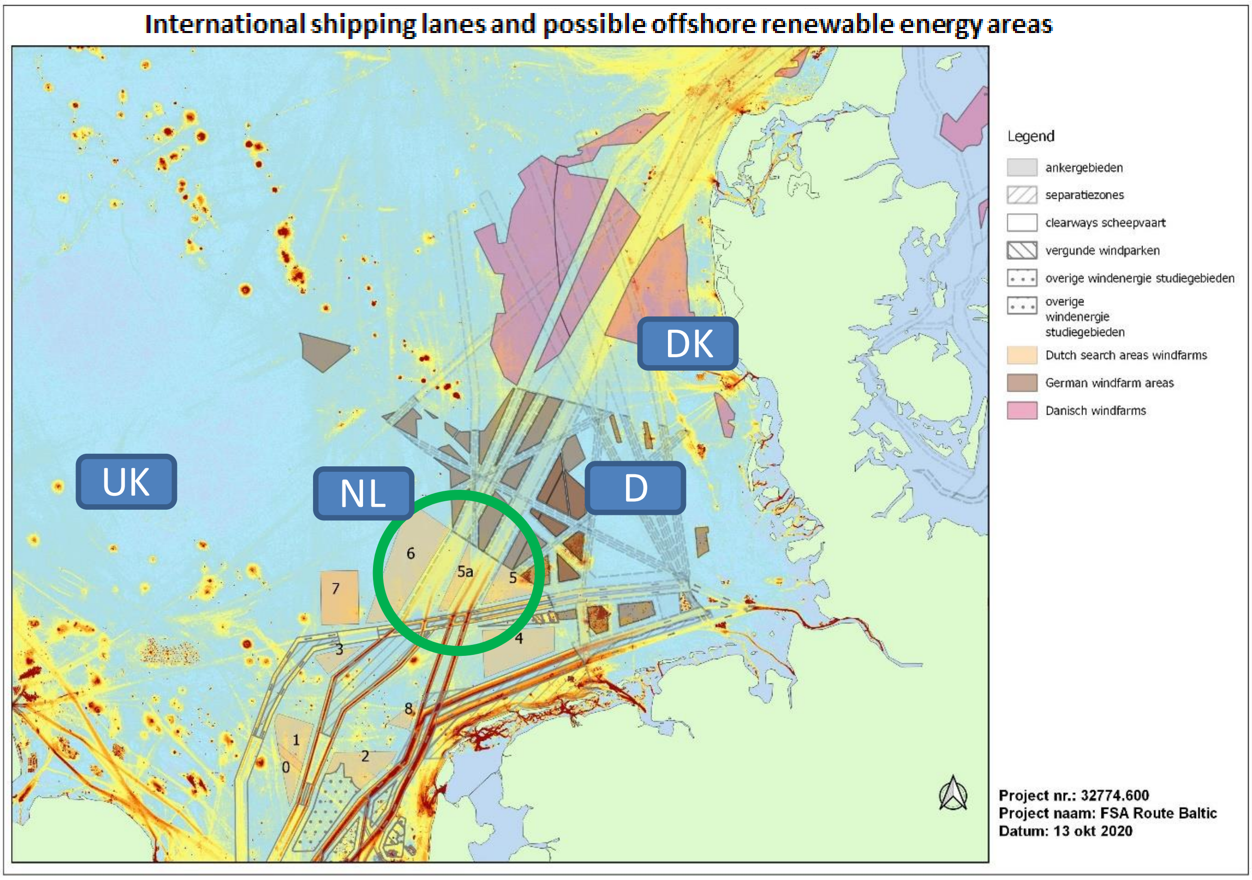


Figure 1-1 Study area

In addition to international MSP developments of neighbouring states, there is a national MSP process as part of the North Sea 2022-2027 program. One of the discussions and part of the program is the investigation of possible combinations or so-called multi-use of the North Sea. Relative new developments in the northern areas of the Dutch EEZ are large-scale offshore wind energy search areas. Therefore, present, non-formalized, important international shipping routes need to be established and formalised by IMO. Before continuing international cooperation, I&W proposes to carry out a national Formal Safety Assessment (FSA) in which different possible designs are assessed on accessibility of ports, safety and convenient shipping links.

1.2 Objective

The aim of the study is to perform the necessary traffic analyses and safety assessments according to the FSA methodology, in such a manner that the effects of the different routing options and international connections can be compared with regard to the impact on the safety of navigation in the area. The effects on accessibility of NW-European ports and efficient and safe manoeuvring of ships under all-weather conditions and sea circumstances in relation to the handling of ships is also part of the assessment.

The FSA assignment consists of two parts; a (1) quantitative and a (2) qualitative risk assessment and final conclusions and recommendations. The first part is a quantitative risk analysis; the second part is a qualitative risk analysis, which has been conducted with involvement of both national and international experts. The final conclusion and recommendations are the combination of the two parts.

The FSA focuses on the possible risks for safe navigation of ships, whereby the identified risks of collisions (both ship-to-ship collisions and collisions with a fixed structure) will be part of the quantitative analysis. This means that the frequency of occurrence is determined for those risks. Because not all effects of the measures can be identified in the quantitative approach (performed by using the SAMSON model), a qualitative analysis has also been performed in the form of two expert sessions.

The Netherlands government has determined an assessment framework (afwegingskader) for safe distance (safety margin) between shipping routes and offshore wind energy installations and this is therefore used as the basis for this FSA. (https://www.noordzeeloket.nl/beheer/afwegingskader/)

2 CONTEXT

The main objective of the study is to compare different marine spatial planning design options for the shipping traffic situation north of the main east-west traffic shipping routes above the Dutch Wadden Islands, in the Dutch EEZ. This chapter contains an overview of the starting points and the framework of the FSA study.
A short introduction of the general approach of the research is given in 2.1.The different options are explained in 2.2.

2.1 Approach of the research

The research consists of two parts: a quantitative analysis in which the effects are translated into numbers and figures (chance of accidents on basis of density, objects, conditions … etc.), and a qualitative analysis that explains the effects that cannot be determined by a model. In addition, the results of the qualitative analysis partly contain substantiation and motivation of the negative impacts of incidents on the marine environment, persons, ships and installations.
The strength of the method is that risks which are not clearly identifiable a quantitative analysis are identified in the expert session. Conversely, the quantitative analysis helps to objectify the risks that emerge from the expert sessions and indicate the chance of occurrence.

The research consists of a number of phases.

Phase 1: Traffic analyses of shipping in the area

In a first phase, a traffic analysis has been carried out which will supplement the analysis already carried out in Network Evaluation North Sea 2019 [Ref 1.]. In addition to the composition of a traffic database, the frequently used international shipping routes in the area will also be examined; which “’natural’’ shipping routes are used, which areas and ports do ships sail from and where are they heading to? The analysis of routes provides information about the traffic in the area that is necessary for the definitive determination of the route pattern deviation of the different options. The results of the analysis if provided in chapter 3.

Phase 2: Determining definitive design options
The definitive starting points for the FSA are determined based on the additional traffic analysis and input from the customer. This concerns both the definitive layout of the wind energy search area and the starting point of traffic flows and possible future MSP scenarios. The final spatial design options (hereafter called options) are given in 2.2.

Phase 3: Quantitative assessment, SAMSON
Quantifying nautical risks is performed by using the SAMSON model (Safety Assessment Model for Shipping and Offshore North Sea). The calculations are performed for five established spatial options of the area in relation to the basic variant (option 0). This is done by creating different route-bound traffic databases for all different options (1 to 5). For the different traffic databases the expected incident frequency (chance of occurrence) are calculated by using SAMSON.

The calculations yield the following results, the frequency of:

- Ship-ship collisions;
- Contact with turbines (both ships underway using their engine(s) and drifting i.e. not under command);

The results are presented in Chapter 3.8

Phase 4: Qualitative Assessment / Expert sessions

Parallel to the performance of the quantitative analysis, two digital expert sessions have been conducted. The first (international) stakeholder session was held on 14 October 2020 and the second (national) stakeholder expert session was conducted two weeks later on the 30th October. Unfortunately, due to restrictive measures in force because of the COVID-19 pandemic, no physical sessions could be held.
During both sessions, the initial results of the traffic analysis and the results of the online survey were briefly explained. Subsequently, it was examined whether the experts recognized themselves in the results and further questions were asked about the motivation behind some of the results to finally reach consensus about possible risks in the area.

The results of these sessions are provided in Chapter 5

2.2 Description of the different options

Within the study, 5 different options have been investigated. All options are outlined below. A more detailed description on the effects for shipping is provided in Chapter 3 as part of the traffic analysis and building up the traffic databases for SAMSON.

Option 0: the Base scenario

The base scenario is the situation without any windfarm(s) in the study area and thus the present situation (2020) in the Dutch EEZ. However, in the base scenario the planned windfarm areas in the German and Danish EEZ's have been included.

Option 1: Maximum navigating area for shipping

- Draft German layout is starting point
- No median strip in-between wind search areas 5 and 6
- Route Esbjerg-Hull through area 5
- Artificial island for H_2 production and transport via pipeline in area 6

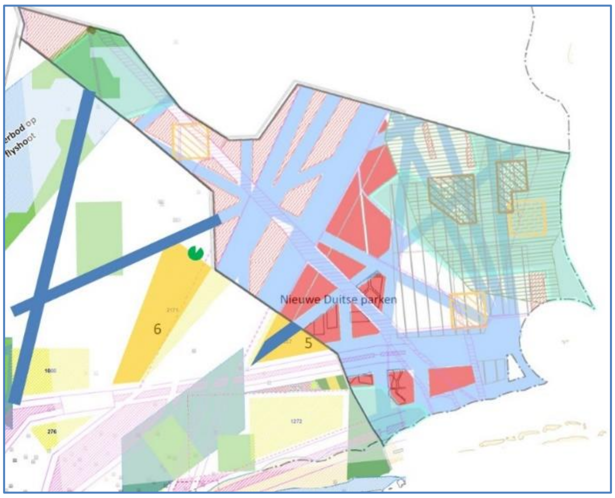


*Figure 2-1 Schematic representation of option 1: **Maximum navigating area for shipping***

Option 2: Maximum Wind energy

- Draft German layout is starting point
- Median strip with search area for wind in Baltic route between areas 5 and 6
- No connection for shipping through search area 5
- Route Esbjerg-Hull north of area 6
- Northern Sea Route connection on EEZ border with Germany
- Artificial island for H^2 production and transport via pipeline (in median strip)

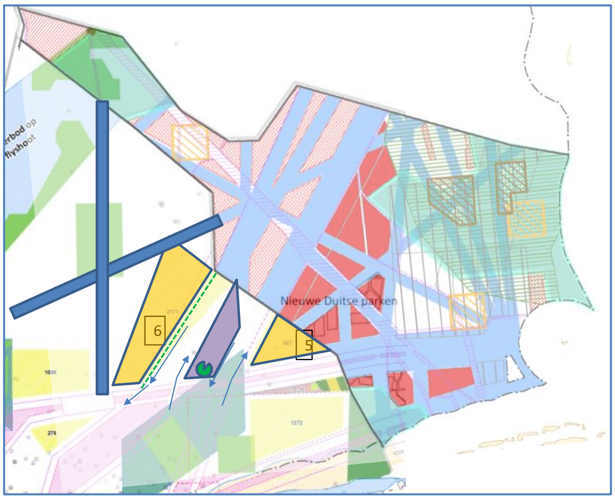


*Figure 2-2 Schematic representation of option 2: **Maximum Wind***

Option 3: Maximum clearway without corridor

- Draft German layout is starting point
- No median strip in-between wind search areas 5 and 6
- No connection for shipping through search area 5
- Route: Esbjerg-Hull north of area 6
- Northern Sea Route connection on EEZ border with Germany
- Artificial island for H^2 production and transport via pipeline in area 6

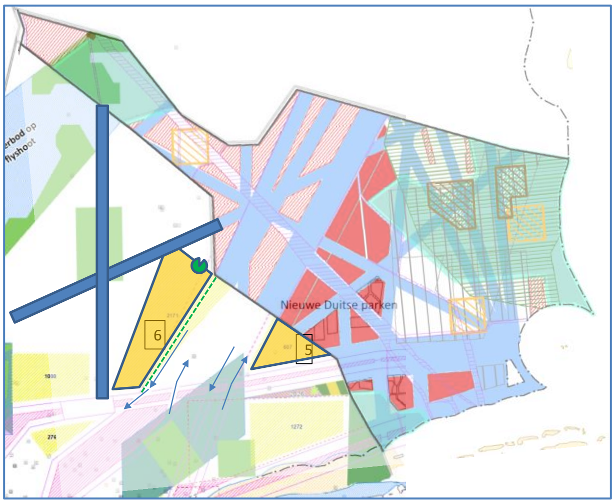


*Figure 2-3 Schematic representation of option 3: **Maximum clearway without corridor***

Option 4: Maximum wind energy with corridor

- Draft German layout is starting point
- Median strip with search area for wind in Baltic route between areas 5 and 6
- Route Esbjerg- Dutch EEZ through area 5
- Route: Esbjerg-Hull north of area 6
- Northern Sea Route connection on EEZ border with Germany
- Artificial island for H^2 production and transport via pipeline (in median strip)

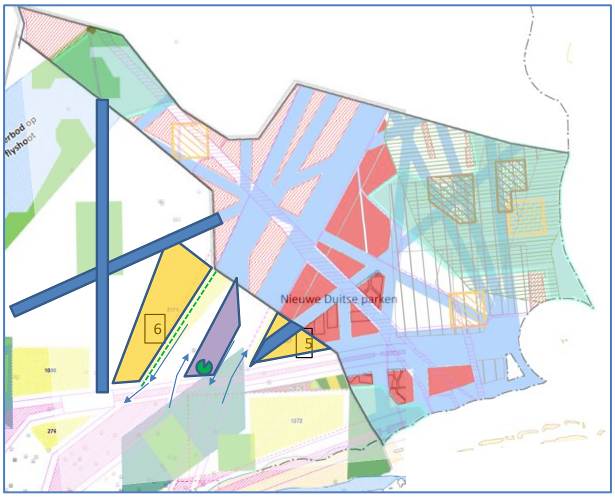


Figure 2-4 Schematic representation of option 4: ***Maximum wind energy with corridor***

Option 5: Ultra wind energy

- Draft German layout is starting point
- Median strip as in option 2 and 4 but extended to the north with windfarm in Baltic route between areas 5 and 6
- Route Esbjerg-– Dutch EEZ through area 5
- Artificial island for H^2 production and transport via pipeline (in median strip)
- Route: Esbjerg-Hull north of area 6
- No Northern Sea Route connection on EEZ border with Germany

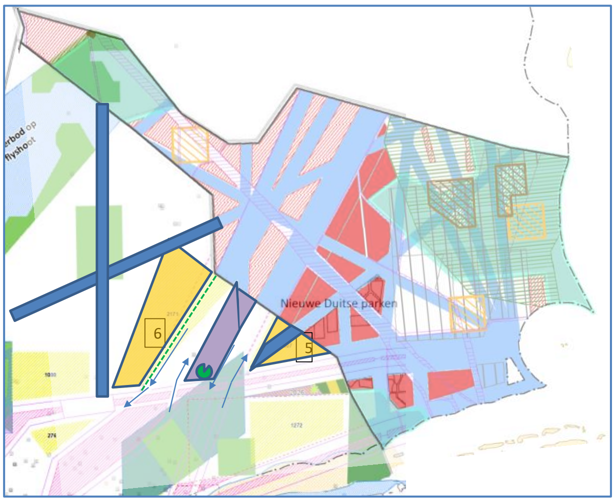


Figure 2-5 Schematic representation of option 5: ***Ultra wind energy***

Remark concerning median strip Germany

For all 5 options described above, the German future layout is used as starting point for the designs of the Dutch EEZ. During the process of this study however it became apparent that the median strip in the German EEZ will be reserved for shipping at least until 2035. The German authorities state that this median strip might be reserved for renewable energy if the probability of a ship – wind turbine collision does not exceed once every 100 year (0.01 collisions per year).

3 SHIPPING – TRAFFIC ANALYSIS

The first part of the FSA is an analysis of the traffic in the area. Part of the results of this traffic analysis is used as input in the two expert . Next to that the observation based on the results of the analysis are part of the quantitative assessment of the effect of the different design options. The traffic analyses also forms the basis for the traffic database used in the quantitative analysis using SAMSON.
The basis for this traffic analysis has been Automatic Identification System (AIS)-data for 2019 and partly 2020; a short description of the data is given in 3.1.
The first step in the traffic analysis is creating different density maps (3.2), this provides a clear picture of the main traffic routes on the North Sea. The second step is visualizing the sailed tracks (3.3) of the tracks of the individual vessels. The tracks are provided for different ship types (cargo/Tanker) and length classes. These different maps give insight in the different traffic patterns for the different ship categories. Both the density maps and the track maps provide insight where the routes are, but they do not yet provide sufficient information about the intensity of the shipping. This is done by analyzing so-called crossing lines (3.4). For different lines, the number of vessels crossing these pre-defined lines are being counted. By "following" an individual vessel over the different lines a so-called "origin-destination matrix is build up (3.5). This matrix contains the number of vessels, per type and size, sailing between different main areas in the study area. This "origin-destination" matrix ultimately forms the basis for creating the traffic database for SAMSON.
Another important part of this traffic database is the route structure, this is a combination of waypoints and connecting lines (links). How this route structure is created is described in 3.6. In addition to the definition of the route structure, the adjustments necessary to include the future windfarm areas are provided in 3.6.
Finally, the number of vessels sailing between different "endpoints" is combined with the route structure to create the final traffic database for SAMSON (3.7).

3.1 Source data, pre-analyzing data and ship types

AIS-data used received from the North Sea Server over period 1 Jan 2019 – 1 June 2020

Ship type
An AIS-message of a vessel contains information regarding the type of vessel. These are intentional defined ship types, a total overview can be found on: https://wwwcdn.imo.org/localresources/en/OurWork/Safety/Documents/AIS/SN.1-Circ.227.pdf.
However, within the SAMSON model a more refined ship type is required. For example to make a difference between bulk cargo vessels and container vessel or between the different types of tankers such as oil, chemical or gas tanker. This refinement is done based on a connection with other ship databases, such as the Lloyds vessel database.

A complete list of Maritime Mobile Service Identity (MMSI)-number is extracted from the AIS data including the provided AIS-type in the messages. For each MMSI-number the corresponding "SAMSON"-ship type is assigned. Next to the detailed ship types, a main distinction is made between so-called route bound and non-route bound vessels. Route bound vessels are merchant vessels and passenger vessels that sail between two ports following the shorted route taken into account the traffic measures. Non-route bound vessels are smaller vessel that have a destination at sea, such as work vessel, fishing vessel and recreation vessels.

The created MMSI-list is the basis for the further analysis. For most of the analysis only the route bound vessels are taken into account.

Ship size
Besides the ship type, also a ship size is added to the list of MMSI-numbers. Within SAMSON, the ship size class is based on the Gross Tonnage (GT) of the vessel. For the analysis of the tracks and the intensity of shipping the length of the vessel is used in the ship size category. The length of the vessel is sometimes better to comprehend than the GT of a vessel.

3.2 Density maps

The first step in the traffic analysis is creating different density maps based on the AIS data. For each grid cell, the average number of vessels presented are determined by counting the total AIS-messages received in the dataset divided by the total period. In Figure 3-1 the density map is shown for all vessel types present in de AIS-data set from 2019. In addition, the different wind energy search areas of the different countries are shown in this map. The maps shows next to the main routes also different "red" areas around the different oil & gas platform locations and within different windfarm areas that are under construction.
In Figure 3-2 only the so-called route bound traffic is shown, this means commercial vessels that sail from one port to another port following more-or-less fixed routes, this are merchant vessels: cargo (bulk and container), tanker and passenger vessels.

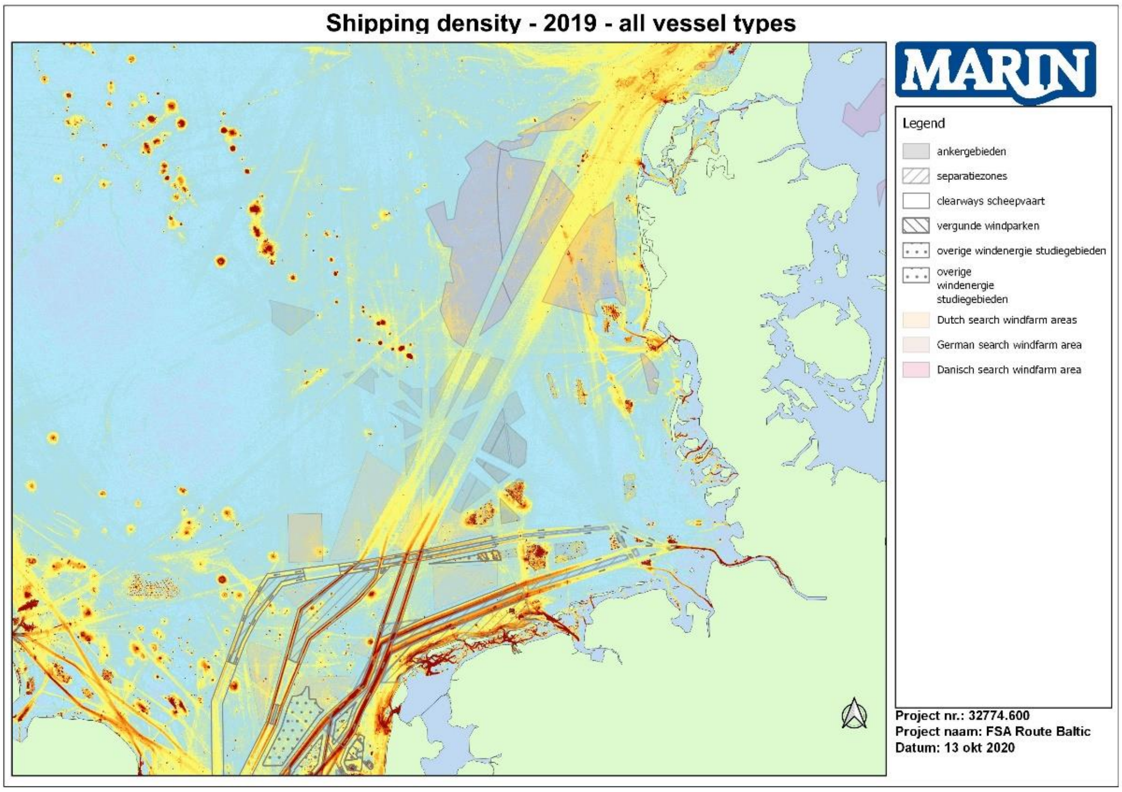


Figure 3-1 Traffic density 2019 all vessel types, based on AIS-data made available by the North Sea server.

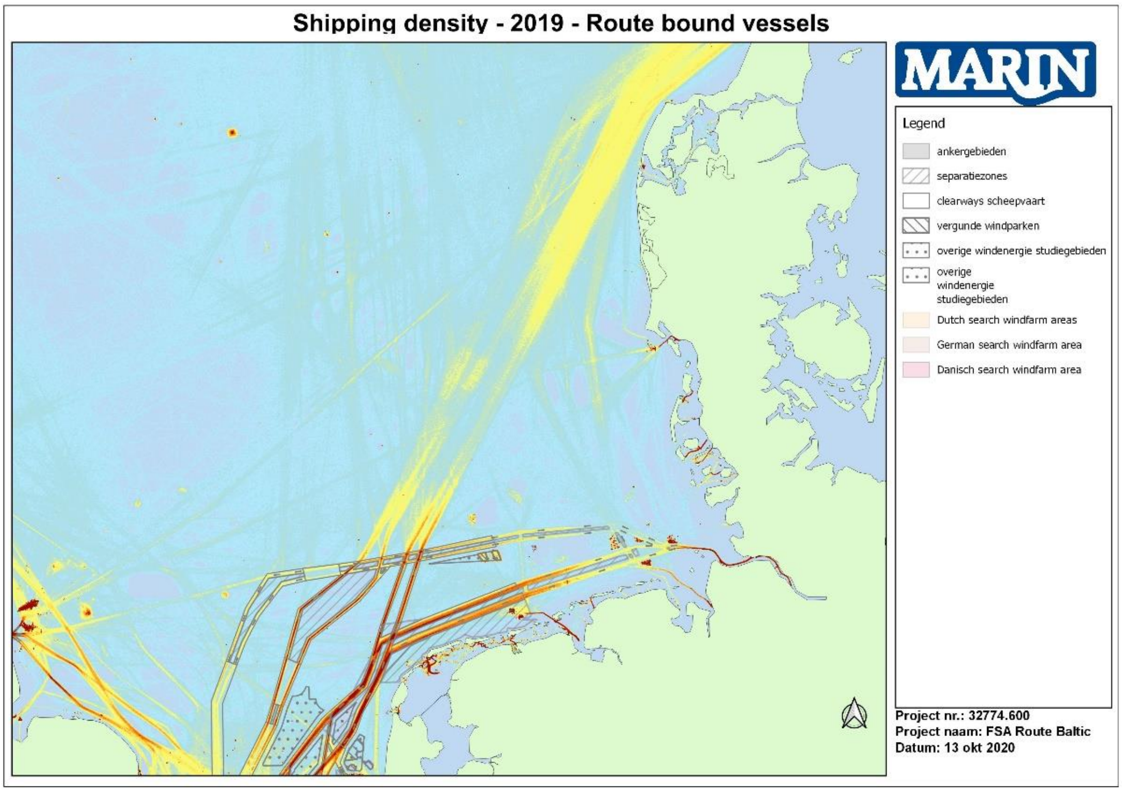


Figure 3-2 Traffic density 2019 only route bound vessel types, based on AIS-data made available by the North Sea server

This map shows the clear define routes on the southern part of the Dutch EEZ, as a result of the different TSS defined in that area. Next to that, the main routes toward the Skagerrak are visible. Less clear, but still visible are some routes (light yellow) leaving the east-west oriented TSS going up north toward Norway.

The density charts provide a clear overview of the historic main international shipping routes at the North Sea. It also shows the location where the present shipping routes pass through the wind energy search areas.

Quality of the AIS-data

Regarding the quality of the AIS-data, it can be concluded from the maps that the coverage is poor in the central part, between the Dutch EEZ and the Danish EEZ. This is because the German AIS-data was not (fully) part of the AIS-dataset of the North Sea server in 2019. For the analysis, also, data for a part of 2020 was received; starting from April 2020 the German AIS-data was included in the data set. This provided a more complete traffic image of the area. In Figure 3-3 the density maps for only the route bound traffic is shown for May 2019 (left) and May 2020 (right). The maps show that the coverage of the AIS-data on the routes going up to Skagerrak are improved. In addition, the coverage in the German Bight is much better in 2020 than in 2019.

However, for the main analysis and the further building up the traffic database 2019 has been used as a basic data set. 2019 was a complete year and now we do not know the exact effect of the COVID-19 related measured in the different countries on the intensity of the shipping traffic. In the further analysis, the poor coverage in the middle of the area has been taken into account in choosing the lines for the analysis and also in the interpretation of the found results. For creating the route network as part of the traffic database for SAMSON the density maps of 2020 are used to get a good impression of the location of the main routes in the area, however the intensity of shipping on the route structure is solely based on the 2019 data. A larger version of both maps is presented in APPENDIX 1.

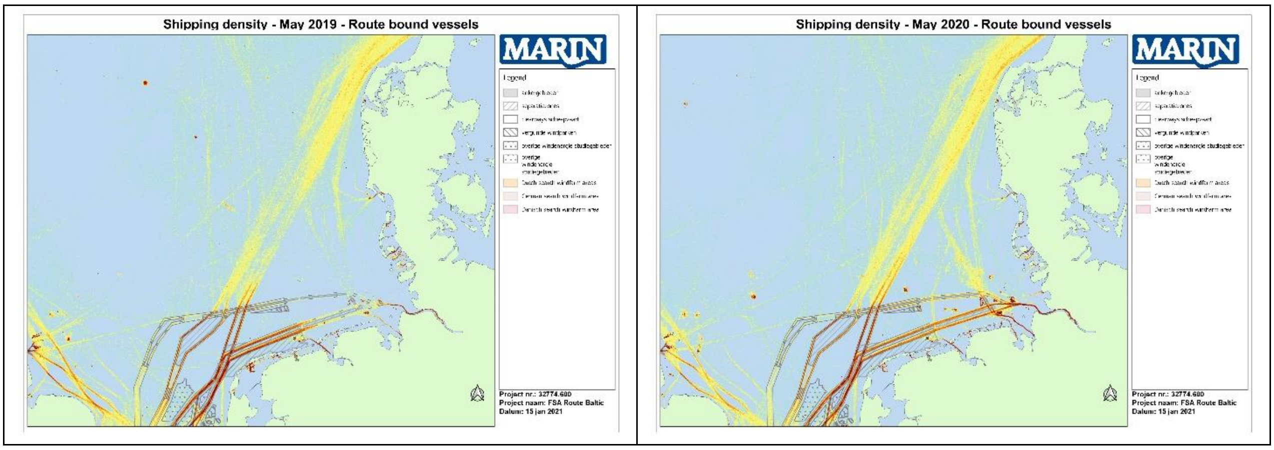


Figure 3-3 Traffic density May 2019 (left) and May 2020 (right)

3.3 Tracks of individual vessels

A second analysis of the AIS-data consists of the analysis of individual tracks of different type of vessels. In separate charts, the sailed tracks of vessels are plotted. In Figure 3-4 an example is given for all cargo, tanker and passenger vessels, in May 2020. Left is an overview of the whole area and on the right a chart is provided with a more zoomed-in view of traffic in the northern Dutch EEZ. The different colours represent different length classes of the vessels.

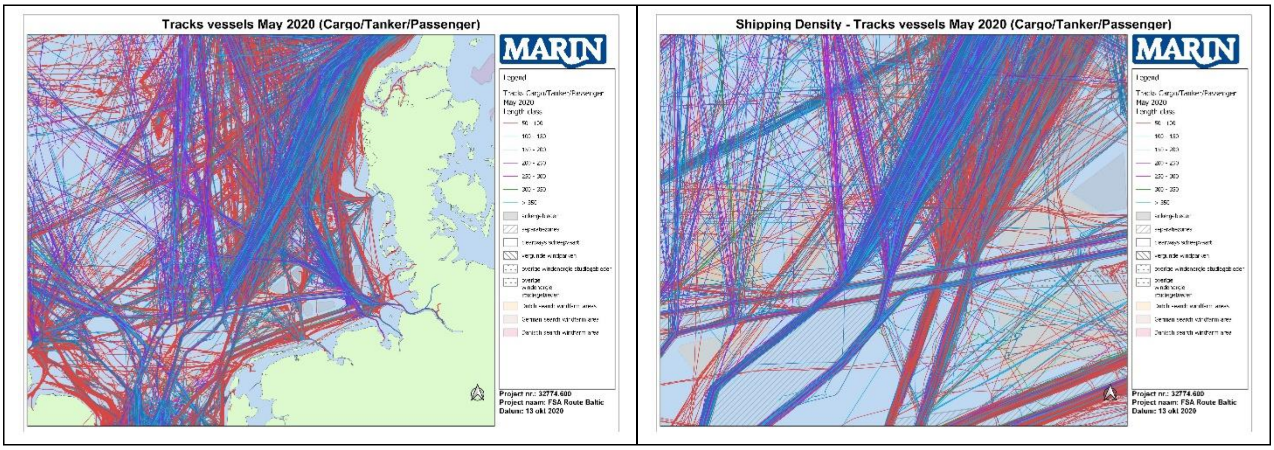


Figure 3-4 Tracks of all cargo, tanker and passenger vessels passing the area in May 2020.

These maps indicate a very diffuse picture of the shipping routes that are used for navigation through the northern area. Therefore, also the tracks of cargo/container vessels and tanker vessels separately are created. These are shown in Figure 3-5

Based on these maps (Figure 3-4 and Figure 3-5) the following observation can be made regarding the traffic in this area:

- On the southern part of the Dutch EEZ the routes show a less diffuse pattern as on the northern part of the North Sea, This is mainly a result of the different TSS[1]s that are defined in this southern part.

[1] TSS: Traffic Separation Scheme: a routing measure aimed at the separation of opposing streams of traffic by appropriate means and by the establishment of traffic lanes (source IMO)

- The routes between the southern and northern part of the North Sea show a more scattered pattern as a result of the many different destinations north going and the fact that vessels choose the shortest route to these destinations starting from the TSSs on the southern part.

- Indicated in the red ellipse on the upper left map (Figure 3-5), a clear northeast-southwest traffic flow is visible of cargo vessels (length class 100-150m), those are mostly smaller cargo vessels sailing between Hull and Esbjerg. These vessels now sail through the northern part of the planned wind farm search area 6.

- In addition, a “clear” route of tankers between 200 and 300m can be observed (red ellipse on the upper right map of Figure 3-5) that are leaving the TSS on the south and sail up north (direction Norway) is observed. These tankers are also now sailing through the planned wind energy area 6. These tankers are currently sailing through the planned wind farm area 6 and need to find another route when the windfarm will be build. These vessels will either pass windfarm 6 on the east side and will change course after passing the windfarms in the German EEZ or the tankers will pass windfarm 6 at the west in the space between windfarm 6 and 7. Both options will result in an increase of the traffic intensities on these routes.In the first observations based on the 2019 data these routes were not that clearly visible, due to the lack of coverage in the AIS-data in the German area, now using the 2020 data they are visible.

- The map of the tankers (right map of Figure 3-5) also shows that some tankers leave the TSS going north more to the east of the study area (dotted ellipses). These tankers now pass the planned wind energy area 7. This area is not part of the study of which the results are presented in the report, however these vessels have to find another route going north if areas 5, 6 and 7 are realized. They can either sail west of area 7 or between areas 6 and 7.

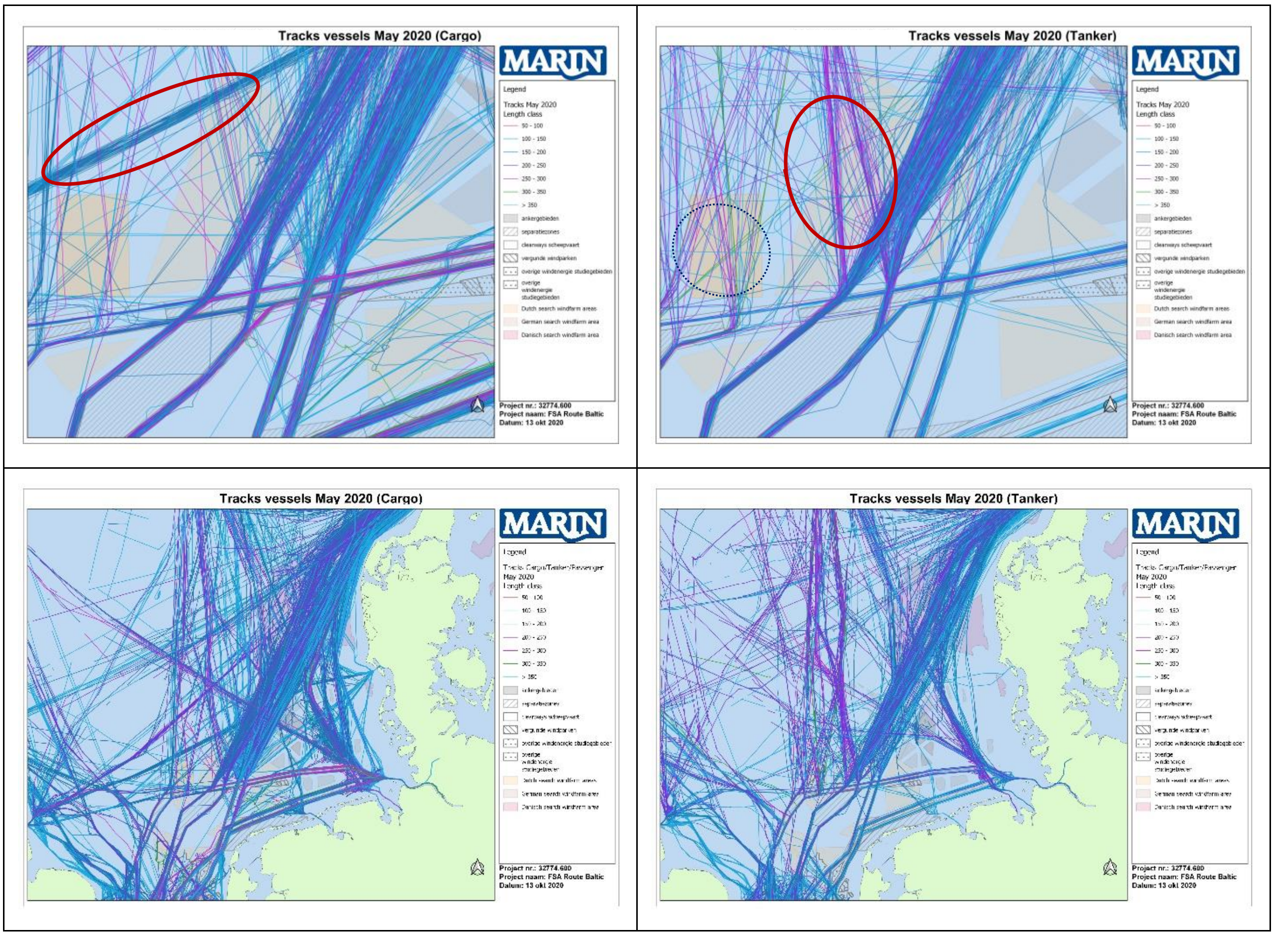


Figure 3-5 Tracks of all cargo (left) and tankers (right) passing the area in May 2020

The maps in Figure 3-5 still show a complex traffic picture, therefore another set of maps have been created for different size classes of the different vessels separately. These maps are shown in Figure 3-6 until Figure 3-11 and provide information for some additional observations regarding the present traffic through the area, also related to the planned wind energy area. Larger versions of the different maps are also included in APPENDIX 1

Observations of traffic flows through the area based on the detailed maps in Figure 3-6 until Figure 3-11:

- Mainly the vessels below 200m LOA “change lanes” after leaving the TSS Off East Friesland (or before entering), so they sail in the area where on some options search areas for offshore wind are located. (Figure 3-6 and Figure 3-7)

- Again the route between Hull and Esbjerg is clearly visible in Figure 3-7, indicated in the blue ellipse, these are mainly cargo vessels. This current route goes through the north part of the planned windfarm area 6, thus these vessels need to change their route somewhat to the north, depending also on the connection possible through the planned German wind energy areas.

