TKI WIND OP ZEE
Topsector Energie

Estimate shipping barriers in the large-scale rollout of offshore wind energy

by Yvonne Koldenhof (MARIN)

4 July 2019

Disclaimer

This report was commissioned by RVO (Netherlands Enterprise Agency) on request of the TKI Wind op Zee (TKI Offshore Wind). The opinions expressed in this report are entirely those of the authors (MARIN) and do not reflect the views of the TKI Wind op Zee. TKI Wind op Zee is not liable for the accuracy of the information provided or responsible for any use of the content.

Inhoudsopgave

1 Introduction

Through the “Topsectorenbeleid”, the Dutch government implements objectives to contribute to the important societal challenges, such as energy and sustainability, as well as contributing to the economic challenge of remaining among the global leaders. The “TKI Wind op Zee” is one of the Top consortia within the Top Sector “Energie” and stimulates, connects and supports Dutch companies and knowledge institutions in the development and application of innovations for a rapid transition to a sustainable, reliable and affordable energy system when it comes to offshore wind.

One of the questions raised by “TKI Wind op Zee” relates to the number of extra work vessels at the North Sea involved in the developments of offshore wind farms. TKI Wind op Zee asked MARIN to look at the possible increase in offshore wind-related work movements at sea and the impact of this increase.

The main research questions are provided in chapter 2. An overview of the general approach to come to the answers is given in chapter 3. As part of the study involved an analysis of AIS-data, the results can be found in chapter 4. Finally, the conclusions, recommendations and answers on the research questions are given in chapter 5.

2 Research questions

The research questions that lie before this are:

- Which ships and how many shipping movements are needed during the life cycle of an offshore wind farm? (development/ surveying, installation, monitoring, maintenance, decommissioning)
- How does this number develop in 2050 as a result of the 60 GW scenario?
- To what extent is this compatible with the current and expected shipping movements of regular shipping? In this context, account must also be taken of growth and innovations such as (semi) autonomous shipping convoys in shipping.
- To what extent do bottlenecks arise at sea or in the port infrastructure? These are both logistical bottlenecks (waiting times, the capacity of shipping routes, ports) and additional safety risks.
- What would be innovation themes to address this problem if this is an obstacle?

The research will ultimately lead to an insight into the number of expected extra ship movements in the North Sea as a result of the construction, maintenance and decommissioning of the wind farms on the NCP and the challenges this will entail in both logistics at sea, as security issues.

3 Approach and assumptions

3.1 General approach

To provide an answer to the different research questions a combination of AIS-analysis and discussions with in-house experts was used.

- Estimation of the number of extra ship movements as a result of the offshore wind activities:
  - AIS-analyses to determine the average number of ship movements involved in the different stages of an offshore wind farm: installation, maintenance and decommissioning.
  - The client provided an estimation of the number of turbines installed and decommissioned for a timeline until 2050.
  - Combining the result of the AIS-analyses with the excepted number of turbines over the years provided a good overview of the expected extra ship movements in the coming years.
- Next to the analysis of the traffic to and from the wind farm also the intensities and traffic densities for the other shipping in the area is determined and put into different maps, to relate the extra movements to the already existing movements.
- Based on the extra movements and the already existing shipping and based on the result of different internal discussions the different research questions were answered as far as possible.
- Next to the recommendations in relation to the increase of work vessels also other recommendations for further research are provided in the last chapter. These recommendations are a result of other work MARIN has performed on the effect of the offshore wind farms on the safety of shipping.

3.2 Assumptions regarding measurements and solutions

To face any possible challenges, different measurements of innovative solutions will be necessary. To estimate potential issues, this memo assumes some of the existence and newly developed measurements. In the memo we distinguish two types of measurements:

- Autonomous developments; developments that are already in place of for which the research and developments are already punted into work. The assumption is that this work (research and developments) will continuous in de future.
- New innovative developments/solution; this involves new ideas and new developments. This is work that has not really started yet.

Some examples of developments autonomous as well as innovative that are already put into motion:

- Development of **larger maintenance vessels**, these vessels make it possible to make fewer trips between the windfarms and the shore, because these vessels make it possible for more people to stay at sea for a longer period of time. These developments are especially necessary for wind farms further away from the coast. If this increase in scale would not take place the extra shipping movements at sea would increase, even more, so to limit this, this development is necessary.

- **Island type of structures at sea,** next to larger (maintenance) vessels are ideas of fixed/floating permanent of temporally island constructions at sea will help to reduce the number of necessary movements at seas. This could help to reduce any logistical of safety-related issues. First ideas for these islands are already created, however more research is necessary, to further develop these ideas in sustainable and safety solutions

- More **intensive traffic monitoring**, to prevent incidents or logistical bottlenecks a more intensive monitoring of the shipping traffic in the whole area of in specific smaller areas, such as port areas is necessary. Intensive monitoring allows the different parties involved in the safe and efficient handling of shipping at sea and in port to be better prepared for what is coming in the near (and further future). By the introduction of AIS and the intensification of the use of more fused data sources a better real live image of the traffic in the area can/is created.

- **Traffic management**, not only monitoring but also managing the shipping traffic could prevent incidents and logistic bottlenecks. Nowadays the traffic is managed in the port approach areas or occasionally at sea during special operations, but in the future, this could be extended to larger sea areas. This could/ will be done to prevent incidents (accidents), but could also improve the logistic chain, especially for traffic, crossing the busy main shipping routes, which is more difficult to manoeuvre, such as large transportation vessels during the installation phase.How to organize this extensive traffic management still needs research and innovative ideas. This has some challenges on the organisational as the technical side. One of the issues is for example how to better connect all the available data sources and present only the relevant information to an operator? Also, the training and the education of the operations involved in managing a larger area needs attention.

Figure 3-1 Artist impression of an artificial island at sea.

4 AIS-analysis

4.1 AIS data

Since January 2005, it is mandatory for all merchant's vessels over 300 Gross Tonnage (GT) to send out AIS-messages. These messages contain information about the ship, such as the Maritime Mobile Service Identity (MMSI)-number, ship type, ship size, and position of the vessel. The messages containing the GPS-position of the vessel are broadcasted every 2 to 10 seconds. This system is developed for collision avoidance, but it is also a valuable source of information on the behaviour of ships. The AIS-data are received by base stations of the Dutch Coastguard along the coast and on some offshore platforms. This data are sent to the Coastguard Centre in Den Helder. MARIN is allowed to use the data for research applications, for example, to improve and/ or build up the traffic image of the whole North Sea. In addition, analyses of the data are performed to improve the knowledge about the behaviour of vessels at sea.

The data set contained only information about ships with an AIS-transponder on board. This means, information about smaller vessels such as recreational vessels is not included in the data set and therefore, these vessels are not taken into account in this study.

4.2 Approach

The AIS-data is used for different purposes. First, the AIS-data is used to determine the traffic from and to the different wind farms locations. Secondly, shipping density charts are created to provide a good overview of the traffic in the area and to provide more insight into the shipping activities.

Based on the location of the tracks of all vessels in the area and the contour of the different wind farms location it is determined whether a ship has sailed inside the contour of the wind farm location at least once during a certain journey. All these journeys are selected and placed in a separate database to be used for further analysis. Figure 4-1 shows three example tracks of work vessels sailing in OWEZ in 2018. In the memo a ship movement means a vessel moving in and out a wind farm area, so a movement is actually a visit to a wind farm area.

The analysis has been performed for five wind farm locations on the Dutch part of the North Sea.

The result of the analysis is shown in different maps, to show the location of the extra movements, and in different tables to estimate the expected number of movements per turbine of per MW in the different operational phases of the wind farm.

The final result of the AIS-analysis is an estimation of the average number of ship movements from and to the wind farm per turbine or installed MW per year.

Figure 4-1 Example tracks of three selected journeys made by working vessels from and to OWEZ wind farm.

4.3 Result: Work vessels from and to wind farms

For the five wind farm locations on the Dutch part of the North Sea the analysis has been performed for a period of 4 years: 2015 until 2018.

In this period, some of the wind farms were already up and running and others built:

- OWEZ and PAWP were already fully up and running in the period, so the traffic observed in these parks are sole maintenance.
- Luchterduinen (LUD) was fully operational starting from September 2015, this means that the work vessels observed before that are vessels involved in the installation phase of the wind farms
- Zee-Energie (ZE) and BuitenGaats (BG) (part of Gemini wind farm) were fully operational May 2017.

	Name	# Turbines	Total MW	Type turbines	Distance to the coast
BG	BuitenGaats	75	300	4 MW	55 km
ZE	ZeeEnergie	75	300	4 MW	55 km
LUD	LuchterDuinen	43	129	3 MW	24 km
PAWP	Prinses Amalia Wind Park	60	120	2 MW	26 km
OWEZ	Offshore Windpark Egmond aan Zee	36	108	3 MW	13 km

Table 4-1 Characteristics of the different analyses of wind farms on the Dutch part of the North Sea.

For almost all months in the years 2015 until 2018, the number of journeys of all vessels sailing inside one of the contours of the wind farm areas are selected from the total AIS-database. This resulted in the total number of journeys/movements by vessels visiting one of the wind farms. Because not all months are included in the analysis due to some errors in the analysis, the average number of movements per month is determined. In the second step, this average total number is divided by the number of wind turbines installed to determine the average number of movements per turbine per month. In Table 4-2 these numbers are provided for the five analysed Dutch wind farms. In Figure 4-2 the average numbers are shown again. The figure clearly shows a higher number of movements in 2015 for Luchterduinen, during the installation phase. Also, the two Gemini locations (Buitengaats and ZeeEnergie) show a higher average number of movements during the years of installation, but a lower number as for Luchterduinen. This could be due to other installation procedures since both Gemini locations are further from the coast.

