

Analysis of IWRAP mk2 application for oil and gas operations in the area of the Baltic Sea in view of fishing vessel traffic

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Abstract

The paper discusses issues of the assessment of collision risk in vicinity of oil and gas production facilities located in the southern Baltic Sea. The authors have used IWRAP mk2 application to assess the probability of collision, focusing on the impact of fishing vessels. The analysis has been performed at the Research Centre for Ship Operation Risk Analyses, Maritime University of Szczecin.

Polish oil and gas industry in the Baltic Sea area

The exploitation of underwater resources by Polish companies takes place in Poland's economic zone. In the complex process of subsea exploitation, the extraction of oil and/or gas is one of the last stages. Starting from the development of a geological model of production sites making use of geophysical survey, the operations include the assembly and fixing of drilling and production platforms and underwater systems of pipelines and networks, seaborne transport of hydrocarbons to land, movement of drilling rigs to new locations and periodical reconstruction of existing wells. Given below are upstream activities related to the oil and gas production and operation and maintenance of existing wells located in the Polish economic zone:

- exploration is performed by:
 - a) seismic reflection survey vessels *Polar Duke* and *St. Barbara* that carry out 3D seismic survey within the licensed area of exploration in fields B21 and B16 (Fig. 1), and drilling of exploration holes;
 - b) drilling holes for geophysical survey and measurements, executed by Petrobaltic Lotos Petrobaltic rigs.
- production performed by various types of rigs:
 - a) jackup – stationary production rigs;

- b) jackup – mobile drilling rigs;
 - c) jacket – stationary unmanned production rigs.
- exploration and exploitation wells are established in licensed areas; exploitation wells are used for oil and gas extraction as well as injection of deposit water and seawater filtered to optimize the production;
 - transfer of gas via an underwater pipeline to Władysławowo;
 - transshipment from a buoy near the Baltic Beta rig and carriage of oil by the mt *IKARUS III* to Gdańsk;
 - continuous supplies to the rigs by offshore vessels and supervision provided by standby vessels; at present, the vessels employed for the purpose are the tugs *Granit*, *Bazalt* and *Kambr* and support ships *Aphrodite I* and *Sea Force*;
 - jackup rigs towage to new drilling locations;
 - submarine work: diving and maintenance, use of remotely operated vehicles.

Exploration and production in the Polish sea territory cover about 29,000 km². LOTOS Petrobaltic licences for the search and identification of hydrocarbon deposits comprise eight fields with a total area of 8,200 km² in the eastern part of the Polish offshore region.

The capital group LOTOS Petrobaltic also has four licences for the extraction of oil and gas from

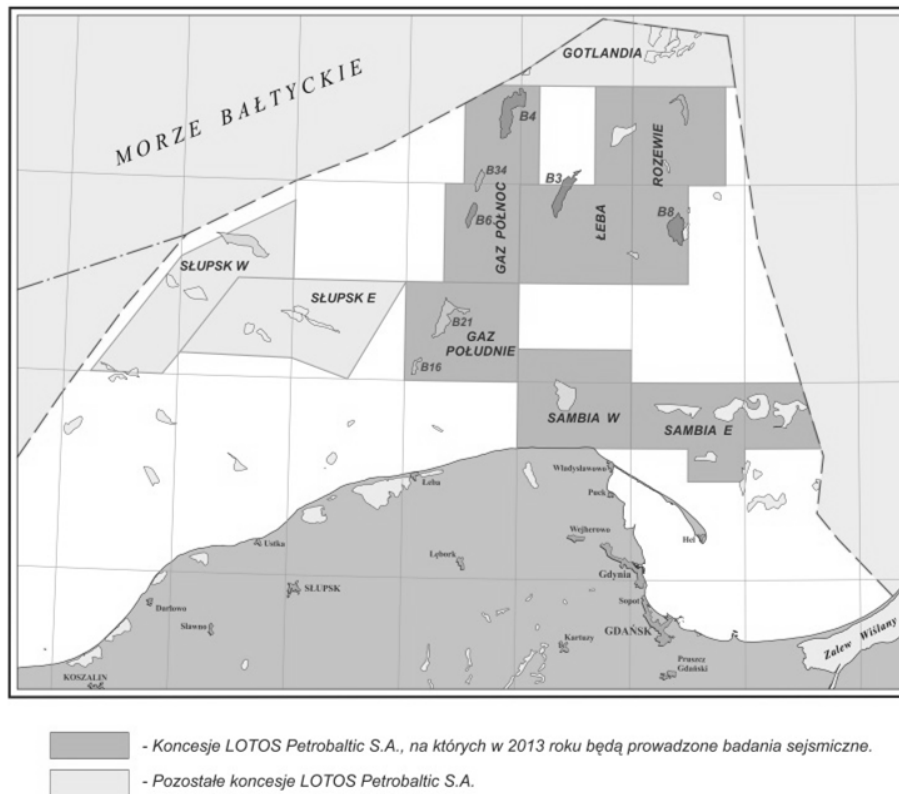


Fig. 1. Licenced areas of oil/gas production within the southern Baltic [1]

fields B3, B4, B6 and B8. At present, crude oil is produced in field B3, while in field B8 preparatory work is in progress. The map below shows areas with licences for exploration and production (Fig. 1).