- Mainly vessel between 200 and 300 leave the Off East Friesland TSS and directly navigate via route up north (up to Norway) and vice versa, these are mainly tankers. (blue circle in Figure 3-8 and Figure 3-9). These vessels sail through the planned wind energy area 6 and need to find an alternative route once the windfarms are realized. These vessels will either pass windfarm 6 on the east side and will change course after passing the windfarms in the German EEZ or the tankers will pass windfarm 6 at the west in the space between windfarm 6 and 7. Both options will result in an increase of the traffic intensities on these routes.

- The median strip search area is sailed by vessels up to 250m, indicated with the red ellipses in Figure 3-6,Figure 3-7 and Figure 3-8. These vessels will be affected by introducing a wind energy area between the two north-south oriented traffic routes.

- Larger vessels (up to 300) follow mostly the east-west TSS and do not sail a route thru the search areas (Figure 3-10 and Figure 3-11).

- Indicated in the dotted circle in different maps are the vessels leaving the TSS to the north at the west side of the study area. These vessels are now crossing the planned wind energy area 7. The effects of this wind energy area is not the direct objective of this study, however these are vessels that have to change their route. By also introducing wind energy 5 and 6, there options are limited to passing at the west side of area 7 or sail between area 6 and 7, if possible.

- Within the different maps also some “abnormal” behaviour can be observed. For example, two complete turning circles can be seen in Figure 3-10 (vessels between 300 and 350m).Detailed information of why these vessels needed to make these manoeuvres is not known based on AIS-data only. In chapter 3.8 more details are provide on the sometimes challenging weather condition in the area, probably this behaviour has a relation with these weather conditions.

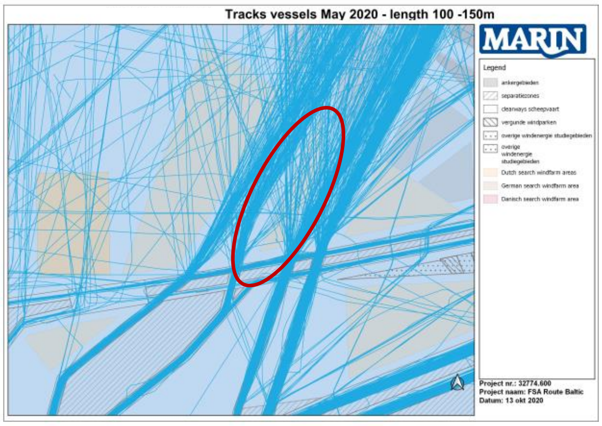


Figure 3-6 Track vessels May 2020 - length 100-150m

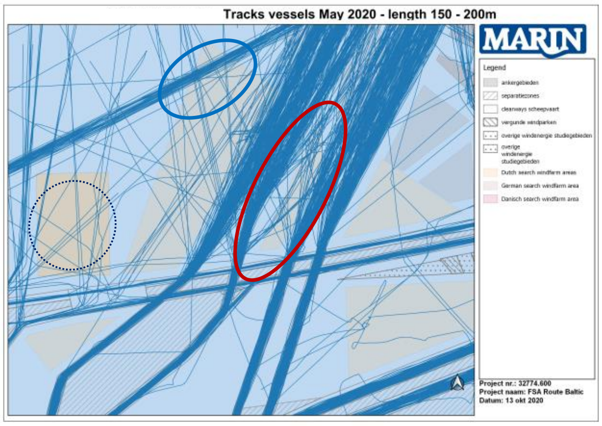


Figure 3-7 Track vessels May 2020 - length 150 - 200m

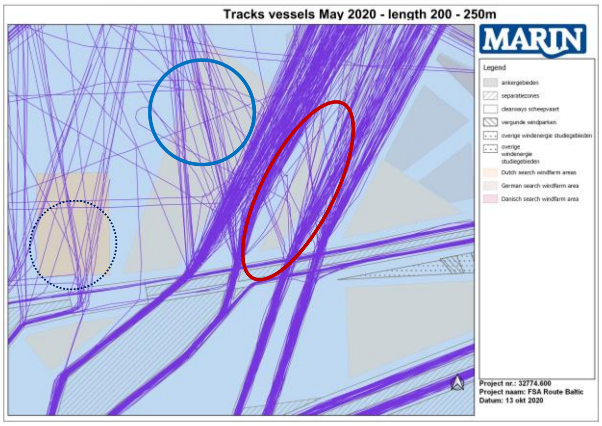


Figure 3-8 Track vessels May 2020 - length 200-250m

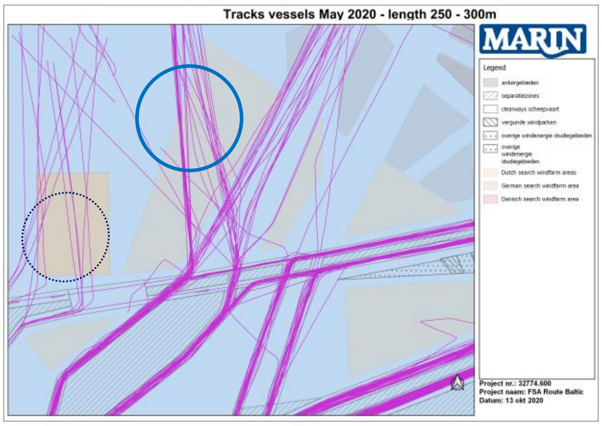


Figure 3-9Track vessels May 2020 - length 250-300m

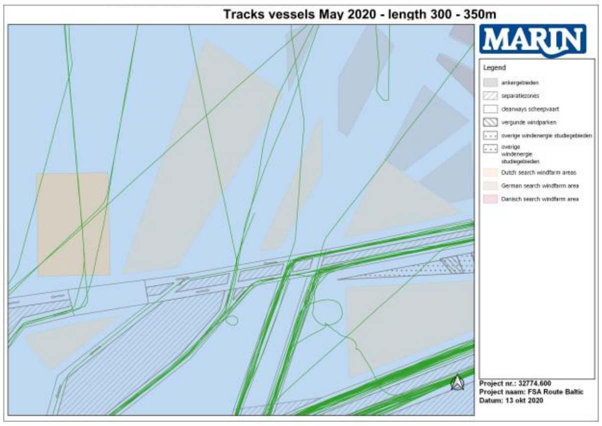


Figure 3-10 Track vessels May 2020 - length 300-350m

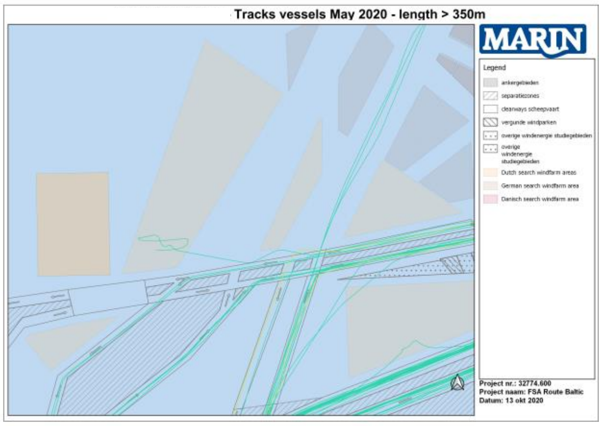


Figure 3-11 Track vessels May 2020 - length >350m

3.4 Intensity of shipping – crossing lines

The density and track maps only show where the main traffic routes are located, to determine the intensity of the shipping in the routes different so-called crossing lines are determined. The number of ships per year passing each line is counted. In total, the analysis is for a number of lines, shown in Figure 3-12. As concluded earlier, the coverage of the AIS-data is not good for the whole period and the whole area, therefore only the results of the analysis of the lines in the areas with good coverage are presented in this report. The lines included in the final analysis for the traffic intensity are presented in Figure 3-13.

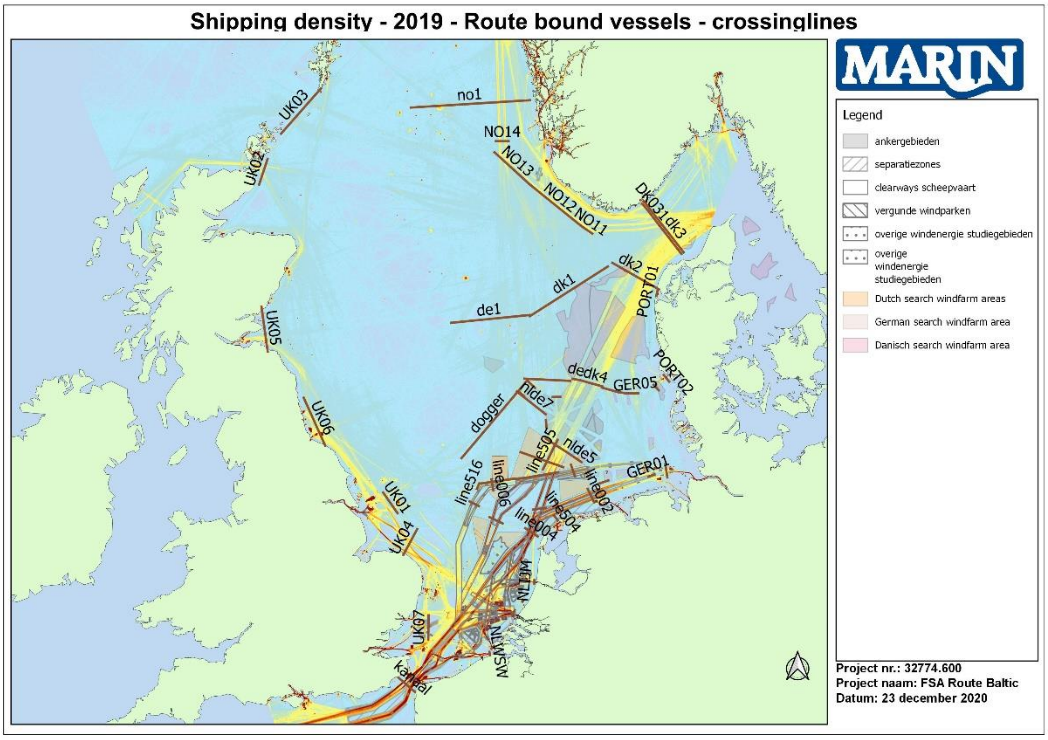


Figure 3-12 Overview of all initial crossing lines used in the intensity analysis.

For the analysis of the traffic intensity in the study area the four lines at the north of the Dutch EEZ are defined (nl01, nl02, nl03 and nl04). These lines represent the traffic intensity of vessels leaving of entering the TSS Texel and TSS West Vlieland going to or coming from the north. Next to the traffic intensity at the Dutch side of the traffic routes through the study area, also the traffic intensity is determined at Skagerrak (DK031, DK032 and D0K33) and three lines parallel to the Norwegian coast (NO11, NO12 and NO13). Finally, also the traffic intensity at the approach of Esbjerg is presented (GER06 and PORT02).

For these relevant lines, the total intensity per ship type and ship size (based on GT) is presented in APPENDIX 3. A summary of the results per individual line and sailing direction is given in Table 3-1 and Table 3-2. The tables provide the total number of vessels (route bound vessels) crossing the different lines (including a total per area) per ship type and crossing direction.

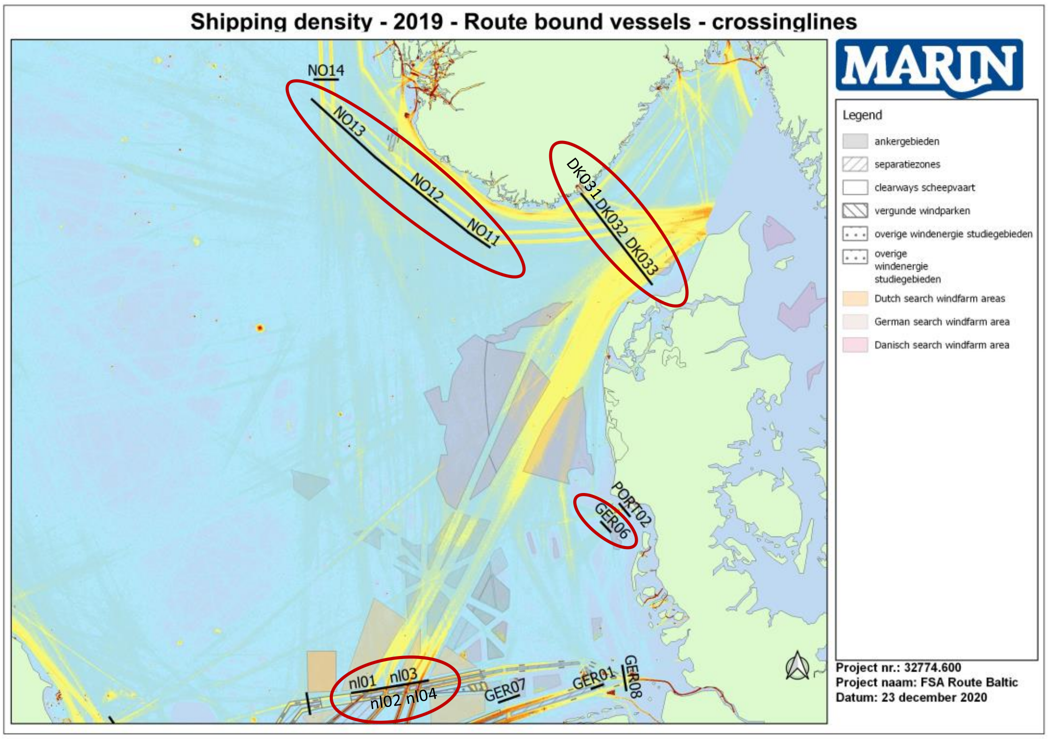


Figure 3-13 Overview of the representative crossing lines for the traffic routes between the Netherlands and Skagerrak and Norwegian Coast.

Table 3-1 Total number of vessels crossing the different lines (Skagerrak and Norway) per ship type in 2019.

Direction	Ship type	Line							
		DK031	DK032	DK033	**Total: Skagerrak**	NO11	NO12	NO13	**Total: Norway**
S	GDC/Bulker/OBO	1425	3196	7223	**11844**	380	2131	1529	**4040**
	Container	201	150	2003	**2354**	4	164	127	**295**
	Tanker - oil	58	392	1339	**1789**	10	91	466	**567**
	Tanker - chem	218	967	2412	**3597**	10	272	650	**932**
	Tanker - LNG/LPG	44	455	575	**1074**	7	381	385	**773**
	Pass/Ferry/Roro	106	810	2327	**3243**	66	737	440	**1243**
	Subtotal	**2052**	**5970**	**15879**	**23901**	**477**	**3776**	**3597**	**7850**
N	GDC/Bulker/OBO	1046	3879	7144	**12069**	679	1969	1633	**4281**
	Container	24	70	1970	**2064**	27	204	64	**295**
	Tanker - oil	57	363	1366	**1786**	44	103	405	**552**
	Tanker - chem	181	938	2606	**3725**	80	204	591	**875**
	Tanker - LNG/LPG	41	390	630	**1061**	39	368	370	**777**
	Pass/Ferry/Roro	101	841	2255	**3197**	71	548	469	**1088**
	Subtotal	**1450**	**6481**	**15971**	**23902**	**940**	**3396**	**3532**	**7868**
	TOTAL	**3502**	**12451**	**31850**	**47803**	**1417**	**7172**	**7129**	**15718**

Table 3-2 Total number of vessels crossing the different lines (Netherlands and Esbjerg) per ship type in 2019.

Direction	Ship type	Line					
		nl01	nl02	nl03	nl04	**Total Netherlands**	GER06 (Esbjerg)
S	GDC/Bulker/OBO	1935	59	4505	50	**6549**	378
	Container	101	6	1175	5	**1287**	49
	Tanker - oil	1171	18	125	33	**1347**	20
	Tanker - chem	1720	15	727	4	**2466**	42
	Tanker - LNG/LPG	447	15	503	4	**969**	6
	Pass/Ferry/Roro	131	17	1365	28	**1541**	302
	Subtotal	**5505**	**130**	**8400**	**124**	**14159**	**797**
N	GDC/Bulker/OBO	126	1467	102	4716	**6411**	384
	Container	13	70	11	1356	**1450**	50
	Tanker - oil	14	1173	19	227	**1433**	21
	Tanker - chem	31	1702	47	913	**2693**	57
	Tanker - LNG/LPG	18	460	11	444	**933**	9
	Pass/Ferry/Roro	72	137	27	1512	**1748**	313
	Subtotal	**274**	**5009**	**217**	**9168**	**14668**	**834**
	TOTAL	**5779**	**5139**	**8617**	**9292**	**28827**	**1631**

In Table 3-3 the shipping intensity for the three areas is summarized per ship type (both sailing direction). In the table, the distribution over the different ships types is also indicated. In total more than 47.800 vessels (130 vessels per day) crossed the line in both directions at Skagerrak, 50% of these vessels were GDC of Bulk carrier, 15% chemical tankers. Over the lines parallel to the Norwegian coastline more than 15.700 vessels (43 per day) sailed in 2019, most of them were also GDC/Bulk carriers. Finally, more than 28.800 vessels crossed the line in the Netherlands entering of leaving the TSS Texel of TSS West Vlieland. This is almost 79 vessels per day in both direction, 3 ships per hour.

In Table 3-2 the total number of vessels sailing to Esbjerg through the study area are given. The line GER06 represents these. In total, 1600 vessels passed the line in 2019. Almost 40% (762) of these vessels were ferry/passenger vessels, mostly the ferry sailing between Hull and Esbjerg.

Table 3-3 Total number of vessels crossing the areas per ship type in 2019.

Ship type	Total number route bound vessels crossing the different lines per ship type in 2019			Distribution over the ship types		
	Skagerrak	Norway	Netherlands	Skagerrak	Norway	Netherlands
GDC/Bulker/OBO	23913	8321	12960	50%	53%	45%
Container	4418	590	2737	9%	4%	9%
Tanker - oil	3575	1119	2780	7%	7%	10%
Tanker - chem	7322	1807	5159	15%	11%	18%
Tanker - LNG/LPG	2135	1550	1902	4%	10%	7%
Pass/Ferry/Roro	6440	2331	3289	13%	15%	11%
Total	**47803**	**15718**	**28827**	**100%**	**100%**	**100%**

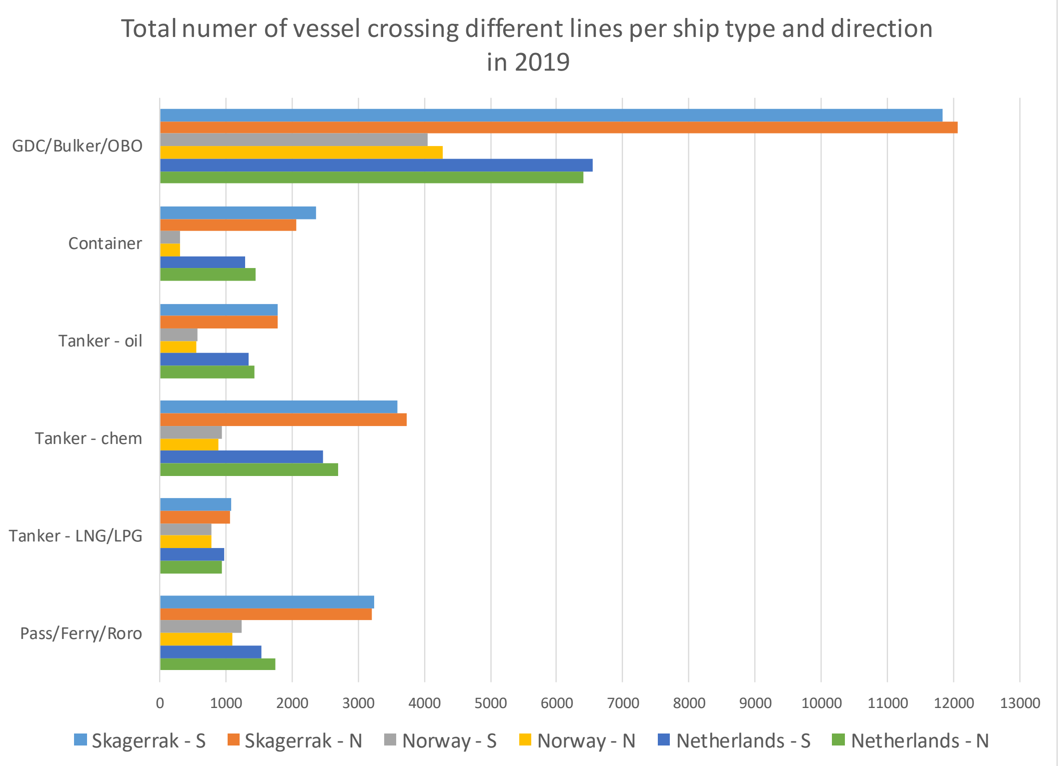


Figure 3-14 Total number of vessels crossing the different lines per ship type in 2019.

3.5 Origin/destination matrix

The next step is to “follow” the vessels that cross a specific line to see in which “final” direction they continue their journey. This analysis results in a so-called: “origin-destination” matrix. This matrix will be the input for the traffic database for SAMSON. For a selection of crossing lines (see Figure 3-15) all crossings are combined and sorted on individual ship and date of crossing. Based on this table the number of movements/journeys between two different crossing lines has been counted per ship type and ship size. Hereby only two successive “crossings” are taken into account when the time between two crossings is less than 100 hours. Also crossing lines combinations that were not “logical”, as a result from coverage issues of the AIS-data, were left out of the analysis, e.g. a vessel that crosses a line at Skagerrak in easterly discretion followed by a crossing over the line at the channel. This was less than 5% of the total journeys.

The number of crossings over the different lines are combined to information regarding the average number of movements by route bound vessels between the different areas, see also Figure 3-15.

The areas area:

- **Norway coast,** this contains three lines parallel to the coast and one line covering the TSS in northern direction.
- **Skagerrak,** this contains three lines covering all vessel that sail towards of coming from the Baltic Sea area
- **Esbjerg,** this are two lines near the approach of the post of Esbjerg.
- **Germany,** this area contains three lines on the German continental shelf and also two lines in the Dutch continental shelf, hereby all movement toward German ports and the North sea are “covered” The lines on the Dutch continental shelf are chosen to take into account the poor coverage on the German part.
- **Netherlands – N,** this area covers the four lines at the north part of the Dutch continental shelf, where vessels leave the TSS (near by the area of interest of this study)
- **Netherlands**, all other lines on the Dutch continental shelf, including the ports.
- **Dover Strait,** one line at the location of Dover Strait
- **UK,** this covers different lines located at the British east coast.

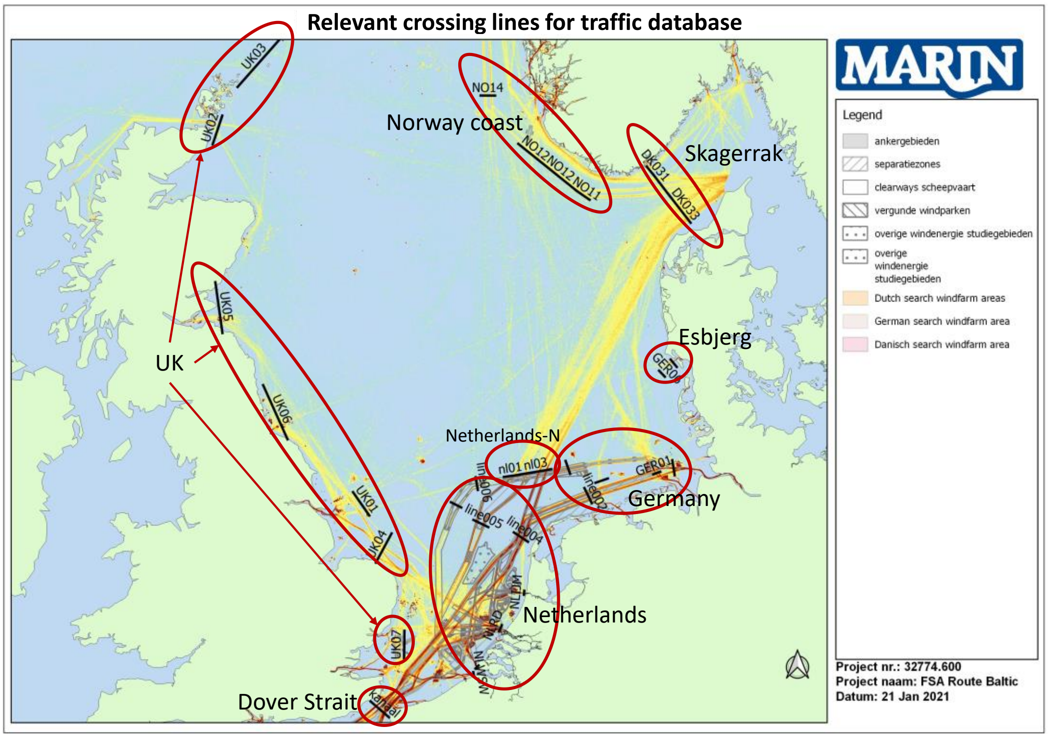


Figure 3-15 Relevant crossings lines including different defines areas

The total number of movements (successive crossing of the different lines in an area) are given in Table 3-4. For example, the number of movements (journeys) from a line in the Skagerrak area to the Netherlands-N area is 10171. It is also possible that there are movements between two lines within one area, e.g. between lines in the area The Netherlands (41653 movement in 2019). This contains for the movements between ports and the lines defined on the different mail traffic routes.
Finally, the number of movements between the individual defined lines are the basis for the final traffic database. In Figure 3-16 the direct connections between the different lines are plotted, the thickness of the lines indicate the number of movements (both directions). On the left, all connections are shown with more than one connection per week and right with more than one connection (movement) per day. Note that the direct connections are plotted, this is not necessarily the actual route the vessels will sail between two areas

Table 3-4 Total number of movement between crossing lines in the different areas in 2019 by route bound vessels.

From	To							
	Dover Strait	Esbjerg	Germany	Nether lands	Netherlands - N	Norway - Coast	Skagerrak	UK
Dover Strait		3	146	25505	74	57	51	3025
Esbjerg	3	1340	143	35	165	137	277	640
Germany	661	130	4964	13211	131	264	1842	826
Netherlands	26546	84	14248	41653	13617	646	395	14632
Netherlands - N	343	228	112	12959	0	2568	10121	185
Norway - Coast	38	127	337	781	2246	271	2561	1143
Skagerrak	66	140	1763	538	10171	2224	0	2337
UK	2088	629	565	15497	119	1267	2200	9283

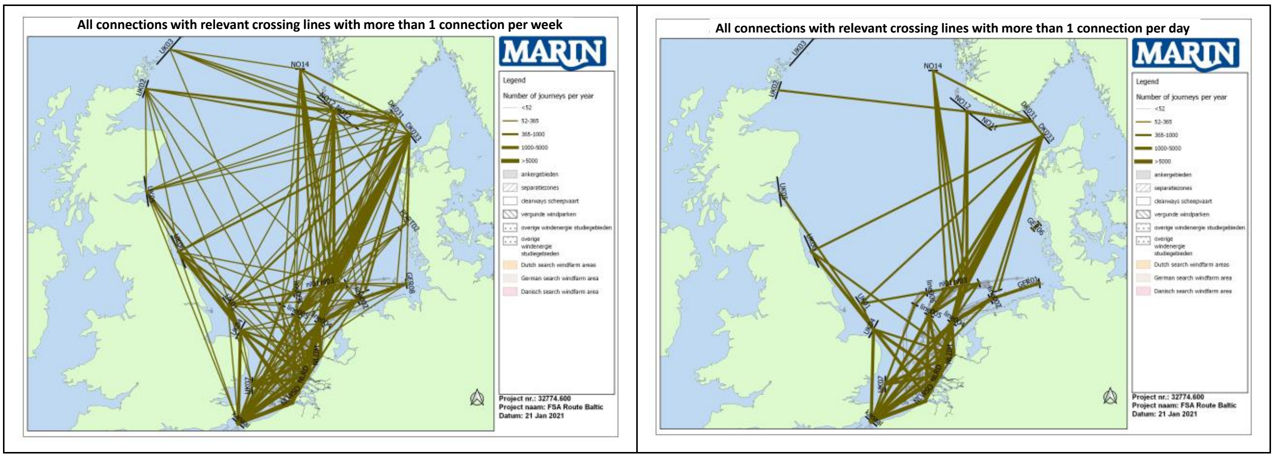


Figure 3-16 All connections between relevant crossing lines left: with more than one journey (connection) per week and right with more than one journey (connection) per day in 2019.

The last figure (right map of Figure 3-16) clearly shows the main movements on the North Sea, between the different ports on the Southern part and the main connection toward Skagerrak and the Norwegian coast. In addition the connections between the different UK ports and Skagerrak are clearly visible. The lines shown are the main "routes"/connections on the North sea on which more than one vessel per day sails. The map does NOT show the actual routes the vessels sailed, but only a direct connection between the middle of the defined crossing lines between which they have sailed in 2019. Finally, this number of "connection" for the basic origin-destination matrix used to create the traffic database for the present and future situations.

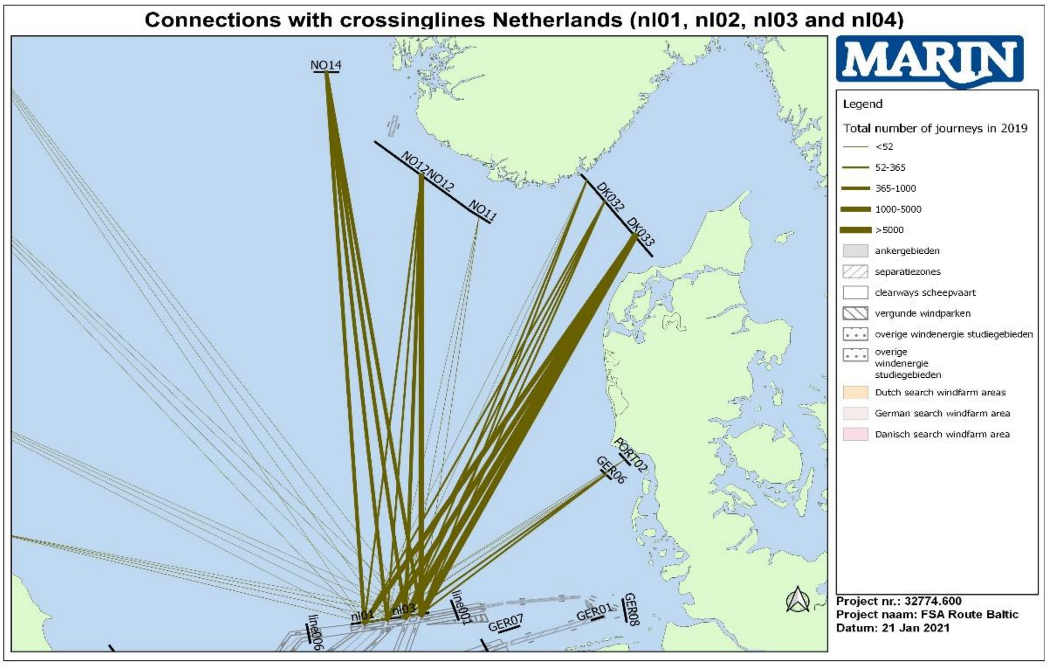


Figure 3-17 All connections between relevant crossing starting form of ending at one of the lines at the Northern part of the Dutch EEZ

3.6 Route structure – route network

To create the final traffic database that is necessary for calculation with SAMSON, the route structure of the North Sea needs to be defined. This route structure consists of waypoints and lines between these waypoints, so-called links. These links have a direction and a defined lateral distribution. This means the average width of the traffic flow over the link.
Creating this route structure is done manually by "clicking" the various routes based on the density maps and so-called track-plots. For the part on the southern section of the North Sea the route structure has been re-used from earlier projects, however the part on the northern section of the North Sea has been added for this study. The main purpose of this study is to see the impact on the safety of shipping of different routing and windfarm options just above the east-west oriented TSS on the northern part of the Dutch EEZ. Therefore for this part of the traffic database and thus for the route structure the level of details is higher than for other parts of the North Sea.

In the first phase, the route structure has been defined based on the traffic flows observed in 2019. In a second phase, the route structure has been adjusted to represent the situation including the planned German windfarms. This final route structure represents "The Basic scenario" (option 0). The route structure based on the location of the current routes (AIS-data 2019) is presented in Figure 3-19. In Figure 3-20 the adjusted (Basic Scenario) is shown, including the assumed location of the wind farm in the German part of the North Sea. These planned locations were provided to MARIN at the start of the study and are the starting point of the traffic database for the "Basic scenario". The final planning of these wind farm areas may be be different in the future, however for this study these locations were assumed. In Figure 3-18 both routes are plotted in one map, zoomed to the study area. In the map, three main changes are indicated with coloured arrows:

- **Yellow arrow:** Routes northeast to southwest are moved to the east to sail between the two planes search areas for wind farm. As a result of this shift the two main traffic routes will be closer to each other than in the current situation
- **Green arrow:** The northwest to southeast oriented traffic flow will move more south. This has no large impact on the situations, only that the location of the crossing area with the other traffic will change compare to the current situation.
- **Blue arrow**: The traffic route toward or from Esbjerg has to change for vessels coming from of going to the westerly routes on the Dutch EEZ.

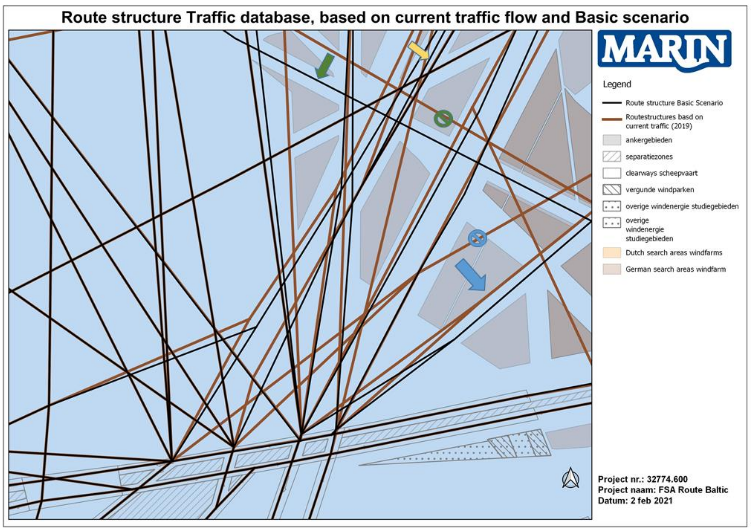


Figure 3-18 Route structure for the current and the Basic Scenario.

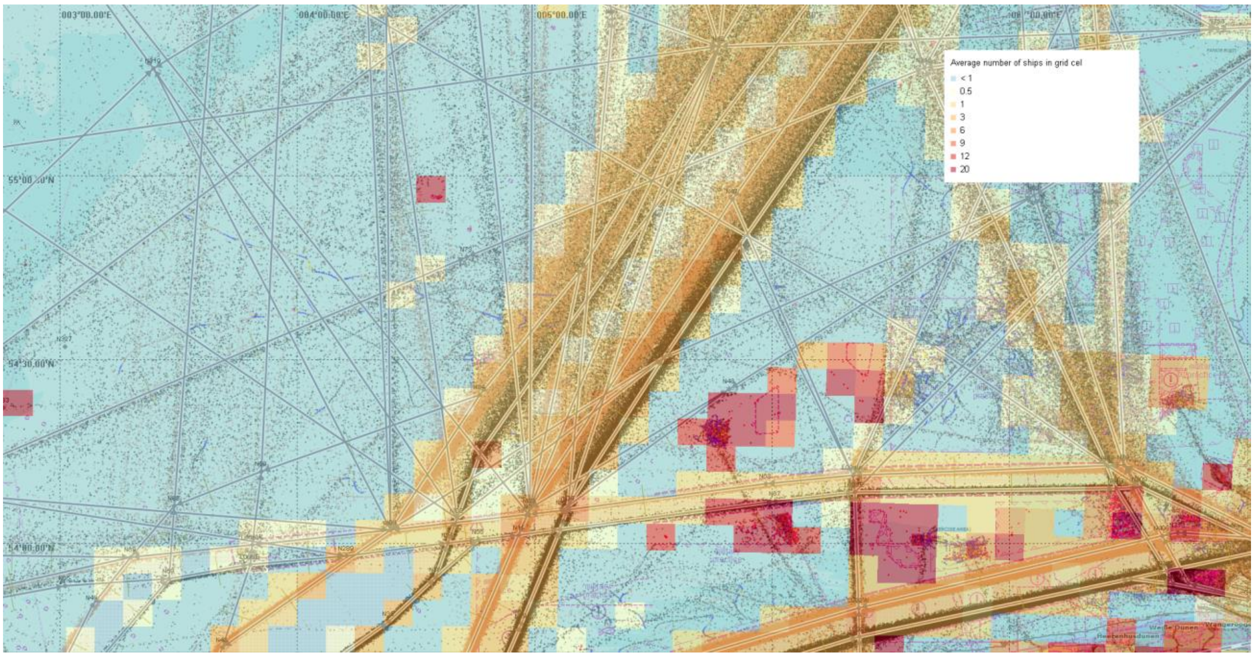


Figure 3-19 Route structure (2019) with tracks of route bound vessels May 2020 (zoom at study area)

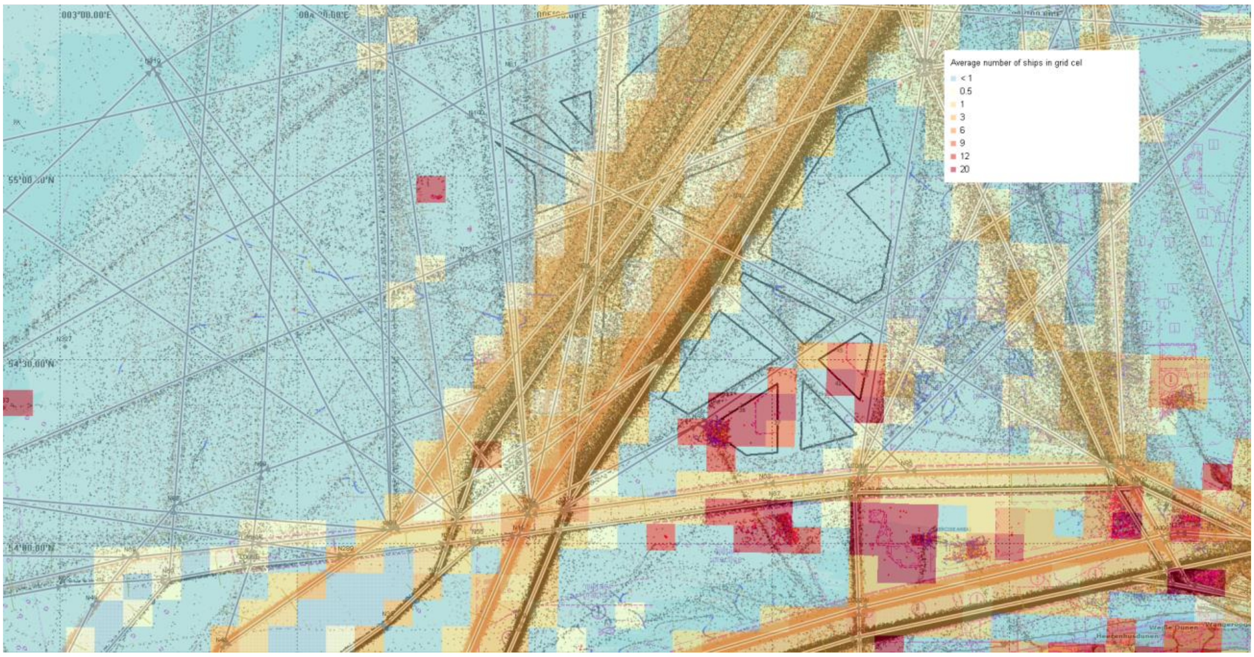


Figure 3-20 Adjusted route structure (Basic) to take into account the planned German windfarms with tracks of route bound vessels May 2020 (zoom at study area)

Route structure for the different options

The next step is to create the route structure for the possible future situation including the planned wind farms on the Dutch EEZ. For this, initially four options are introduced. The details of the different options are described in chapter 2.2.
For this alteration of the route structure, the assumed windfarm areas for the different options are introduced as a “forbidden” area. This means that link that goes through such an area is no longer taken in to account. Furthermore, for the options with a median strip the route structure has been altered manually to create a route going up north between the median strip on the Dutch EEZ and the search area on the German EEZ.