Wind farm area	# Turbines	Average number of movements of work vessels per month				Average number of movements of work vessels per month per turbine			
		2015	2016	2017	2018	2015	2016	2017	2018
Buitengaats	75	68	97	24	36	0.901	1.287	0.324	0.480
Zee-Energie	75	49	80	22	34	0.655	1.062	0.298	0.451
LUD	43	321	86	46	31	7.469	2.005	1.078	0.716
PAWP	60	267	61	61	33	4.453	1.015	1.011	0.557
OWEZ	36	149	122	60	27	4.141	3.380	1.660	0.756

Table 4-2 Average number of movements/visits per month per wind farms area for the different years

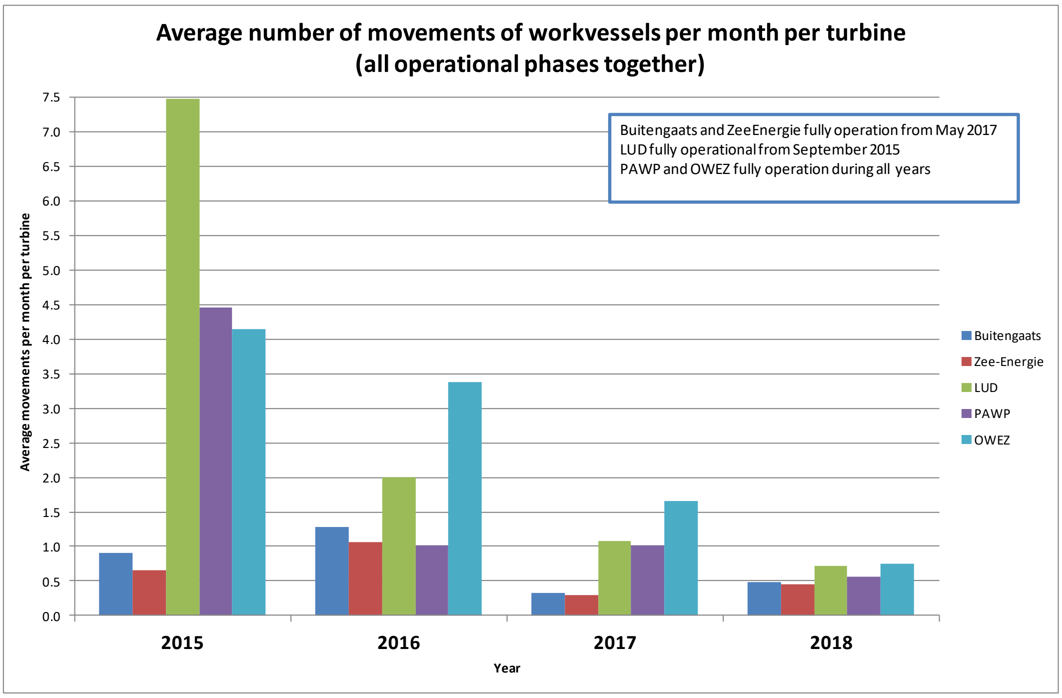

Figure 4-2 Average number of movements/visits per month per wind farms area for the different years

Three of the five wind farms were built during the period for which the data was analysed; Buitengaats, ZeeEnergie and Luchterduinen (LUD). As shown from Figure 4-3 the number of movements during the installation phase differs from the maintenance phase. Therefore, a more detailed analysis is made per month. Figure 4-3 and Figure 4-4 show the average number of extra movements per turbine for the different analysed months. The figures also show that the number of movement is not constant over the year but is lower in the winter months (notice that the scaling is different for the two figures!). Striking is the number of movements for OWEZ (light blue) in 2015 in relation to the other years.

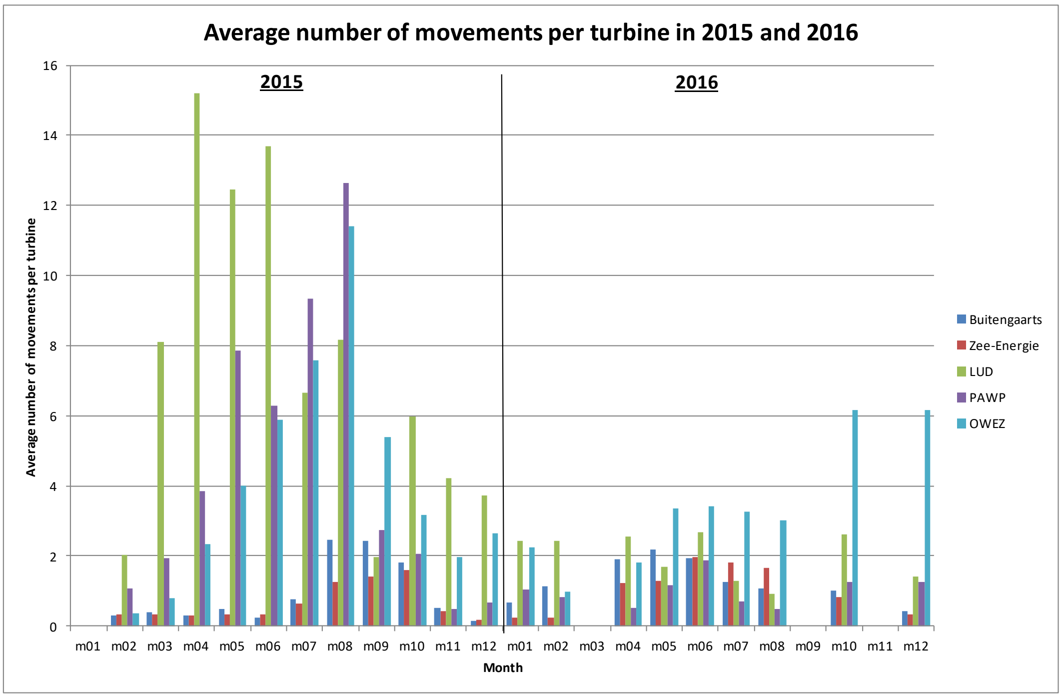

Figure 4-3 Average number of movements/ visits per turbine per wind farms area for the different month in 2015 and 2016

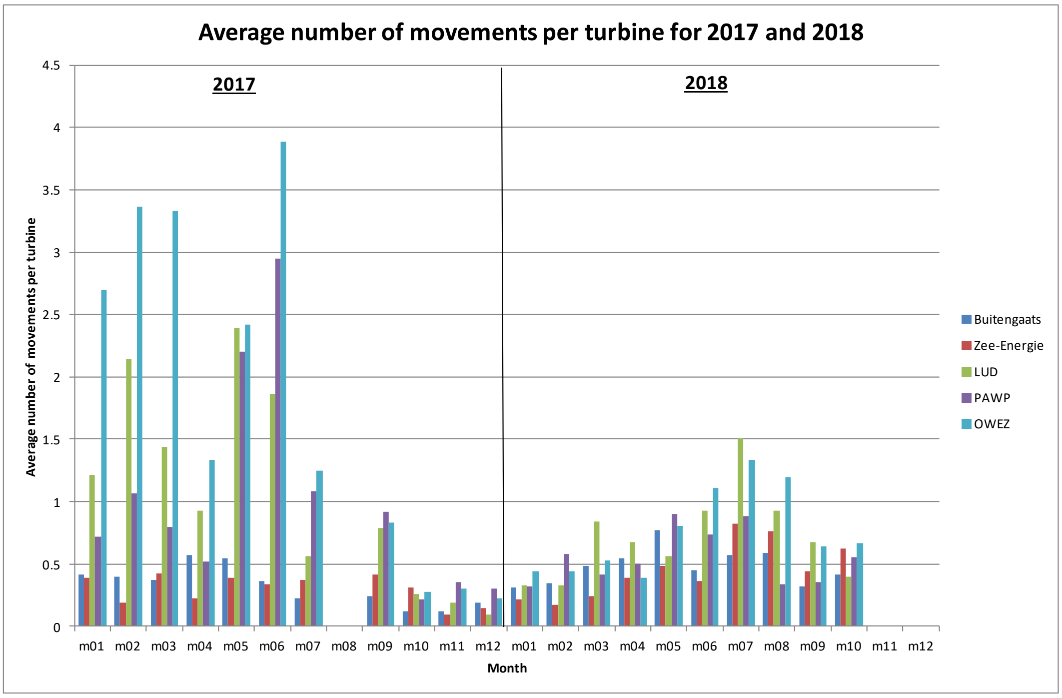

Figure 4-4 Average number of movements/ visits per turbine per wind farms area for the different months in 2017 and 2018

The average number of movements per turbine provides information that can be used to create a “prognoses” for the future, however, it does not provide insight in the actual number of movement at one specific moment. Therefor the same figures are created, but that providing the total number of movement per month. These figures are shown in Figure 4-5 and Figure 4-6. From the figures can be seen that the number of total movements varies a lot during the year. In busy times these were up to 1800 movements per month (adding all areas together), this means almost 60 movements per day.

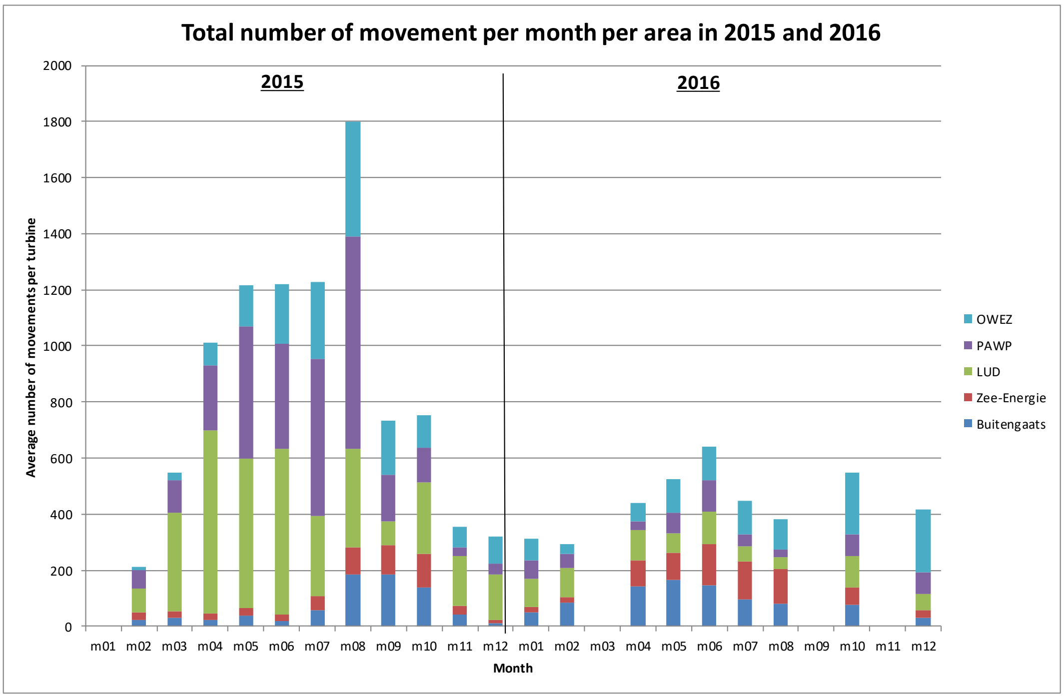

Figure 4-5 Total number of movements/visits per wind farms area for the different months in 2015 and 2016