Recent years have witnessed an increasingly fast rate of identifying new deposits in licenced areas. Production has been intensified by starting up unmanned rigs and installation of new jackup rigs. Geophisic reflection survey is also extending, while the existing geological models of hydrocarbon deposits are being verified.

Influence of vessel traffic on upstream activities

Statistical data analysis shows that vessel traffic does affect the safety of offshore facilities. Shipping routes and fishing grounds are getting closer to oil/gas production areas, consequently risks of collision, close quarter situations or fishing gear related hazards increase. Surface and underwater infrastructure, pipelines and wells in particular, are liable to damage. Table 1 classifies craft that may participate in collisions with offshore facilities. Of the two types of traffic, one group includes ships passing near an oil field or do work unrelated to upstream sector activities, e.g. fishing. The other group comprises vessels engaged in offshore activities.

The interaction between vessel traffic stream and offshore facilities results in collisions. Four such collisions, resulting in major production rig damage, are indicated below:

- i. 1988: Osberg B – jacket rig sank after a collision with the submarine U27. The crew was transferred to an accommodation vessel mooring by the rig;
- ii. 1995: the *Reint* en route to Aalborg crashed into a rig, despite attempts to protect the rig by a standby vessel;
- iii. 2004: a supply vessel, 5000 ton displacement, sailing at 7.3 knots struck the Vest Venture rig; both were severely damaged;
- iv. 2005: in foggy weather, a 5600 ton supply vessel proceeding at 6 knots collided with the Ekofisk rig, which sustained serious damage.

The World Offshore Accident Database, established and maintained by Det Norske Veritas (DNV), contains information on marine accidents since 1970. Our analysis making use of that database focused on collisions with mobile offshore units. A closer look at statistics shows that both jacket and jack-up platforms, such as those operated in the southern Baltic, are vulnerable to collisions and other accidents. 53.1% of dangerous events involve jacket and jack-up rigs. This is due to the mobility of jack-up platforms which relatively frequently are moved from one site to another.

Table 1. Categories of vessels that may be involved in collisions with offshore facilities

Type of traffic	Type of ship	Subtype	Remarks
Vessels moving in vicinity of offshore facilities, not involved in upstream activities	Merchant vessels	Container ships, bulk carriers, ro-ro & lo-ro ships, general cargo ships, oil / gas / product tankers	Commercial passages at distances recommended by the master or enforced by traffic safety zones
	Warships	Surface and submarine ships	
	Fishing craft	Fishing vessels and boats	Those proceeding to fishing grounds and engaged in fishing near offshore activity sites
	Passenger ships	Passenger ships, cruise ships, ferries	Ships manoeuvring at some distance from offshore activity areas
	Yachts	Sailing ships, yachts, small tourist ships	Ships entering the security zone of offshore operations
	Offshore traffic	Stand-by and supply vessels, tankers, tugs	Ships moving to other offshore areas, towing platforms, flotel, ships supplying other fields
Vessels involved in upstream activities	Offshore traffic	Standby vessels supervising an area	These ships monitor a specific area or facility
		Supply vessels	Frequent cargo and supplies handling operations
		Vessels actively participating in upstream activities, such as AHTS (Anchor Handling Tug Supply Vessel), diving, seismic survey vessels, flotel, floating cranes, cable layers and so forth	Vessels performing various functions within the offshore industry
		Tankers	Collect crude oil and gas
	Drilling rigs	MODU – Mobile Offshore Drilling Unit	Mobile rigs co-operating with stationary and jacket rigs creating risk of collision