The results for the four options are shown in Figure 3-21 to Figure 3-24. In the different maps, the basic route structure is indicated with black dotted lines and the route structure for the various options are indicated with a green line. In addition, the search areas for wind farms is indicated in the maps.

It needs to be pointed out that the north point of area 6 will not be part of the search area, therefore the east-west oriented line/route is still valid, even when the wind farm is build. Also with option 1 and 4 a corridor will be made in windfarm area 5 (east wind farm). The corridor is not shown in the overlay for the search area, but the route to and from Esbjerg through this area is still possible for these two option.

In the maps, the main changes are indicated with an orange arrow and “no-go” sign. The main effect will be the fact that it will not be possible to sail directly up north when leaving the Dutch EEZ (or the other way around), due to the present of wind farm area 6. Furthermore vessel on the route north-south who in the current situation sail through the median strip of area 5, will have to change their course and sail in the corridor between the two windfarms (On the Dutch EEZ and the German EEZ).

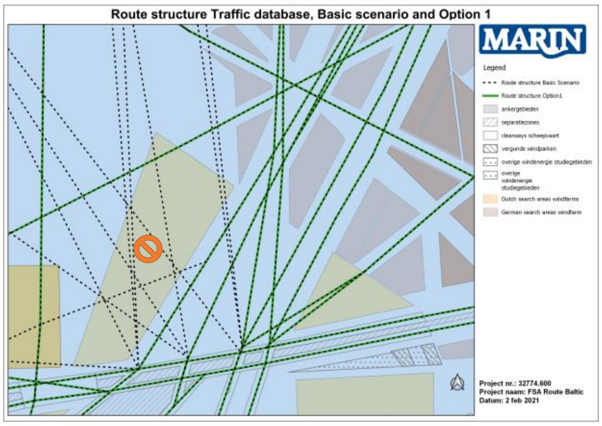


Figure 3-21 Route structure: Option 1

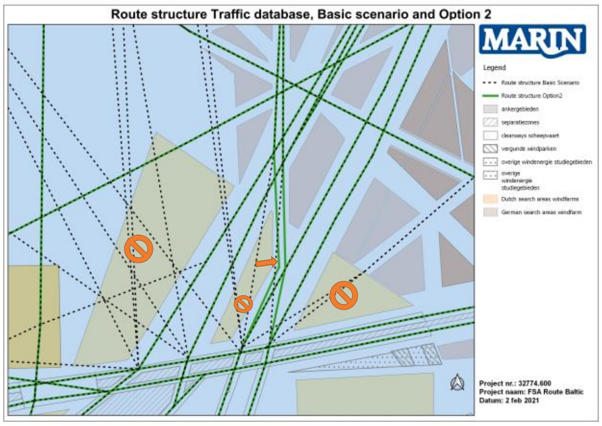


Figure 3-22 Route structure: Option 2

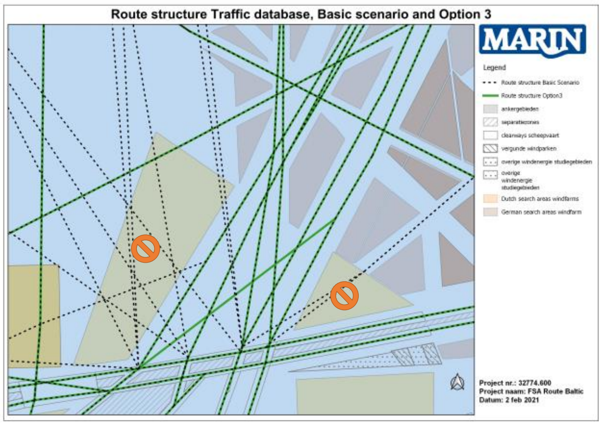


Figure 3-23 Route structure: Option 3

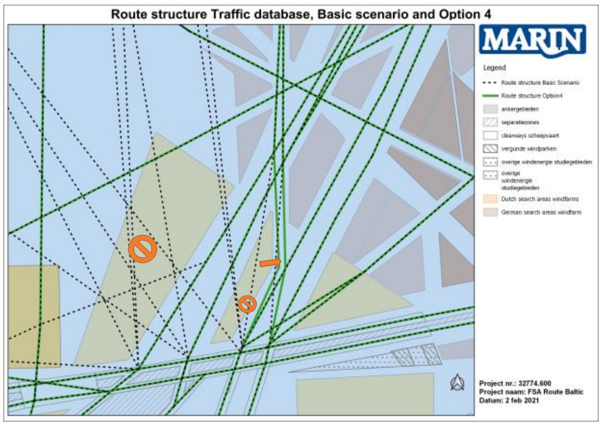


Figure 3-24 Route structure: Option 4

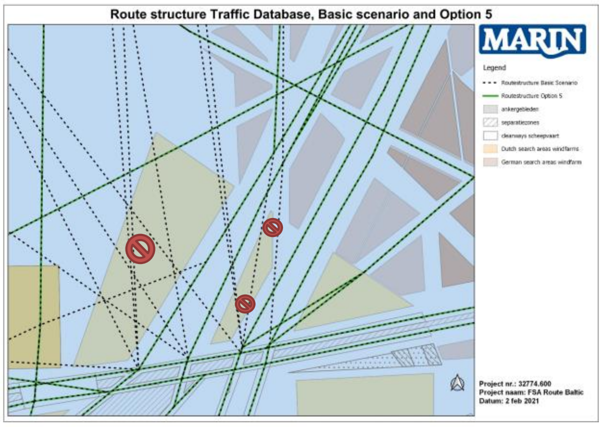


Figure 3-25 Route structure: Option 5

3.7 Traffic database – input SAMSON

The last phase is combining the origin-destination matrix and the route structure (3.6) to create the final traffic database. This database will be used in the calculations with SAMSON. Based on the route structure the vessels are assigned to a certain combination of links (line between two waypoints of the route structure) to simulate their voyage between a start and end point (based on the analysis of the crossing lines). Finally, the total number of vessels per link, per ship type and size per year is determined; this is called the traffic database for SAMSON.

The traffic database for the "Basic scenario" is shown in Figure 3-26. The red lines are the routes and the black numbers indicate the total number of vessels passing per year (in one direction). In the charts, also the planned search areas for wind farms in the German EEZ are indicated.

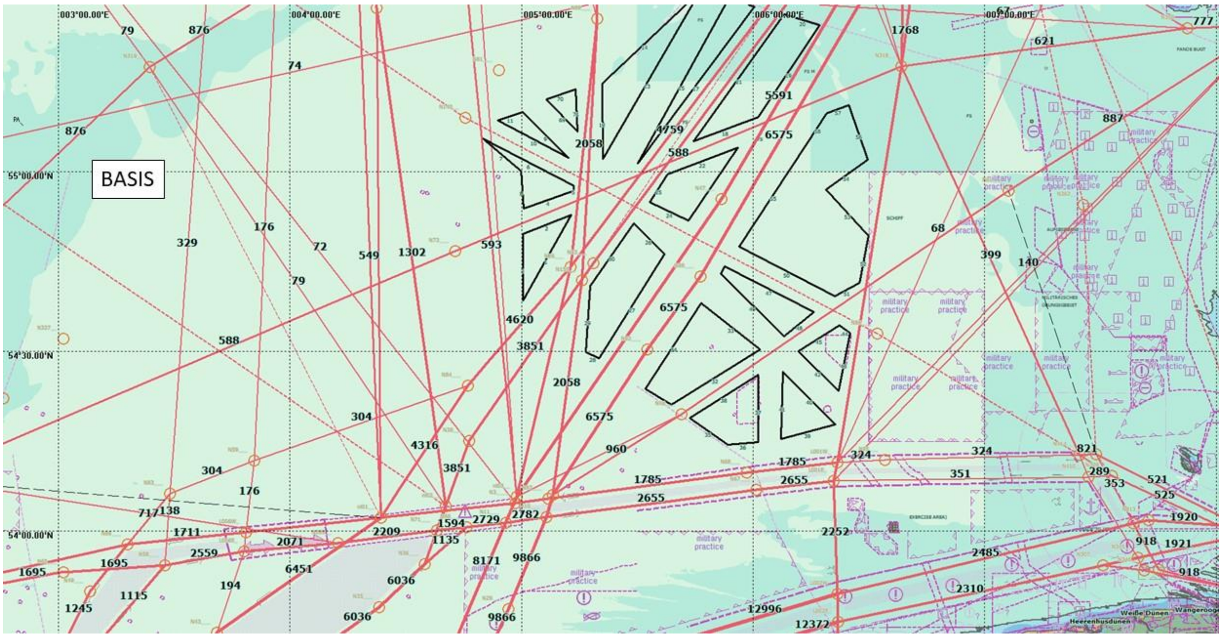


Figure 3-26 Route bound traffic database used for the Basic scenario

Using the route structures created for the different options (see 3.6) also the traffic database for these options are created: Figure 3-27 until Figure 3-30 .

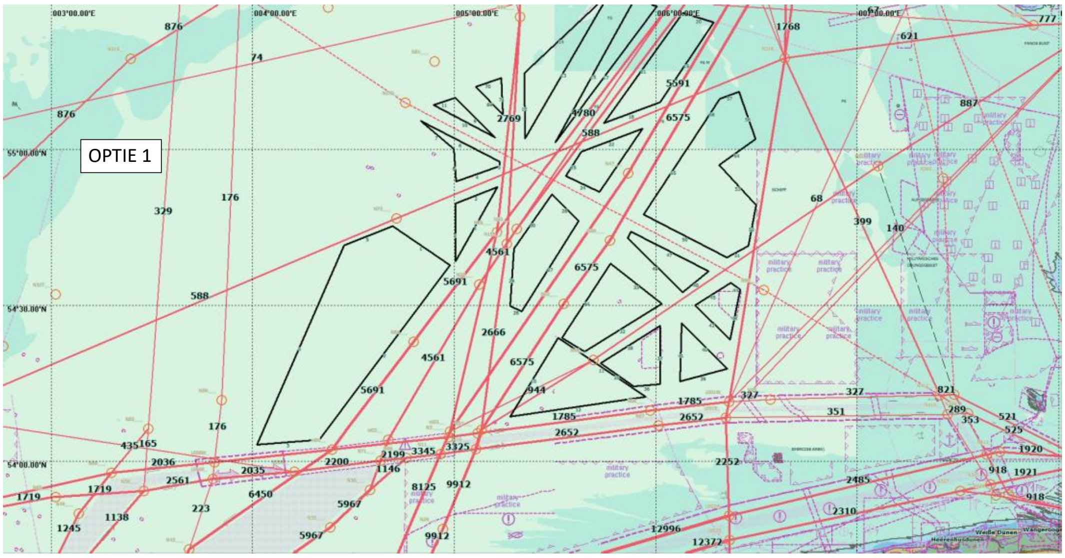


Figure 3-27 Route bound traffic database used for Option 1

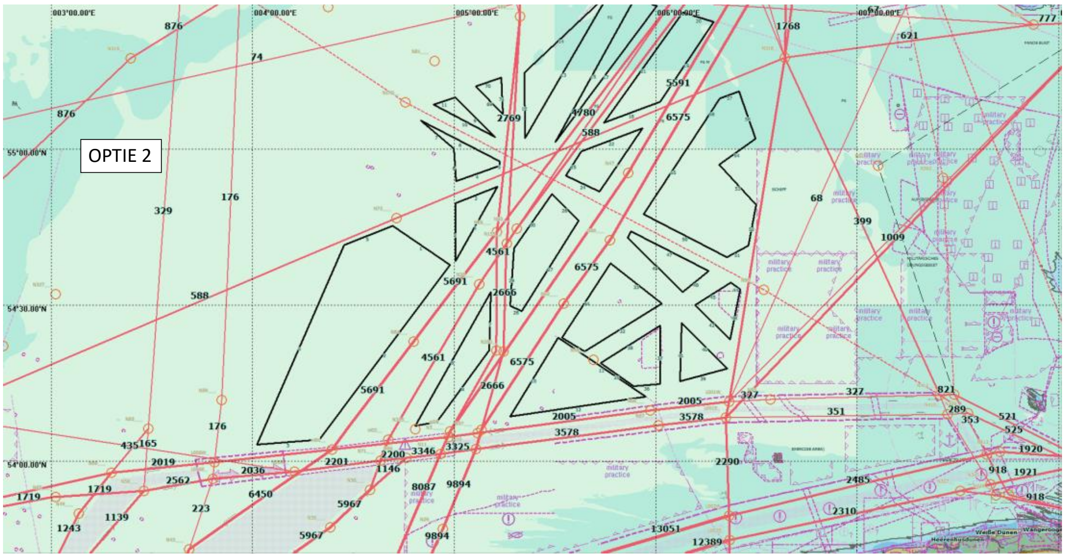


Figure 3-28 Route bound traffic database used for Option 2

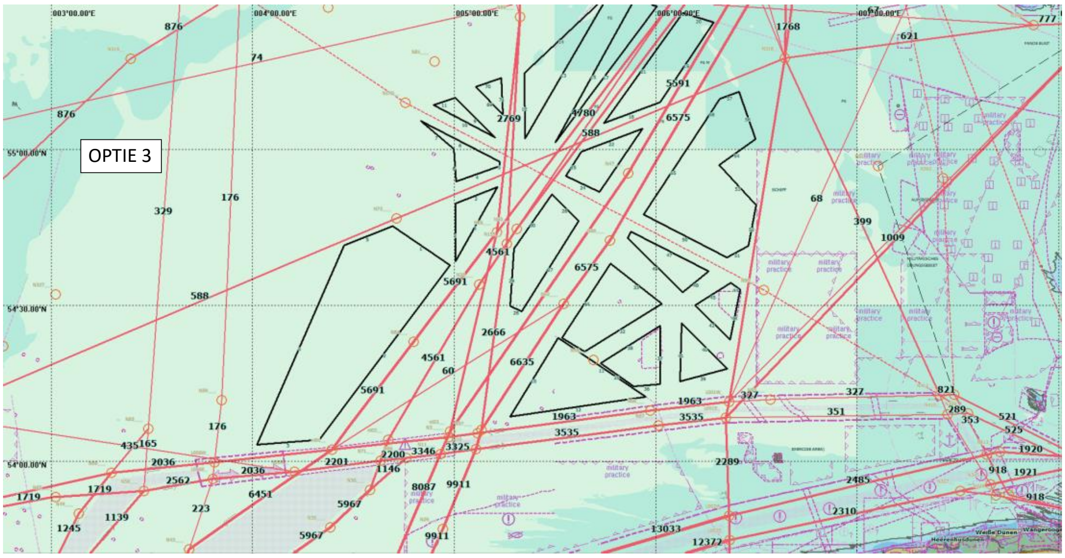


Figure 3-29 Route bound traffic database used for Option 3

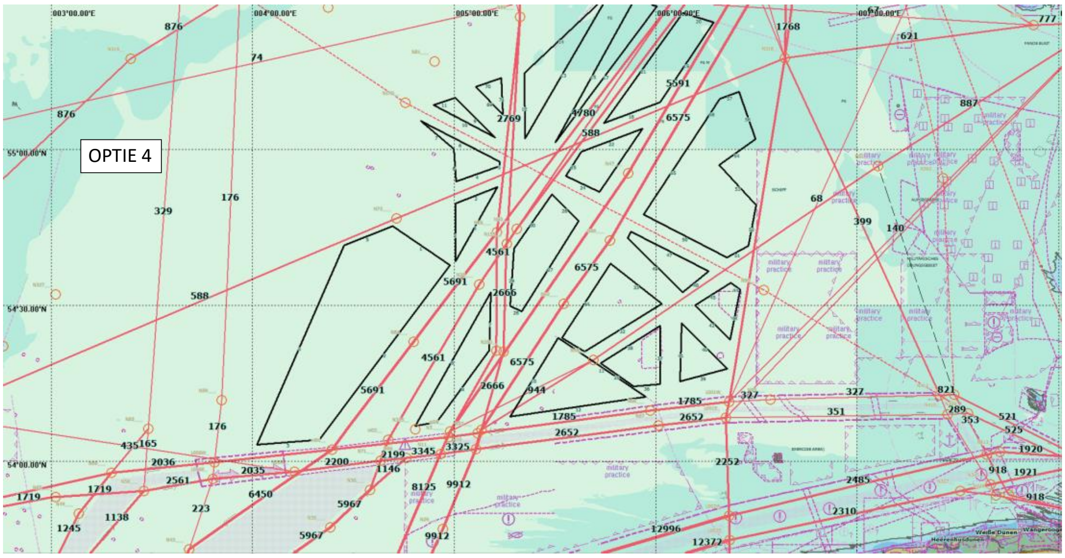


Figure 3-30 Route bound traffic database used for Option 4

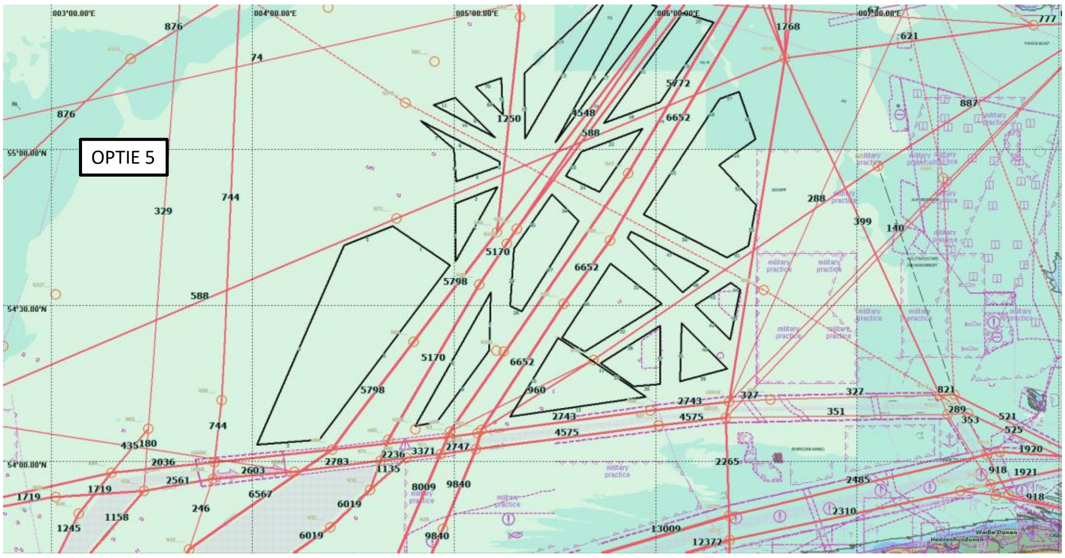


Figure 3-31 Route bound traffic database used for Option 5

For the four main traffic routes (see Figure 3-32) thru the study area the assumed number of vessels passing per year are provided in Figure 3-33

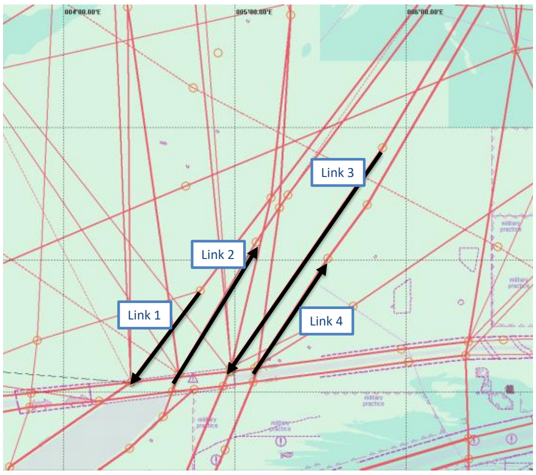


Figure 3-32 Location of the four main routes thru the study area

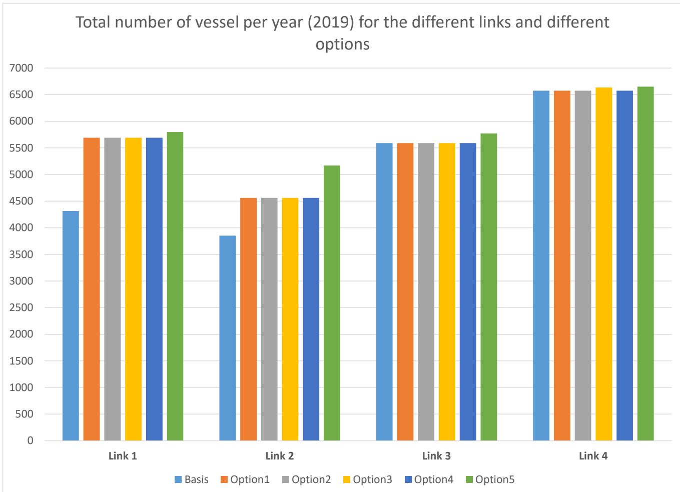


Figure 3-33 Total number of vessels per year (2019) for the four links and for the different option

From the charts can be concluded that the number of vessels in the two main traffic routes in the west part of the study area increase compared to the basic (current) situation. This increase is mainly the result of the closure of the route going of coming from the North thru windfarm search area 6. Furthermore, a small increase of traffic in all main links can be found for option 5, due to the fact that it will not be possible any more to “switch” lanes going to or coming from the north.

3.8 Area description: Environmental conditions in relation to ships heading and vessel type

This area is specifically known for its typical hydrological and meteorological phenomena. Reference is made to the recent incident with MSC Zoe.

- Figure 3-34 Tracks of all vessels on the night 2-3 January 20219, the night that the MSC Zoe lost containers. The tracks of all vessels in the area show that many vessels needed space to deal with the challenging weather conditions that night

- Figure 3-35 Tracks of all merchant vessels in May 2020. In black are some tracks of vessels highlighted that show an path different from the other paths of the other vessels. The reason behind these manoeuvers can be different and cannot be read from the AIS-data. For some it could be collision avoidance manoeuver or it could be due to engine failures. All the same the chart shows that in one month time between 6 to 10 vessels needed space outside the main traffic lanes.

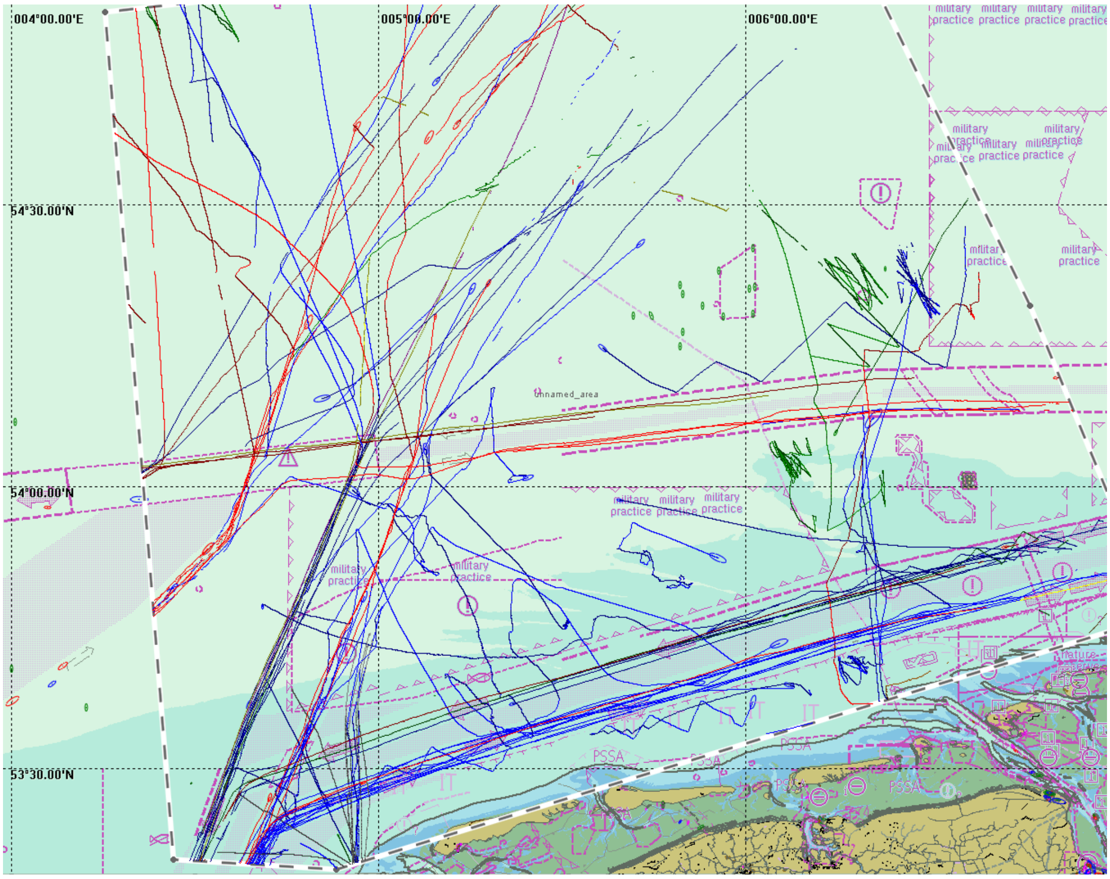


Figure 3-34 Tracks vessels on the night 2-3 January 2019 (MSC Zoe -incident)

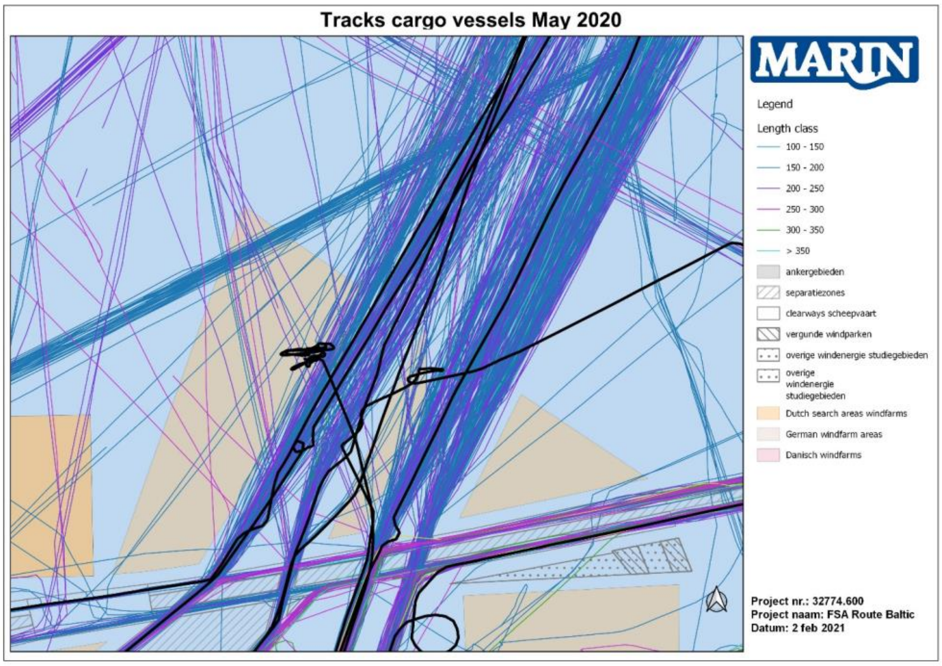


Figure 3-35 All tracks in May 2020, indicating tracks with "abnormal" track

4 QUANTITATIVE ANALYSIS – SAMSON

4.1 SAMSON

To perform the quantitative risk assessment, the SAMSON-model has been used. SAMSON stands for: Safety Assessment model for Shipping and Offshore on the North Sea. With the model, various risk assessment calculations can be performed regarding maritime safety. Although the name suggests SAMSON is only applicable for the North Sea, it is a generic model can be applied to any defined geographic location. The model was developed to determine the probabilities, locations and consequences of various marine accidents, taking into consideration various mitigation measures that could be used to reduce the likelihood of a marine accident (e.g.: pilotage). The parameters of the casualty models are derived from the worldwide casualty data of 1990-2015. The SAMSON model was originally developed over 40 years ago and since that time it has been extended, validated and improved by MARIN in various studies performed for Rijkswaterstaat, the EU and Transport Canada.

A detailed system diagram of the SAMSON model is presented in highlighting the numerous parameters, systems, and impacts that can be considered with SAMSON. The objective of the quantative part of the FSA is to to determine what the risks are with respect to the different spatial design options. The different design option will have an impact on the expected number of ship-ship collsions and the expected number of vessels colliding with a wind turbine. Therefore only these models of SAMSON are used. More information of SAMSON can be found in APPENDIX 2 and on https://www.iala-aism.org/wiki/iwrap/index.php/SAMSON

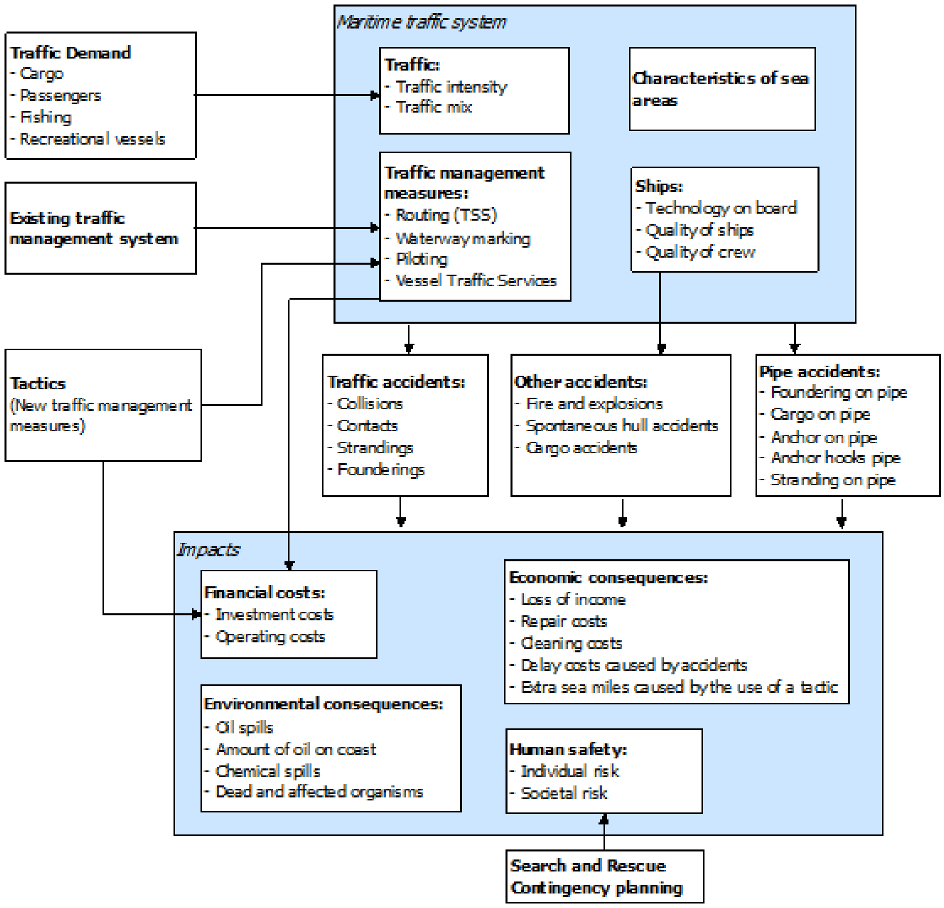


Figure 4-1 System diagram SAMSON

4.2 SAMSON - Input

The main input for the calculation for this study are the different traffic database (see 3.7) and the windfarm locations. Because the actual locations of the different wind turbines in the different areas are not know, the windfarm areas are represented by lines on the border of the area. Instead of calculating the collision frequencies of an individual turbine due to either a navigational error (ramming) of an engine failure (drifting), the number of vessels are determined that will "enter" the different areas. The frequency of crossing a line defined at the border of the area is calculated per line. This is not the expected number of actual collision with a wind turbine, it is possible that a vessel "enters" a windfarm area and not actual hits a turbine.

However, the one of the main objectives of this study is to compare the different options with each other. For all options, this same starting point is taken, so still the comparison can be made on the number of vessels at risk due to the fact that they enter a windfarm area.
In Figure 4-2 all so-called "collision lines" are shown, including the traffic database for Option 4.For all options all lines are included during the calculations, however in the results only the relevant lines per option are taken into account.

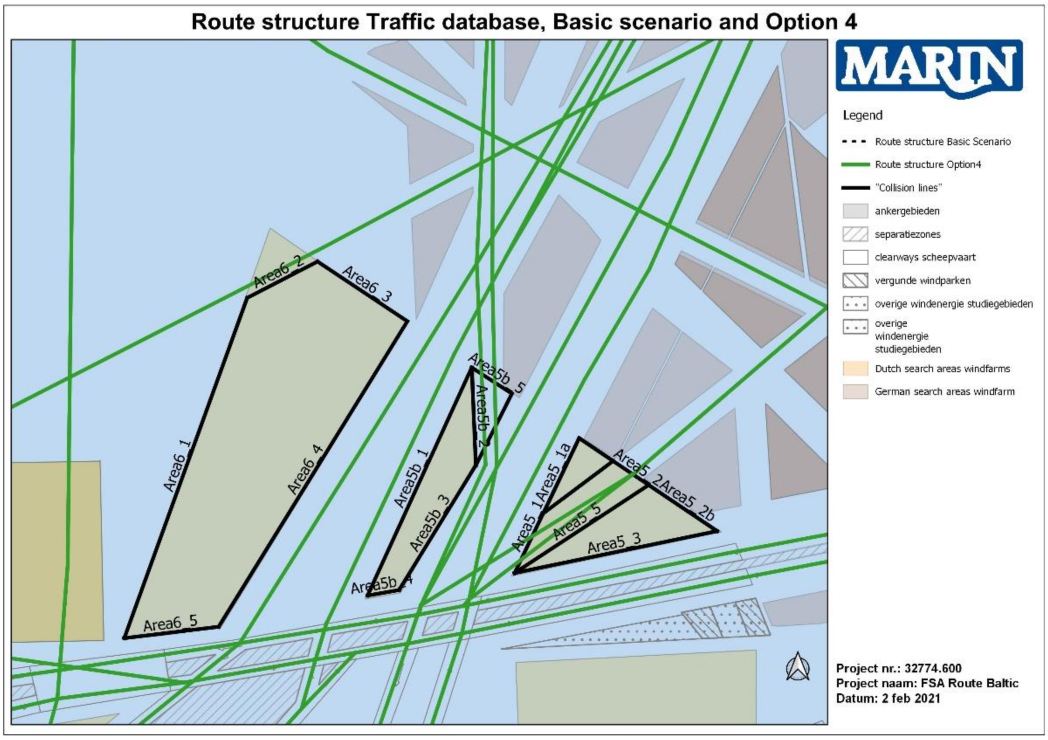


Figure 4-2 Locations of the so-called "Collision Lines"

4.3 Ship-ship collisions

The number of ship-ship collisions between route bound vessels is calculated for grid cells of 8x8km covering almost the whole eastern part of the North Sea. However, the main focus of this study is the change in collision risk (frequency) on the Northern part of the Dutch EEZ, nearby the planned windfarm area 5 and 6. The final traffic database are also optimized for this part of the North Sea. Therefore, the results for the ship-ship collisions are summarized for this specific area. In Figure 4-3 the selection of grid cells is shown that are taken into account in the resulting tables.

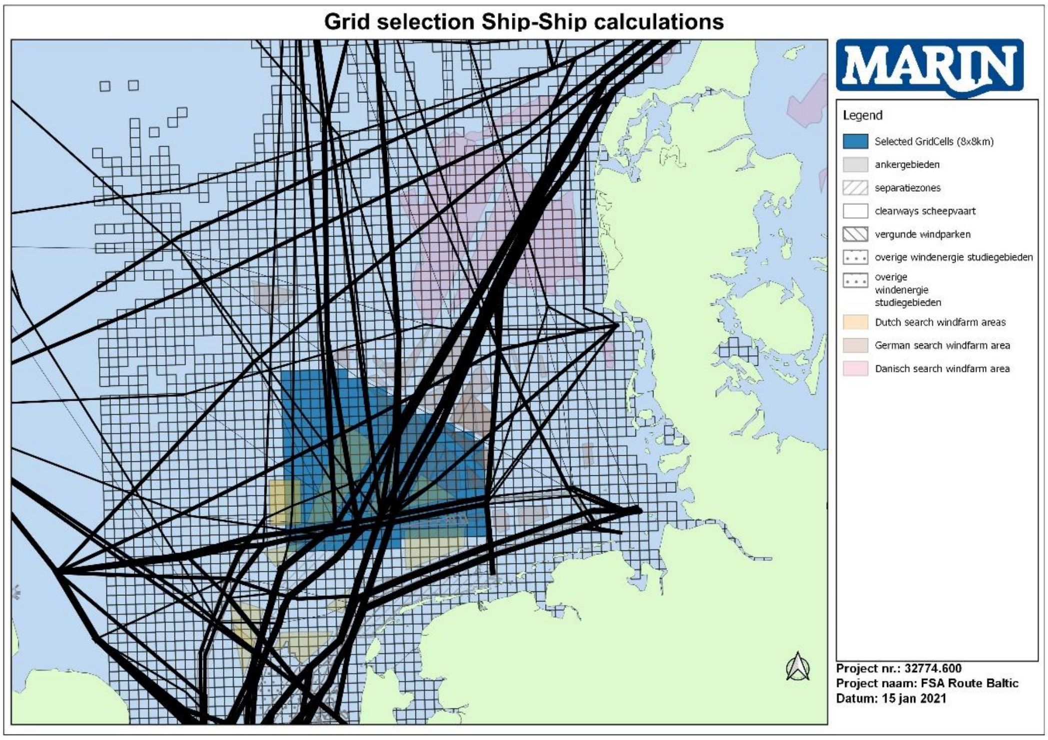


Figure 4-3 Location of the selected grid cells for the ship-ship collisions

Table 4-1 shows the general results of the ship-ship calculations. Per option the average number of vessels (route bound/merchant vessels) present at any moment in the area, the total number of sailed nm per year and the expected number of ship-ship collisions in the area. In column 2 until 4 the absolute number are presented and in column 5 until 7 the expected growth per option compared to the basic scenario.