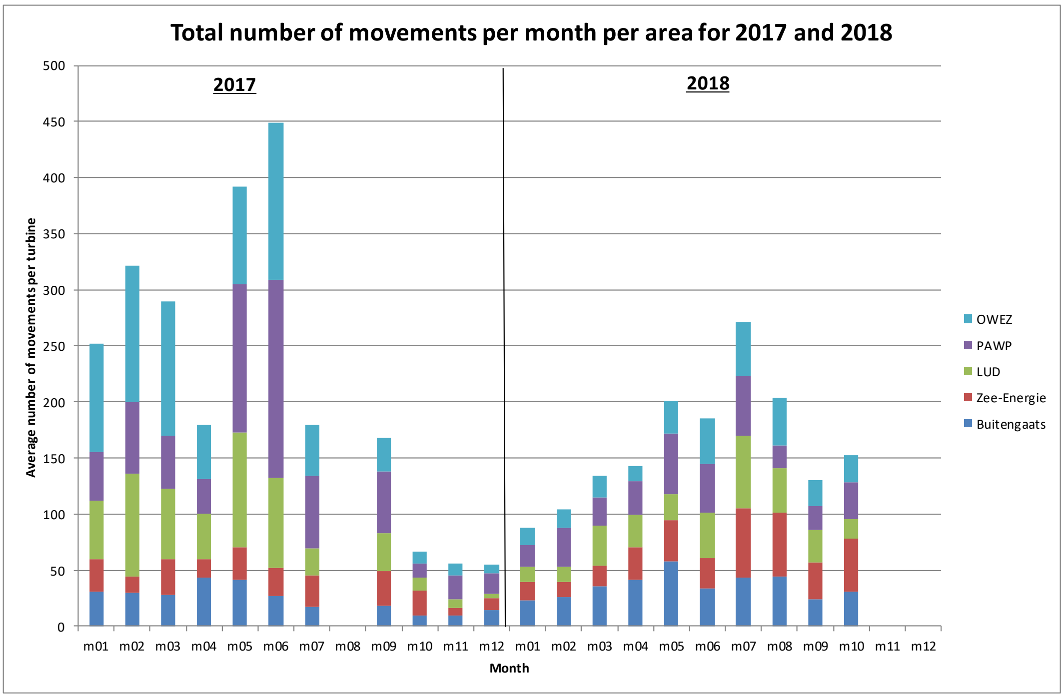

Figure 4-6 Total number of movements/visits per wind farms area for the different months in 2017 and 2018

Still, Figure 4-5 and Figure 4-6 show the average number of movements per month. To further illustrate the fluctuation in the number of movements in 2015 for Luchterduinen were extracted from the database per day. Figure 4-7 shows the number of movements per day (blue) and the average number of movements per day over one month period (orange). From the figure, it becomes clear that for some days the total number of movements is 2 to 3 times the average number of movements for that month.

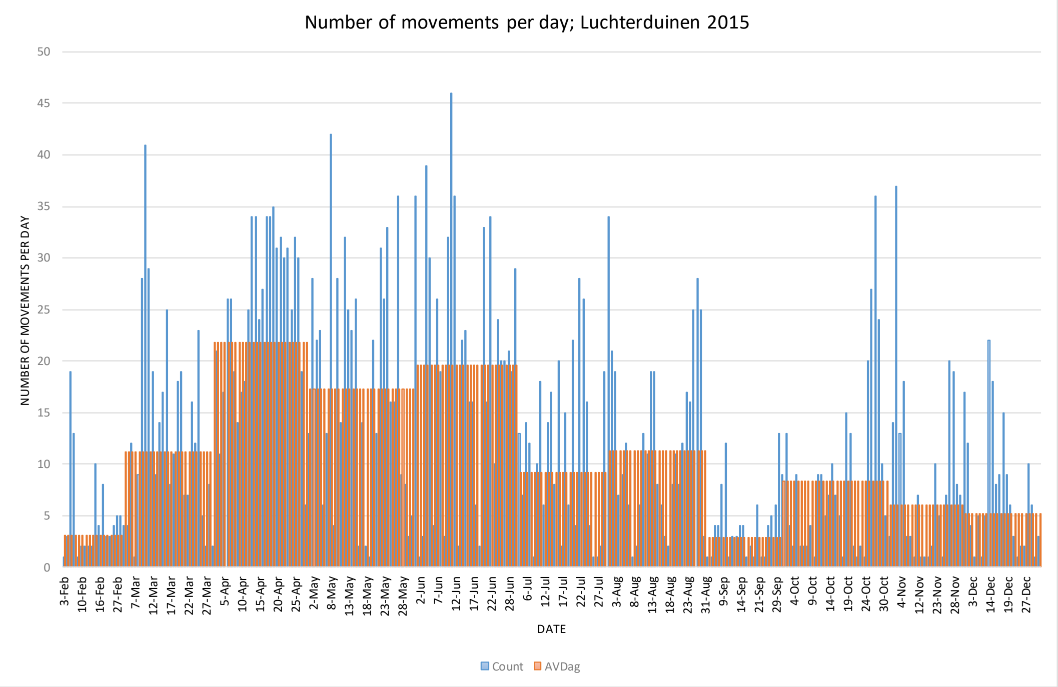

Figure 4-7 Number of movements per day for Luchterduinen over 2015.

Based on the information about when the different wind farms were up-and-running the number, two phases were distinguished in the analysis: installation phase and maintenance phase. Table 4-3 contains the average number of visits/ movements per turbine per year for these two phases. The last columns provide the average number of visits/ movements per wind farms area per phase over the whole 4 years. The areas are also shown in Figure 4-8.

	Average number of ship movements per turbine per month during different operational phases									
	2015	2015	2016	2016	2017	2017	2018	2018	2015 - 2018	2015-2018
	Inst.	Maint.	Inst.	Maint.	Inst.	Maint.	Inst.	Maint.	Inst.	Maint.
Buitengaats	0.90	0.00	1.29	0.00	0.21	0.11	0.00	0.48	0.58	0.15
Zee-Energie	0.65	0.00	1.06	0.00	0.15	0.15	0.00	0.45	0.45	0.15
LUD	6.21	1.26	0.00	2.01	0.00	1.08	0.00	0.72	1.66	1.24
PAWP	0.00	4.45	0.00	1.01	0.00	1.01	0.00	0.56	0.00	1.82
OWEZ	0.00	4.14	0.00	3.38	0.00	1.81	0.00	0.76	0.00	2.52

Table 4-3 Average number of ship movements per turbine per month during different operational phases

On the left side of Figure 4-8, the average number of visits/ movements in the installations phase are shown for the different locations. As seen before the total number of visits per turbine for Luchterduinen is (much) higher than the number for Buitengaats and ZeeEnergie. This could be related to the distance to the coast of new installation techniques. The number of visits/ movements per turbine in the maintenance phase is shown on the right side of the figure. This figure shows a strong decrease in visits over de years for OWEZ and PAWP. The number of average visits per turbine in 2018 is similar for the different locations in 2018.

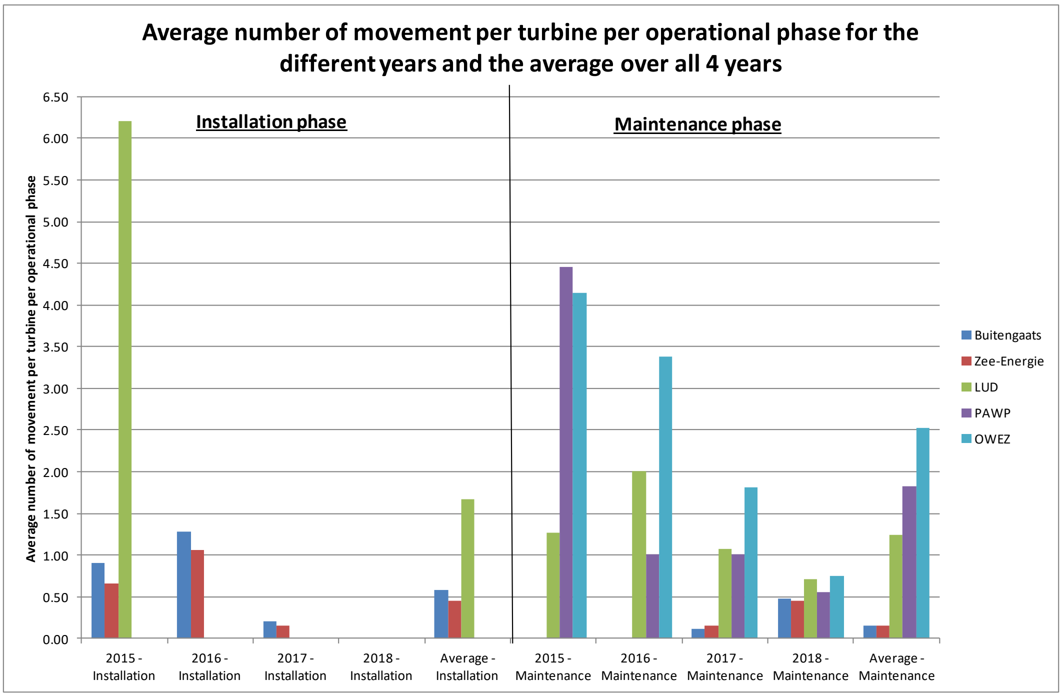

Figure 4-8 Average number of ship movements per turbine per month during different operational phases

Finally, the results for the Dutch offshore wind farms are summarised in table 4-4. This table shows the characteristics of the different locations and the average ship movements per turbine per month for the installation phase and the maintenance phase. For the maintenance phase, two numbers are provided, one based on the average overall 4 years (2015-2018) and one only based on the average over 2018. This is done because it is assumed that in this year all installation work for all the locations was finished so really only the maintenance movements are in the data. This also the average number that is based on the newest information, thus it can be assumed that it represents the situation taken into account most of the latest developments.

	# Turbines	Total MW	Type turbines	Distance to the coast [km]	average movement per turbine per month per phase		
					Installation	Maintenance (2015-2018)	Maintenance (2018)
Buitengaats	75	300	4 MW	55	0.58	0.15	0.48
Zee-Energie	75	300	4 MW	55	0.45	0.15	0.45
LUD	43	129	3 MW	24	1.66	1.24	0.72
PAWP	60	120	2 MW	26	0.00	1.82	0.56
OWEZ	36	108	3 MW	13	0.00	2.52	0.76
Average					0.90	1.18	0.59

Table 4-4 Summarised results AIS-analyses visits/movements of work vessels different wind farm locations of the North Sea

Summary AIS-analyses

Installation phase
During the installation phase, the number of extra movements is different for a location near the coast (LUD) and further away from the coast (Gemini). Nearby the coast, the average number of extra movement per installed turbine per month is 1.6. For a location further away this is 0.5 movements per turbine per month during the whole installation period.