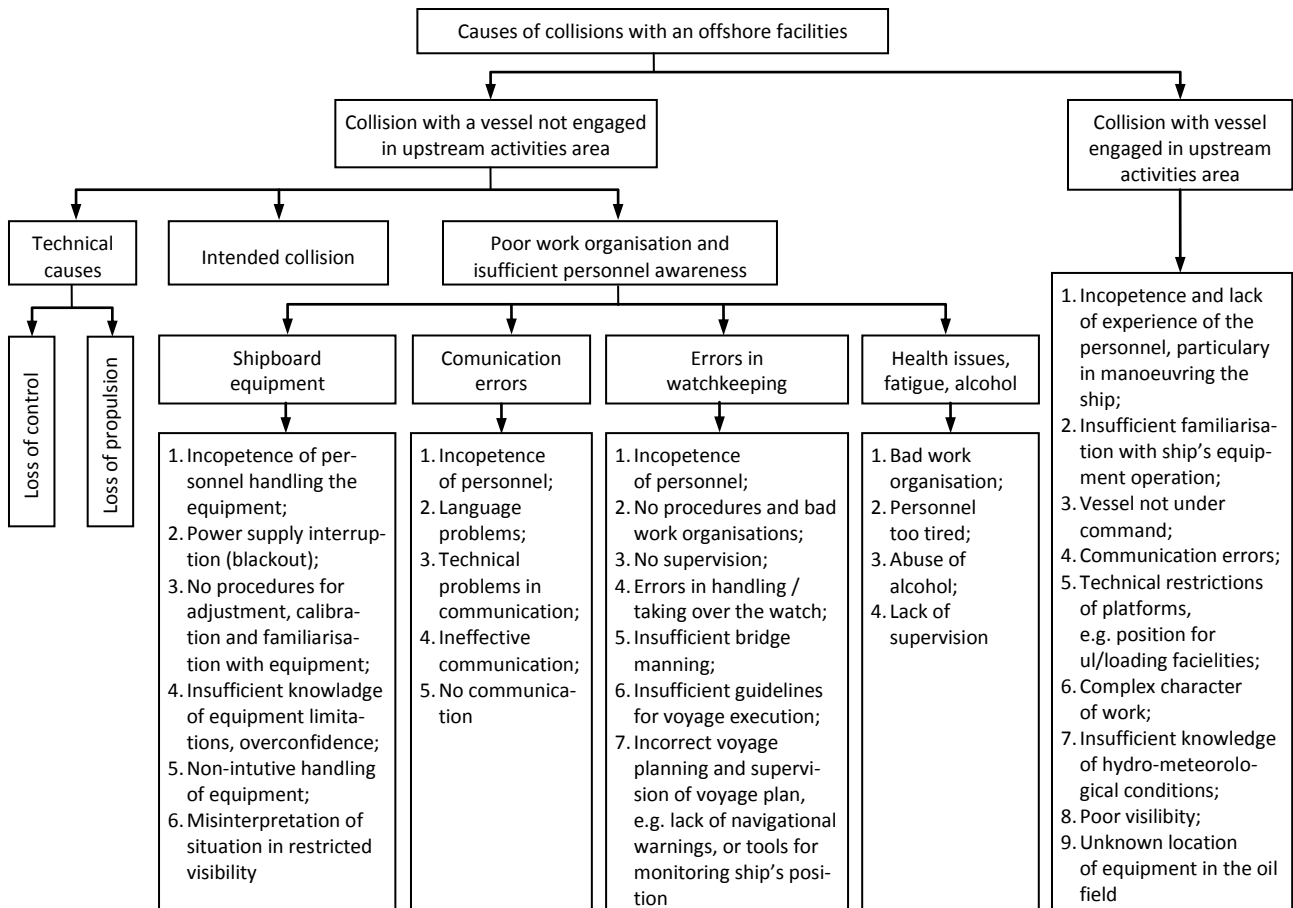


Fig. 2. Causes of collisions with offshore facilities [own study]

Such movement means platforms have to be towed between oil fields, sometimes jack-ups are established over a jacket rig to reconstruct a well or perform maintenance work.

The movement of a jack-up rig consists of a number of activities: unloading of drilling equipment, preparation of the platform for lowering onto the sea surface, pulling up the legs, towage,

re-establishment of the platform on the seabed and fitting it with drilling equipment and gear. The complexity of the process increases the probability of dangerous events. Apart from risks of collision during operation, the probability of accidents increases during un/loading operations and transport of drilling equipment, diving works, drilling. Of all the collisions with offshore facilities, those with jacket platforms and mobile jack-ups are most frequent. The total number of collisions with mobile facilities amounted to 280, while permanent installations were involved in 209 accidents in the years 1970–2014. Although the most collisions recorded were those with units working in oil fields, the serious accidents causing loss or serious damage to the facility have been those involving a passing vessel.

According to statistics, the most frequent cause of collision is human error or technical factor. Figure 2 schematically presents causes of collisions.