Table 4-1 Expected number of ship-ship collisions (between route bound vessels) per year in de selected area.

Scenario	**Absolute numbers (frequency) per year**			**Relative % growth compare to Basic scenario**		
	Average number of route bound vessels	**Number of sailed nm**	**Ship-Ship collision (R-R)**	**Average number of route bound vessels**	**Number of sailed nm**	**Ship-Ship collision (R-R)**
Basic	21.2	2522959	0.145	0.0%	0.0%	0.0%
Option 1	21.0	2494592	0.158	-1.1%	-1.1%	8.3%
Option 2	20.9	2482968	0.162	-1.5%	-1.6%	11.4%
Option 3	20.9	2480622	0.159	-1.6%	-1.7%	9.7%
Option 4	21.0	2497288	0.160	-1.0%	-1.0%	9.8%

On average around 21 route bound vessels are present in the indicated area at any given moment. This number of average number of vessels does not changes much for the different options. It decreases somewhat, due to the fact that some vessels have to alter their route and sail therefor outside the selected area. However this change is not a significant one, so one can conclude that the number of vessels stays the same in the selected study area.
Based on the number of vessels on the links it was concluded in chapter 3.7 that the number of vessels on the main links between the Dutch EEZ and Skagerrak increased. However due to the fact that the vessels that first sailed through area 6 now shifted their route more to the east, the time spend in the "selected grid cells" is less, and this the average number of vessel in the selected area decreases.

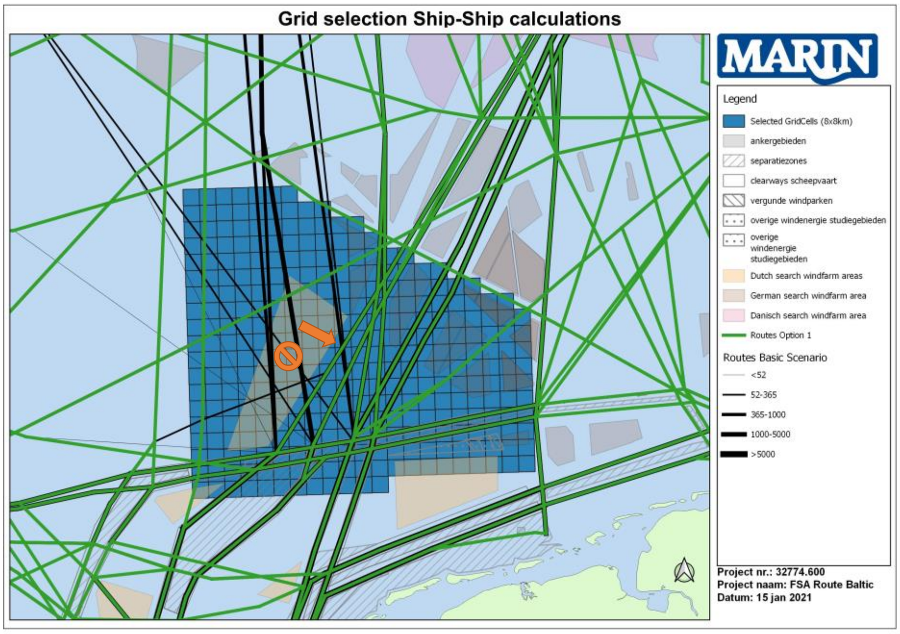


Figure 4-4 Location of the route structure for the Basic and Option 1 scenario related to the selected grid cells

The total number of expected ship-ship collision in the area is 0.145 per for the Basic Scenario, this means once every 6.9 year. The results of the SAMSON calculations for the different traffic databases for the different options show that in all cases the number of expected ship-ship collision will increase. This is due the fact that vessels will sail closer to each other in most of the scenarios and due to the fact that some routes that "existed" in the basic scenario are not possible any more in the scenarios with windfarms, more vessels "use" the already existing routes, thus the shipping intensity on these routes increases and thus the probability of a collision.

Table 4-2 Total number of expected ship-ship collision per collision type in de selected area

		HEAD-ON	OVERTAKING	CROSSING	TOTAL
Total expected collision per year	Basis	0.014	0.095	0.036	0.145
	Option 1	0.019	0.104	0.035	0.157
	Option 2	0.017	0.107	0.039	0.162
	Option 3	0.020	0.105	0.035	0.159
	Option 4	0.015	0.106	0.038	0.160
	Option 5	0.024	0.103	0.035	0.162
Once every … year	Basis	71.6	10.5	27.8	6.9
	Option 1	53.8	9.6	28.5	6.4
	Option 2	60.3	9.4	25.9	6.2
	Option 3	50.9	9.6	28.5	6.3
	Option 4	64.6	9.4	26.1	6.3
	Option 5	41.0	9.8	28.2	6.2
Growth compared to Basic Scenario	Basis	0.0%	0.0%	0.0%	0.0%
	Option 1	32.9%	8.8%	-2.5%	8.3%
	Option 2	18.7%	11.9%	7.2%	11.4%
	Option 3	40.6%	9.8%	-2.4%	9.7%
	Option 4	10.7%	11.0%	6.5%	9.9%
	Option 5	74.6%	7.5%	-1.6%	11.7%

Table 4-3 Total expected number of ship-ship collision per ship type per option.

Ship Type	Excepted number of ship-ship collision per ship type (based on type of collided ship)				
	Basis	Option1	Option2	Option3	Option4
Bulk/GDC	0.067	0.072	0.074	0.072	0.073
Tanker	0.051	0.056	0.057	0.057	0.057
Container	0.012	0.013	0.013	0.013	0.013
Pass/Ferry/Roro	0.015	0.017	0.017	0.017	0.017
Total	0.145	0.157	0.162	0.159	0.160

4.4 Ship-Windfarm

For the risk due to the windfarm area, the expected number of vessels “entering” one of the areas is calculated using SAMSON. This is not the number of expected actual collisions with wind turbines. The details regarding the number and configuration of the area is not yet known, therefor the expected collision frequency with the individual turbines cannot yet be determined. That is way the expected number of vessels “at risk” is determined instead of the actual number of expected collisions. A vessels is considered to be “at risk of a contact with a wind turbine” when she enters one of the different windfarm areas.

Table 4-4 shows the number of vessels “at risk of a contact with a wind turbine” for the different options. The table contains the total numbers per windfarm area, this means so-called ramming (navigational error) and drifting (engine failure) incidents together.

The total number of vessel expected to enter area 6 does not vary much for the different options, on average it is expected that 0.3 vessel per year enters the area unintentionally, this means one every 3.3 years. Also the expected number of vessels inside area 5 is for all option almost the same; 0.19 vessel per year. This means once every 5.3 years. The most vessels will unintentionally enter the median strip (area 5), based on the calculation it is expected that 0.3 vessels (once every 3.3 year) will enters this area per year. This is mainly due to the fact that on both side of this wind farm area busy traffic routes will be located. For area 5 and area 6 this will only be at one side of the windfarm area.

Based on this it can be concluded that the number of vessels “at risk” is the highest for option 2, 4 and option 5.

Table 4-4 Expected number of route bound vessels “entering” a wind farm area per year per option per windfarm area

Option	Windfarm areas included	Expected number of route bound vessels “entering” a wind farm area per year per option per windfarm area			
		Area 5	Area 5 – median strip	Area 6	Total
Option 1	Area 5 - with corridor + Area 6	0.189	0.000	0.302	0.491
Option 2	Area 5 - without corridor + Area 5 - median strip + Area 6	0.191	0.340	0.300	0.831
Option 3	Area 5 - without corridor + Area 6	0.187	0.000	0.302	0.488
Option 4	Area 5 - with corridor + Area 5 - median strip + Area 6	0.193	0.342	0.300	0.835
Option 5	Area 5 - with corridor + Area 5 - median strip + Area 6	0.216	0.304	0.301	0.821

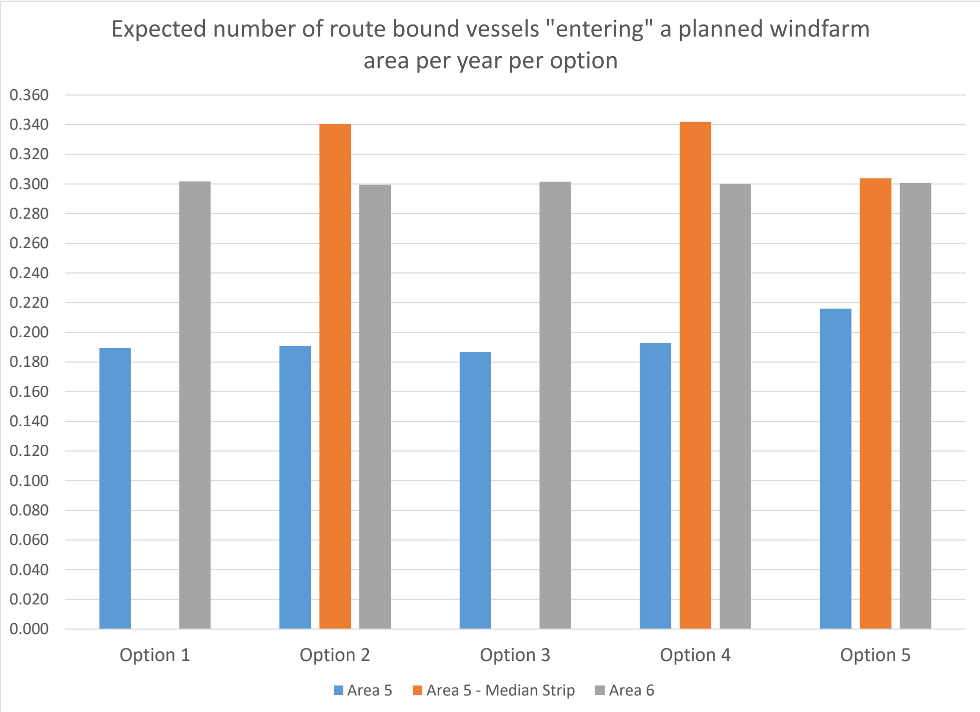


Figure 4-5 Expected number of route bound vessels "entering" a wind farm area per year per option per windfarm area

4.5 Conclusions quantitative analysis: total expected incidents

The combined effect on both ship-ship collisions as on ships at risk due to entering a windfarm area are given in Table 4-5 and Table 4-6. In the basic scenario only ship-ship collisions occur in the selected study area. Based on the calculation once every 6.8 year a ship-ship collision will occur in this area. The extra incidents when building a wind farm are the incidents whereby vessels enter a wind farm area unintentionally. The number of expected incidents also this type varies between 0.48 and 0.83 per year depending on the option. This means that the total number of expected incidents in the area increases from once every 6.8 year to between once every year up to even 1.5 incidents per year. This is an increase of 346% for option 1 and 3 and even an increase of 580% for option 3, 4 and 5. The increase of the number of expected incidents between the options with a median strip (option 2, 4 and 5) compared to the options without this strip (option 1 and 3) is 53%.

Table 4-5 Total number of expected incident per year involved route-bound vessels

Option	Windfarm areas included	Ship-ship collision	Route bound vessels at risk due to "entering " a windfarm area			Total number of "incidents" per year
			ramming	drifting	total	
Basic	No Windfarm areas on Dutch EEZ (not area 5 or 6)	0.1454	0.0000	0.0000	0.0000	0.1454
Option 1	Area 5 - with corridor + Area 6	0.1575	0.0813	0.4099	0.4912	0.6487
Option 2	Area 5 - without corridor + Area 5 - median strip + Area 6	0.1619	0.1339	0.6967	0.8306	0.9925
Option 3	Area 5 - without corridor + Area 6	0.1595	0.0800	0.4083	0.4883	0.6478
Option 4	Area 5 - with corridor + Area 5 - median strip + Area 6	0.1597	0.1351	0.6996	0.8347	0.9944
Option 5	Area 5 - with corridor + Area 5 - median strip + Area 6	0.1624	0.1174	0.7033	0.8207	0.9831

Table 4-6 Total number of expected incidents, once every …. years involved route-bound vessels

Option	Windfarm areas included	Ship-ship collision	Route bound vessels at risk due to "entering " a windfarm area			Number of "incidents" every …. years
			ramming	drifting	total	
Basic	No Windfarm areas on Dutch EEZ (not area 5 or 6)	6.88	--	--	--	6.88
Option 1	Area 5 - with corridor + Area 6	6.35	12.31	2.44	2.04	1.54
Option 2	Area 5 - without corridor + Area 5 - median strip + Area 6	6.18	7.47	1.44	1.20	1.01
Option 3	Area 5 - without corridor + Area 6	6.27	12.50	2.45	2.05	1.54
Option 4	Area 5 - with corridor + Area 5 - median strip + Area 6	6.26	7.40	1.43	1.20	1.01
Option 5	Area 5 - with corridor + Area 5 - median strip + Area 6	6.16	8.52	1.42	1.22	1.02

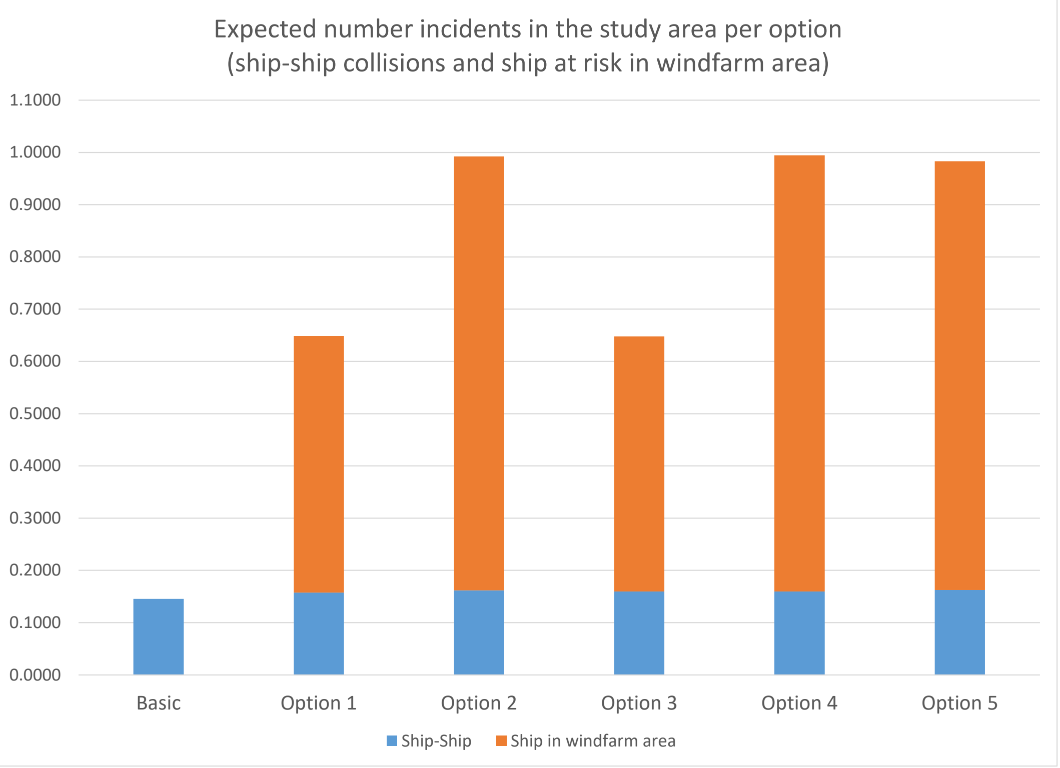


Figure 4-6 Expected number of incidents per year in the study area per design option.

5 QUALITATIVE ANALYSIS

5.1 Introduction

The qualitative analysis being part of the Formal Safety Assessment (FSA) consists of two expert workshops and supporting questionnaires. The first expert session was participated by a number of experts from neighboring coastal states; all involved in their national planning processes for future wind energy areas on the North Sea. After this workshop, a questionnaire was sent to collect more specific, in-depth information and further opinions from the participants. At the international expert workshop it was the participants were encouraged, to specifically express their shipping expert opinion and not their formal political member states point of view. The second expert workshop has been conducted a national setting with partition of various shipping experts from both governmental and commercial stakeholders. In advance, the experts were asked to fill in a questionnaire covering ten hazards for which the probability of occurrence and the possible impact on persons, economy and marine environment was asked to score.
This chapter covers the outcome of both expert workshops and will provide a conclusion based on the outcome of those workshops and questionnaires. In the end, a final conclusion of combined results will provide the final outcome of the FSA study.

5.2 National expert workshop

The national expert workshop was held on the 30th October 2020. Meaning in the middle of the Covid19 pandemic and therefore the workshop was organized as an online event. At the MARIN studio, the session was hosted and all participants were remotely participating by video connections.
During the workshop the five design options were discussed, safety matrices based on pre-workshop questionnaires were discussed and finally possible mitigating measures to reduce risks were discussed.

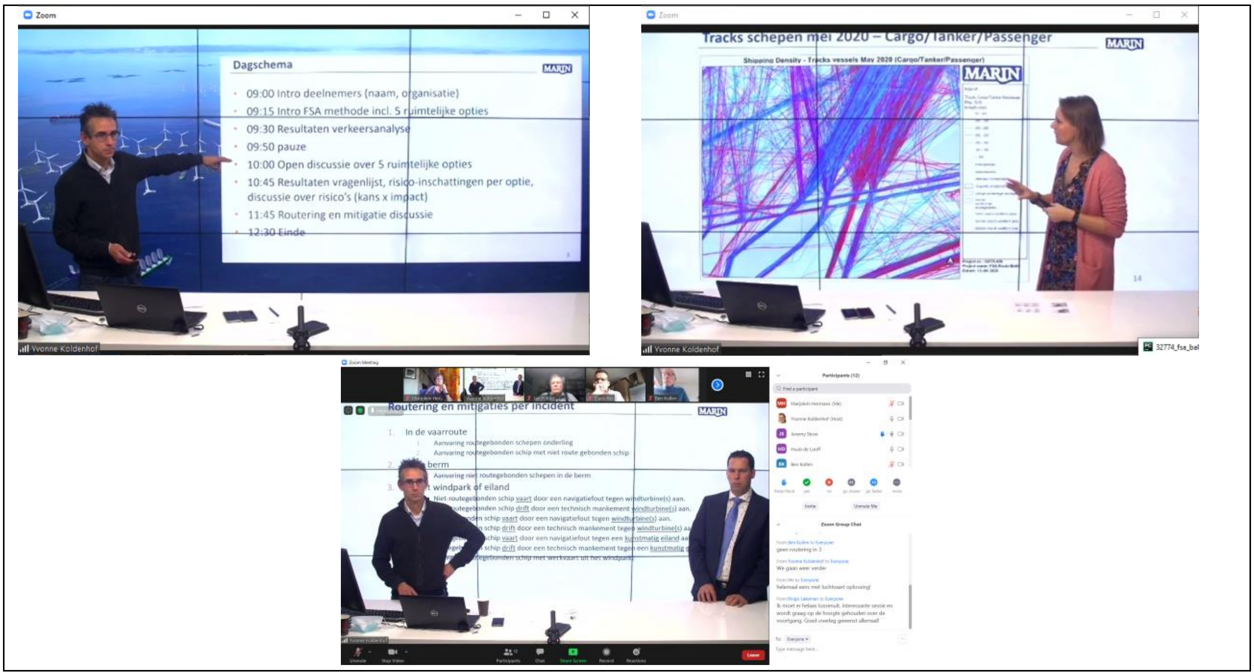


Figure 5-1 Online session of the FSA expert workshop

5.2.1 List of participants in the expert national session

The following organisations were represented by an expert in the workshop.

Experts:

- Board member of the Shipping Advisory Group North Sea (Scheepvaart Adviesgroep Noord zee, SAN). Former master)
- Pilot at Redwise, Deep Sea pilot services and VTS service
- Policy advisor nautical affairs, Netherlands Coastguard (Kustwacht), former head of nautical operations and watch officer Netherlands Coastguard
- Senior Policy Officer at Ministry of Infrastructure and Water Management, Directorate General of Aviation and Maritime affairs (DGLM)
- Board member of the Netherlands Association of Captains of Commercial Shipping (Nederlandse Vereniging van Kapiteins ter Koopvaardij, NVKK). Retired master
- Technical and nautical expert of the Royal Netherlands Association of Ship Owners (Koninklijke Nederlandse Vereniging van Reders, KNVR). Former master
- Nautical expert, instructor, former master.

Client:

- Joris Brouwers, MSc (Senior policy advisor Shipping, Ministry of Infrastructure and Water Management, DGLM. Former Royal Netherlands Navy officer (navigator))
- Sjoerd Jansen (Senior policy advisor, Ministry of Infrastructure and Water Management, DGWB)
- Jeremy Stroo (Policy advisor Ships' routeing and Safety, Rijkswaterstaat. Former Merchant Navy navigational watch officer)

MARIN:

- Hans Huisman (Team Leader Human Factors at MARIN, workshop chair)
- Yvonne Koldenhof (Team Leader Traffic & Safety at MARIN, project leader of FSA)

5.2.2 Discussion on the 5 design options

The 5 spatial design options for the northeaster part of the Dutch EEZ of the North Sea are included in this chapter and will be referred to in this section with option number 1 to 5. This set of 5 options is composed of a number of basic building blocks and will be explained per option in this section. In the discussion during the workshop, those building blocks were more leading than the design options themselves. Therefore, in the discussion in this section the option numbering will be used besides explicitly naming the building blocks which form the essential parts of each individual option. Relevant for each option is that the German draft MSP design was used as starting point of the five design options at the Dutch EEZ. During the process it became apparent that the draft MSP design of the German EEZ starting from to the EEZ border with the Dutch EEZ was still not finalised at that time. For this report and the workshops with the experts, however the available draft MSP design of the German EEZ is taken as basis for the discussion and maps. Within the maps used to visualize the five options, the red shaded areas on the German side of the border indicate the wind energy areas. Deep blue areas are allocated for (international) shipping routes; light blue areas are reserved for shipping until 2035. Transparent red areas are indicated as search areas for offshore renewable energy after 2035.

On content, all experts unanimously underlined the conclusion that any option besides option 0 will have significant impact on the safety of navigation, freedom of navigation and accessibility of ports. Any increased risk on the aspect of safety of navigation shall be mitigated on forehand, where the responsible ministry for the development of offshore renewable energy will take initiative to cover the financial budget required for the measures required.

5.2.3 Option 1: Maximum navigating area for shipping.

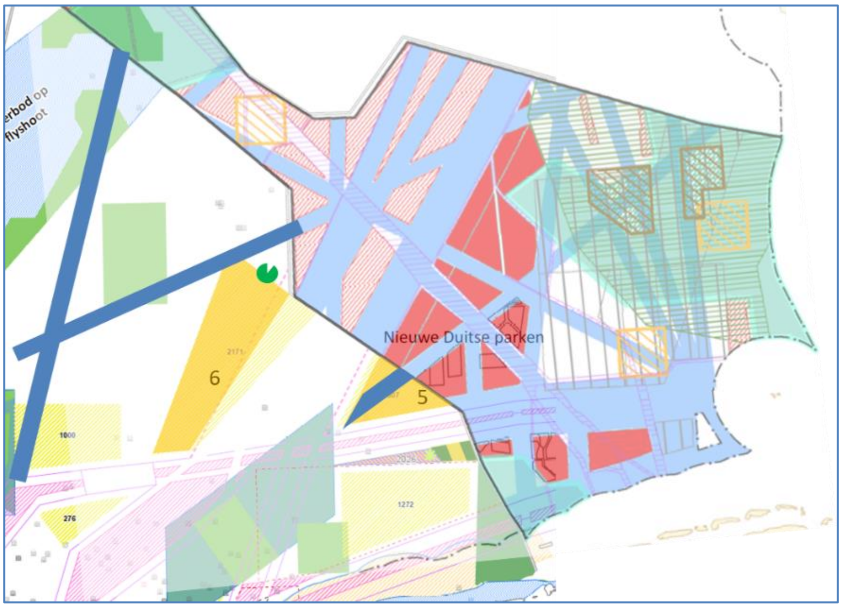


Figure 5-2 Schematic representations of option 1

Option 1 is composed of the following building blocks:

- Windfarms 5 and 6
- Corridor through windfarm 5
- Open sea space between windfarms 5 and 6
- Artificial island in the north of windfarm 6

Discussion during the workshop:
The group agrees that option 1 looks realistic and is from accessibility perspective one of the preferred solutions. The safety of navigation around the SW-corner of search area 5 with the corridor leading into 2 major shipping traffic flows is a large concern.

There is consensus in the group that the corridor through windfarm 5 is less preferable since this corridor causes crossing traffic in and north of the TSS East Friesland. Crossings in this area increase the risk of ship-ship collisions. A remark was made that closing this corridor cuts off a route to Esbjerg which is an ambitious port aiming to grow in the future. This remark was counteracted by a remark that the cargo volume will likely increase due to larger ships and not so much by increasing traffic movements. Traffic taking the corridor (current traffic density is 2 movements a day) can easily take an alternative route via the main route north and turn east towards Esbjerg was the shared opinion in the group. The corridor through windfarm 5 will become quite narrow since the Dutch Safety margin framework (*Afwegingskader)* will be applied. This Safety margin framework applied to this corridor through windfarm 5 will not only lead to a narrow corridor for shipping but will also consume a lot of space which

might be made available for wind turbines. The group expects that vessels will not take this narrow corridor in adverse weather conditions. Thereby, it was seen as an opportunity and preference by the group to compensate the sea space needed for the corridor near the Westerly and Southerly borders of search area 5 to create a larger safety margin. Conclusion of group: maximise area 5 for wind, enlarge safety margins (W and S) as far as possible and focus on main route (clearway) for shipping.
In Figure 5-3 the hotspot is depicted as the corridor through windfarm 5 connects with the existing crossing of routes making it more complex.

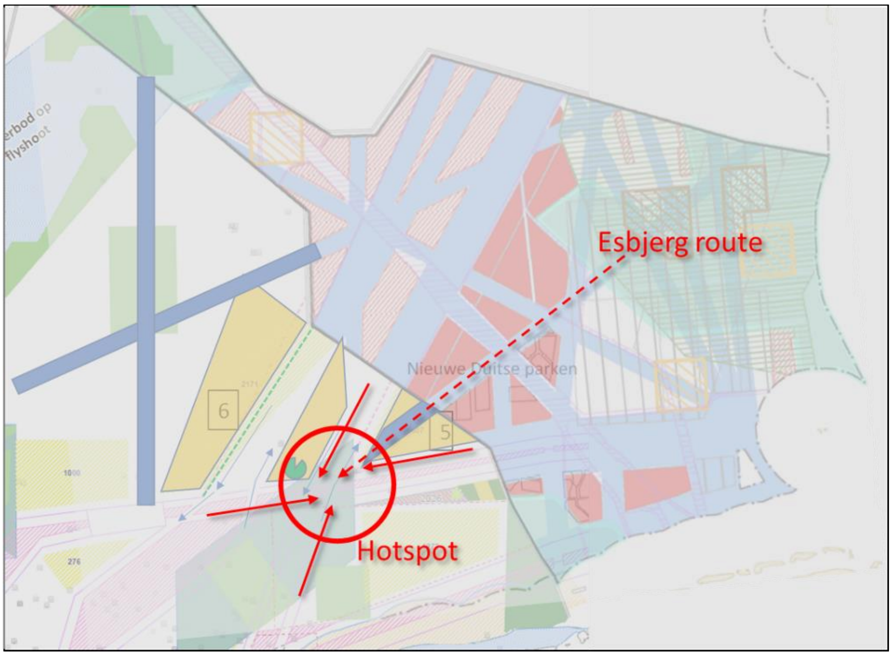


Figure 5-3 Traffic crossing hotspot created by the corridor through windfarm 5

The open space between windfarms 5 and 6 was preferred by the group, since the windfarms 5 and 6 will lead to concentration of traffic in this area relative to existing traffic patterns in option 0. The sea room between area 5 and 6 is to cover 4 traffic flows. The space available is intentionally assumed to be sufficient to safely navigate without any mandatory routeing measures (like TSS). Increase of traffic density is not foreseen to cause any additional risks in case the median strip would not be used for offshore renewable energy.
In addition it was indicated that the open space between area 5 and 6, being 25NM, might be reduced to 21NM width. Leaving sufficient width to allow for safe shipping. Additional routeing measures in the future are still possible if practise or monitoring results show unsafe situations.

A separate discussion was held about the open space between windfarms 5 and 6. This open space might be interesting for fishing activities. In case no TSS would be defined, fishing activities are still possible in this area. There was no agreement in the group whether this is an issue. Part of the group indicated that this might be a point of attention in the future. Others indicated this would not be an interesting fishing site anyway, so no intense fishing activities are to be expected.

Whether or not the open space would require any (mandatory) routeing measure cannot be concluded at this moment. A quantitative traffic analysis would be required to decide upon a route structure or not was concluded by the group. This all depends on marine spatial decisions and the use of the sea area between 5 and 6. In case of open sea space, future traffic analysis will provide the required insight whether additional routeing measures are required.

Another positive remark about option 1 is the location of the artificial island. An island in the north of windfarm 6 has little impact for shipping. This applies for the island itself but also expected traffic movements to and from the island. The group indicated that from a shipping point of view the island should be located as much as possible to the west within windfarm 6.

5.2.4 Option 2: Maximum Wind energy.

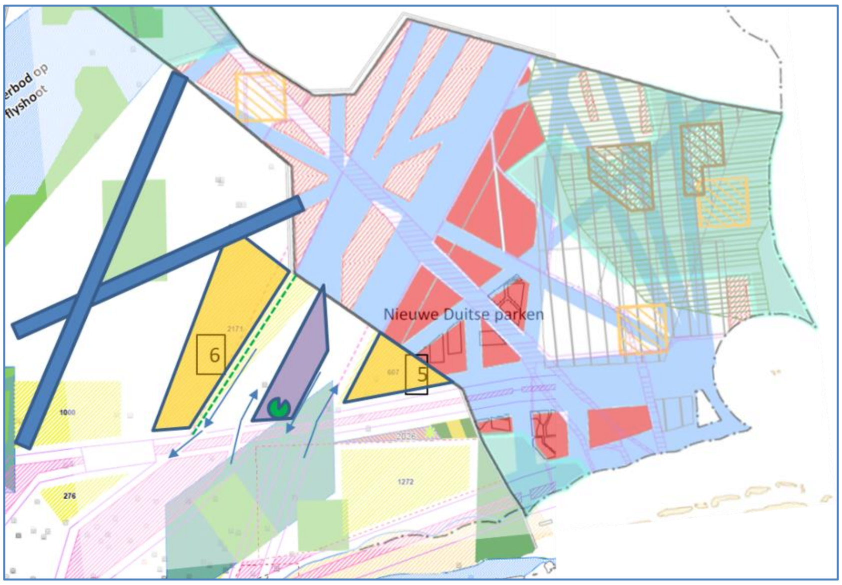


Figure 5-4 Schematic representation of Option 2

Option 2 is composed of the following building blocks:

- Windfarms 5 and 6
- No corridor through windfarm 5
- Median strip as wind energy area (in-between windfarms 5 and 6)
- Artificial island in the south of the wind energy area median strip

Discussion during the workshop:
The group agrees that wind energy developments at the median strip between area 5 and 6 is in general no option from a shipping safety point of view. Further, serious concerns are raised with respect to impact on associability of ports.

The phrase “not negotiable” was used by some members of the group. At sheltered sea areas the design might have been a workable option to develop an area like the median strip, but in an open sea area like this, with regular adverse weather, in particular swell and wave conditions it is regarded as not workable. This particular (non-sheltered) sea area on the northern North Sea is by its position prone were ships encounter high waves and swell perpendicular to the course of the ship, leading to environmental conditions which also occurred at the fatal incident with MSC Zoe. The waves and swell built up on the North Atlantic, further increased on the shallower North Sea, resulting in short-period, steep waves and heavy sea conditions in case of north-western storms occurring several times a year.

The space between the median strip and both windfarms 5 and 6 is relatively small in relation to sea conditions and traffic density that apply for this area. Defining this area as open sea on both sides of the median strip is seen as not sufficiently safe. The argument for this is that vessels in a relative narrow lane (Colreg rule 9) will choose a course and position within the traffic lane as near to the outer limit on starboard as possible. This means close to the outer line of turbines and higher risks of collisions and

contact. High traffic densities close to the outer turbines, in case only the max. safety zone of 500m is applied, are not sufficient safe. It provides too little space for collision avoidance manoeuvres, especially in case of technical issues or human errors. To force vessels to take a larger safety margin, a TSS as routeing measure should be defined.
The space between the median strip and both windfarms 5 and 6 is considered as too narrow to make evasive steering manoeuvres to avoid traffic, let alone emergency manoeuvring. Also under heavy western wind conditions, some vessel types may require to alter course and deviate from their planned track due to heavy weather conditions. This requires sufficient space. The group was very reluctant whether the remaining sea space would be sufficient in the traffic lanes between the median strip and windfarms 5 or 6. Not being able to deviate from the original track to keep a safe heading in such sea conditions may lead to significant ship motions causing excessive acceleration forces, which leads to high chances of cargo losses or even worst consequences.

In this particular open area of the North Sea, mariners will choose a track on the windward side of obstructions during heavy western and north-western winds, to create as much distance as possible to dangerous objects on their leeward side. In case of engine or other technical failures, this gives maximum response time before drifting into a windfarm and possible contact with a turbine. The design option with the median strip hardly provides sufficient space to mariners in order to select such a safe course.

When a Not under Command vessel in heavy weather conditions is drifting in the direction of a windfarm, the group indicated this could cause heavy contact with a structure, with all possible consequences. For example the worst-case scenario: sinking of the vessel. The persons in immediate danger can most likely only be saved by means of complicated SAR helicopter operations far from land. Search and rescue operations by other vessels in the area can be very complicated or even impossible, especially under severe weather conditions. The helicopter SAR-operation will also be a complex operation that need to be executed within the windfarm, in-between the high wind turbine structures. The conditions are likely to occur in heavy weather conditions causing that these SAR operations will be hampered and may require more time to rescue shipping personnel or passengers in case it concerns a passenger ship.

The artificial island in the south of the median strip is broadly considered as not favourable. Its location is very close to a complex area where multiple different traffic flows cross and alter course. The east-west TSS East Friesland crosses the north-south traffic stream between windfarms 5 and 6. Creating an artificial island in an area with a complex traffic situation and an area of the North Sea which suffers several times a year heavy weather and high sea state conditions was regarded as “asking for troubles” by the group. A further north location might be an option to investigate more in detail, although it was repeated that the median strip was, by consensus, not seen as an option with regard to safety of navigation, accessibility and legal aspects based on global conventions (UNCLOS).
It should be noted that this imaginary artificial island and its possible location(s) has been used in this FSA to stimulate the discussion with the experts in order to further explore the possibilities and its effects. In other words the artificial island has been discussed to collect operational safety arguments from the experts rather than assessing its necessity either or its location.

No shipping corridor through windfarm 5 was by consensus considered as the safer option. Reference is made to option 1 for arguments.

5.2.5 Option 3: Maximum clearway without corridor.

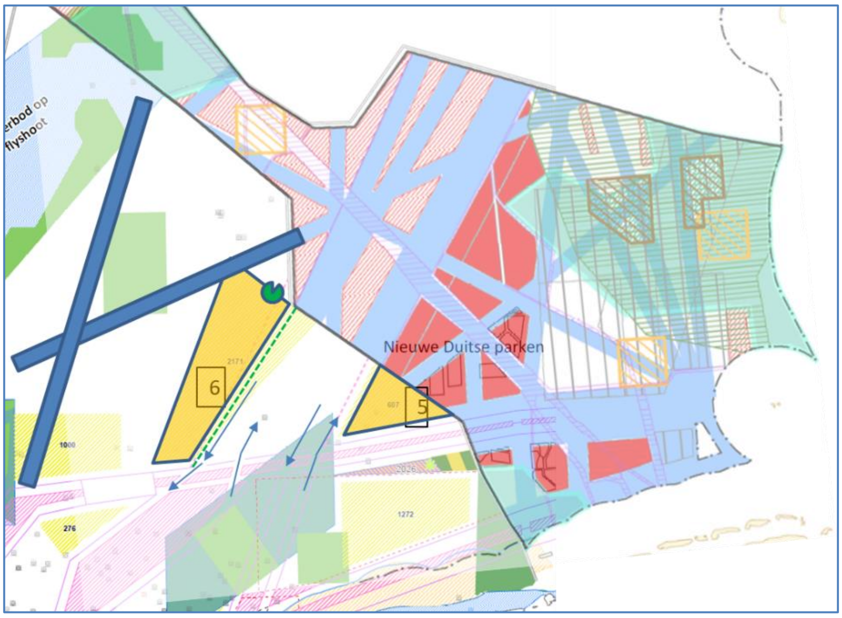


Figure 5-5 Schematic representation of option 3: Maximum clearway without corridor

Option 3 is composed of the following building blocks:

- Windfarms 5 and 6
- No corridor through windfarm 5
- Open sea space between windfarms 5 and 6
- Artificial island in the north of windfarm 6

Although it was stated that also this option has a negative impact on safety of navigation, arguments were expressed why this could be the least worse option.

This option has no shipping corridor through windfarm 5, which was found safer and therefore favourable. See argumentation under option 1 and 2. The open sea space between windfarm 5 and 6 is the most favourable and flexible option needed for safe navigation of ships under all-weather circumstances. For argumentation, see option 1. The artificial island in the north of windfarm 6 is favourable, for argumentation see option 1. The exact position of gas pipelines and platforms in the area need to be shown on a map to further asses the option of energy islands.

Discussion during the workshop:
During the discussion of option 3 a discussion was held about the artificial island. Explained was that the intention is to create an artificial island to convert electricity. This can either be large scale conversion of AC to DC or conversion of electricity into hydrogen at sea. Hydrogen can be transported via already available gas pipelines ashore. In addition it was mentioned that creating the windfarms and the artificial island will create temporarily extra offshore support and installation traffic in the area.
Although the expectation is that the artificial island is not creating significant traffic movements, it was indicated by the group that an artificial island of 1.5 NM square will contain installations which require maintenance and possibly daily operation. Both requiring staff to be transported to and from the island leading to extra shipping movements to and from the island.