The difference can be caused by the distance to the coast. When the wind farm is further offshore, it is more likely that larger vessels will be used. Since Luchterduinen is located in a more dens shipping area, this means that an extra guard vessel could be present. For the further analyses, it is assumed that during an installation period each turbine will generate on average 1 extra movement per month.

Maintenance phase
During the maintenance phase of an offshore wind farm, the average number of movements per turbine per month differs much, between 2.5 until 0.15. Over the whole period analyse the average number of extra movements is 1.18 per turbine per month, however over 2018, the year that all farms were fully operational the average number of movements is 0.59 and varies less over the different locations. Therefore it is assumed that the average number of extra movements per turbine per month during the maintenance phase is 0.5 per operational turbine

Decommission phase
Since there is no data yet on the number of movements during the decommissioning phase, it is assumed that this will involve the same amount of movements as for the installation phase.

Remark
The numbers mentioned above are the average number of expected movement per turbine per month. These numbers are necessary to determine the total expected extra movement per year for the coming years. However, the analysis also showed that the movements are not equally distributed over the year. The assumption is that the maintenance vessels will be distributed more evenly over the year (with exception of the winter months), however, the movements during the installation and decommission phase will be concentrated during this period.

4.4 Result: Location

Next to the total number of the “extra” movements due to the installations and the maintenance phase of the different wind farms, the AIS-analysis also provide some insight in the routes the different work vessels took.
For each vessel that visited one of the analysed locations the track some hours before and after the visit is logged.

In both maps in Figure 4-9, the tracks of the selected work vessels visiting one of the Gemini locations are shown in 2015 and 2016. The two maps show clearly that during the installation phase (2015) the work vessels also came from different places over the North Sea; IJmuiden, Den Helder, Rotterdam. On the left maps, one can see that after the installation phase was over, the work vessels mainly came from the Eems and less from other places.
This shows that the extra movements during the installation phase will be more “scattered” over the North Sea during the maintenance phase.

Figure 4-10 shows all tracks of all work vessels visiting one of the locations in 2017 and 2018 for all five analysed locations. These figures show again that during the maintenance phase the movements are mostly in a direct line between the wind farm location and the nearest port (IJmuiden and Eemshaven).
Clearly one can see that in 2018 most movements were by so-called HSC (High-Speed Crafts), these are mainly “wind-cat” type of vessels transporting people from and to the wind farms. Only for the locations further away from the coast (Buitengaats and ZeeEnergie) also larger work vessels are involved.

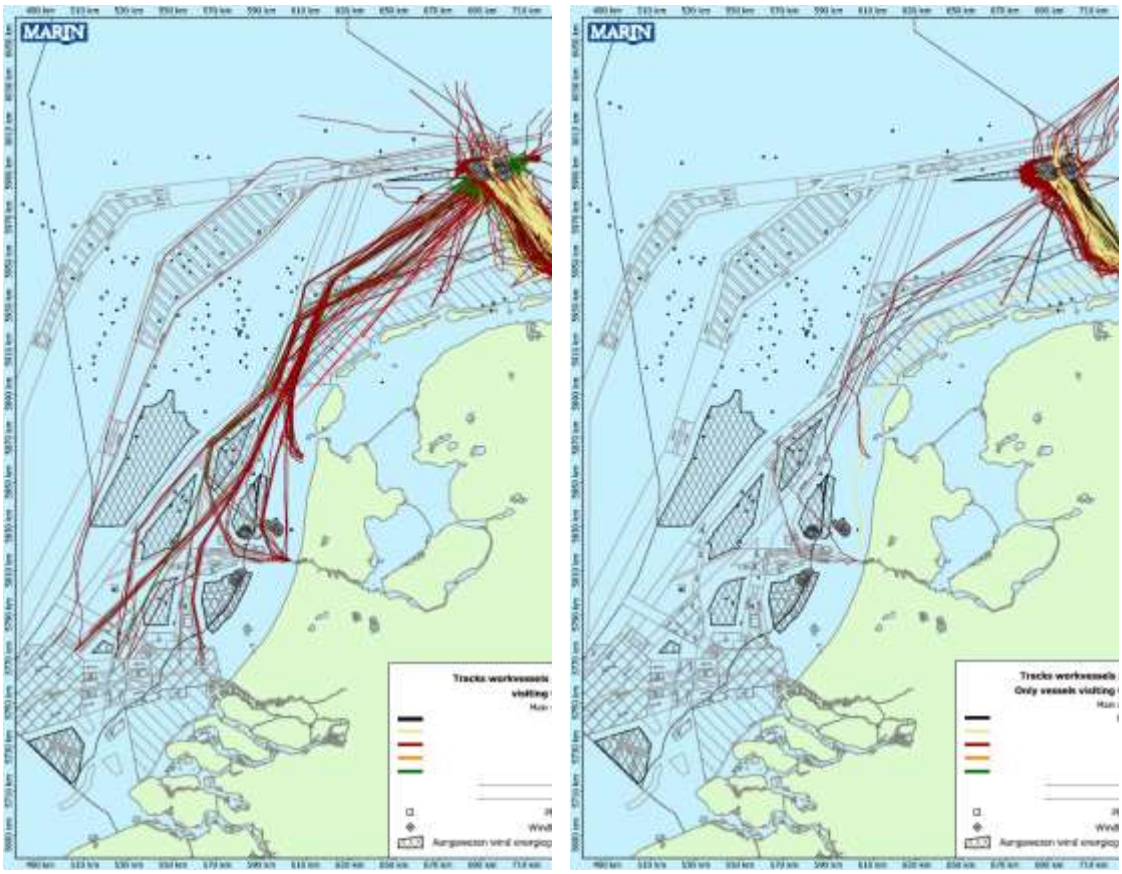

Figure 4-9 Tracks of work vessels visiting one of the Gemini locations in 2015 (left) and 2016 (right)

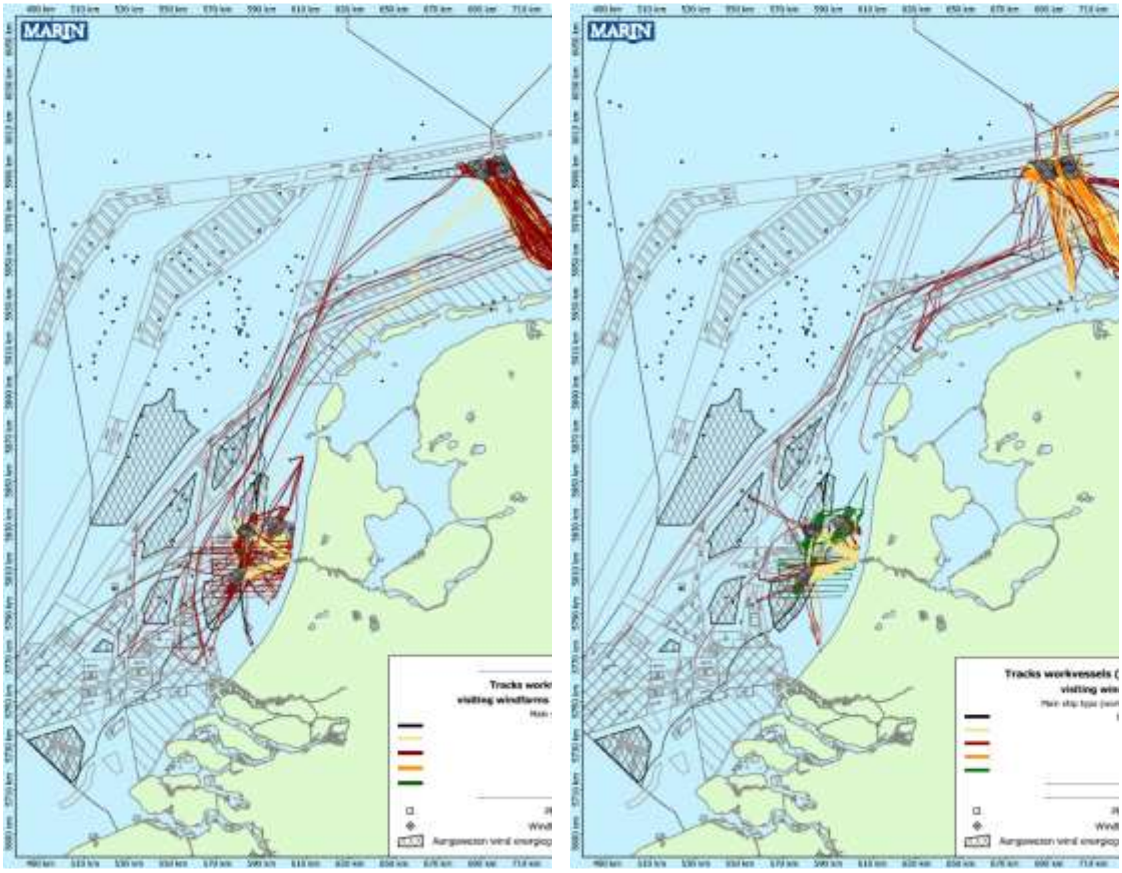

Figure 4-10 Tracks of all work vessels visiting one of the wind farm locations of the Dutch part of the North Sea in 2017 (left) and 2018 (right)

To illustrate also the different behaviour of different work vessels Figure 4-11 shows the tracks nearby Luchterduinen in two different phases and two different types of work vessels. Left the tracks of 'stand-by vessels' during the installation phase and right the tracks of an HSC (High-Speed Craft) during the maintenance phase. The figures show a very different sailing pattern. The 'stand-by vessel' manoeuvres mostly outside the wind farm area and the HSC really needs to go inside the area and manoeuvres very close to the different turbines in order to transfer the people on and of the turbines.

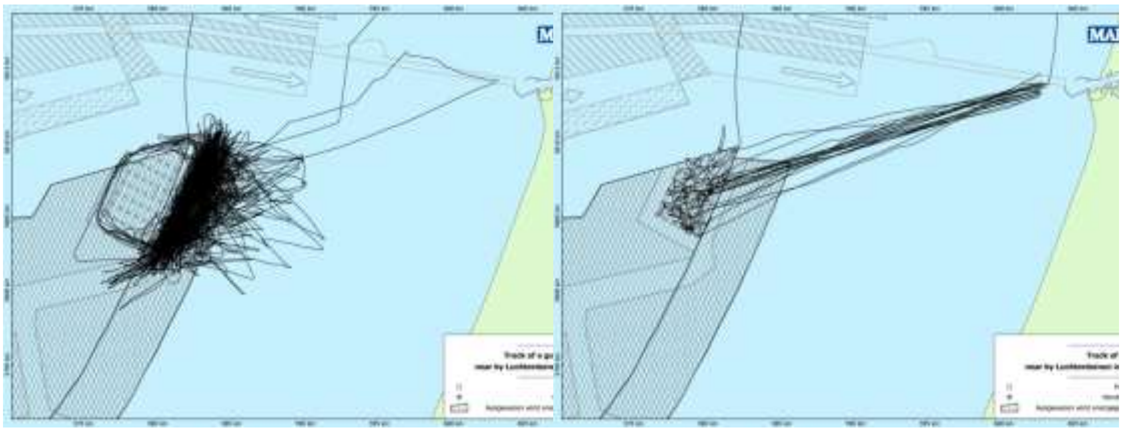

Figure 4-11 Track of different type of work vessels in different operational phases of the wind farm Luchterduinen.