Methodology for probability analysis of offshore facility collisions in the southern Baltic

Estimation of the probability of collision of an offshore facility operating in the Baltic Sea can be divided into a number of functional elements, i.e. probability analyses of:

- a) collisions of units / facilities during the supply process;
- b) collisions of service-providing vessels with offshore facilities;
- c) collisions of geophysical survey vessels;
- d) collisions of vessels passing near an oil field with units engaged in field operations;
- e) damage to underwater infrastructure, such as pipelines, wells, risers, flowlines;
- f) collisions of tugs towing jack-up platforms.

The probability of collision of offshore facilities is obtained from the estimation of geometric probability accounting for human error. The commonly used geometric model incorporated in the IWRAP application is Petersen’s model [2], which divides collisions into two variants:

- 1. Collisions along vessel’s route: during overtaking or passing when vessels are on opposite courses;
- 2. Collisions of vessels on crossing courses: in areas where courses are converging, crossing or the route turns.

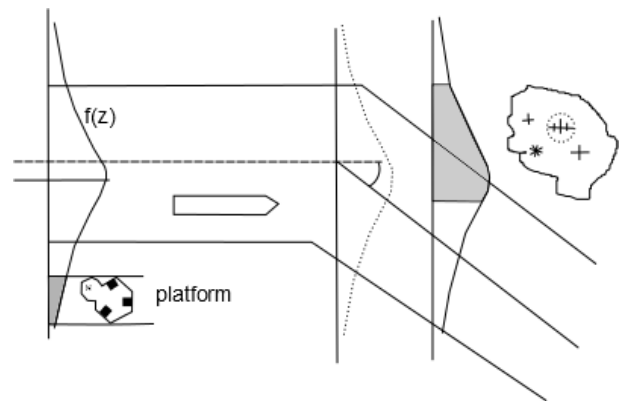


Fig. 3. A model of vessel’s collision with an offshore rig [3]

Here is a model of a vessel-platform collision:

$$C_F = N \cdot F_d \cdot P_1 \cdot P_2 \cdot P_3 \cdot P_4 \quad (1)$$

where

- C_F – frequency of collision with a platform in an assumed time interval, e.g. one year;
- N – yearly number of vessels crossing the area of platform operation, including fishing craft;
- F_d – geometric probability of an event in which a vessel is moving along a line crossing the platform position (Fig. 3);

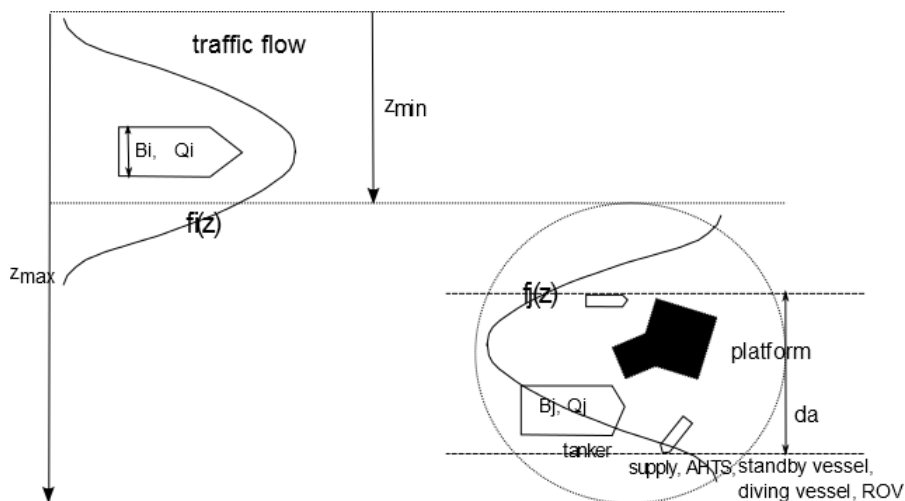


Fig. 4. Model of collision of a vessel with a platform or vessels operating in an oil field [own study]

- P_1 – probability of incorrectly prepared voyage plan;
- P_2 – probability of improper navigational watchkeeping;
- P_3 – probability of failing to respond by a platform or standby vessel after a detection of collision situation or failure to detect such situation;
- P_4 – probability of technical equipment failure.

A model of collision of a vessel proceeding in the traffic stream with an object located within an oil field can be written as follows:

$$N_a = \sum_{i,j} Q_i \tau_o Q_j P_{i,o} \quad (2)$$

where

- N_a – possible number of vessels that might collide with objects found within an oil field in examined time interval;
- Q_i – traffic intensity of i vessels;
- τ – examined time interval;
- Q_j – traffic intensity of units working within an oil field;
- $P_{i,o}$ – probability of an event in which a vessel is moving along a line crossing the oil field;
- d_a – distance between facilities within an oil field (Fig. 4);
- $F_{i,j}(z)$ – functions of probability density distribution for vessels/units i and j (Fig. 4).