The group agrees that above mentioned topics require attention during the design and installation phase of the island and the normal operation of the island with respect to impact on safety on mostly route bound traffic in the vicinity of the island.
It was even mentioned that coastguard SAR operations and ETV services might be operated from this island as second hub in the northern area, leading to minimum traffic in regard of related staff travelling to and from the island.

5.2.6 Option 4: Maximum wind energy with corridor

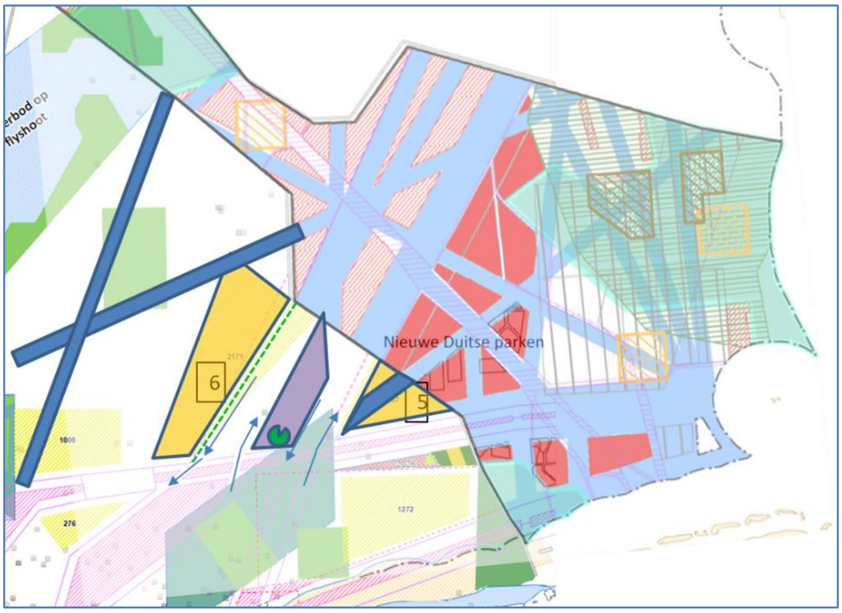


Figure 5-6 Schematic representation of option 4: Maximum wind energy with corridor

Option 4 is composed of the following building blocks:

- Windfarms 5 and 6
- A shipping corridor through windfarm 5
- Median strip wind energy area between windfarms 5 and 6
- Artificial island in the south of the wind energy area “median strip”

The group discussion was very unanimous and brief about this option. This option was regarded as an unsafe not-negotiable option. One participant phrased it as follows: this option combines all negative elements of all options into one.

For arguments against the corridor through windfarm 5, see discussion of option 1. For the median strip, see discussion of option 2. For the island south in the median strip, reference is made to description of the discussion of option 2.

5.2.7 Option 5: Ultra wind energy

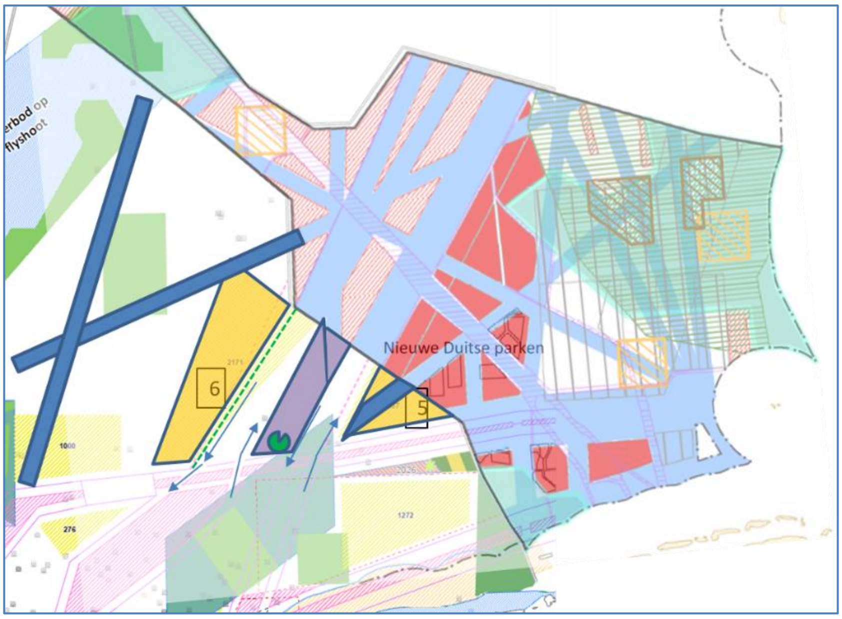


Figure 5-7 Schematic representation of option 5: Ultra wind energy

Option 5 is composed of all building blocks of option 4:

- Windfarms 5 and 6
- A corridor through windfarm 5
- Maximum median strip area between windfarms 5 and 6
- Artificial island in the south of the wind energy area “median strip”

In addition option 5 has an extended, maximum median strip up to the Dutch-German EEZ border.

The group decided that all negative elements of option 4 remain and in addition the northern shipping route is completely blocked by this option, creating additional negative arguments on safety of navigation, accessibility of NW-European ports and interference with UNCLOS. This blockage of a corridor through the median strip was seen as not an option since future traffic patterns via the Northern Sea Route will need this corridor to be able to make calls to Dutch and German ports.

The group indicated that every argument against this option was already mentioned before. For arguments against the shipping corridor through windfarm 5, see discussion of option 1. For the median strip, see discussion of option 2. For the island south in the median strip, see discussion of option 2.

The group indicated that navigational space was required in order not to increase the commercial pressure on masters unacceptably high as this option might cause ships unable to sail causing days of delay.

One participant reacted that there is a strong need for renewable wind energy in the future. The search area 5, 6 and the median strip are not decided upon to be turned into windfarms yet, it concerns possible reservation areas for possible windfarms in the future. For now those remain available for shipping until 2035 in Germany.

5.2.8 Safety matrices discussed during the expert workshop

Most of the participants filled in a questionnaire in advance of the workshop. This questionnaire covered 10 hazards and participants were asked to rate the probability of occurrence of each hazard and the impact of the hazard with respect to people, economy and environment.

List of hazards is presented in the table below.

Hazards
In the shipping route: 1. Ship-ship collision between two route bound vessels 2. Ship-ship collision between a route bound ship and a non-route bound ship
In the verge: 3. Ship-ship collision between two non-route bound ships
Near windfarm or artificial island: 4. Non route bound ship collides against turbine due to navigational error 5. Non route bound ship drifts against turbine due to technical malfunctioning 6. Route bound ship collides against turbine due to navigational error 7. Route bound ship drifts against turbine due to technical malfunctioning 8. Route bound ship collides against artificial island due to navigational error 9. Route bound ship drifts against artificial island due to technical malfunctioning 10. Route bound ship collides with workboat to/from windfarm or artificial island

The ratings for indicating the probability for a hazard to occur:

Improbable	Unlikely	Occasionally	Regularly	Often
< 1x per 20yr	1x20 yr – 1x5 yr	1x5 yr – 1x 2 yr	1x 2 yr – 5x per yr	5-50x per yr

The ratings for indicating the impact for people:

Catastrophe	Serious	Moderate	Small	Negligible
> 10 fatalities	< 10 fatalities > 10 severely injured	1x5 yr – 1x 2 yr No fatalities < 10 severely injured	1x 2 yr – 5x per yr Only slightly injured	5-50x per yr No injuries

The ratings for indicating the impact for economy and environment:

Catastrophe	Serious	Moderate	Small	Negligible
Large impact	Significant impact	Local impact	Minor impact	No effect

The differences between the current situation (option 0) and the option 1 to 5 is very clearly rated as a negative safety impact. In the risk matrix in Figure 5-8, all 5 options together with option 0 being the current situation are plotted. The dots represent the average score of the 10 identified hazards.

- What is clearly visible that option 0 has a much lower probability of the hazard to occur. Which is by itself not a surprise since the current situation is an open sea area for navigation of ships without any structures or large-scale installations that could lead to high probability of ship-ship interaction, collisions or contact with a turbine.

- Option 1 and 3 score equally and is therefore considered as the preferred options of all 5 options by the group.

- Option 2 gets an increased rating in probability of the hazards to occur and also an increase of the caused impact.

- Option 4 and 5 both get the same worst rating and score even worse than option 2 in probability and equal in impact level of the hazards.

During the expert workshop these ratings were presented and participants reacted that the differences between the options should definitely be larger than depicted in the risk matrix earlier. Common understanding was that it was very difficult to give these ratings since it is a quantification of arguments and that both the impact and probability scales do cover quite a wide range. Having a proper discussion and listen to the arguments in the group lead to a far more clear overview of the situation including all aspects to take into account. The differences between the various options from a safety point of view have become more clear during the discussion of the group.

In addition it is worth mentioning that the reply percentage of the respondents who were invited to fill in the questionnaire was around 60%.

				A	B	C	D	E
		Impact		Probability of occurrence				
				Improbable	Unlikely	Occasional-ly	Regularly	Often
	Qualitative description	People	environment and economy	A. Improbable (< 1x per 20 yr)	B. Unlikely (1x per 20 yr - 1 x per 5 yr)	C. Occasionally 1 x per 5 yr - 1 x per 2 yr	D. Regularly 1 x per 2 Yr - 5 x per yr	E. Often 5-50 x per yr
Rank		Defenitie		A	B	C	D	E
5	Catastrophe	> 10 fatalities	Large impact	5	10	12.5	15	20
4	Serious	<10 fatalities and >10 severly injured	significant impact	4	8	(2) (4,5)	12	16
3	Moderate	No fatalities and < 10 severely injured	Local impact	3	(0) 6 (1,3)	7.5	9	12
2	Small	Only slightly injured	Minor impact	2	4	5	6	8
1	Negligible	No injuries	No effect	1	2	2.5	3	4

Figure 5-8 Average scores of all hazards per option

In Figure 5-9 per option the single hazard which scores maximal in probability or impact is plotted in the risk matrix.

				A	B	C	D	E
		Impact		Probability of occurrence				
				Improbable	Unlikely	Occasional-ly	Regularly	Often
Qualitative description		People	environment and economy	A. Improbable (< 1x per 20 yr)	B. Unlikely (1x per 20 yr - 1 x per 5 yr)	C. Occasionally 1 x per 5 yr - 1 x per 2 yr	D. Regularly 1 x per 2 Yr - 5 x per yr	E. Often 5-50 x per yr
Rank		Defenitie		A	B	C	D	E
5	Catastrophe	> 10 fatalities	Large impact	5	10	12.5	15	20
4	Serious	<10 fatalities and >10 severly injured	significant impact	4	8	1,2,3	4,5	16
3	Moderate	No fatalities and < 10 severely injured	Local impact	3	0	7.5	9	12
2	Small	Only slightly injured	Minor impact	2	4	5	6	8
1	Negligible	No injuries	No effect	1	2	2.5	3	4

Figure 5-9 Maximum scores in probability and impact per option

During the workshop the group agreed that the most important hazards are drifting ships due to technical malfunctioning of the ship (loss of engine power or rudder problems etc.) and loss of cargo, most likely due to uncontrollable ship movements in adverse weather conditions. Also mentioned were ships executing emergency anchoring after a technical malfunctioning trying to prevent a ship-ship collision in a narrow traffic lane. Heavy weather conditions could also lead dangerous situation as ships might be seriously restricted in their manoeuvrability (not under command) in combination with being unable to alter course due to the proximity of wind installations.

In the discussion concerning the impact of a hazard the group indicated that impacts “people”, “economy” and “environment” does not cover societal impact. It was illustrated by means of two examples. A sailing ship capsizing resulting in four fatalities will get less attention in the media than a relatively small nautical incident with a container vessel losing hundreds of containers drifting ashore, like the MSC Zoe. The societal and the subsequent political impact of the latter being far larger than the first example. So, societal impact should be taken into account in this process. A likely hazard, not in the list as part of the questionnaire, is loss of cargo (mainly containers) in adverse weather and sea conditions causing heavily reduced alteration options for masters to select a safer course that reduces acceleration forces and therewith ship and cargo movements.

Therefore, one additional hazard was added:

New added hazard: loss of cargo (most likely containers) due to adverse weather and sea conditions.

Societal impact was also mentioned as important in relation to the hazard nr. 7 (Route bound ship drifts against turbine due to technical malfunctioning) in case it should concern a passenger vessel or ferry. Current social media platforms will directly distribute many posts, pictures and movies spreading the news of such a hazard occurring. This also creates a significant societal impact and contributing to the sense of risk introduced by navigating close to windfarms, even if the real impact of the incident (either being people, economy or environment) might be small.

The arguments given by the experts indicate a risk of loss of cargo which cannot be neglected. The area of concern in the North Sea is often tormented by high waves caused by strong and persevering westerly to northerly winds. Crews are experiencing large ship motions (roll, pitch and yaw) due to these waves from the north-west. In such cases reducing ship motions is often required to lower the risk of loss of cargo. In order to reduce these motions the crew has several options: adapt speed and or change heading. A speed change has impact on the ship motions depending on the wave length and the ships length. Speed changes are often not sufficient to limit the ship motions however. A more effective way to reduce the ship motions is changing the heading of the ship. Changing the heading reduces the impact of the waves on the ship which decreases motions.

In the current situation there is no Traffic Separation Scheme (TSS) in this part of the North Sea so the master is free to sail any heading which is deemed necessary to reach the destination safely. When introducing a relative narrow passage including a TSS ships are limited in choosing their heading and in adverse weather conditions they will be forced to maintain thir heading resulting in large ship motions and an increased risk of loss of cargo. Wave conditions are forecasted, so one could say that good seamanship requires to check the forecast in advance and make sure not to sail through these “confined waters” in the time period the wave conditions may result in high risk of cargo loss. However these forecasts loose their accuracy over time and ships sail for a long period of time, a period in which the conditions can deteriorate faster than forecasted. For example a typical transit between the Dover Strait and southern Norway takes 40 hours.

Why does this problem not occur in the existing TSS in southern part of the Dutch EEZ? This more southern part experiences far less high wave conditions than the area considered in this FSA. Therefore ships do not need to alter their heading and or speed to avoid risk of cargo loss (unless their draught becomes a restricting factor).

In the map in Figure 5-10 multiple tracks can be identified of ships which have changed heading during adverse wind and wave conditions. This is indicative since no information is available of the decisions taken by the various masters of these ships. In normal conditions however such patterns have not been observed which leads to the conclusion that adverse weather conditions lead to such decision making.

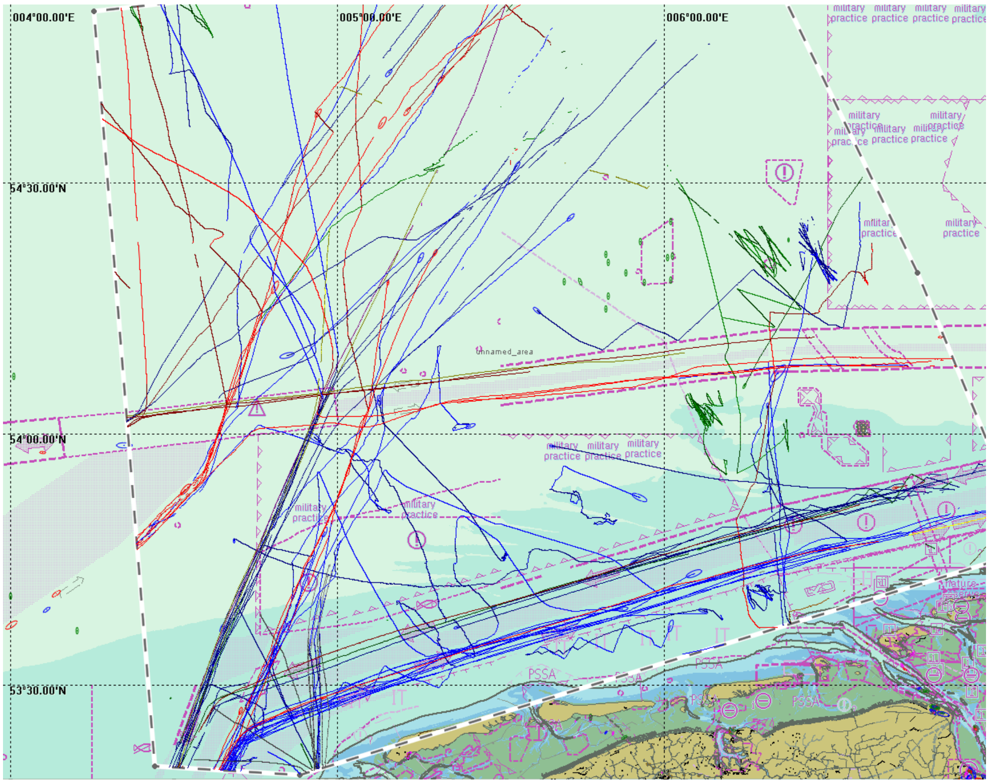


Figure 5-10 Tracks vessels on the night 2-3 January 2019 (MSC Zoe -incident)

5.2.9 Mitigating measures

During the session a number of mitigating measures were mentioned. Which set of measures would be required for which specific option was not discussed due to limited time available at the workshop, but also mainly due to the fact that the participants regarded it as too early in the process to be able to discuss into this level of detail. Again, reference was made to the general interest in the principle on mitigating measures as described in paragraph 4.2.2
The mitigating measures which were discussed by the group are described in random order below. It was recognised that the costs of these measures varies and the expected benefit is further researched and monitored the coming years as the first mitigating measures in the Dutch southern North Sea area will start 2021.

- When applying the so called *Safety Margin framework*, this includes safety buffers between shipping routes and the windfarms as a starting point. These safety buffers have a positive effect on safety. Although the group discussed that creating free sea space is a hard non-negotiable requirement and shall not be seen as additional required mitigating measure.

- Sufficient coverage of nautical and metrological sensor systems such as VHF communication, Radio Direction Finders, AIS and RADAR systems, possibly supplemented by camera systems and satellite surveillance and communication. In and near windfarms, coverage of those sensors is regarded as a basic and therefore minimum requirement to ensure a basic level of safety by aiming to create situational awareness based on a recognised maritime surface picture. Monitoring this picture to actively avoid hazards to develop and take place and to support as early and efficient as possible. This measure counts as activities to minimize the impact of a (possible) hazard to occur.

- Vessel Traffic Service and/or monitoring gives added value to support masters and this service is able to detect unusual and deviating behaviour of vessels due to technical malfunctioning, navigational errors or any other cause. VTS might also become important to assist crews on board confronted with distorted RADAR images due to radar disturbance by windfarms. Finally VTS is known to play a critical role in on-scene-coordination during incidents with primary contribution in gathering initial information, establishing communication and later minimising the impact of the incident on ongoing shipping and environment.

- Vessel Traffic Management including shore-based traffic planning. Possibly filing shipping control plans comparable to the aviation industry, where each flight requires to file flight plans in advance of the flight. This would allow a VTM (coastal) entity to plan total traffic and spread traffic over time if a bunch of vessels is planning to take the same route at the same time. It was commented that this would require changes in international regulations since the region is outside the 12NM territorial waters and therefore national regulation do not apply for such measures.

- Insistent advice (in Dutch "*dringend advies*") provided by the Coastguard is seen as a measure to influence traffic in adverse conditions for example. This may concern a generic navigational warning to be issued for all ships in the area or direct contact with a single ship providing dedicated advice. A discussion concerning the adherence of those advices by masters outside the 12NM zone was held. Mentioned was that advice from the Coastguard is optionally and not mandatory to adhere. However insurance companies follow a different approach. In their policy, conditions often state that masters are to follow-up advice from the Coastguard (good seamanship, due diligence, etc.) otherwise recklessness, gross-negligence can more easily being applied. So, an advice from the Coastguard is not as unconditional as it legally seems. Another topic that was mentioned was that if the advice includes waiting before entering the narrow route system there should be sheltered waiting areas with sufficient capacity available. One remark was made that having a proper detection mechanism and a provision to issue such advices will require more capacity than currently available at the Coastguard centre at this moment.

- Emergency Towing Vessel stationed near the windfarms. These can both help to prevent a hazard to occur when early detection of a drifting ship is feasible. After a hazard having occurred an ETV is useful to prevent or reduce the impact of the hazard. An ETV is one of the few mitigating measures to reduce the frequency of vessels drifting towards a wind turbines, next to emergency anchoring or towing assistance of other vessels in the neighbourhood. It was indicated that the availability of one or more ETV's will become a requirement for those planned large windfarms developed near high density shipping routes.

- A more natural mitigating measure was mentioned as part of the decision making process of the master: in adverse weather and wave conditions with a narrow route system, masters will try to avoid entering this narrow route system under those conditions and may decide to either wait for improved sea conditions or plan a different route avoiding the complex area.

- Mentioned was that the German authorities applies cardinal buoys to create a 1NM safety zone around a windfarm without defining a TSS. Discussed was whether this is legally a valid option for usage in combination with permanent structures outside the 12 NM zone.

5.2.10 Concluding remarks of the experts

At the end of the workshop all participants were asked to recap. Agreement in the group can be summarized as follows:

Option 3 is the preferred option and considered as the only feasible option from perspectives of safety of navigation, international legal aspects (freedom of navigation) and accessibility of ports.
Option 1 is second best however not preferred due to the increased risk on safety of navigation.
Options 2, 4 and 5 are unanimously considered as non-options from a shipping perspective. They have huge impact on the aspects safety of navigation, accessibility of Dutch and German ports and finally, they are likely to require the largest financial budget for mitigating the increased risks.

When the median strip should be developed, the artificial island in the south of the median strip is too close to multiple complex crossing traffic flows. Further the group explicitly warns that a similar impact or consequences as huge cargo losses recently occurred when containership MSC Zoe lost containers in January 2019 due to heavy weather conditions. The reasoning is that the median strip decreases the option for masters to select a safe course (e.g. heading into waves) which is required due to adverse weather and sea conditions. Not having the possibility to select a safe course under certain conditions can lead to heavy ship motions leading to loss of cargo.

5.3 International session

During the meeting of the EU Shipping Group on October 14th 2020 a part of the agenda was reserved for an expert session as part of the FSA at hand. This section describes only the FSA session of the meeting.
The meeting is planned as an knowledge exchange between international governmental maritime experts, with the intention to align the various national plans. During the meeting all experts were asked to express their expert knowledge and experience and so much the official formal member state viewpoint. The contribution and statements made during the expert session are reflected in the report. Some clarification and justification on details was added via a short written round in the week after the expert meeting.

5.3.1 List of participants in the international expert session

The following people were participating in the workshop.

Experts:

- Head of Division ”Spatial Planning” at the Federal Maritime and Hydrographic Agency of Germany
- Spatial planner at the Federal Maritime and Hydrographic Agency of Germany
- Directorate-General for Waterways and Shipping Germany
- Nautical advisor at the Danish Maritime Authority, Denmark
- Nautical Superintendent at the Danish Maritime Authority, Denmark
- Senior advisor at the Norwegian Coastal Administration, Norway
- Maritime expert at the French Maritime Administration, Cerema, France
- Policy advisor at the Federal Public Service Mobility and Transport, Belgium
- Offshore Energy Liaison Officer at the Maritime & Coastguard Agency, United Kingdom
- Offshore Renewables Advisor at the Maritime & Coastguard Agency, United Kingdom

Client:

- Joris Brouwers, MSc (Senior policy advisor Shipping, Ministry of Infrastructure and Water Management, DGLM. Former Royal Netherlands Navy officer (navigator))
- Sjoerd Jansen (Senior policy advisor, Ministry of Infrastructure and Water Management, DGWB)
- Jeremy Stroo (Policy advisor Ships’ routeing and Safety, Rijkswaterstaat. Former Merchant Navy navigational watch officer)

MARIN:

- Hans Huisman (Team Leader Human Factors at MARIN, workshop chair)
- Yvonne Koldenhof (Team Leader Traffic & Safety at MARIN, project leader of FSA)

5.3.2 International expert session conclusions of the 5 design options

Below the initial statements and positions of the member states are summarised based on the discussions during the session as well as a questionnaire filled in afterwards. The responses below focus mainly on the direct neighbouring member states.

Germany
General: very valuable to organise and participate in those type of meetings. Without a central formal body taking the lead, it is important to have this type of informal meetings sharing national (spatial) plans and try to efficiently connect national (spatial) plans, especially close to EEZ borders.

Regarding option 2 and 3: The route to/from Esbjerg might be relevant for Denmark but for Germany it is not a real issue to delete this ‘’additional’’ option in case other options remain available for shipping to Esbjerg, which there seem to be. Therefore Germany could accept and support either choice.
Germany foresees an issue whether deleting this the route through windfarm 5 is in in line with UNCLOS.

Option 1 and 3 might look promising but we all need to find areas for windfarms, so removing the median strip as in option 2,4 and 5 is from a maritime point of view logical but where do you find a comparable area for windfarms? Accessibility of the German ports and adhering to international regulations such as UNCLOS should be a fundamental concern from both an economic and legal perspective and would be an argument for Germany to prefer option 1 or 3.

Regarding Option 5, it seems very unusual to block an important shipping route. This route will become even more important in the future, so blocking it will lead to issues of congestion, safety of navigation and possible even non-compliance with UNCLOS. Also accessibility and port connections between ports in the future might be impaired. Connections with the northern ports in the Netherlands and probably also the port of Rotterdam will decrease. Germany possibly sees this option as a no-go, however no firm statement is given at this moment during the meeting. During the discussion a number of first arguments *against* option 5 were given:

- The route is a major connection for the Netherlands and German ports to the polar route;
- Port connections for several EU ports is negatively impacted by this blockage;
- It requires investigation where traffic will be redistributed in case this connection would be blocked.

In all options, the design of windfarm area 5 indicates an eye-catching difference in safety margin between the Netherlands and Germany. This is worth noting in this phase. The coming years, further alignment is required to solve this issue. All participants concluded that different safety zones in two neighbouring member states will result in a confusing, unsafe situation for navigation officers on-board ships.

It is stated that windfarm 5 is considered to be designed too close to the TSS East Friesland, leaving too little manoeuvring space to give way or for emergency anchoring. Even some Collision regulation rules might not be feasible. In case traffic volumes increase over this route there is no space available to cater for this and routing limitations will be required.

Concerning mitigating measures it is stated that this is hardly an option if insufficient space is left between a windfarm and a shipping route. Mitigating measures will be necessary and are likely to be efficient in normal situations, but in disturbed situations hardly any mitigating measure will have a positive and sufficient safety effect on forehand and could only contribute to minimise the impact of an incident.

The median strip in Germany will be reserved for shipping at least until 2035. Whether after 2035 windfarms will be planned in the median strip is not clear at this moment in time. Since it is all a complex

area from a shipping point of view the question arises whether it will be legally possible to plan windfarms as median strip. For now the expectation seems to be that this will not be feasible.
Special attention was given to UNCLOS art 58 para 1 and art 60 para 7 which gives clear legal arguments and restrictions for interaction between shipping activities and offshore (renewable) energy installations. Germany states that for the reason of the fast development of offshore renewable energy, they have included the legal justification in their Maritime Spatial Plan.
A remark was made that planning windfarms in the median strip in the Netherlands as well as Germany seems illusionary and not regarded a serious option.
In addition for option 5, which blocks the connection through the median strip ,was regarded not to be an option at all. Apart from the arguments against the median strip, it was stated that the corridor through the median strip has to be kept clear and not block this connection.

Be aware that the largest container vessels are operated on the route towards the Baltic sea. In addition when an ice free arctic route might become available on the long-term, the traffic developments will show an increase in this whole area.

Denmark
Option 2 and 3 in which the route to Esbjerg is blocked by area 5 is an issue for Denmark. There are alternative routes via the main shipping routes however the corridor through windfarm 5 is regarded important for the port of Esbjerg. The alternative routing will increase a single voyage by approximately 8.5 NM.
Although the traffic density is low (< 2000 vessels a year) and concerns mostly cargo (ro/ro) ships of about 200m length. It is recognised that closing this route will reduce crossings in a complex area and might have safety wise a beneficial effect. During the discussion it became clear the majority of the experts would prefer option 3 over option 1. Denmark stated that they understand that choice given the arguments with negative impact on safety of navigation on the Westerly side of the corridor near two intensively used shipping routes. Further they would invite Germany and Netherlands for a trilateral meeting on optimising the situation which would occur when Netherlands should choose option 3.

The median strip in option 2 and 4 is not a good idea when using friendly words at least. It is a very complicated area with a lot of crossings.
Working for 3 years now on new Danish plans, they still learn every day. One lesson learned is that there should be enough width for making turns for ships within the route structure. Option 2, 4 and 5 hardly cater for evasive (emergency) manoeuvres and are therefore seen as not feasible.
For safety margins, the Dutch whitepaper (based on the *Safety margin framework)* will be the starting point for Denmark to apply.

Option 5 is blocking the corridor through the median strip and this corridor should remain open due to focus on artic routes in the future.

France
France made a remark on option 2, 4 and 5. Organising the traffic north-south in two-way direction routes is challenging with a fixed median strip full of installations. It is narrow and regarding safety it will most likely require at least significant and challenging mitigating measures to reach a reasonable level of safety. Serious concerns were expressed regarding safety of navigation explicitly for those options. Probably the median strip needs to remain clear of fixed long-term obstacles in order to secure enough manoeuvring space in an sea area, in which a lot of crossings takes place. Options 2, 4 and 5 lead to crossings of two, two-way routes (two east-west routes, TSS Friesland East and TSS Terschelling, and two routes on both sides of the median strip north-south) and are therefore not feasible. The crossing requires sufficient space and these three options do not cater for that. Alternative to options 2,4 and 5 might be to create two one-way routes. The impact on safety of navigation and impact on changes of existing connecting routes should be worked out in that case.
By far, options 1+3 seems to be the safest and most likely achievable.

On the side a remark: wind turbines continue to get taller. The higher the turbine the larger the area in which GNSS systems (GPS, AIS and VHF communication) will be impacted. (GPS multipath issue close to obstacles). This should be carefully considered. Reference was made to chapter 5 of WG 161 PIANC: https://izw.baw.de/publikationen/pianc/0/marcom_wg_161.pdf and http://www.pianc-aipcn.be/figuren/5%20BTV/extra%20pdf/08%20PIANC%20WG161,%20Jean%20Charles%20Cornillou.pdf)

Belgium
Has made a statement more from a legal point of view and not really a maritime point of view.
Agreed with France: option 1 and 3 are the most promising. Option 5 will be very difficult to get an agreement from IMO with respect to closing the corridor through the median strip. Definitely not the best way forward. In addition already mentioned UNCLOS articles 58 and 60 requires attention when developing this area.
Closing the corridor through windfarm 5 might be conflicting with UNCLOS art 58, especially if neighbouring member states or stakeholders should insist. IMO has no vote, the member states are relevant and many are likely to oppose against the negative impact on designs such as option 5.
Belgium states: be aware you make the right design choices, if not, you are bound for 40 years to a sub-optimal solution. This is an important lesson learned by Belgium recently on their routeing design in the Schelde Estuary.

Conclusion international expert session
Option 3 has impact on the safety of navigation, freedom of navigation and accessibility of ports, although the negative impact is considered as least out of the 5 options. This option is broadly considered as the best feasible option from a shipping perspective.

Option 1 has an increased impact on the safety of navigation due to the connection of the corridor though search area 5 into an intense shipping route. Freedom of navigation and accessibility of ports is slightly better with respect to option 1 although the overall negative impact is considered as non-preferred. This option might be considered as a second best option from a shipping perspective.

Strongly negatively advised: options 5, 4 and 2, based on estimated negative impact on safety of navigation and connectivity of NW-European ports and expected legal challenges.

5.4 Conclusion qualitative analysis

Based on the questionnaire, the national expert workshop and the international expert workshop the following conclusions can be made from a qualitative perspective.

The differences between the 5 design options in the questionnaire ratings were smaller than when discussed during the meeting when arguments were shared verbally. After having discussed these arguments the differences between the 5 design were stated more clearly by arguments. Below the conclusions for the 5 design option based on the qualitative assessment is described. It should be noted that all 5 options lead to reduction in safety level compared to the current Freedom of Navigation situation.

5.4.1 Newly added hazard: loss of cargo

In the questionnaire, probabilities and impact of 10 hazards were asked to rate for the current situation and the 5 design options. All 5 design options score clearly worse than the current situation for all 10 hazards both on probability and on impact. This is no surprise since the current situation includes no windfarms in the concerned area while all 5 design options contain windfarms in a high density traffic area. During the national workshop one new hazard was identified: loss of cargo (most likely containers) due to adverse weather and wave conditions. This hazard is mainly relevant for the options in which masters are constrained by choosing a safe heading to decrease ship motions and therewith decrease the risk of losing cargo or even worse incidents.

5.4.2 Option 1

The open sea space between windfarms 5 and 6 provides sufficient space for ships to safely navigate in this high density traffic area including multiple ship crossings. Expected is that no traffic scheme is required and the standard safety zone of 500m is sufficient to start with. Though mitigating measures will be required to create a sufficient safety level in the event when ships suffering failures and start to drift in the direction of a windfarm.
The corridor through windfarm 5 creates crossing traffic with the TSS German Bight western approach increasing probability of ship-ship collisions.
The artificial island positioned in the north of windfarm 6 was expected not to create substantial risks. The preferred location of the island to as far west as possible in the north of windfarm 6. All options need to be displayed on a map to further analyse more in detail.

5.4.3 Option 2

The median strip between windfarms 5 and 6 leads to narrow shipping lanes. Under smooth sea conditions, those will provide sufficient space to accommodate the traffic flows in the area. However in heavy weather conditions and in case of ships facing technical failures that lead to loss of control, collision risks and contact or dangerous situation on board the ship is higher than acceptable. It concerns both ship-ship collisions and ship-turbine contact besides local on-board issues as excessive ship motions causing high accelerations forces on cargo leading to cargo losses. A traffic scheme with safety margins based on the *framework* is seen as basic requirement. Even implementing mitigating measures, the situation with the median strip is not expected to reach an acceptable safety level. Most likely hazard is expected loss of cargo (containers mainly) due to the limitation of course alterations the median strip imposes on masters to select only very limited course alterations to decrease ship motions.
Having no corridor through windfarm 5 is seen a good option, eliminating extra crossing.
The artificial island in the south of the median strip is regarded as increasing collision risks in a high density traffic area with many crossings of traffic from multiple directions increasing risks to an most likely unacceptable high level.

5.4.4 Option 3

This option is the best, most preferred option by the group. It combines the safest design elements.
The open sea space between windfarms 5 and 6 provides sufficient space in this high density traffic area including all ship crossings. Expected is that no routeing measures as traffic separation schemes are required and that the standard safety zone of 500m is sufficient at this moment. Mitigating measures will be required to create a sufficient safety level in the event of ships suffering unforeseen technical failures or human errors that can cause for example drifting in the direction of a windfarm.
No shipping corridor through windfarm 5 is seen a good option, eliminating an extra crossing area.
The artificial island positioned in the north of windfarm 6 was expected not to create substantial risks. The preferred location of the island to as far west as possible in the north of windfarm 6.

5.4.5 Option 4

The median strip between windfarms 5 and 6 leads to narrow shipping lanes. Under normal ship operations and smooth sea conditions these will provide sufficient space to accommodate the traffic flows in the area. However in case of ships with a technical failure leading to loss of control, the collision risk or contact with installations is higher than acceptable. It concerns both ship-ship collisions and ship-turbine contact. A traffic separation scheme with safety margins based on the *framework* is seen as basic requirement. Even with additionally implementing mitigating measures, the situation including the median strip is not expected to reach an acceptable safety level. Most likely hazard whereby expected loss of cargo (containers mainly) due to the limitation the median strip imposes on mariners in order to choose a safe heading to decrease ship motions and therewith the reduce chances of cargo loss etc.
The corridor through windfarm 5 creates crossing traffic with the TSS German Bight western approach increasing collision risks.
The artificial island in the south of the median strip is regarded as increasing collision risk in a high density traffic area including many crossings of traffic flows leading to an unacceptably high level of risks.

5.4.6 Option 5

This option was regarded as the option combining all worse elements into one.
The median strip between windfarms 5 and 6 leads to narrow shipping lanes. In normal operation these will provide sufficient space to accommodate the traffic flows in the area. However in case of ships with a technical failure or human error leading to a loss of control, collision risk or contact is higher than acceptable. It concerns both ship-ship collisions and ship-turbine contact. A traffic separation scheme with safety margins based on the *framework* is seen as basic requirement. Even when implementing mitigating measures, the situation including the median strip is not expected to reach an acceptable safety level. Most likely hazards as loss of cargo (containers mainly) are expected due to the limitations, the median strip imposes on masters to choose the safest heading to decrease ship motions. Stretching the median strip which additionally blocks the route through the median strip was regarded as not future proof since arctic traffic is expected to increase in the near future. In addition it reduces options for ships adapting their route.
The corridor through windfarm 5 creates additional crossing traffic with the TSS German Bight western approach increasing collision risk.
The artificial island in the south of the median strip is regarded as increasing collision risk in a high density traffic area with many crossings of multiple traffic flows leading to an unacceptable high risk level.

5.4.7 Mitigating measures

Sufficient coverage of nautical and metrological sensor systems such as VHF communication, Radio Direction Finders, AIS and RADAR systems, possibly supplemented by camera systems and satellite surveillance and communication is seen as a requirement. This measure potentially the probability of a hazard to occur but definitely can help to decrease the impact of a hazard.

Insistent advice (in Dutch "*dringend advies*") provided by the Coastguard is seen as a measure to influence traffic in adverse conditions for example. This may concern a generic navigational warning to be issued for all ships in the area or direct contact with a single ship providing dedicated advice. This measure is both seen as potentially reducing the probability and the impact of a hazards. More general VTS was also indicated as a measure to investigate.

Emergency Towing Vessel stationed near the windfarms was seen as required. This may prevent a hazard to occur when early detection of a drifting ship is feasible and reduce impact such a hazard.

Mitigating measures were seen as essential to create a sufficient safe solution. Which mitigating measure would be most effective end feasible requires further investigation.

6 CONCLUSIONS AND RECOMMENDATION

This chapter contains the main observations, conclusion and recommendations of the different parts of the FSA for various spatial planning options for wind farm search areas 5 and 6 in the Dutch EEZ and the main route from and to the Skagerrak.
The FSA has three main parts; an analysis of the existing shipping traffic in the area, a quantitative analysis of the 5 different provided spatial planning options and a qualitative analysis of those options. The conclusions and observations of these three parts are initially provided individually in paragraphs 6.1, 6.2 and 6.3. Finally the overall combined conclusions and recommendations are given in paragraphs 6.4 and 6.5

6.1 Conclusion/observations from traffic analysis

Using AIS-data from 2019 and partly 2020 the current existing traffic flows in the study area have been analyzed. Based on this analysis some observations are made regarding the combination of the traffic flows and the different options for the spatial planning in the area. Secondly, the results of this analysis are used as the basis for the traffic database which is required to perform calculations with the safety assessment model SAMSON.