4.5 Total expected extra movements in 2050

The client has provided the expected number of wind energy (wind turbines) installed between now and 2050. It is expected that in 2050 in total almost 4000 turbines will be built on the Dutch part of the North Sea

Figure 4-12 shows the total number of turbines installed (blue) and decommissioned (orange) per year (with the left axis) and the development of the total number of operational wind turbines (grey line, right axis).

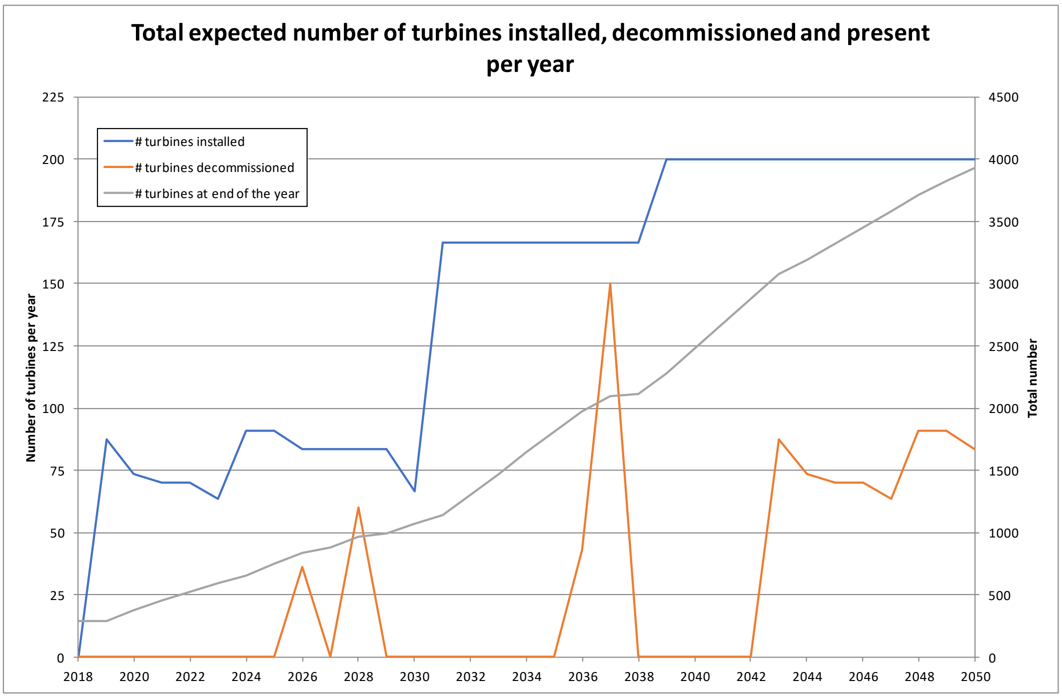

Figure 4-12 Total expected number of turbines installed, decommissioned and present per year until 2050.

These numbers were combined with the results of the AIS-analysis to estimate the average number of extra movements of working vessels per year as a result of the offshore wind energy.

The results presented in Figure 4-13 show a large increase in the extra movements up to 26.000 per year in 2050. This means on average 71 per day (26.000/ 365), when it is assumed that one only sails during the daytime, this means 6 extra movements/ visits per hour. *Assuming that the maintenance regime will be similar to the one in 2018.*

The figure shows that the contribution of the installation-related activities will be relatively constant between the 2000 and 2500 movement per year, based on the assumption of one movement per turbine per month. These numbers are also based on the assumption that the increase in wind turbines is distributed evenly over the different years (an equal number of turbines is installed per year). It is possible (also after discussions with the client) that more turbines are built in certain years than in others, this means that the total number of movement per year may be much higher. But since not the real number of the actual expected installed turbines per year are

known yet, it is not possible to give real numbers on the possible “spikes” in installation movements.
Also, these movements will however not be evenly distributed over the year, this “phenomenon” will increase the possible “spikes” in movements even more.

The highest contribution comes from increased maintenance. Again, these numbers are based on the average number of movements derived from the five existing wind farms, which are located relatively close to the coast. The turbines installed from 2020/2030 will be much further from the coast. This means the not all movements will start in the different port areas and thus not all the movements will cross the whole area.

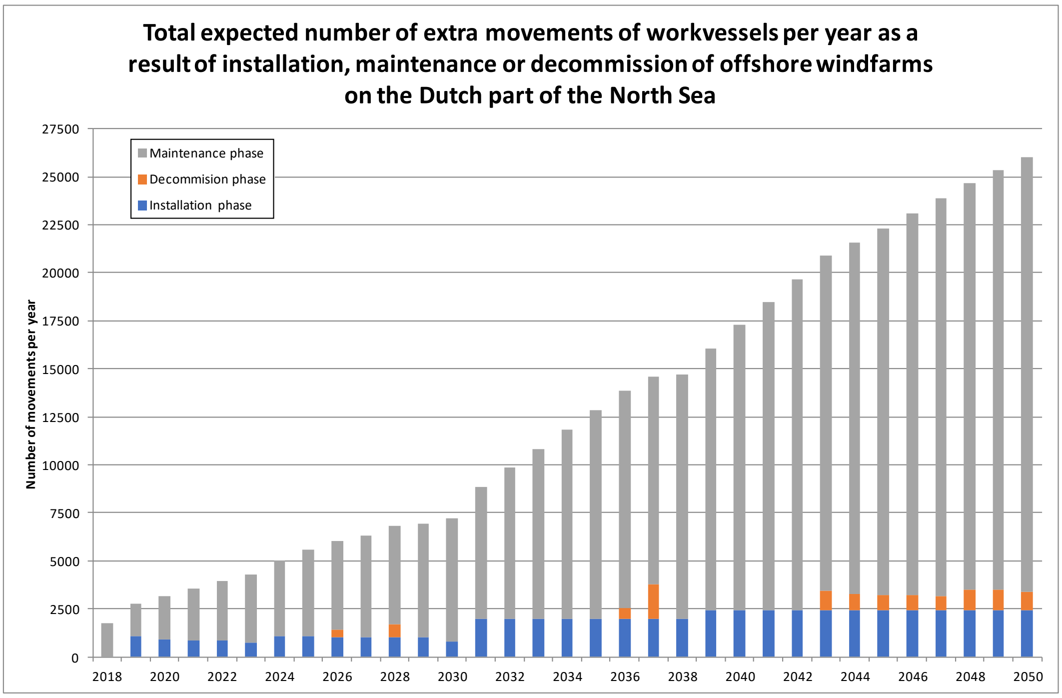

Figure 4-13 Total expected number of extra movements/visits of work vessels per year as a result of installation, maintenance or decommissioning of offshore wind farms on the Dutch part of the North Sea.

4.6 Result: relation to other traffic

From an analysis over 2016-2015, it was found that 220.000 ship movements take place on the NCS (Netherlands Continental Shell) each year. This means a 10% increase towards 2050 as a result of the installation and maintenance of the wind turbines. This increase will, however, be spread out over the various locations on the North Sea.

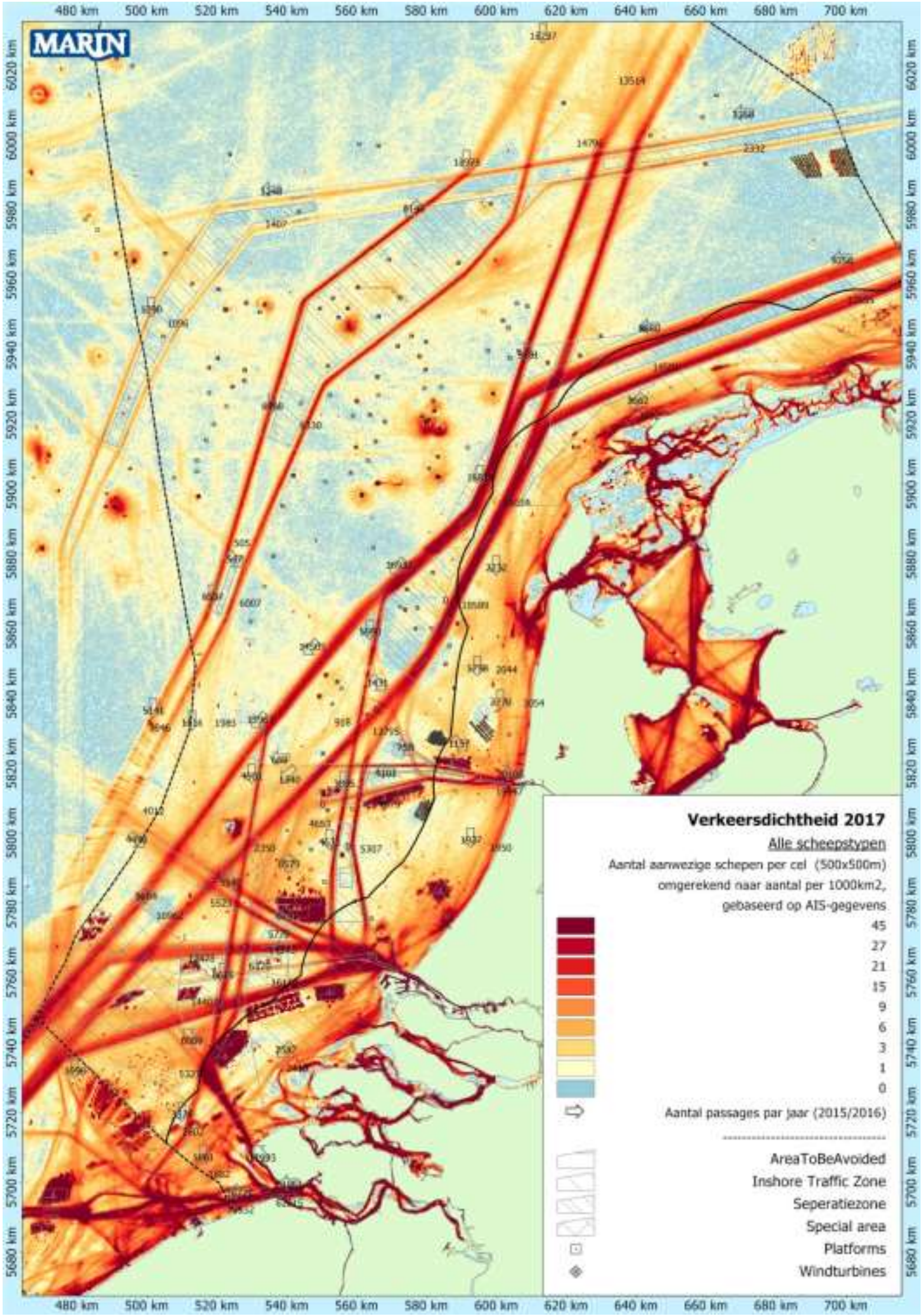

Figure 4-14 Traffic density over 2017; all type of vessels observed based on AIS-data.