Fishing area in the southern Baltic, planned wind farm installations and production and drilling rigs

Figures 5 and 6 present a map with locations of platforms in the Polish economic zone. The oil field B-3 (Fig. 5) comprises the Baltic Beta platform, tanker Ikarus III and unmanned jacket-type platform PG-1. Positions of the other platforms depend on operations within the fields B-3, B-21, B-23 and B-8 (Fig. 5). Their deployment varies depending on planned exploration and exploitation works. As the areas of these works change, so do positions where offshore platforms are to be fixed. Information on their positions and towing operations is transmitted as navigational warnings by the Hydrographic Office of the Polish Navy. Notably, many small vessels in particular, maneuvering in immediate vicinity of offshore rigs, do not receive or plot navigational warnings on their navigational charts, which raises a collision risk. This also refers to fishing vessels.

Figure 6 depicts fishing grounds and a marked network of platforms and planned wind farms. Fields B-21 and B-23 are located within fishing areas. Routes of platform supply vessels cross these

areas too. The locations of wind farms will lengthen routes of fishing vessels from ports to fishing grounds and vice versa and will densify the traffic, mainly in the area of field B-21.

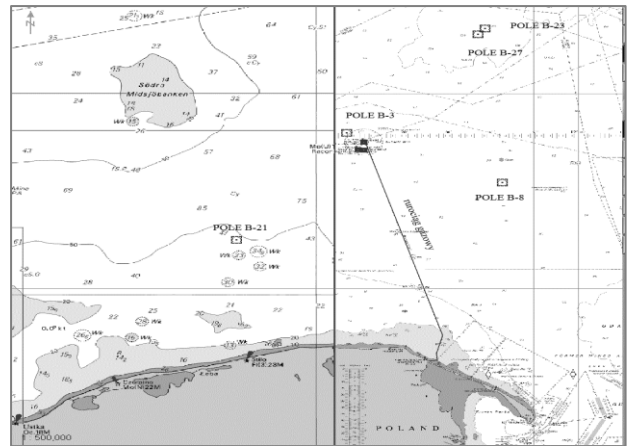


Fig. 5. A network of platforms in the southern Baltic, and marked gas pipeline [authors' sketch]

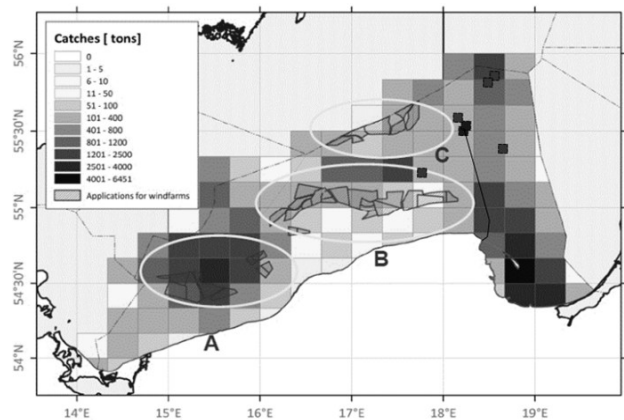


Fig. 6. A chart showing fishing grounds in the region of the southern Baltic Sea [4]

It can be seen from figure 6 that upstream sector activities in the Polish economic zone take place within fishing grounds. The platforms, supply, seismic and survey vessels as well as subsea infrastructure are vulnerable to collisions with fishing vessels. Collision risks in this region have been assessed using the IWRAP mk2 application.

Use of IWRAP mk2 for an analysis of collision probability in offshore production areas

The risk assessment was made at the Research Centre for Ship Operation Risk Analyses, Institute of Marine Navigation, Maritime University of Szczecin. The IWRAP application allows to select vessel routes leading to a given platform. Figure 7 displays traffic routes of supply and standby vessels sailing between Gdańsk or Władysławowo and the

platforms, obtained from the Automatic Identification System. The program has an option of choosing types of vessel for collision situations analysis. Figure 8 illustrates the traffic density of selected fishing vessels and superimposed platform supply routes, marked as firm lines.