Using the AIS-data from the period May 2020, the tracks of individual vessels are plotted in different charts (Figure 6-1). Based on these maps the following observations can be made regarding the shipping traffic in this area:

- In the southern part of the Dutch EEZ the routes show a less diffuse pattern than on the Northern part of the North Sea. This is mainly a result of the various TSS[2]s that are located in this southern part.

- The routes between the southern and northern part of the North Sea show a more scattered pattern as a result of the many different destinations up north and the fact that vessels chose the shortest route to these destinations starting from the TSSs in the southern part.

- Indicated in the red ellipse on the upper left chart (Figure 6-1), a clear northeast-southwest traffic flow of cargo vessels (length class 100-150m LOA) is visible; those are mostly smaller cargo vessels sailing between Hull and Esbjerg. These vessels currently sail through the northern part of the planned wind farm area 6.

- Also a “clear” route of tankers between 200 and 300m LOA can be observed (red ellipse on the upper right map of Figure 6-1) that are leaving the TSS on the south and sail up north (direction Norway) is observed. These tankers are also currently sailing through the planned wind farm area 6 and need to find another route when the windfarm will be build. These vessels will either pass windfarm 6 on the east side and will change course after passing the windfarms in Germany or the tankers will pass windfarm 6 at the west in the space between windfarm 6 and 7. Both options will result in an increase of the traffic intensities on these routes.

- The map for the tankers (right map of Figure 6-1) shows that some tankers leave the TSS going north more to the east of the study area (dotted ellipses). These tankers pass in the current situation the planned wind farm area 7. This area is not part of this study for which the results are presented in the report, however these vessels have to find another route going north when areas 5, 6 and 7 are realized. They can either sail west of area 7 or between areas 6 and 7.

- The median strip search area is used by vessels up to 250m LOA. These vessels will be affected by introducing a wind energy area between the two north-south oriented traffic routes.

[2] TSS: Traffic Separation Scheme: a routing measure aimed at the separation of opposing streams of traffic by appropriate means and by the establishment of traffic lanes (source IMO)

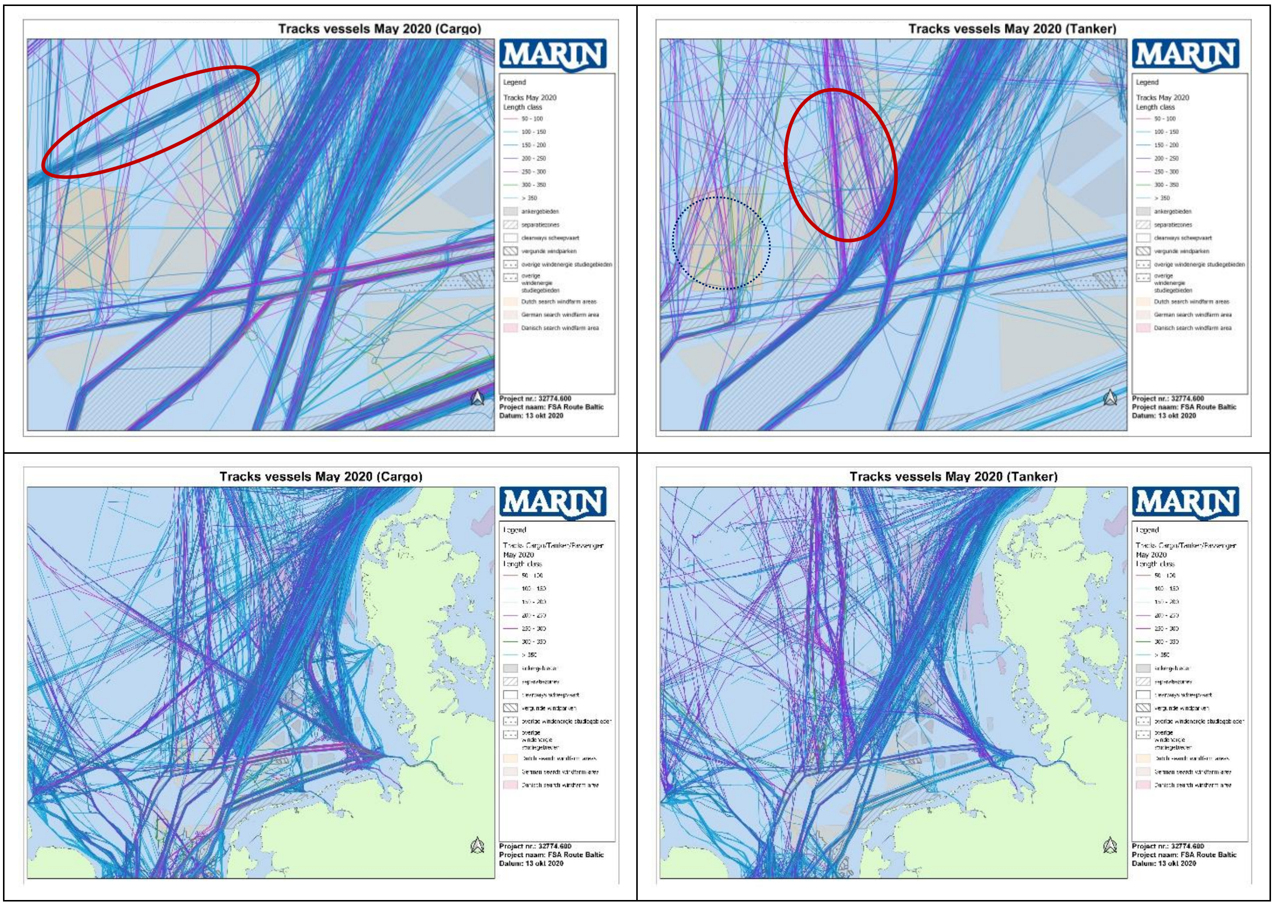


Figure 6-1 Tracks of all cargo (left) and tankers (right) passing the area in May 2020

Finally the results of the traffic analysis is translated into different so-called traffic databases for the 5 different options, taking into account the closure of the windfarm areas for shipping traffic. For the four main traffic routes through the study area (see Figure 6-2) the assumed number of vessels passing per year are provided in Figure 6-3

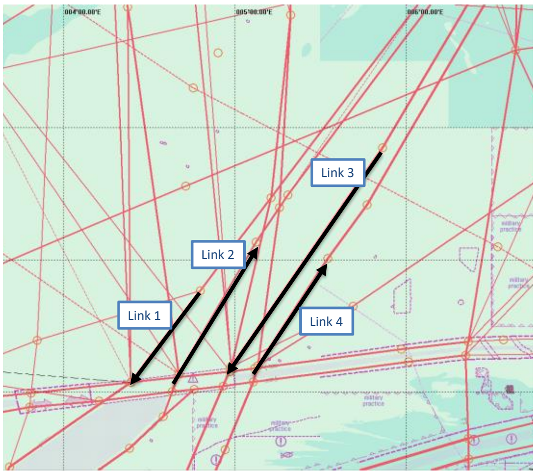


Figure 6-2 Location of the four main routes thru the study area

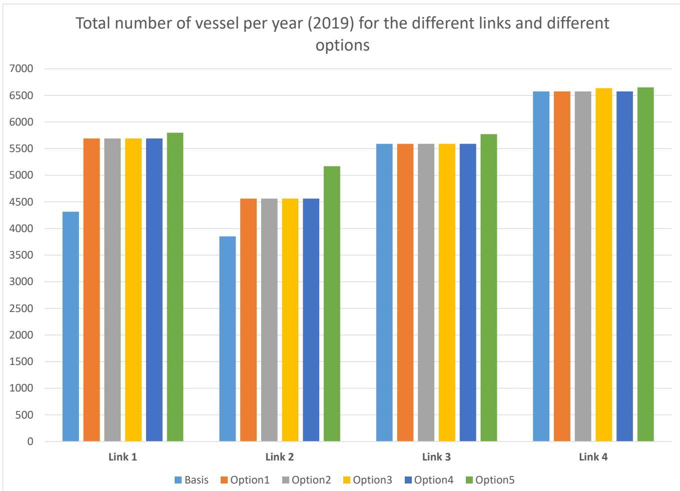


Figure 6-3 Total number of vessels per year (2019) for the four links and for the different options

From the charts it can be concluded that the number of vessels in the two main traffic routes in the western part of the study area will increase compared to the basic (current) situation. This increase is mainly the result of the closure of the route going to and coming from the north and therefor passing through windfarm search area 6. Furthermore a small increase of traffic in all main links can be found for option 5, due to the fact that it will not be possible any more to “switch” lanes going to, or coming from, the north.

6.2 Conclusion quantitative analysis

Using the results of the traffic analysis and the safety assessment model SAMSON the frequency of two types of incidents in the study area have been calculated. Firstly the number of ship-ship collisions (between merchant vessels) is calculated for a selected area widely overlapping the study area. The second incident type is a collision of a ship with a wind turbine as a results of either an engine failure (drifting) of a navigational error (ramming). Because the actual locations of the different wind turbines in the different areas are not yet known, the windfarm areas are represented by lines on the border of the area. Instead of calculating the collision frequencies for an individual turbine due to either a navigational error (ramming) of an engine failure (drifting), the number of vessels are determined that will “enter” the different areas, so-called: “vessels at risk due to entering a windfarm area”.

The combined effect on both ship-ship collisions as on ships at risk due to entering a windfarm area are given in Table 6-1. In the basic scenario only ship-ship collisions occur in the selected study area. Based on the calculation once every 6.9 year a ship-ship collision (between merchant vessels) will occur in this area. The extra incidents when building a wind farm are the incidents whereby vessels enter a wind farm area unintentionally. The number of expected incidents of this type also varies between 0.48 and 0.83 per year depending on the option. This means that the total number of expected incidents in the area increases from once every 6.8 year to once every year up to even 1.5 incidents per year. This gives an increase of 346% for options 1 and 3 and even an increase of 580% for options 2, 4 and 5 compared to the basic scenario.
The increase of the number of expected incidents between the options with a median strip (option 2, 4 and 5) compared to the options without this strip (option 1 and 3) is 53%.

Table 6-1 Total number of expected incidents per year involved route-bound vessels

Option	Windfarm areas included	Number of incidents per year			Total once every … year	% grow compared to Basic scenario	% grow compared to Option 3
		Ship-ship collision	Route bound vessels at risk in windfarm area	Total			
Basic	No Windfarm areas on Dutch EEZ (not area 5 or 6)	0.1454	0.0000	0.1454	6.88	0%	
Option 1	Area 5 - with corridor + Area 6	0.1575	0.4912	0.6487	1.54	346%	0.1%
Option 2	Area 5 - without corridor + Area 5 - median strip + Area 6	0.1619	0.8306	0.9925	1.01	583%	53%
Option 3	Area 5 - without corridor + Area 6	0.1595	0.4883	0.6478	1.54	346%	0%
Option 4	Area 5 - with corridor + Area 5 - median strip + Area 6	0.1597	0.8347	0.9944	1.01	584%	54%
Option 5	Area 5 - with corridor + Area 5 - median strip-plus + Area 6	0.1624	0.8207	0.9831	1.02	576%	52%

6.3 Conclusion qualitative analysis

Based on the questionnaire, the national expert workshop and the international expert workshop the following conclusions can be drawn from a qualitative perspective.

The differences between the 5 spatial planning options in the questionnaire ratings were smaller than when discussed during the meeting when arguments were shared verbally. After having discussed these arguments the differences between the 5 design options were stated more clearly by arguments. Below the conclusions for the 5 design options based on the qualitative assessment is described. It should be noted that all 5 options lead to reduction in safety level compared to the current freedom of navigation situation.

Option 3 has impact on the safety of navigation, freedom of navigation and accessibility of ports, although the negative impact is considered the least out of the 5 options. This option is broadly considered as a feasible option from a shipping perspective.

Option 1 has an additional increased impact on the safety of navigation due to the connection of the corridor though search area 5 into an intense shipping route compared to option 3. Therefore this option is less preferable than option 3, however still feasible and an option to consider.

Options 2, 4 and 5 are strongly negatively advised due to their significant negative impact on safety of navigation. This negative impact on safety includes ship-wind turbine collisions, ship-ship collisions and loss of cargo in adverse weather and sea conditions.

6.4 Combined overall conclusion

Compared to the current situation in the Northeastern part of the Dutch EEZ, all five design options for future windfarms increase the risk of ship-ship collisions slightly. This increase is relatively small when looking only at the results of the quantitative analysis, however by the experts in two expert sessions the decrease in available space in the area due to the windfarms 5 and 6 is addressed as having a negative impact on the interaction between vessels.

The risk of a ship-wind turbine collision increases for all options as the concerned area includes no wind turbines at all in the current situation. The risk of ship-wind turbine collision, both due to navigational errors and technical failures onboard a ship is larger and a more important factor than the increase in ship-ship collisions.

From the quantitative analysis option 1 and option 3 show the smallest increase of incident frequencies and are more or less comparable. Both options provide the most open sea space. These two options were regarded as feasible by the experts in the qualitative analysis, though mitigating measures were assessed as essential to allow safe navigation. Which mitigating measures could be applied is to be determined.
In the end however in the qualitative sessions the narrow corridor in windfarm area 5 was a reason to favour option 3 above option 1.

Option 2, 4 and 5 show a larger increase in incident frequencies, especially the ship-wind turbine collision risk. The median strip narrows the shipping route and therefore increases the traffic density locally between the windfarms 5, 6 and the median strip. Also the shipping route is close to windfarms, increasing the collision risk both due to navigation errors and technical ship failures. The latter effect is clearly visible in the results of the quantitative analysis. In the expert sessions, the options 2, 4 and 5 were regarded as not safe and therefore not seen as realistic design options. Apart from collision risks an, additional hazard was indicated by the group of experts being the risk of loss of cargo. Options 2, 4 and 5 limit the possibilities for a master to select a course to limit ship movements in adverse weather and sea conditions. Conditions occur several time a year in the concerned area of the North sea requiring to select a course deviating from the planned route in order reduce ship movements. Not reducing ship movements in these conditions lead to the risk of losing cargo. Options 2, 4 and 5 allow too little for such course adaptations in adverse weather and sea conditions.

6.5 Recommendations

Option 3 is the most safe design option from a shipping safety point of view. Option 1 is an alternative to consider although extra mitigating measures may be required to solve the issue of crossing south of windfarm 5.
Options 2, 4 and 5 introduce risks for which the probability of occurrence can only marginally be reduced by taking mitigating measures. Consequences can be reduced to a large extend by mitigating measures. From a shipping safety point of view options 2, 4 and 5 are not recommended to select.

The experts indicated that the location of the artificial island in options 2, 4 and 5 is too close to a dense traffic route and a route crossing area. The risk of a ship collision with this artificial island including a hydrogen production plant was seen as too high since the consequence of a collision is large. Option 1 and 3 include a preferred location for the artificial island form shipping safety point of view.

A number of possible mitigating measures were indicated during the different expert sessions. However a thorough analysis of the effect of these mitigating measures was not part of this study. Therefore it is recommended to further determine the effectiveness of each of these possible measures or combinations. For the indicated mitigating measures it is important to determine their effect on decreasing the probability of a hazard to occur and in what way the impact may be reduced by it. This is necessary knowledge to make a proper cost-benefit analysis between the costs of extra mitigating measures and benefits; the reduction of the number of incidents and/or the consequences. Furthermore it is important to look into the acceptance of risk, what number of incidents related to wind turbines is acceptable in the area from the perspective of the different stakeholders such as shipping companies, captains, governments and windfarm operators.
Finally it is important to further investigate how to design the area in more details, e.g. introduction of a TSS, to accommodate the increased and changed traffic flows in the future situation in a safer manner to reduce the impact on ship-ship incidents.

REFERENCES

[Ref 1.] Y. Koldenhof, M.Hermans, K. Kauffman, S. Indah-Everts
Netwerkevaluatie Noordzee 2018-2019
MARIN, 32091-1-MO-rev.1, 29 oktober 2020

APPENDICES

APPENDIX 1 GLOSSARY / ABBREVIATIONS

AIS	Automatic Identification System
DGLM	Directoraat-generaal Luchtvaart en Maritieme zaken
EEZ	Exclusieve economische zone
FSA	Formal Saefty Assessment
GT	Gross Tonnage
I&W	Infrastructuur en Waterstaat (Ministry of Infrastructure and Water Management)
LOA	Length Over All
MMSI	Maritieme Mobile Service Identiteit-nummer
MSP	Marine Spatial Planning
RWS ZD	RijksWaterStaat Zee & Delta
SAMSON	Safety Assessment Model for Shipping and Offshore on the North sea
TSS	Traffic Seperation Scheme

APPENDIX 2 SAMSON

A2_1 Introduction

Maritime traffic and its behaviour is essential for a successful nautical risk assessment. For many years, such knowledge has been built up and improved. The knowledge has been acquired within Dutch national projects for the Maritime Safety Agency (DGLM with former names DGTL, DGG and DGSM) and the North Sea Directorate (Dienst Noordzee/Dienst Zee en Delta), both part of the Ministry of Infrastructure and Water Management, and within the European projects, COST 301, EURET, SAFESHIP, EMBARC, MarNIS, BE-AWARE and OpenRisk, for the European Commission. Based on this knowledge the SAMSON-model has been developed. The core of this model is a very detailed statistical traffic image surrounded by a number of accident models. The models predict the frequency of different accident types e.g. collisions, contacts, foundering, grounding, ramming and drifting against offshore platforms, wind farms etc. The models predict the frequency of occurrence combined with geographical position. This is essential for answering questions dealing with contingency planning.

A2_2 Model use in policy evaluation

SAMSON is used as a decision support system for the assessment of the effect of policy measures concerning:

- Re-routeing of traffic or part of the traffic to avoid sensitive areas. Is the new situation safer and what are the ship costs?
- What is the effect of training on the accident rate and what does that mean in terms of benefits?
- What is the effect of changes in the construction and/or loading regulations of vessel on the frequency of spills as consequence of a accident?
- What is the effect of the introduction of a “clearways system” in the North Sea and other waters of interest?

A2_3_Examples of application of the model

- Presenting traffic images in sea areas.
- Assessment of the spillage of oil and chemicals in case of collisions, grounding and foundering on the basis of the expected hull damage.
- Assessment of the pollution of the environment due to normal operations.
- Collision risk assessment for offshore platforms. How safe is the intended position? What is the probability that the platform will be collided by a ship and what will be the distribution of the ship sizes in that case? What are the possible risk control measures and what does it yield?
- Frequency of hitting pipelines by containers, anchors and sinking ships.
- Assessment of the optimum location and capacity for the salvage tug and oil recovery vessels for a required safety level.
- Assessment of the optimum location and capacity of units for the Search and Rescues capacity plan.
- Collision Risk Assessment for offshore wind farms.

A2_4_Accident models in SAMSON

The frequency in which a certain type of (collision) accident occurs at sea is modelled by multiplying a certain ***exposure measure*** with a ***basic accident rate***.

- An exposure measure can be explained as a certain elementary "traffic situation" which is representative for a certain type of accident.

- The basic accident rate is the probability that the situation leads to a real collision. The accident rate is determined from accident data from the different accident databases.

The main thought behind all models (except the ship/ship-model) is that accidents can be divided in accidents at low speed and accident occurring at high speed. An accident occurring at low speed is caused by an ***engine failure***, a failure in the propulsion engine or in the steering equipment. Because of this engine failure the ship slowly becomes uncontrollable as it loses speed, the combined effect of wind, waves and current may cause it to drift. An accident occurring at high speed is caused by a ***human error*** or ***navigational error***.

The different type of accidents defined in SAMSON with their cause and exposure measure can be found in Table A2-1.

Table A-1 Overview of the different types of accidents distinguished in SAMSON

Type	Subtype	Cause	Exposure measure
Ship/Ship collision		Human error	Encounter
	Ramming ship/anchored ship anchor area	Human error	Anchored ship ramming opportunity
	Ramming ship/anchored ship anchor area	Engine failure	Danger miles
Contacts	Objects with fixed position	Engine failure	Danger miles
	Objects with fixed position	Navigational error	Ramming opportunity
Sinking			Ship miles
Fire and Explosion			Ship miles
Stranding		Engine failure	Danger miles
		Navigational error	Stranding opportunity
Incident Hull/Machinery			Ship Miles

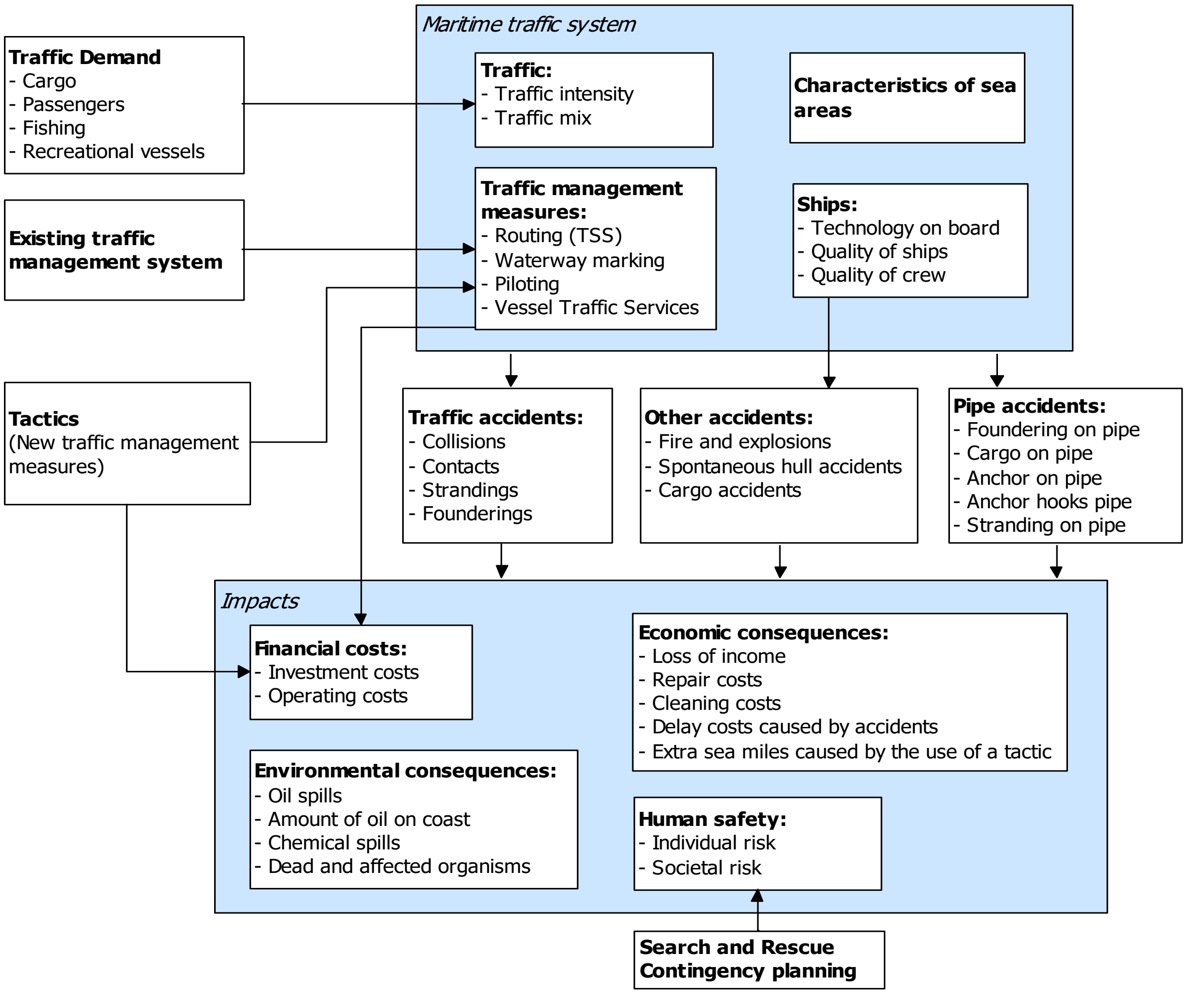


Figure A-1 System diagram SAMSON

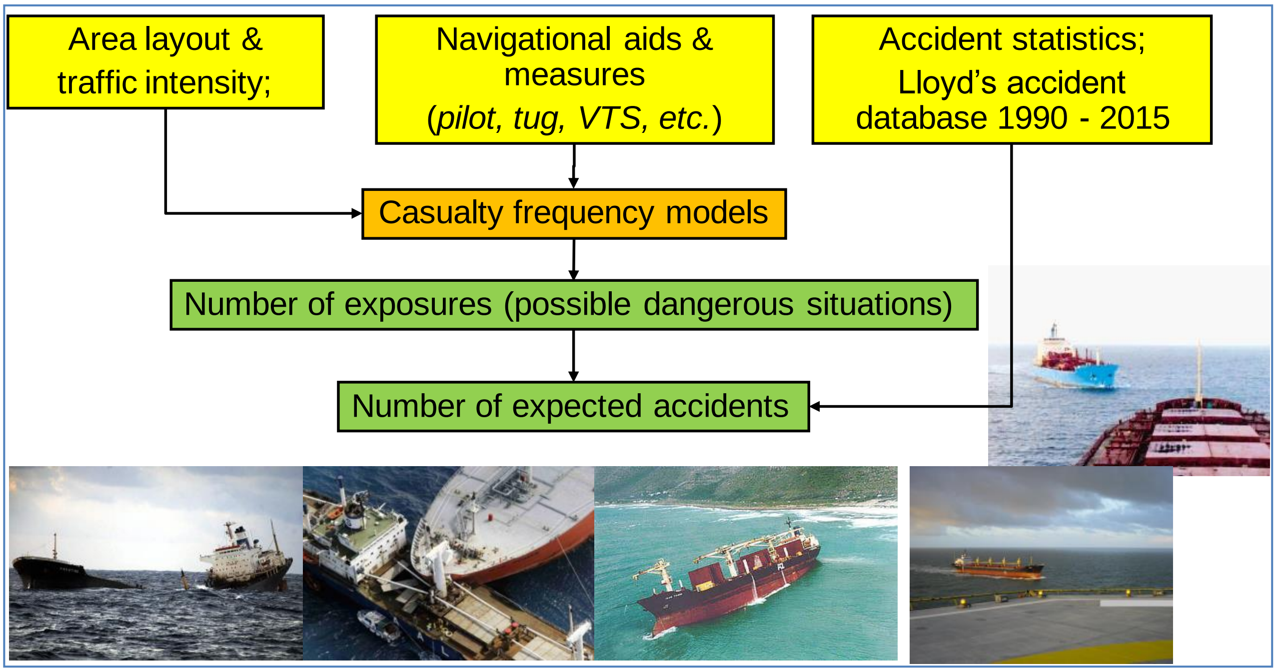


Figure A-2 Schematic overview of the accident frequency modelling of SAMSON

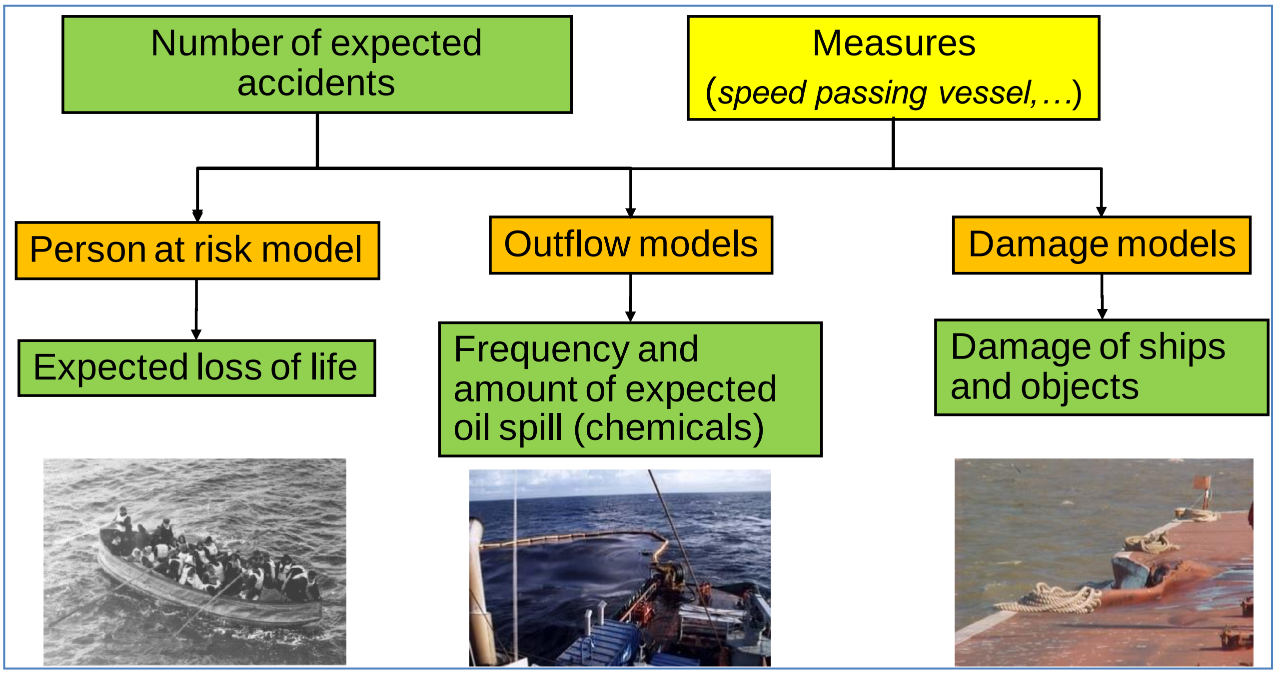
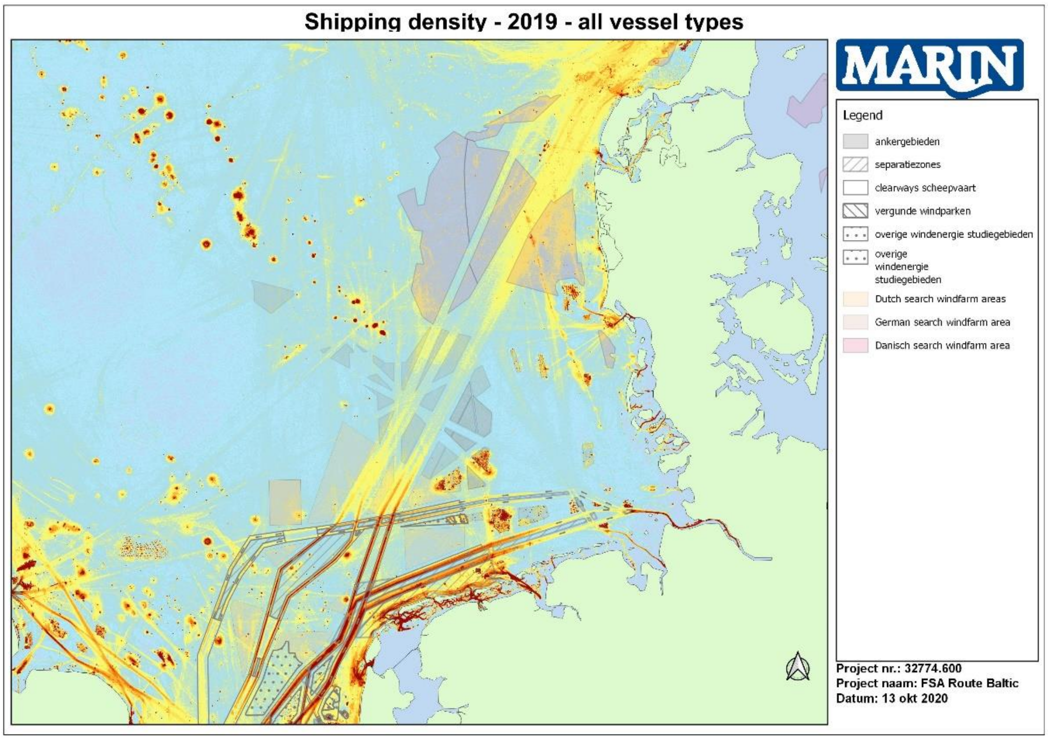
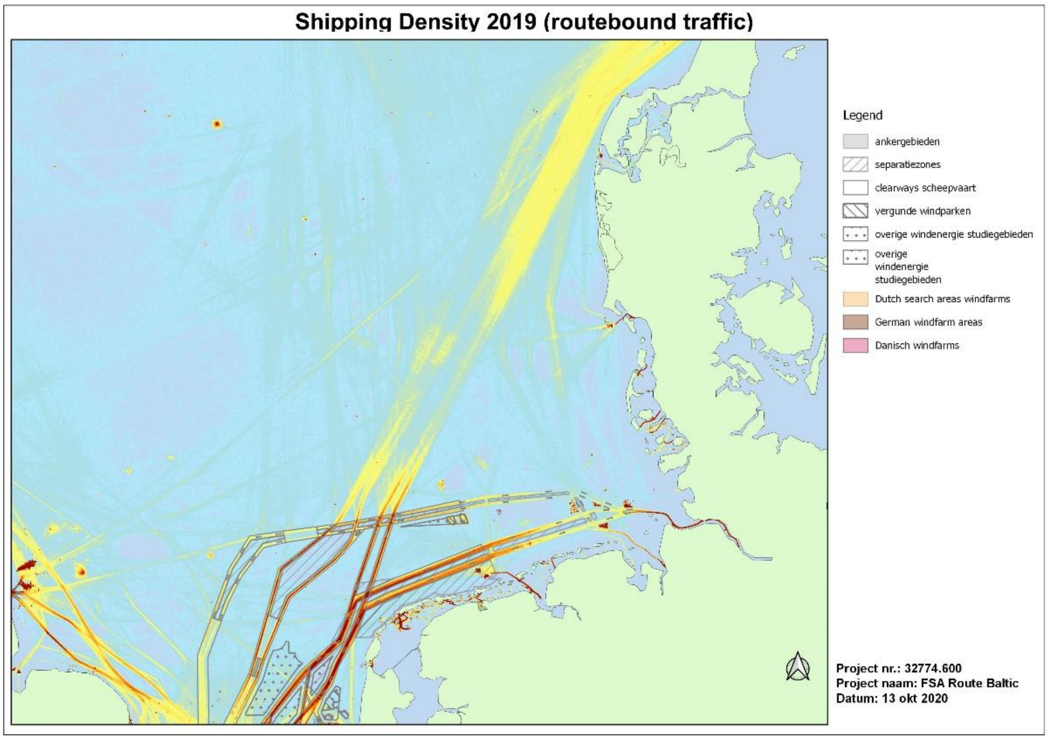


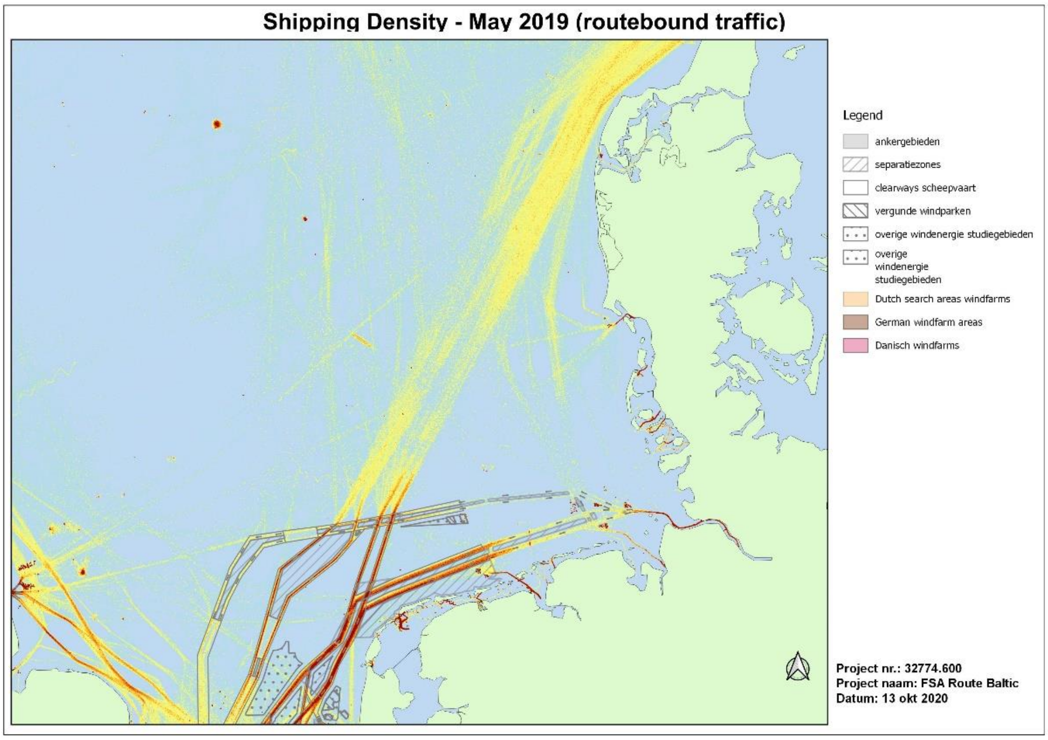
Figure A-3 Schematic overview of the consequence modelling of SAMSON