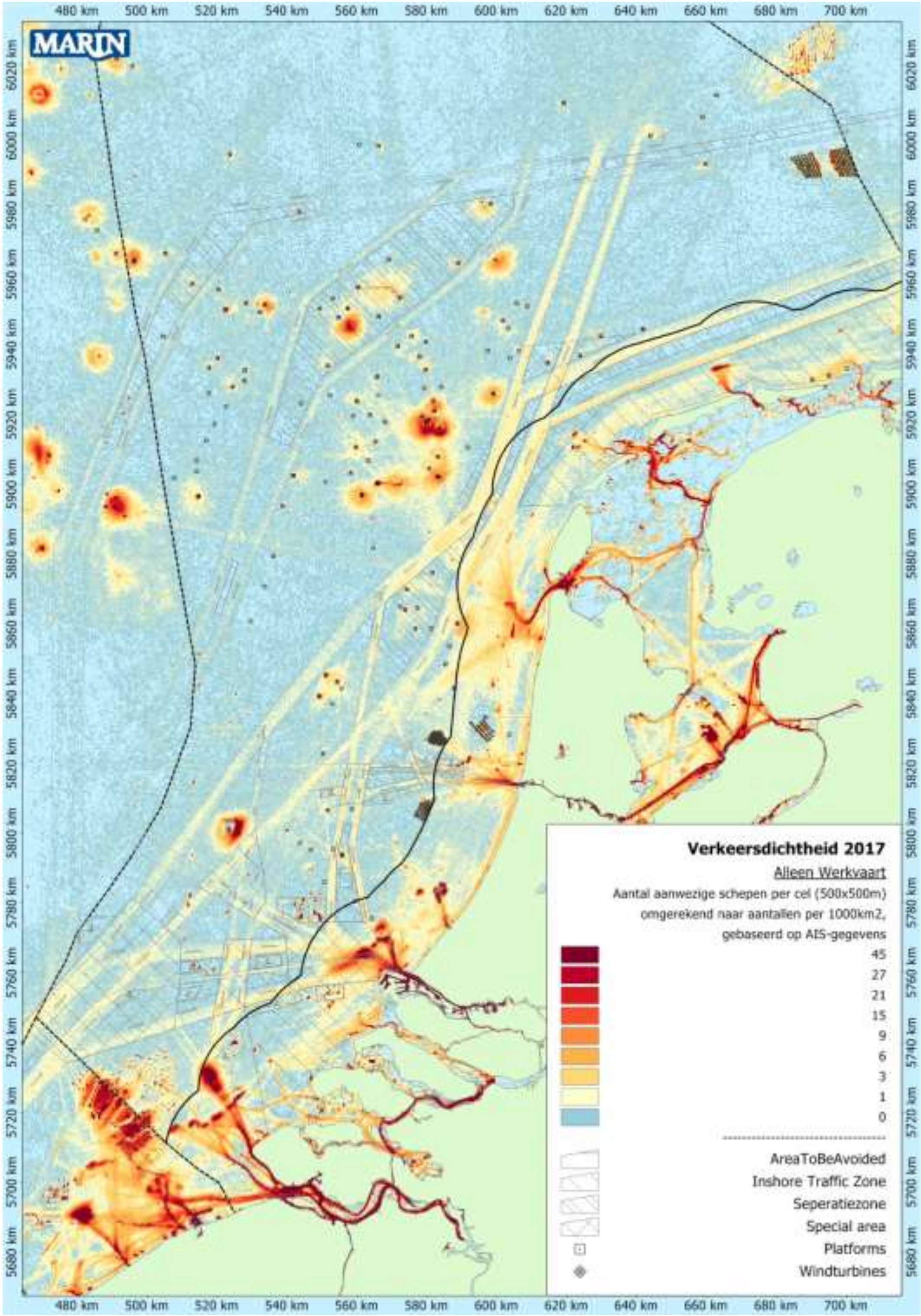

Figure 4-15 Traffic density over 2017; only work vessels observed based on AIS-data.

4.7 Traffic intensities near the approach Rotterdam and IJmuiden

In 2015-2016, a study has been performed on the traffic intensities on the North Sea based on AIS-data. In this study also the intensities in the different port approaches have been analysed. Some results are summarised in the maps and table below.

A part of the extra movement will sail from and to Rotterdam, IJmuiden, Eemshaven, Vlissingen or Zeebrugge. As mentioned, the number of movements is approximately 26.000 per year. Assuming that the number of movements is low in wintertime (4 months) and assuming that most movements will be done during daytime (12 hours) the traffic intensity is approximately 9 ships per hour. Therefore, for individual ports, this will be in the order of 2 ships per hour.

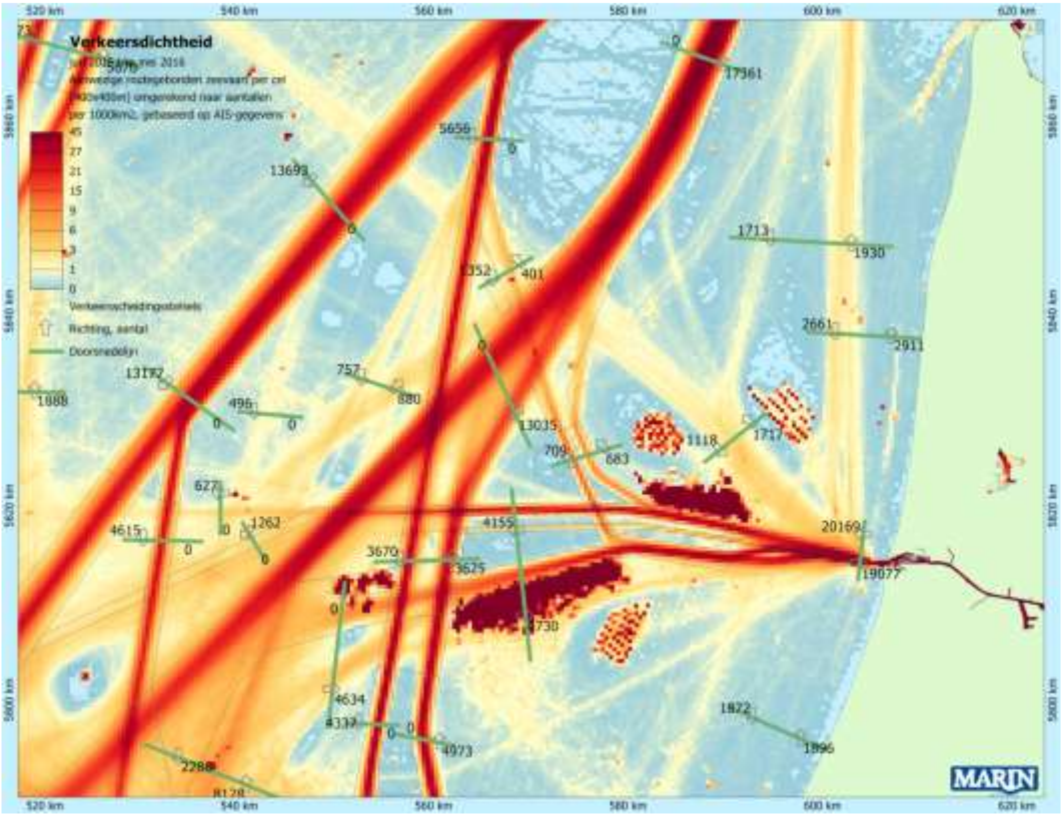

Figure 4-16 Traffic intensities nearby IJmuiden.

Aantal scheepspassages lijn 420: Haven IJmuiden													
			Grootteklasse										
Type	richting	Totaal	Onb.	0	1	2	3	4	5	6	7	8
Bulker	W	689					34	7	140	389	119	
	O	655					34	6	138	362	115	
CHEMICAL	W	1490				10	280	393	722	85		
	O	1472				10	278	369	728	87		
Container	W	14					10	1	2	1		
	O	14					11		2	1		
Fishing	W	1807		709	892	17	45	140	4			
	O	1796		691	908	17	43	132	5			
GDC	W	2664	1		98	334	1920	238	55	15	2	1
	O	2643	2	2	99	327	1918	220	57	16	1	1
LNG												
LPG	W	49					47	2				
	O	48					46	2				
Miscellaneous	W	2835		1634	263	116	431	158	223	4	5	1
	O	2799		1596	255	119	443	152	226	3	5	
OBO	W	6									6	
	O	6									6	
Oil	W	555		1		6	43	45	181	122	33	124
	O	532	1	1		4	41	24	183	120	34	124
Pass/Ferry	W	2208		305	1408	1	4	14	33	368	48	27
	O	1343		282	562	1	5	12	32	367	54	28
Pilot	W	4942		2846	54		2		2040			
	O	4964		2879	54		2		2029			
Recreation	W	2143		1885	242	12	4					
	O	2020		1777	230	10	3					
RoRo	W	228					2	37	47	91	51	
	O	227					1	38	48	89	51	
Supply	W	342		222	50	3	46	17	4			
	O	356		229	53	3	48	18	5			
Tug	W	197		6	158	22	11					
	O	202		20	149	22	11					
Totaal	W	20169	1	7608	3165	521	2879	1082	3461	1078	264	153
	O	19077	3	7477	2310	513	2884	973	3453	1045	266	153

Table 4-5 Number of vessels per type and size class observed entering of leaving the port near IJmuiden.