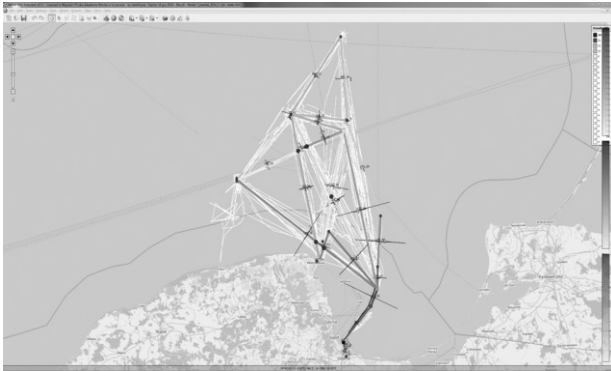


Fig. 7. Platform supply routes, the tug Kambr – platform supply and standby vessel – Jan.-March 2014

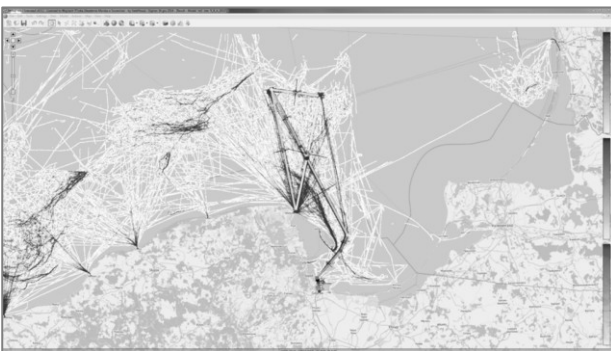


Fig. 8. Platform supply network against fishing vessels' routes

If any platform is to be relocated, appropriate navigational warnings will be broadcast. An example radio message is given below. The warnings inform about the positions of established platforms and planned or continued towage. Here is a specimen message actually sent by the Hydrographic Office of the Polish Navy.

NAVIGATIONAL WARNING NO156
SOUTHERN BALTIC
PLATFORM LOTOS PETROBALTIC IS BEING
TOWED BY THREE TUGS:GRANIT, AKUL AND
URAN FROM POSITION:
LAT:55-10,400°N LONG:017-41,600°E
TO POSITION:
LAT:55-21,200°N LONG:018-42,500°E
NAVIGATE WITH CAUTION

The mentioned mobility of offshore units engaged in production and related operations changes the route patterns of supply vessels, which in turn affects the probability of collisions. IWRAP mk2 has been used to analyze collision probabilities for various configurations of platform positions.

Figure 9 presents example arrangements of the testing ground. Vessel traffic streams described by traffic density have been superimposed on the network of platform positions and supply routes. Platform supply vessels depart from the ports of Gdańsk and Władysławowo, usually heading for each of the platform in turn. The analyses of collision probability have been performed for operational scenarios involving: two platforms, Baltic Beta and PG-1; three platforms, Baltic Beta, PG1 and one mobile unit; four platforms, Baltic Beta, PG-1 and two mobile rigs. Collision risks have been estimated for each of these vessel types:

- a. Crude oil tanker;
- b. Oil product tanker;
- c. Chemical tanker;
- d. Gas tanker;
- e. Container ship
- f. General cargo ship;
- g. Bulk carrier;
- h. Ro-Ro cargo ship;
- i. Passenger ship;
- j. Fast ferry;
- k. Support ship;
- l. Fishing ship;
- m. Pleasure boat;
- n. Other ship.

The analysis results represent total probabilities of collision situations of vessels:

- a. on opposite courses;
- b. while overtaking;
- c. on crossing courses;
- d. on route turns;
- e. on convergent routes;
- f. in areas with declared traffic density.

Specimen results for diagram 2 (Fig. 9), are given in table 1.

Table 1 contains analysis results of traffic density from the first three months of 2014. Depending on the tested period, the probability of collision in the platform's supply network can be estimated for each route configuration. Estimated risk of vessel-platform collision can be obtained by adopting the platform position as a waypoint in the IWRAP application. Then traffic densities of vessels on platform collision courses should be examined. Such model can be supplemented with data from simulation or expert methods. The following scenarios have been analyzed:

- 1) two platforms in operation in field B-3: Baltic B and PG-1 (to date – permanent installations);
- 2) three platforms in operation: two in field B-3 and one in a selected field: B-8, B-7 or B-21;