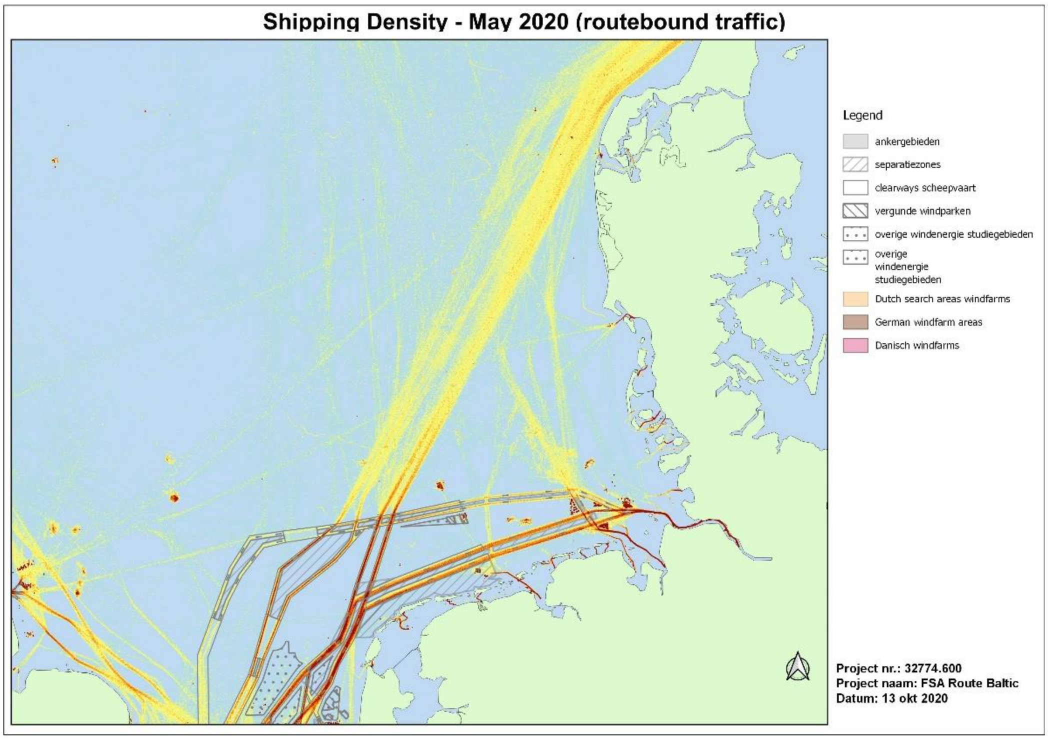
APPENDIX 3 TRAFFIC ANALYSIS

Density charts

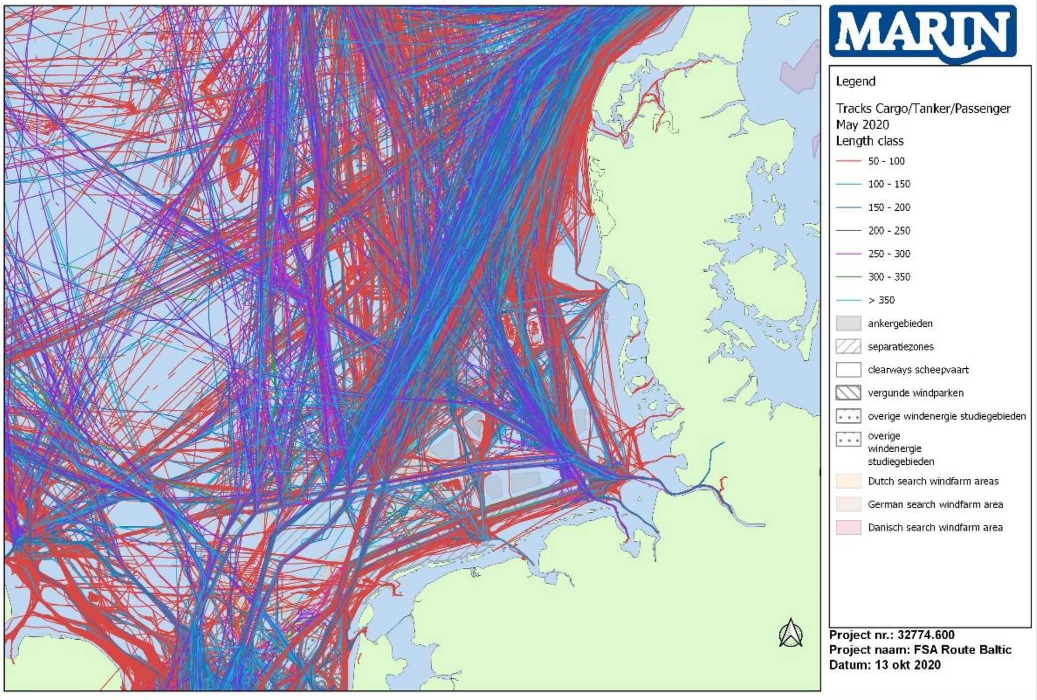




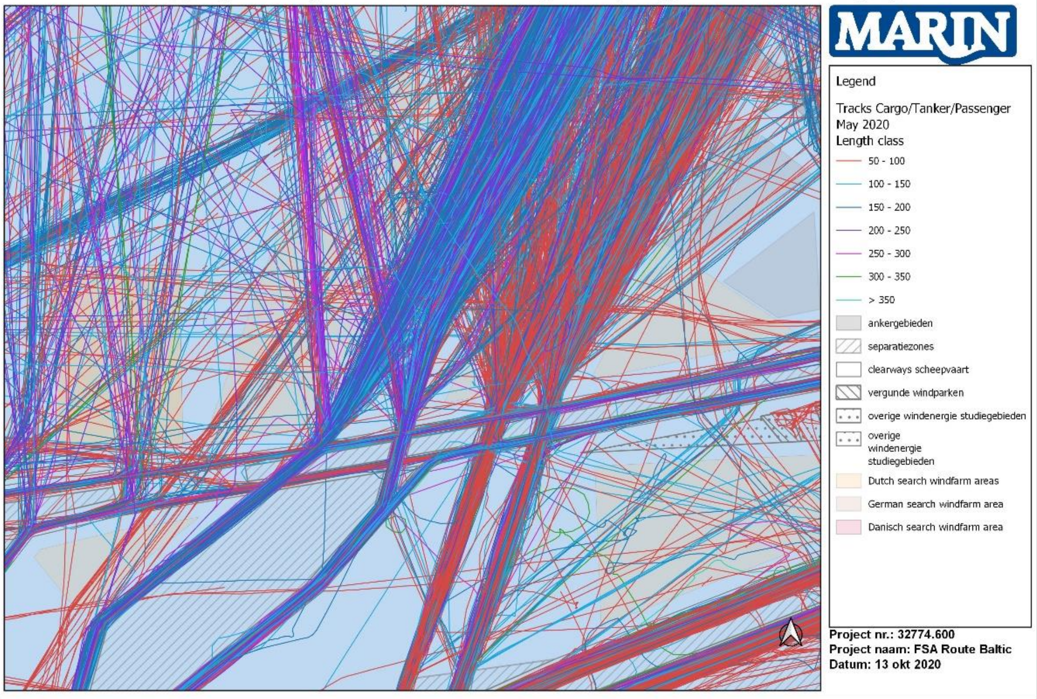

Shipping Density - May 2019 (routebound traffic)
Legend
ankergebieden
separatiezones
clearways scheepvaart
vergunde windparken
overige windenergie studiegebieden
overige windenergie studiegebieden
Dutch search areas windfarms
German windfarm areas
Danisch windfarms
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

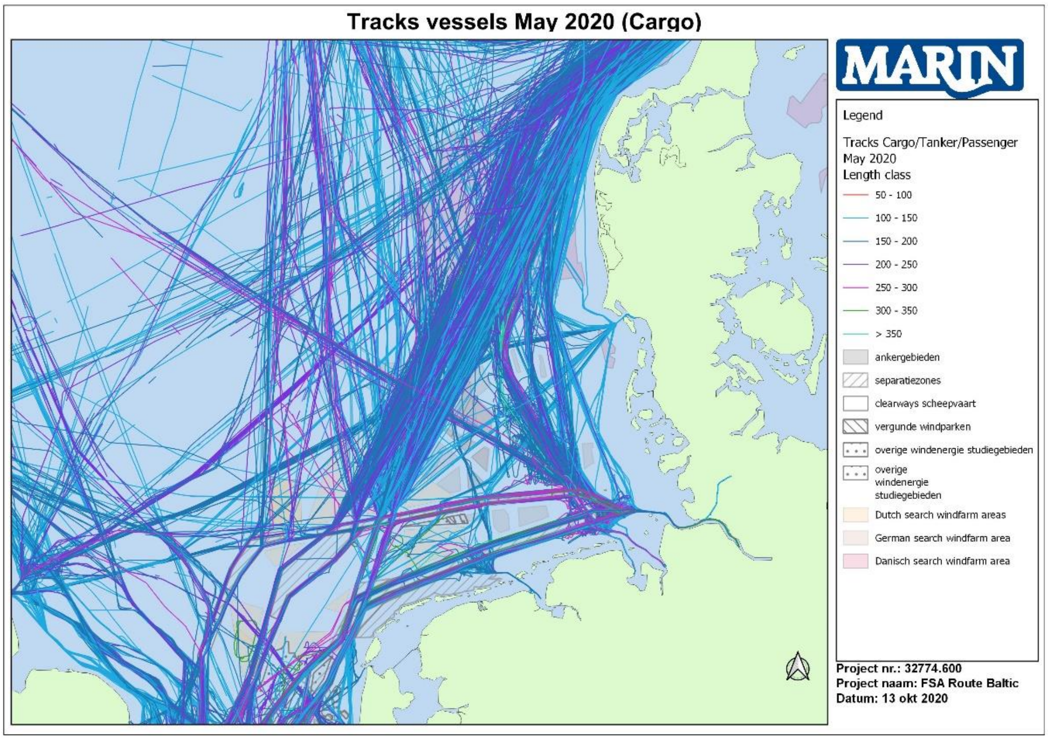

Shipping Density - May 2020 (routebound traffic)
Legend
ankergebieden
separatiezones
clearways scheepvaart
vergunde windparken
overige windenergie studiegebieden
overige windenergie studiegebieden
Dutch search areas windfarms
German windfarm areas
Danisch windfarms
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

Tracks vessels May 2020 (Cargo/Tanker/Passenger)

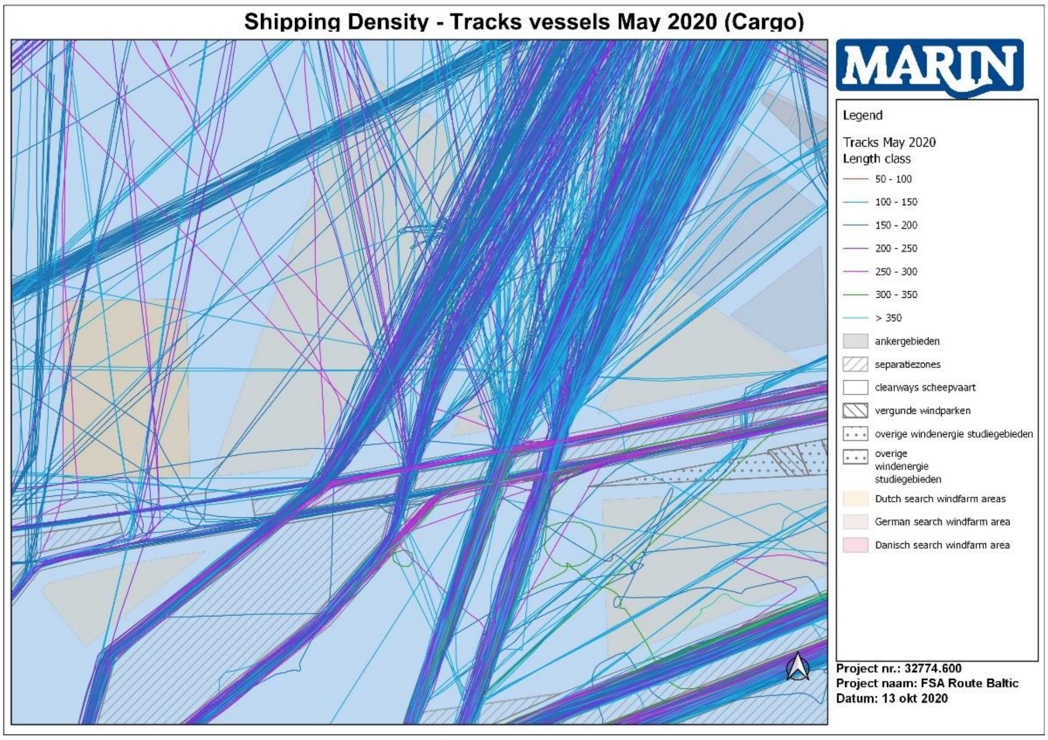


Shipping Density - Tracks vessels May 2020 (Cargo/Tanker/Passenger)

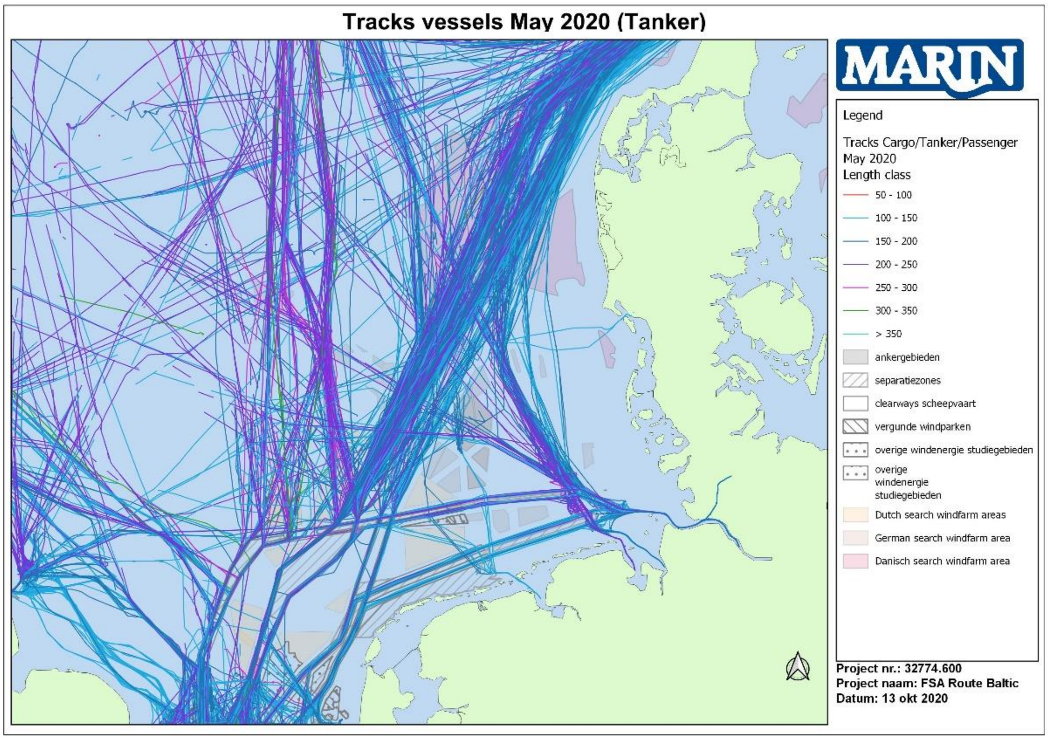


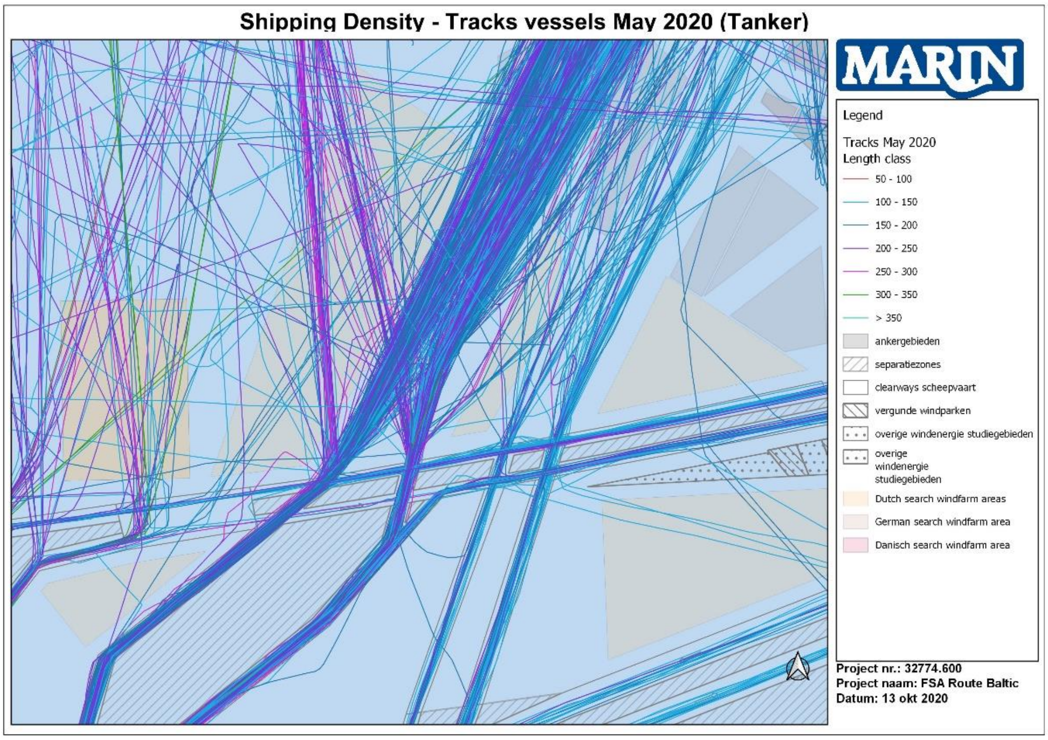


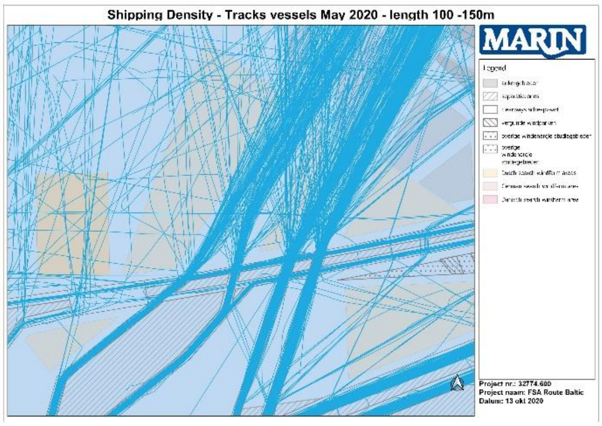
Tracks vessels May 2020 (Cargo)
MARIN
Legend
Tracks Cargo/Tanker/Passenger
May 2020
Length class
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
> 350
ankergebieden
separatiezones
clearways scheepvaart
vergunde windparken
overige windenergie studiegebieden
overige windenergie studiegebieden
Dutch search windfarm areas
German search windfarm area
Danisch search windfarm area
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

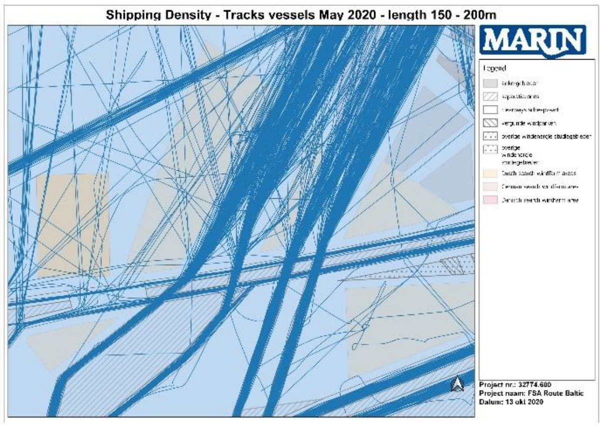


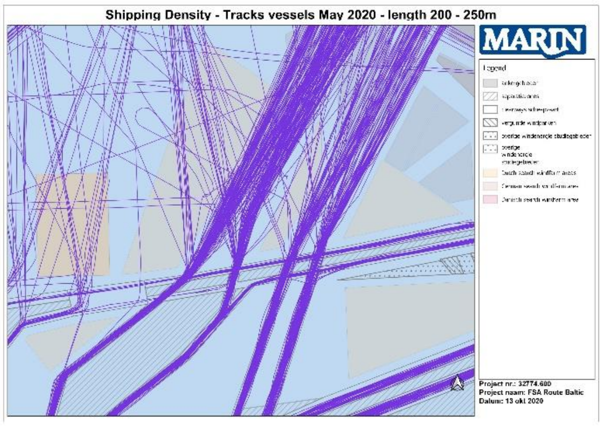
Shipping Density - Tracks vessels May 2020 (Cargo)
MARIN
Legend
Tracks May 2020
Length class
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
> 350
ankergebieden
separatiezones
clearways scheepvaart
vergunde windparken
overige windenergie studiegebieden
overige windenergie studiegebieden
Dutch search windfarm areas
German search windfarm area
Danisch search windfarm area
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

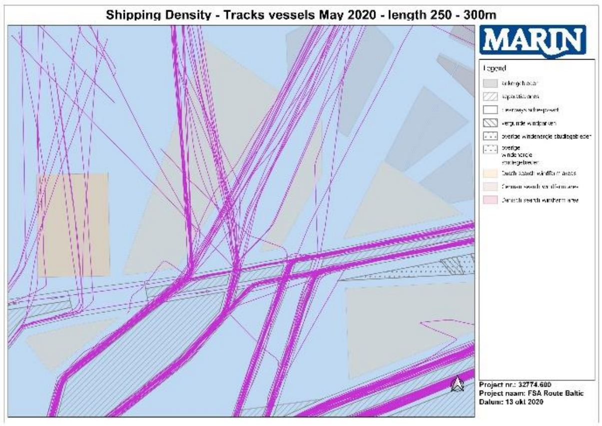

Tracks vessels May 2020 (Tanker)
MARIN
Legend
Tracks Cargo/Tanker/Passenger May 2020
Length class
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
> 350
ankergebieden
separatiezones
clearways scheepvaart
vergunde windparken
overige windenergie studiegebieden
overige windenergie studiegebieden
Dutch search windfarm areas
German search windfarm area
Danisch search windfarm area
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

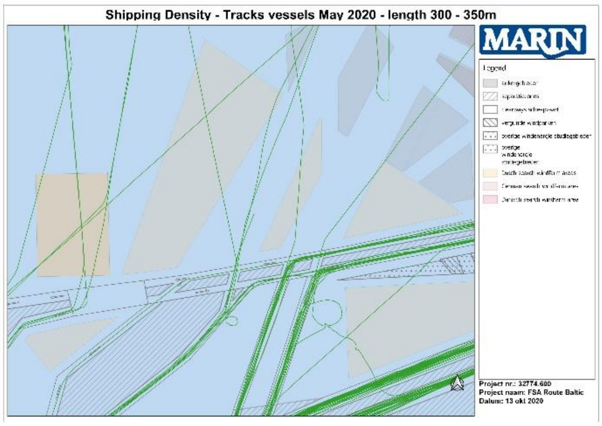

Shipping Density - Tracks vessels May 2020 (Tanker)
MARIN
Legend
Tracks May 2020
Length class
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
> 350
ankergebieden
separatiezones
clearways scheepvaart
vergunde windparken
overige windenergie studiegebieden
overige windenergie studiegebieden
Dutch search windfarm areas
German search windfarm area
Danisch search windfarm area
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

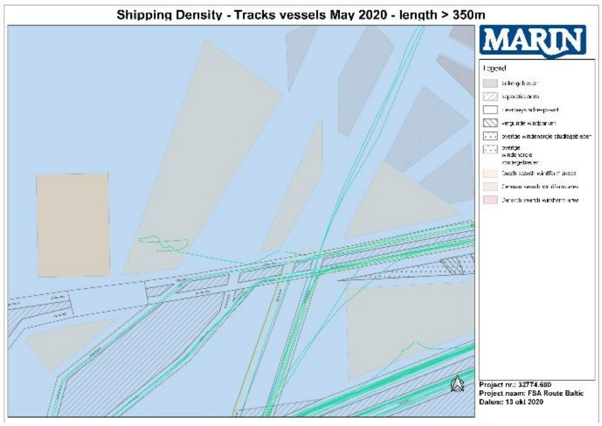

Shipping Density - Tracks vessels May 2020 - length 100 -150m
MARIN
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

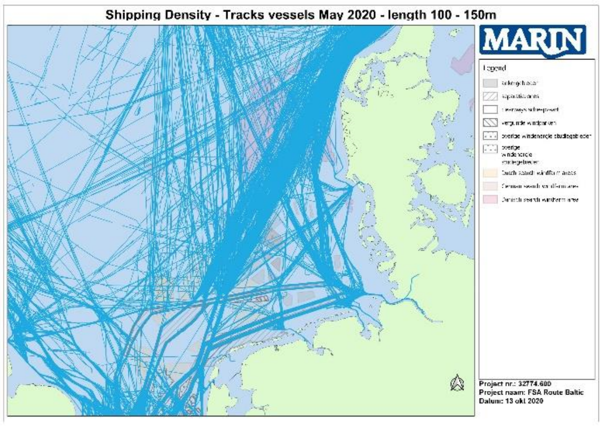

Shipping Density - Tracks vessels May 2020 - length 150 - 200m
MARIN
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

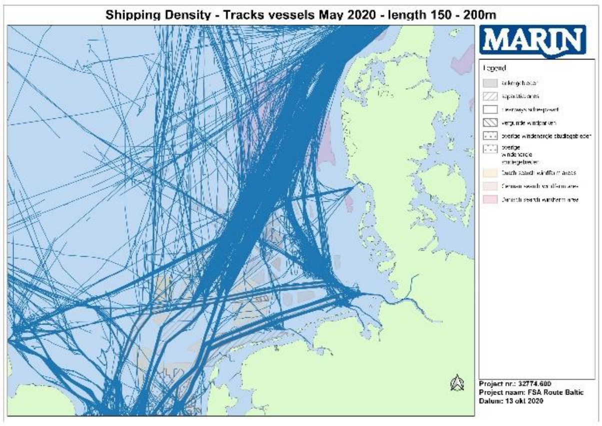

Shipping Density - Tracks vessels May 2020 - length 200 - 250m
MARIN
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

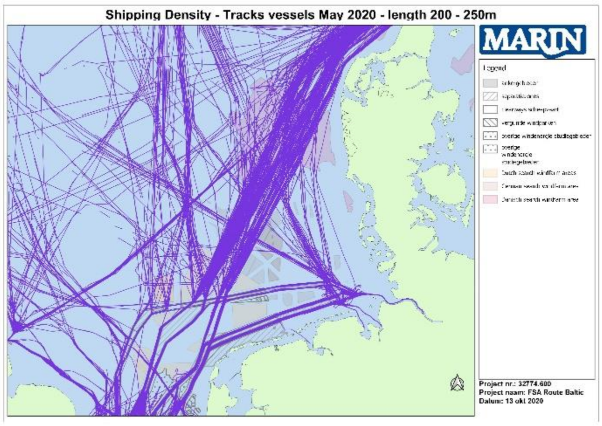

Shipping Density - Tracks vessels May 2020 - length 250 - 300m
MARIN
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

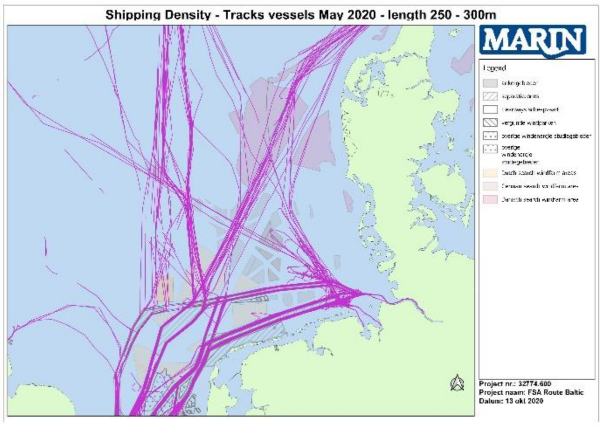

Shipping Density - Tracks vessels May 2020 - length 300 - 350m
MARIN
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

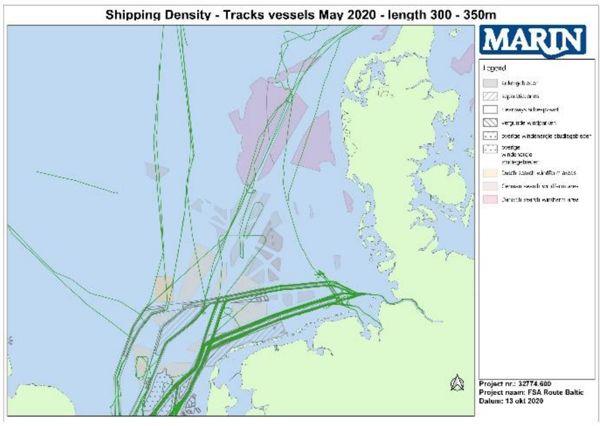

Shipping Density - Tracks vessels May 2020 - length > 350m
MARIN
Project nr.: 32774.600
Project naam: FSA Route Baltic
Datum: 13 okt 2020

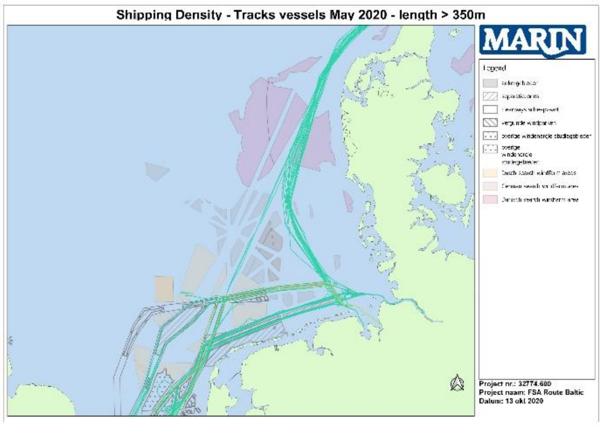

Shipping Density - Tracks vessels May 2020 - length 100 - 150m


Shipping Density - Tracks vessels May 2020 - length 150 - 200m

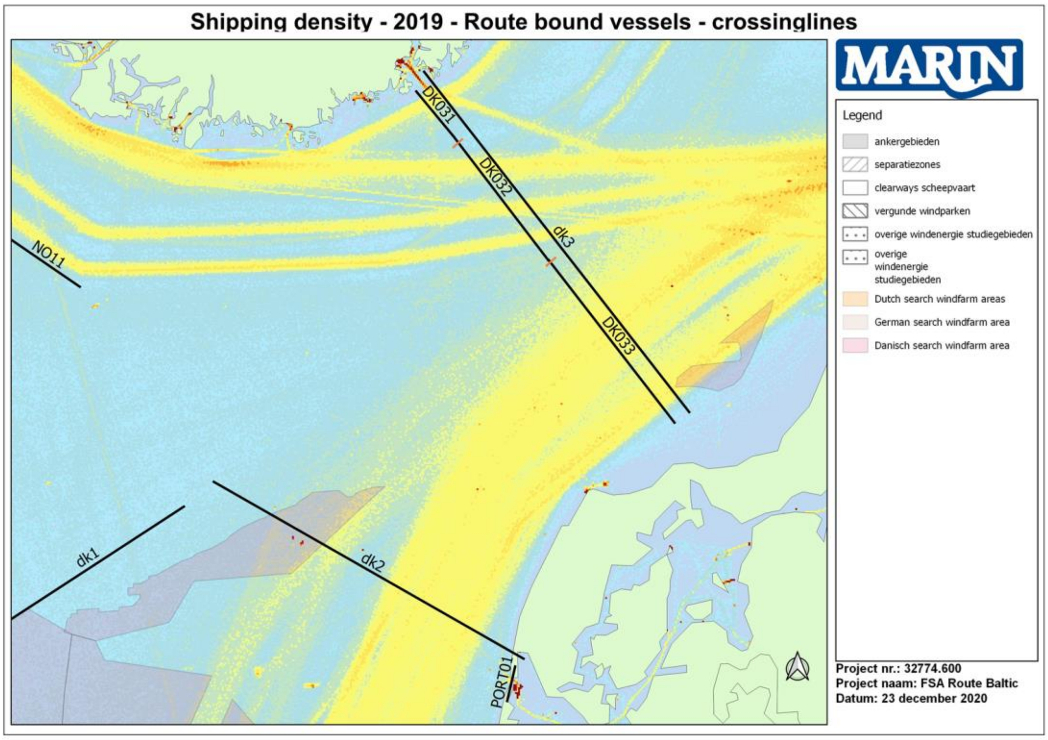

Shipping Density - Tracks vessels May 2020 - length 200 - 250m


Shipping Density - Tracks vessels May 2020 - length 250 - 300m


Shipping Density - Tracks vessels May 2020 - length 300 - 350m


Shipping Density - Tracks vessels May 2020 - length > 350m

Shipping intensity Skagerak



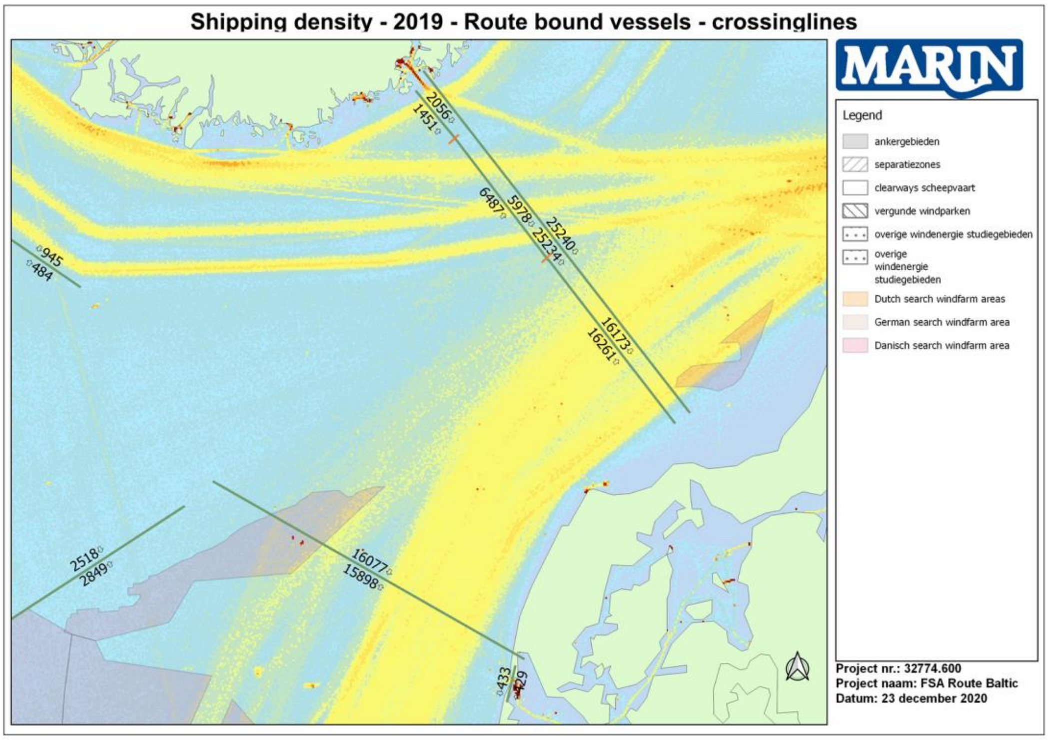


*Table A- 2 Total number of route bound vessels crossing line **DK031 – Entrance Skagerak – Coast Norway** in 2019*

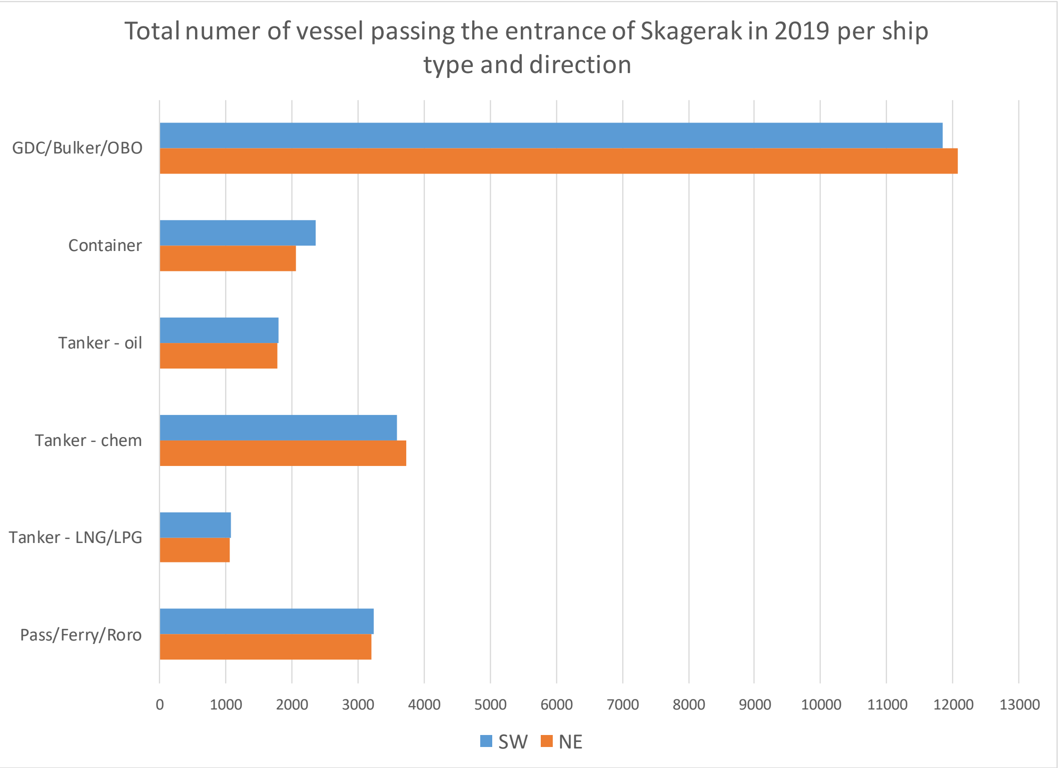
Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
SW	GDC/Bulker/OBO	0	65	195	1084	60	20	1	0	0	1425
	Container	0	0	0	0	140	61	0	0	0	201
	Tanker - oil	0	3	0	7	1	47	0	0	0	58
	Tanker - chem	0	4	6	43	154	11	0	0	0	218
	Tanker - LNG/LPG	0	0	0	3	18	23	0	0	0	44
	Pass/Ferry/ Roro	6	9	1	15	9	10	28	22	6	106
	Subtotal	**6**	**81**	**202**	**1152**	**382**	**172**	**29**	**22**	**6**	**2052**
NE	GDC/Bulker/OBO	0	58	146	761	54	24	2	0	1	1046
	Container	0	0	0	0	20	4	0	0	0	24
	Tanker - oil	0	3	0	7	4	43	0	0	0	57
	Tanker - chem	0	4	8	26	133	10	0	0	0	181
	Tanker - LNG/LPG	0	0	0	1	17	23	0	0	0	41
	Pass/Ferry/Roro	1	4	1	19	12	11	24	23	6	101
	Subtotal	**1**	**69**	**155**	**814**	**240**	**115**	**26**	**23**	**7**	**1450**
	TOTAL	**7**	**150**	**357**	**1966**	**622**	**287**	**55**	**45**	**13**	**3502**

*Table A- 3 Total number of route bound vessels crossing line **DK032 – Entrance Skagerak – route from/to Norway** in 2019*