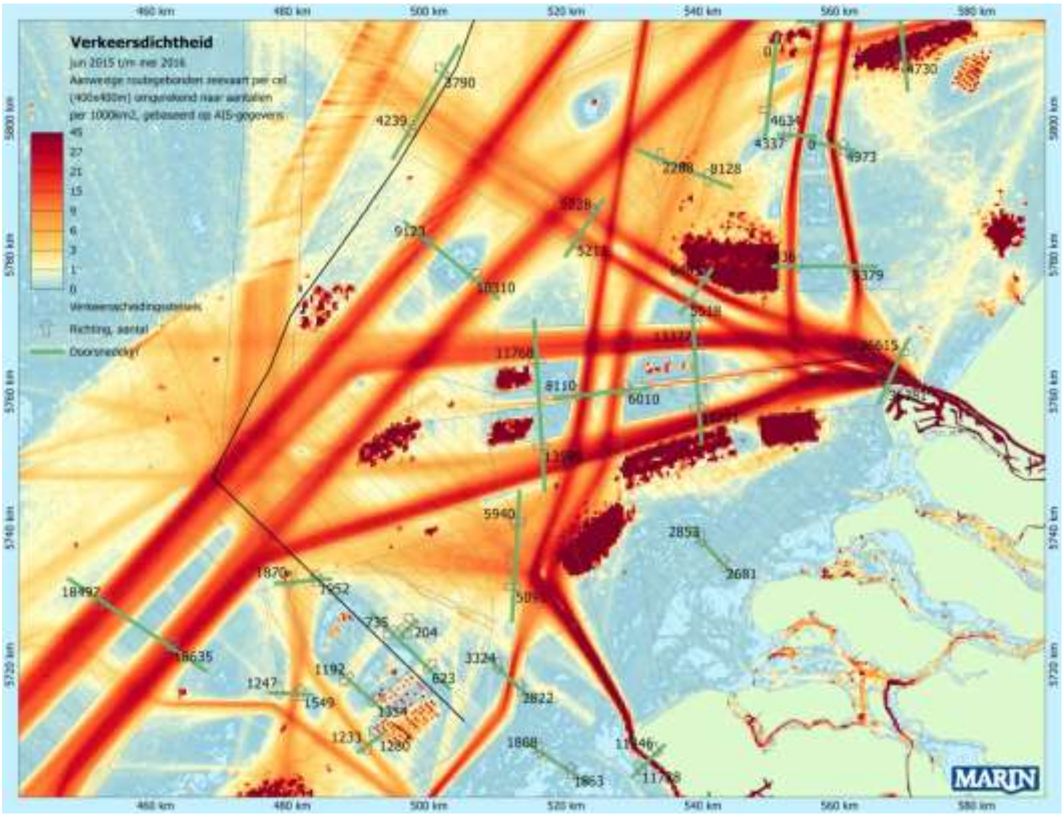

Figure 4-17 Traffic intensities nearby Rotterdam en Westerschelde

Aantal scheepspassages lijn 421: Haven Rotterdam													
			Grootteklasse										
Type	richting	Totaal	Onb.	0	1	2	3	4	5	6	7	8
Bulker	W	1052			15		72	27	233	404	249	52
	O	1068			15		70	29	232	412	258	52
CHEMICAL	W	5279				96	2352	935	1795	101		
	O	5303				96	2352	942	1809	104		
Container	W	6861					502	2429	1501	793	681	955
	O	6829					500	2426	1482	798	671	952
Fishing	W	598		230	362	3	3					
	O	596		235	357	2	2					
GDC	W	4984	4		86	632	3079	841	261	50	1	30
	O	4976	1	1	87	631	3080	834	258	49	3	32
LNG	W	34						4	1	1	5	23
	O	34						4	1	1	5	23
LPG	W	591					419	117	53	2		
	O	586					416	116	52	2		
Miscellaneous	W	4632		707	573	89	2851	95	288	13	5	11
	O	4601		686	581	83	2855	86	287	11	5	7
OBO	W	9									6	3
	O	9									6	3
Oil	W	2026			2	23	147	109	408	389	804	144
	O	2028			1	24	149	106	415	383	804	146
Pass/Ferry	W	1441	1	35	14	1	1	1	14	672	697	5
	O	1493	1	32	13	4	4	1	14	678	741	5
Pilot	W	4093		3637	195		102		159			
	O	4089		3637	196		96		160			
Recreation	W	1384		1336	38	8	2					
	O	1161		1126	27	7	1					
RoRo	W	3013					10	82	2518	362	41	
	O	3013			1		10	78	2521	362	41	
Supply	W	108		44	13	4	33	3	11			
	O	109		38	19	6	32	3	11			
Tug	W	511		15	391	20	81	3	1			
	O	486		15	370	18	80	3				
Totaal	**W**	**36616**	**5**	**6004**	**1689**	**876**	**9654**	**4646**	**7243**	**2787**	**2489**	**1223**
	O	**36381**	**2**	**5770**	**1667**	**871**	**9647**	**4628**	**7242**	**2800**	**2534**	**1220**

Table 4-6 Number of vessels per type and size class observed entering of leaving the port near Rotterdam.

Aantal scheepspassages lijn 422: Monding Westerschelde (thv Vlissingen)													
			Grootteklasse										
Type	richting	Totaal	Onb.	0	1	2	3	4	5	6	7	8
Bulker	W	1097					19	32	569	434	43	
	O	1084					19	33	562	426	44	
CHEMICAL	W	4457				46	2173	736	1401	101		
	O	4477				48	2175	742	1409	103		
Container	W	4139					73	399	1094	1455	650	468
	O	4127					70	401	1104	1440	649	463
Fishing	W	1384		700	672		1	11				
	O	1437		739	687		1	10				
GDC	W	6407	12	158	90	545	3615	1071	767	126	1	22
	O	6762	27	236	129	682	3693	1085	765	126	1	19
LNG	W	19						1	18			
	O	20						1	19			
LPG	W	1634					1016	365	204	49		
	O	1646					1027	370	200	49		
Miscellaneous	W	3805		1182	633	786	659	467	51	15	10	2
	O	4572		1336	1184	844	666	462	51	15	9	5
OBO	W	24							1		23	
	O	56							1		55	
Oil	W	1572	3	169		50	592	147	258	230	121	2
	O	1644	8	169	1	105	586	159	263	232	119	2
Pass/Ferry	W	7330	15	128	7037	2	15	13	64	55	1	
	O	7346	27	157	6976	2	20	45	64	54	1	
Pilot	W	19587		18140	1339		63		45			
	O	19524		18065	1347		68		44			
Recreation	W	1779		1261	494	21	3					
	O	7553		2985	3167	1398	3					
RoRo	W	2395					172	36	984	993	210	
	O	2422					171	33	989	1014	215	
Supply	W	154		86	19	4	37	4	4			
	O	155		94	14	4	36	4	3			
Tug	W	669		62	589	3	14	1				
	O	719		106	592	5	15	1				
Totaal	**W**	**56452**	**30**	**21886**	**10873**	**1457**	**8452**	**3283**	**5460**	**3458**	**1059**	**494**
	O	**63844**	**62**	**23886**	**14097**	**3068**	**8550**	**3346**	**5474**	**3459**	**1093**	**489**

Table 4-7 Number of vessels per type and size class observed entering of leaving the port near Westerschelde.

In Figure 4-11 the numbers of port visits are summarized. The number of ship visits/movements to the wind farms is the total for the Dutch part of the North Sea. This number will be divided over the various ports. Therefore, to one port one can assume an increase of approximately 6.000 movements, which means an increase between 5

to 15 per cent. Given the fact that during the maintenance phase most wind farm support vessels are not very large, it can be assumed that this is not a problem for most ports. Also because it is taken into account that personnel on board of these work vessel is well trained and that these vessels are good manoeuvrable.
Also, when the vessels will be larger during the installation phase, it is assumed that this will not lead to major issues. It is expected that during the maintenance phase of the larger wind farms further from the coast, the vessels will also be larger; however, this will therefore also lead to fewer movements.

Ship movements/ visits for the offshore wind (estimation for 2050)	Number of vessels based in analysis for 2050-2016 (all ship types, both directions)		
	IJmuiden	Rotterdam	Westerschelde
26.000	39.246	72.997	119.996

Table 4-8 Total number of port visits per year in 2015-2016

The focus of this study was on the expected effects and issues regarding the increase in ship movements in ports and sea areas as a result of the installation of the offshore wind on the North Sea, therefore we did not focus on the available quay space inside the different port areas. It is possible that some logistical challenges develop onshore, but this memo only focusses on the “offshore” challenges.

5 Conclusion and recommendations

5.1 Research Questions and conclusions

"Which ships and how many shipping movements are needed during the life cycle of an offshore wind farm? (development/ surveying, installation, monitoring, maintenance, decommissioning)"

Based on AIS-analyses the number of vessel movements is analysed for different wind farms in the Dutch part of the North Sea. These wind farms were during the study period in different phases of their life cycle.
OWEZ, PAWP and LUD (from Sept 2015) were already up and running during the study period
LUD was installed during the first months of 2015 (until Sept 2015)

Using the AIS-analysis an average number of ship movements is estimated for the installation period and for maintenance of the wind farm.

Installation phase
During the installation phase, the number of extra movements is different for a location near the coast (LUD) and further away from the coast (Gemini). Nearby the coast, the average number of extra movements per installed turbine per month is 1.6. For a location further away this is 0.5 movements per turbine per month during the whole installation period.

The difference can be caused by the distance to the coast. When the wind farm is further offshore, it is more likely that larger vessels will be used. Since Luchterduinen is located in a more dens shipping area, this means that an extra guard vessel could be present. For the further analyses, it is assumed that during an installation period each turbine will generate on average 1 extra movement per month.

Maintenance phase
During the maintenance phase of an offshore wind farm, the average number of movements per turbine per month differs much, between 2.5 until 0.15. Over the whole period analyse the average number of extra movements is 1.18 per turbine per month. However, over 2018, the year that all farms were fully operational the average number of movements is 0.59 and varies less over the different locations. Therefore it is assumed that the average number of extra movements per turbine per month during the maintenance phase is 0.5 per operational turbine

Decommission phase
Since there is no data yet on the number of movements during the decommissioning phase, it is assumed that this will involve the same amount of movements as for the installation phase.

Remark
The numbers mentioned above are the average number of expected movement per turbine per month. These numbers are necessary to determine the total expected extra movement per year for the coming years. However, the analysis also showed that the movements are not equally distributed over the year. The assumption is that the maintenance vessels will be distributed more evenly over the year (with exception of the winter months), however, the movements during the installation and decommission phase will be concentrated during this period.

> **“How does this number develop in 2050 as a result of the 60 GW scenario?”**

The client provided information on the expected number of MW installed and decommissioned in the years up to 2050. Based on the expected average number of movements per turbine/MW the total extra movements are determined.