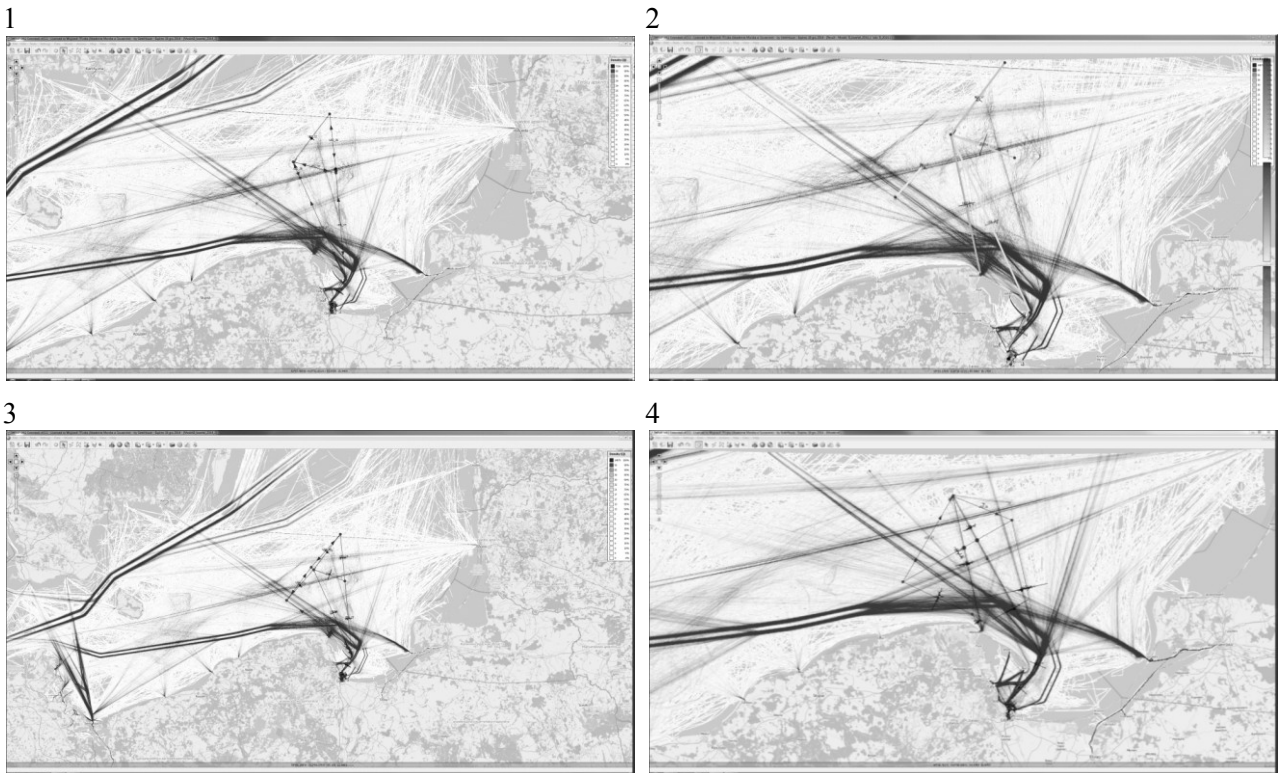


Fig. 9. Example locations of platforms and traffic density in their operating areas. Traffic density data – Jan.-March 2014

Table 1. Probabilities of collision situations calculated by IWRAP mk2 application

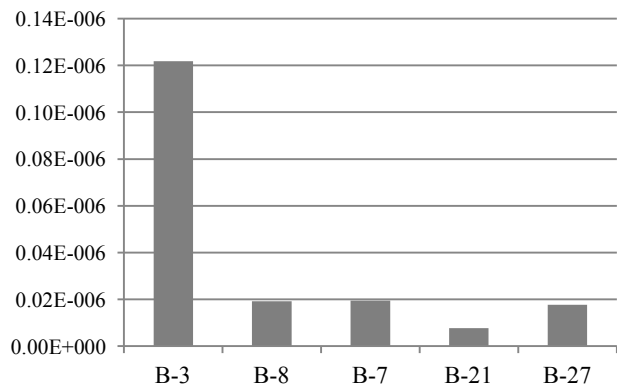
	Crude oil tank	Oil products t	General carg	Passenger sh	Fast ferry	Support ship	Fishing ship	Pleasure boat	Other ship	Sum
Crude oil tanker										
Oil products tanker	5,24E-006	3,96E-005	1,67E-006	4,13E-008	3,76E-005	3,15E-006	6,41E-007	7,11E-006	9,50E-005	
General cargo ship	3,14E-005	0,00028915	1,40E-005	3,01E-007	0,00022365	2,51E-005	3,96E-006	6,04E-005	0,00064797	
Passenger ship	1,30E-006	1,22E-005	4,90E-007	9,79E-009	7,98E-006	8,34E-007	1,25E-007	2,82E-006	2,58E-005	
Fast ferry	5,87E-008	4,99E-007	2,21E-008	5,31E-010	3,59E-007	1,77E-008	1,07E-008	6,41E-008	1,03E-006	
Support ship	2,77E-005	0,00023185	9,80E-006	2,02E-007	0,00014952	1,83E-005	2,92E-006	4,48E-005	0,00048506	
Fishing ship	1,61E-006	2,18E-005	8,02E-007	4,95E-009	1,28E-005	3,35E-006	2,64E-007	7,35E-006	4,80E-005	
Pleasure boat	3,87E-007	3,05E-006	1,23E-007	5,23E-009	2,09E-006	2,04E-007	5,39E-008	5,94E-007	6,50E-006	
Other ship	5,67E-006	6,73E-005	3,10E-006	3,39E-008	5,05E-005	8,24E-006	7,24E-007	1,67E-005	0,00015229	
Sum	7,34E-005	0,00066546	3,00E-005	5,98E-007	0,00048454	5,92E-005	8,70E-006	0,00013973	0,00146165	