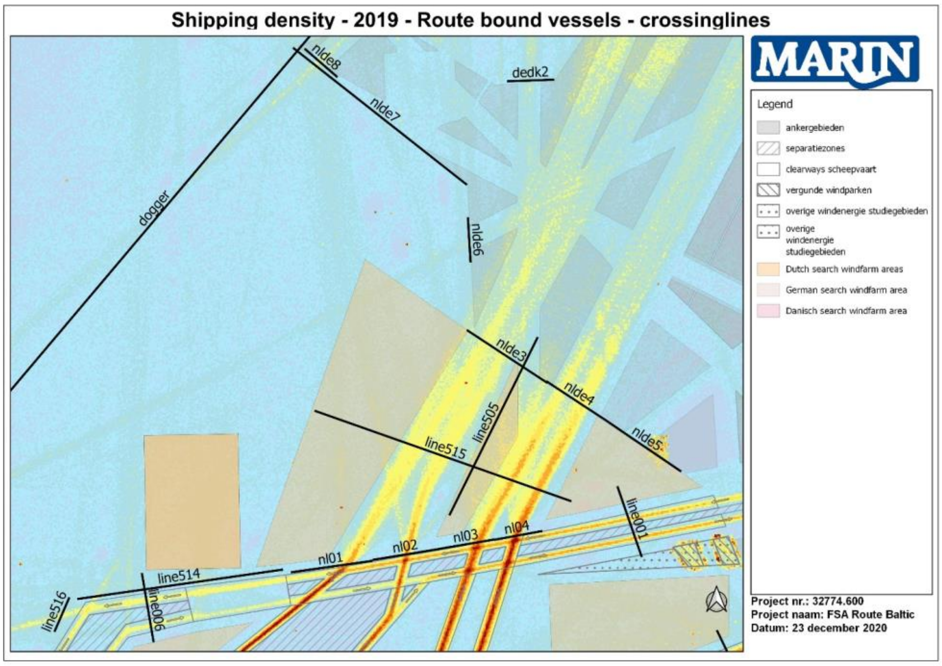
Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
SW	GDC/Bulker/OBO	1	29	209	1896	514	399	109	9	30	3196
	Container	0	0	0	2	76	70	2	0	0	150
	Tanker - oil	0	3	0	17	16	83	50	223	0	392
	Tanker - chem	0	2	5	375	219	304	60	2	0	967
	Tanker - LNG/LPG	0	0	0	107	150	144	11	1	42	455
	Pass/Ferry/ Roro	19	7	0	62	23	37	514	94	54	810
	Subtotal	**20**	**41**	**214**	**2459**	**998**	**1037**	**746**	**329**	**126**	**5970**
NE	GDC/Bulker/OBO	2	19	209	2326	638	483	185	9	8	3879
	Container	0	0	0	1	12	54	3	0	0	70
	Tanker - oil	0	2	0	28	23	72	34	203	1	363
	Tanker - chem	0	9	3	332	254	287	49	4	0	938
	Tanker - LNG/LPG	0	0	0	85	128	132	12	1	32	390
	Pass/Ferry/Roro	1	6	0	64	74	35	512	97	52	841
	Subtotal	**3**	**36**	**212**	**2836**	**1129**	**1063**	**795**	**314**	**93**	**6481**
	TOTAL	**23**	**77**	**426**	**5295**	**2127**	**2100**	**1541**	**643**	**219**	**12451**

*Table A- 4 Total number of route bound vessels crossing line **DK033 – Entrance Skagerak – route from/to Germany/The Netherlands** in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
SW	GDC/Bulker/OBO	1	49	172	2231	848	1604	1473	122	723	7223
	Container	0	0	0	55	581	851	322	34	160	2003
	Tanker - oil	0	11	1	57	43	421	239	553	14	1339
	Tanker - chem	0	32	31	431	325	1365	223	5	0	2412
	Tanker - LNG/LPG	0	0	0	184	197	149	10	1	34	575
	Pass/Ferry/Roro	91	5	0	12	193	966	856	161	43	2327
	Subtotal	**92**	**97**	**204**	**2970**	**2187**	**5356**	**3123**	**876**	**974**	**15879**
NE	GDC/Bulker/OBO	1	59	238	2291	893	1443	1355	123	741	7144
	Container	0	0	0	63	633	762	322	33	157	1970
	Tanker - oil	0	12	1	56	41	413	260	569	14	1366
	Tanker - chem	1	27	32	520	392	1399	232	3	0	2606
	Tanker - LNG/LPG	0	0	0	198	230	149	8	1	44	630
	Pass/Ferry/Roro	31	5	0	14	219	917	859	165	45	2255
	Subtotal	**33**	**103**	**271**	**3142**	**2408**	**5083**	**3036**	**894**	**1001**	**15971**
	TOTAL	**125**	**200**	**475**	**6112**	**4595**	**1043 9**	**6159**	**1770**	**1975**	**31850**



Shipping intensity North part Dutch EEZ



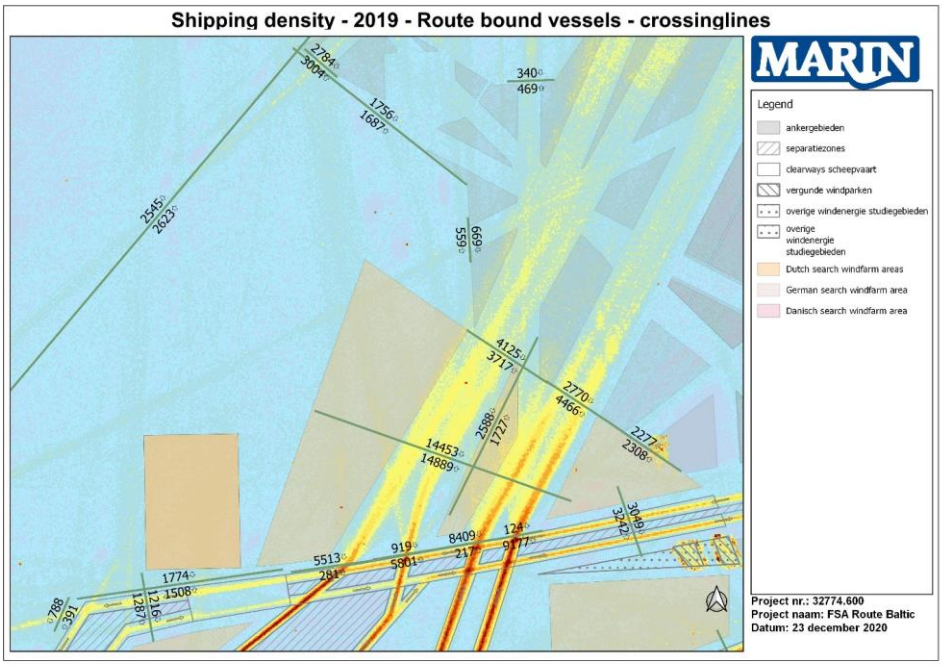


*Table A- 5 Total number of route bound vessels crossing line **nl01** in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	1	5	9	154	144	709	842	70	1	1935
	Container	0	0	0	1	41	22	33	3	1	101
	Tanker - oil	0	0	0	3	6	323	228	605	6	1171
	Tanker - chem	0	1	1	55	220	1178	226	38	1	1720
	Tanker - LNG/LPG	0	0	0	17	27	218	15	1	169	447
	Pass/Ferry/Roro	2	0	0	1	28	30	21	33	16	131
	Subtotal	**3**	**6**	**10**	**231**	**466**	**2480**	**1365**	**750**	**194**	**5505**
N	GDC/Bulker/OBO	1	2	7	32	16	8	60	0	0	126
	Container	0	0	0	1	9	2	1	0	0	13
	Tanker - oil	0	0	0	0	1	13	0	0	0	14
	Tanker - chem	0	0	1	4	7	19	0	0	0	31
	Tanker - LNG/LPG	0	0	0	1	15	2	0	0	0	18
	Pass/Ferry/Roro	1	0	1	0	6	40	6	14	4	72
	Subtotal	**2**	**2**	**9**	**38**	**54**	**84**	**67**	**14**	**4**	**274**
	TOTAL	**5**	**8**	**19**	**269**	**520**	**2564**	**1432**	**764**	**198**	**5779**

*Table A- 6 Total number of route bound vessels crossing line **nl02** in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	0	1	3	15	8	2	28	1	1	59
	Container	0	0	0	0	2	3	0	1	0	6
	Tanker - oil	0	0	0	1	5	11	0	1	0	18
	Tanker - chem	0	0	0	1	4	9	1	0	0	15
	Tanker - LNG/LPG	0	0	0	0	14	1	0	0	0	15
	Pass/Ferry/Roro	1	3	0	0	1	0	5	7	0	17
	Subtotal	**1**	**4**	**3**	**17**	**34**	**26**	**34**	**10**	**1**	**130**
N	GDC/Bulker/OBO	0	6	12	193	105	515	531	90	15	1467
	Container	0	0	0	8	37	8	9	3	5	70
	Tanker - oil	0	0	0	15	20	264	235	618	21	1173
	Tanker - chem	0	1	0	76	282	1090	220	33	0	1702
	Tanker - LNG/LPG	0	0	0	18	31	215	15	2	179	460
	Pass/Ferry/Roro	1	2	0	0	17	45	29	27	16	137
	Subtotal	**1**	**9**	**12**	**310**	**492**	**2137**	**1039**	**773**	**236**	**5009**
	TOTAL	**2**	**13**	**15**	**327**	**526**	**2163**	**1073**	**783**	**237**	**5139**

*Table A- 7 Total number of route bound vessels crossing line **nl03** in 2019*

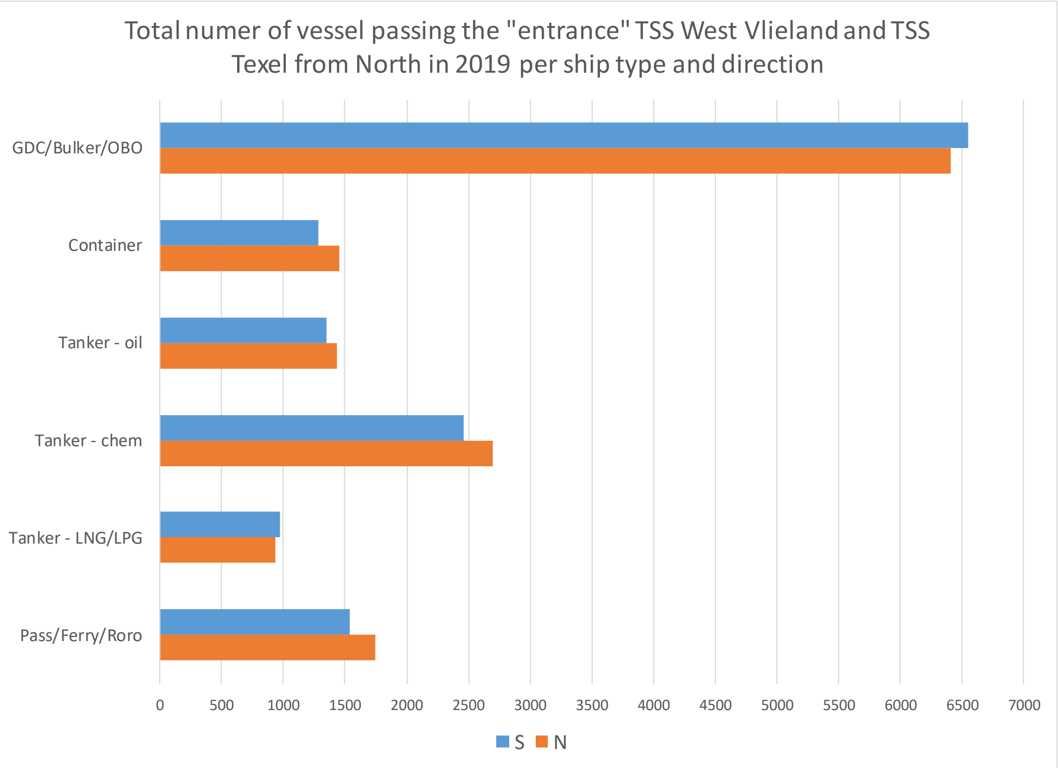
Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	1	46	262	1926	745	848	606	56	15	4505
	Container	0	0	0	67	459	431	207	8	3	1175
	Tanker - oil	0	0	0	41	24	33	12	13	2	125
	Tanker - chem	0	0	22	409	179	109	8	0	0	727
	Tanker - LNG/LPG	0	0	0	298	190	12	0	1	2	503
	Pass/Ferry/Roro	0	56	0	9	62	645	500	68	25	1365
	Subtotal	**1**	**102**	**284**	**2750**	**1659**	**2078**	**1333**	**146**	**47**	**8400**
N	GDC/Bulker/OBO	0	0	2	27	10	4	58	1	0	102
	Container	0	0	0	0	3	3	2	2	1	11
	Tanker - oil	0	0	0	1	0	16	1	1	0	19
	Tanker - chem	0	0	0	4	13	30	0	0	0	47
	Tanker - LNG/LPG	0	0	0	1	7	3	0	0	0	11
	Pass/Ferry/Roro	0	1	1	0	9	6	3	7	0	27
	Subtotal	**0**	**1**	**3**	**33**	**42**	**62**	**64**	**11**	**1**	**217**
	TOTAL	**1**	**103**	**287**	**2783**	**1701**	**2140**	**1397**	**157**	**48**	**8617**

*Table A- 8 Total number of route bound vessels crossing line **nl02** in 2019*

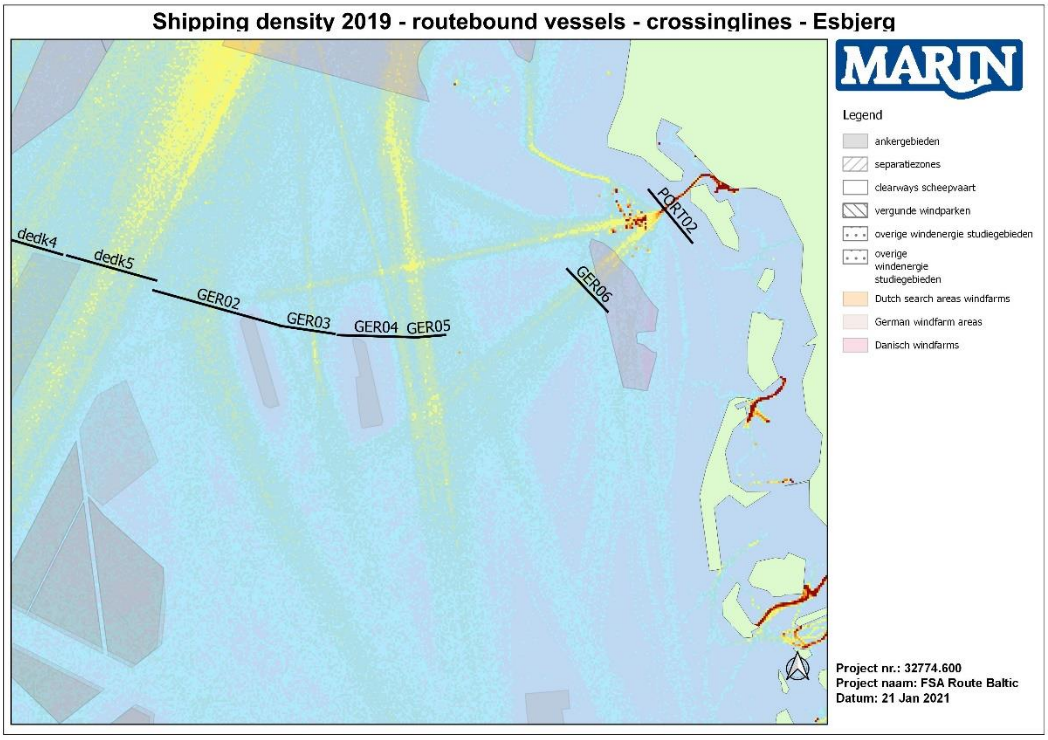
Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	0	1	2	8	9	2	28	0	0	50
	Container	0	0	0	0	1	2	0	0	2	5
	Tanker - oil	0	0	0	1	0	32	0	0	0	33
	Tanker - chem	0	0	0	0	1	3	0	0	0	4
	Tanker - LNG/LPG	0	0	0	0	4	0	0	0	0	4
	Pass/Ferry/Roro	0	2	0	0	0	1	22	2	1	28
	Subtotal	**0**	**3**	**2**	**9**	**15**	**40**	**50**	**2**	**3**	**124**
N	GDC/Bulker/OBO	0	37	262	2022	824	809	649	73	40	4716
	Container	0	0	0	69	523	434	289	4	37	1356
	Tanker - oil	0	0	0	24	24	124	23	29	3	227
	Tanker - chem	1	0	22	434	176	248	32	0	0	913
	Tanker - LNG/LPG	0	0	0	254	181	8	0	0	1	444
	Pass/Ferry/Roro	0	3	0	9	153	726	499	94	28	1512
	Subtotal	**1**	**40**	**284**	**2812**	**1881**	**2349**	**1492**	**200**	**109**	**9168**
	TOTAL	**1**	**43**	**286**	**2821**	**1896**	**2389**	**1542**	**202**	**112**	**9292**

*Table A- 9 Total number of route bound vessels crossing line **nl01, nl02, nl03 and nl04** (entering of leaving Dutch part North Sea toward North (Skagerrak) in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	2	53	276	2103	906	1561	1504	127	17	6549
	Container	0	0	0	68	503	458	240	12	6	1287
	Tanker - oil	0	0	0	46	35	399	240	619	8	1347
	Tanker - chem	0	1	23	465	404	1299	235	38	1	2466
	Tanker - LNG/LPG	0	0	0	315	235	231	15	2	171	969
	Pass/Ferry/Roro	3	61	0	10	91	676	548	110	42	1541
	Subtotal	**5**	**115**	**299**	**3007**	**2174**	**4624**	**2782**	**908**	**245**	**14159**
N	GDC/Bulker/OBO	1	45	283	2274	955	1336	1298	164	55	6411
	Container	0	0	0	78	572	447	301	9	43	1450
	Tanker - oil	0	0	0	40	45	417	259	648	24	1433
	Tanker - chem	1	1	23	518	478	1387	252	33	0	2693
	Tanker - LNG/LPG	0	0	0	274	234	228	15	2	180	933
	Pass/Ferry/Roro	2	6	2	9	185	817	537	142	48	1748
	Subtotal	**4**	**52**	**308**	**3193**	**2469**	**4632**	**2662**	**998**	**350**	**14668**
	TOTAL	**9**	**167**	**607**	**6200**	**4643**	**9256**	**5444**	**1906**	**595**	**28827**



Shipping intensity Approach Esbjerg



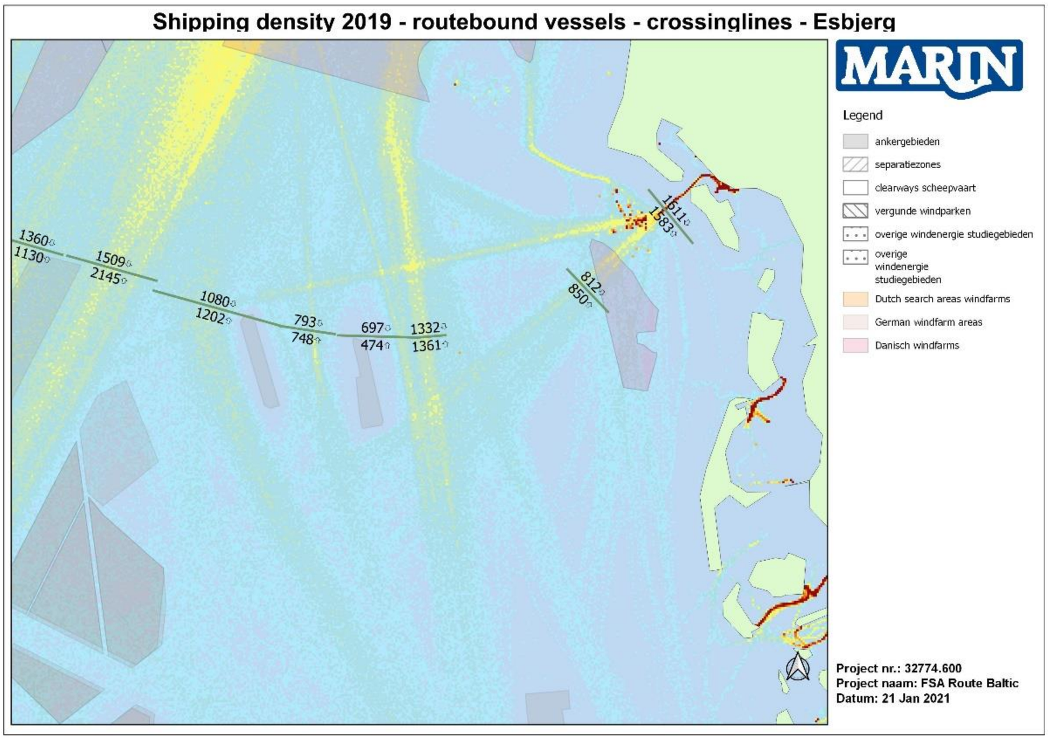


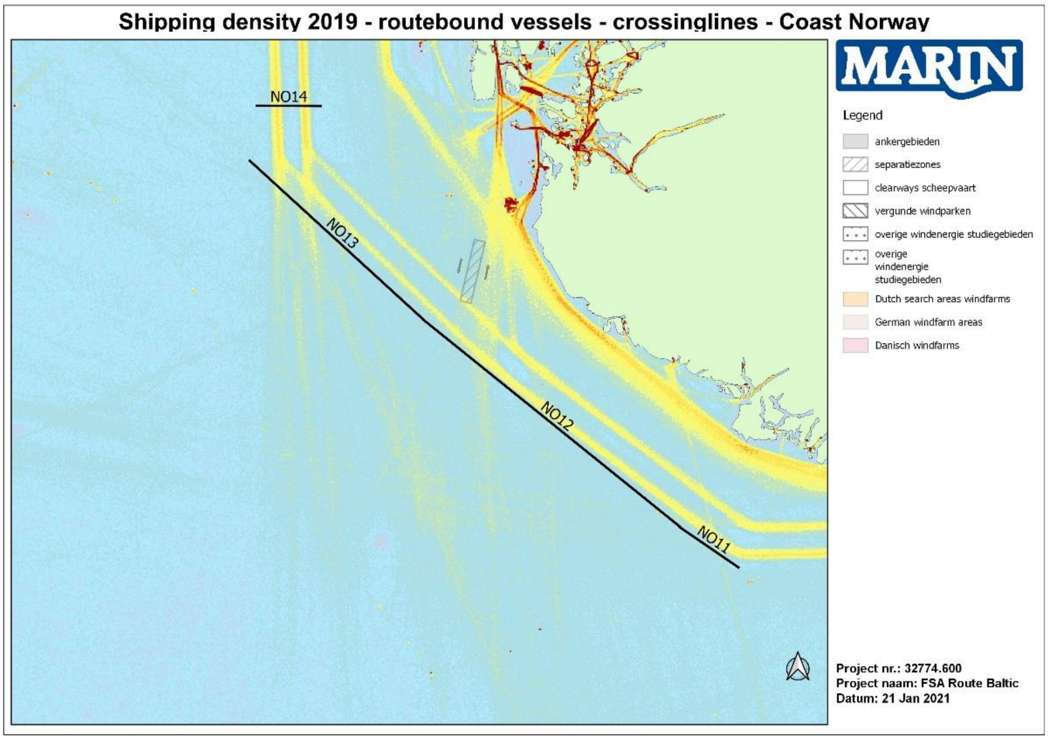
Table A- 10 Total number of route bound vessels crossing line ***GER06 (Route between south and Esbjerg)*** *in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	0	3	66	159	56	87	7	0	0	378
	Container	0	0	0	11	29	7	0	0	2	49
	Tanker - oil	0	2	0	0	2	11	3	2	0	20
	Tanker - chem	0	0	13	17	2	10	0	0	0	42
	Tanker - LNG/LPG	0	0	0	5	1	0	0	0	0	6
	Pass/Ferry/Roro	2	105	0	0	61	77	47	7	3	302
	Subtotal	**2**	**110**	**79**	**192**	**151**	**192**	**57**	**9**	**5**	**797**
N	GDC/Bulker/OBO	0	3	62	156	64	89	10	0	0	384
	Container	0	0	0	11	30	7	0	0	2	50
	Tanker - oil	0	1	0	0	3	11	4	2	0	21
	Tanker - chem	0	0	9	35	2	11	0	0	0	57
	Tanker - LNG/LPG	0	0	0	8	1	0	0	0	0	9
	Pass/Ferry/Roro	1	90	0	0	23	115	74	7	3	313
	Subtotal	**1**	**94**	**71**	**210**	**123**	**233**	**88**	**9**	**5**	**834**
	TOTAL	**3**	**204**	**150**	**402**	**274**	**425**	**145**	**18**	**10**	**1631**

Table A- 11 Total number of route bound vessels crossing line ***PORT02 (approach Esbjerg)*** *in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	1	5	78	222	134	118	12	0	1	571
	Container	0	0	0	4	37	7	0	0	3	51
	Tanker - oil	0	13	0	2	5	9	3	2	0	34
	Tanker - chem	0	1	15	85	16	13	0	0	0	130
	Tanker - LNG/LPG	0	0	0	8	2	0	0	0	0	10
	Pass/Ferry/Roro	8	114	0	1	152	153	361	5	3	797
	Subtotal	**9**	**133**	**93**	**322**	**346**	**300**	**376**	**7**	**7**	**1593**
N	GDC/Bulker/OBO	0	5	79	216	131	119	13	0	1	564
	Container	0	0	0	4	37	5	0	0	3	49
	Tanker - oil	0	13	0	2	4	9	3	2	0	33
	Tanker - chem	0	1	15	84	16	13	0	0	0	129
	Tanker - LNG/LPG	0	0	0	7	2	0	0	0	0	9
	Pass/Ferry/Roro	6	102	0	1	152	152	362	4	4	783
	Subtotal	**6**	**121**	**94**	**314**	**342**	**298**	**378**	**6**	**8**	**1567**
	TOTAL	**15**	**254**	**187**	**636**	**688**	**598**	**754**	**13**	**15**	**3160**

Shipping intensity Norwegian Coast



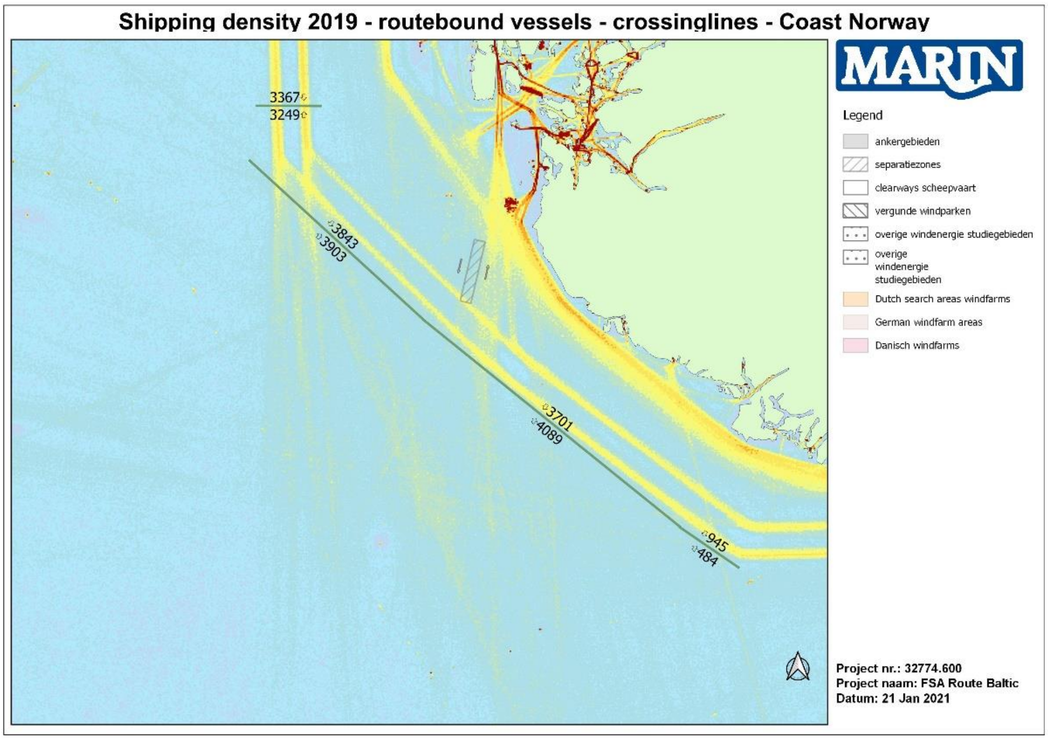


Table A- 12 Total number of route bound vessels crossing line ***NO11*** *in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	0	4	104	239	18	13	2	0	0	380
	Container	0	0	0	1	3	0	0	0	0	4
	Tanker - oil	0	1	0	1	1	2	0	5	0	10
	Tanker - chem	1	1	0	1	4	2	1	0	0	10
	Tanker - LNG/LPG	0	0	0	3	3	1	0	0	0	7
	Pass/Ferry/Roro	35	7	0	2	2	1	4	12	3	66
	Subtotal	**36**	**13**	**104**	**247**	**31**	**19**	**7**	**17**	**3**	**477**
N	GDC/Bulker/OBO	1	3	84	261	112	135	78	3	2	679
	Container	0	0	0	1	13	11	2	0	0	27
	Tanker - oil	0	1	1	3	3	5	6	25	0	44
	Tanker - chem	1	0	0	21	16	33	9	0	0	80
	Tanker - LNG/LPG	0	0	0	3	3	31	2	0	0	39
	Pass/Ferry/Roro	8	4	0	4	27	4	4	17	3	71
	Subtotal	**10**	**8**	**85**	**293**	**174**	**219**	**101**	**45**	**5**	**940**
	TOTAL	**46**	**21**	**189**	**540**	**205**	**238**	**108**	**62**	**8**	**1417**

Table A- 13 Total number of route bound vessels crossing line ***NO12*** *in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	4	19	161	1185	287	417	41	4	13	2131
	Container	0	0	0	16	126	20	1	0	1	164
	Tanker - oil	0	0	1	4	1	25	17	43	0	91
	Tanker - chem	0	3	0	120	30	98	20	1	0	272
	Tanker - LNG/LPG	0	0	0	139	114	102	21	0	5	381
	Pass/Ferry/Roro	78	138	0	24	154	118	66	110	49	737
	Subtotal	**82**	**160**	**162**	**1488**	**712**	**780**	**166**	**158**	**68**	**3776**
N	GDC/Bulker/OBO	1	14	186	1114	200	399	45	2	8	1969
	Container	0	0	0	18	182	3	0	0	1	204
	Tanker - oil	0	1	0	8	2	25	9	58	0	103
	Tanker - chem	0	2	0	111	28	47	14	2	0	204
	Tanker - LNG/LPG	0	0	0	126	119	99	18	0	6	368
	Pass/Ferry/Roro	40	23	0	25	149	96	67	89	59	548
	Subtotal	**41**	**40**	**186**	**1402**	**680**	**669**	**153**	**151**	**74**	**3396**
	TOTAL	**123**	**200**	**348**	**2890**	**1392**	**1449**	**319**	**309**	**142**	**7172**

*Table A- 14 Total number of route bound vessels crossing line **NO13** in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	20	11	68	586	293	287	232	29	3	1529
	Container	0	0	0	1	106	19	1	0	0	127
	Tanker - oil	0	0	0	2	4	68	51	335	6	466
	Tanker - chem	1	0	0	163	196	187	64	39	0	650
	Tanker - LNG/LPG	0	0	0	71	80	70	11	1	152	385
	Pass/Ferry/Roro	18	70	0	30	59	46	57	95	65	440
	Subtotal	**39**	**81**	**68**	**853**	**738**	**677**	**416**	**499**	**226**	**3597**
N	GDC/Bulker/OBO	19	8	47	620	326	283	260	58	12	1633
	Container	0	0	0	0	19	45	0	0	0	64
	Tanker - oil	0	0	0	2	7	59	42	288	7	405
	Tanker - chem	1	1	0	118	185	201	54	31	0	591
	Tanker - LNG/LPG	0	0	0	82	79	59	13	0	137	370
	Pass/Ferry/Roro	17	58	0	26	60	75	66	116	51	469
	Subtotal	**37**	**67**	**47**	**848**	**676**	**722**	**435**	**493**	**207**	**3532**
	TOTAL	**76**	**148**	**115**	**1701**	**1414**	**1399**	**851**	**992**	**433**	**7129**

*Table A- 15 Total number of route bound vessels crossing line **NO11, NO12 and NO13** in 2019*

Direction	Ship type	Ship size (based on GT)									Total
		??	100-1000	1000-1600	1600-5000	5000-10000	10000-30000	30000-60000	60000-100000	> 100000	
S	GDC/Bulker/OBO	24	34	333	2010	598	717	275	33	16	4040
	Container	0	0	0	18	235	39	2	0	1	295
	Tanker - oil	0	1	1	7	6	95	68	383	6	567
	Tanker - chem	2	4	0	284	230	287	85	40	0	932
	Tanker - LNG/LPG	0	0	0	213	197	173	32	1	157	773
	Pass/Ferry/Roro	131	215	0	56	215	165	127	217	117	1243
	Subtotal	**157**	**254**	**334**	**2588**	**1481**	**1476**	**589**	**674**	**297**	**7850**
N	GDC/Bulker/OBO	21	25	317	1995	638	817	383	63	22	4281
	Container	0	0	0	19	214	59	2	0	1	295
	Tanker - oil	0	2	1	13	12	89	57	371	7	552
	Tanker - chem	2	3	0	250	229	281	77	33	0	875
	Tanker - LNG/LPG	0	0	0	211	201	189	33	0	143	777
	Pass/Ferry/Roro	65	85	0	55	236	175	137	222	113	1088
	Subtotal	**88**	**115**	**318**	**2543**	**1530**	**1610**	**689**	**689**	**286**	**7868**
	TOTAL	**245**	**369**	**652**	**5131**	**3011**	**3086**	**1278**	**1363**	**583**	**15718**

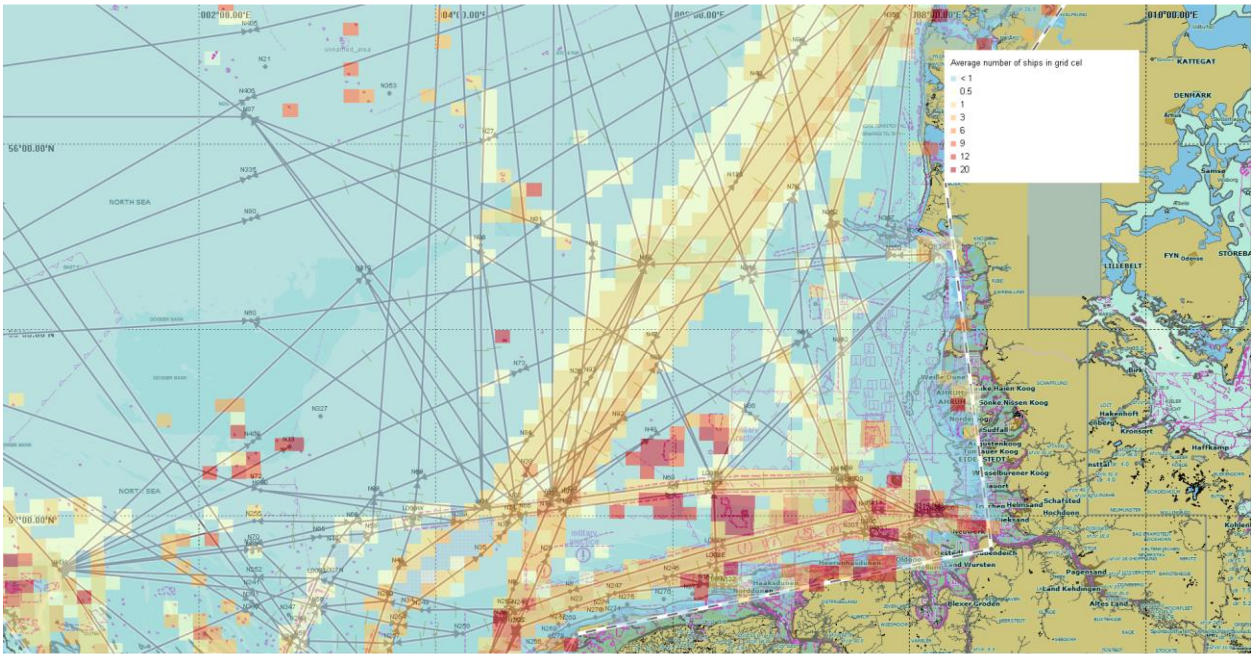


Figure A-4 Route structure (2019) with density for route bound traffic over April - July 2020

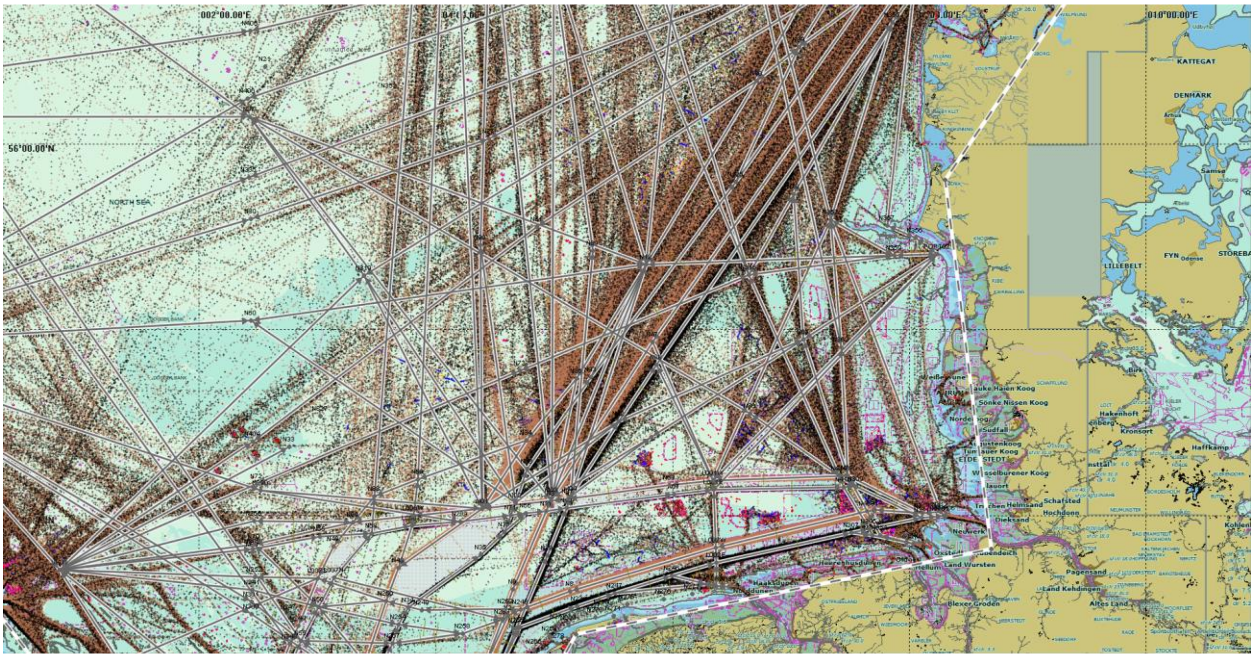


Figure A-5 Route structure (2019) with tracks of route bound vessels May 2020

M A R I N
P.O. Box 28
6700 AA Wageningen
The Netherlands
T +31 317 49 39 11
E info@marin.nl
I www.marin.nl