The results that are shown in Figure 5-1 the figure shows a large increase in the extra movements up to 26.000 per year in 2050. This means on average 71 per day (26.000/365), when it is assumed that one only sails during the daytime, this means 6 extra movements/visits per hour. *Assuming that the maintenance regime will be similar to the one in 2018.*
The figure shows that the contribution of the installation-related activities will be relatively constant, between the 2000 and 2500 movement per year, based on the assumption of one movement per turbine per month.
These numbers are also based on the assumption that the increase in wind turbines is distributed evenly over the different years (an equal number of turbines is installed per year). It is possible (also after discussions with the client) that more turbines are built in certain years than in others, this means that the total number of movement per year will be much higher. But since not the real number of the actual expected installed turbines per year are known yet, it is not possible to give real numbers on the possible “spikes” in installation movements.
Also, these movements will however not be evenly distributed over the year, this “phenomenon” will increase the possible “spikes” in movements even more.

The highest contribution comes from increased maintenance. Again, these numbers are based on the average number of movements derived from the five existing wind farms which are located relatively close to the coast. The turbines installed from 2020/2030 will be much further away from the coast.

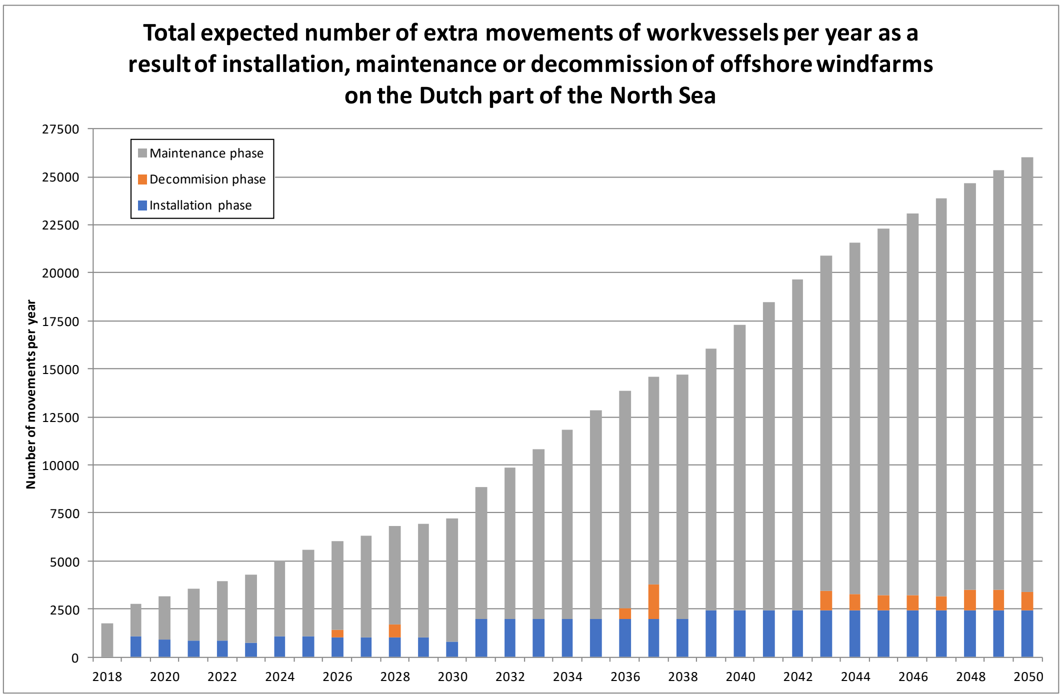

Figure 5-1 Total expected number of extra movements/visits of work vessels per year as a result of installation, maintenance or decommissioning of offshore wind farms on the Dutch part of the North Sea.

> **“To what extent is this compatible with the current and expected shipping movements of regular shipping?”**

And

> **“To what extent do bottlenecks arise at sea or in the port infrastructure? These are both logistical bottlenecks (waiting times, the capacity of shipping routes, ports) and additional safety risks.”**

And

> **“What would be innovation themes to address this problem if this is an obstacle?”**

Logistical bottlenecks

Based on the number of port approaches, the shipping intensities, and the (estimated) extra number of movements per year on a “global” view no real logistical bottlenecks are foreseen in the sea area. This means that there will be some real local logistics challenges at certain times and locations, for example during the installation of a specific location with increased traffic flow from one specific port. These temporary challenges/difficulties need to be addressed to prevent delays in the installation process of eventual delays of incidents with other (passing) traffic.

Already existing developments (research) of new type installation vessels will reduce the number of movement at sea and could therefore also decrease the issue of any logistic bottlenecks. More innovative developments e.g. an island type structures at sea will also help to decrease the number of movements.

The existing traffic management in port and approach areas will/can reduce any logistical issues in these areas, however further development in monitoring and managing the traffic at sea could also help to prevent issues in that area, certain during the periods and locations with an extra spike movements for example during the installation and decommissioning of the wind farms.

In general, one could say that it is necessary to continue the already running research and developments on new ship types and innovative ideas like artificial islands to prevent any temporal and local logistic issues, which will occur in the future

Safety of shipping

Increased number of activity in the area between the wind farms and the main traffic routes will create a more complex traffic situation at these locations. In 2018, MARIN has performed a study on the cumulative effects of the offshore wind farms on the safety of shipping towards 2030. This study showed a small increase in accidents related to the increase of work vessels in the area. However, this was not a significant increase. Therefore, towards 2030 the extra working vessels, *provided that extra monitoring and management during certain periods and locations are in place*, will not impose real issues related to the safety of shipping of the existing traffic.
Towards 2050 the number will increase even more, so again locally this will lead to some real effects on the safety of shipping at certain time periods. It is our assumption that *with proper monitoring and traffic management* most of these issues can be "solved". However, this implies that the developments and research that is conducted now will continue in order to come to improved solutions such as traffic management, extra guard vessels etc.

The study on the cumulative effects showed some remaining issues that could be input for further research. These are summarised below:

Consequences drifting collision turbines for the vessel and turbine

One of the accident types that is difficult to mitigate is the accident of a drifting vessel colliding with a turbine. This means that a passing vessel could encounter engine or steering problems such that the vessel is no longer under control and starts drifting. A vessel could eventually drift against a wind turbine. Based on the current layout of the planned wind farms the distance between the main traffic routes and the turbines of minimal 2 nm. With a drifting speed of 4 kn., this means that a vessel could reach a turbine 30 minutes after encountering problems. This is too short of a time to really take action to avoid contact.

After some searching, it was found that no real studies have been performed on the consequences of a drifting contact between a vessel and a turbine. What will happen to the ship and what will happen to the turbine? Will there be a leakage from the ship as a result of the contact? Could this lead to the sinking of the vessel? Will the turbine drop on the deck or will it break away from the ship. There are some studies known that are used in the design of the turbine, but not on a large scale and not for the new generation of turbines and vessels.

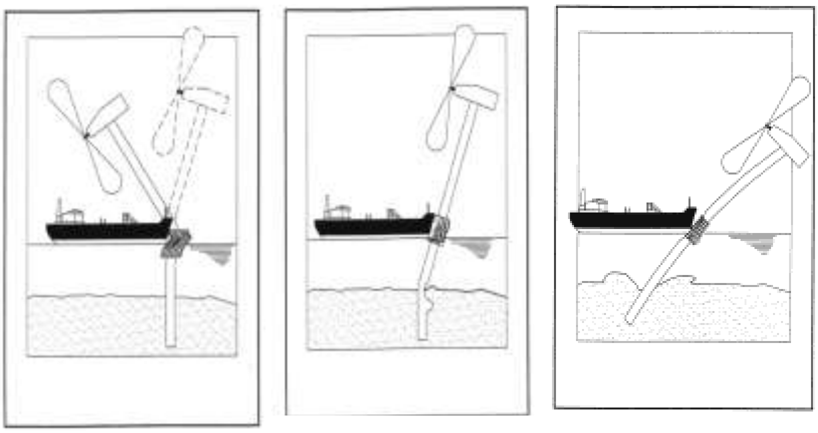

Figure 5-2 Possible deformations of wind turbines as a result of contact with a vessel.

Consequences drifting collision turbines for the people on a turbine
The probability that a vessel will drift against a turbine is small, however, the consequences for the turbine could be large. Especially when there are persons working on a specific turbine. As mentioned the time between the reporting of the possible accident and the moment that a turbine is actually hit could be as short as 30 minutes. Assuming that a working vessel is not always close by after dropping off people on wind turbines, 30 minutes could be too short to get the crew of the turbine. Therefore, a recommendation is to look at solutions for a way to get off the turbine in case of an emergency.

Modelling the risk of sailing in a wind farm
The existing techniques and models to estimate the safety of shipping do not fully include the possible risks involved in sailing inside a wind farm area. Still much is unknown on the number of vessels that will sail inside a wind farm (besides the working vessels). Also, how do they behave inside the area and how and where they will leave the areas is not clear yet and not properly included in the existing models.

5.2 Summary of the recommendations

Already many innovations and developments (research) are running in relation to the offshore work during the installation, maintenance and decommissioning of the offshore wind farms. The question for this study was whether the extra work vessels at sea impose logistic of safety-related problems/ challenges looking at the increase of offshore wind toward 2050.

Based on the analysis of AIS-data and the estimation of the growth of offshore wind by 2050, offshore wind will introduce 26.000 extra movements at the North Sea. This number represents the situation without any new (innovative) developments, such as the use of larger maintenance vessels and the possible development of an offshore island that can be used as a logistic hub.

The extra number of movements will show spikes in time and space, this means that temporary logistical and safety-related challenges will arise at specific times and locations if no further developments or innovation will take place.

The new innovations in vessels and installation techniques and already existing developments and research related to traffic monitoring and traffic management provide solutions for some of the foreseen logistics and safety-related bottlenecks. However, these (innovative) developments that are already running are essential to provide a smooth and safe installation, maintenance and decommission of the foreseen wind farm. This means that the research and developments that are conducted now need to continue in the future. Also, new innovative ideas, such as improved traffic management or artificial islands need to be picked up.

Regarding the safety of shipping and personnel on the turbine, a recommendation is to further look at the consequences of contract between a passing (drifting) vessel and a turbine.

A recommendation, related to this topic, is to perform some additional research regarding the modelling of the (shipping) risks of working vessels operating inside a wind farm area and related to the interaction with other traffic. This modelling and the results can also be used in a more efficient way of monitoring and managing the different extra operations at sea.

Figure 5-3 Installation vessel used in Gemini wind farms (Source: https://geminiwindpark.nl/turbines--nacelles--rotorblades.html)

TKI WIND OP ZEE
Topsector Energie

Klik hier en voeg via Invoegen Afbeeldingen een foto in. Om te vergroten: klik op een hoek en sleep. Om te verschuiven: klik op Bijsnijden in het rechtertabblad Opmaak. De grootte van dit vak

Postadres
Postbus 24100
3502 MC Utrecht

Bezoekadres
Arthur van Schendelstraat 550
Utrecht

T +31 30 73 70 541
E secretariaat@tki-windopzee.nl
T www.tki-windopzee.nl