3) four platforms in operation: two in field B-3 and two in selected fields: B-8, B-7, B-21 or B-27.

In the period under consideration, April-June 2014, four platforms were working: Baltic Beta, PG-1, Petrobaltic and Lotos Petrobaltic. Each platform location variant should be examined. Periodically, due to reconstruction work and classification surveys all examined arrangements are realistic.

It follows from the results that the most intensive vessel traffic is observed within the operating area of field B-3, with two platforms and a tanker. The chart below illustrates probabilities of collisions of vessels supplying the platforms for various arrangements of platform positions. The probabilities of collision are also presented as functions of encounter types.

The above data can be used for an analysis of collision risks depending on the locations of platforms and associated arrangements of supply routes. Other data, presented in figure 14, provide



Areas of platform operation	
B-3	1.21832E-05
B-8	1.91194E-06
B-7	1.94064E-06
B-21	7.71398E-07
B-27	1.76202E-06

Fig. 10. Probability of collision with platforms located in fields B-3, B-8, B-7, B-21 and B-27

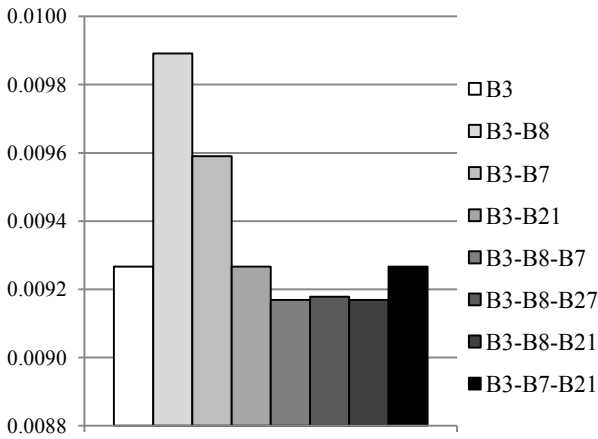


Fig. 11. Probability of collision of supply vessels serving the platforms located in fields B-3, B-8, B-7, B-21, B-27

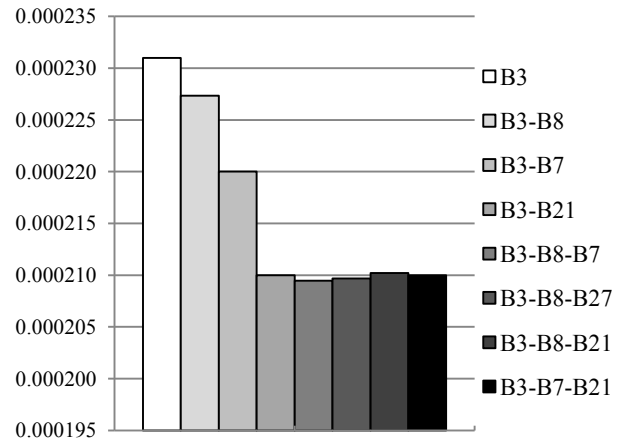


Fig. 12. Probability of collision of vessels supplying the platforms engaged in fields B-3, B-8, B-7, B-21, B-27 with fishing vessels.

a basis for the estimation of risks faced by facilities operated in the oil/gas fields depending on the type of vessels creating threats. The data in the charts illustrate risks created by fishing vessels.

Analyzing the above data for the impact of fishing vessels operating in offshore fields we can state that fishing vessels created greatest collision risks in fields B-3 and B-21. In fields B-8 and B-7 general cargo ships make up a group imposing the highest risk. Although fishing vessels in those fields create lower collision risk, in field B-8 they are second in terms of collision risk.

Conclusions

An expanding network of oil and gas production facilities in the southern Baltic and planned wind farms call for an analysis of risks of collision of offshore platforms with cargo and fishing vessels. IWRAP application has proved to be a suitable tool for building a relevant risk model.

Frequent changes of geographical positions of jack-up platforms and related towing operations create collision risk.

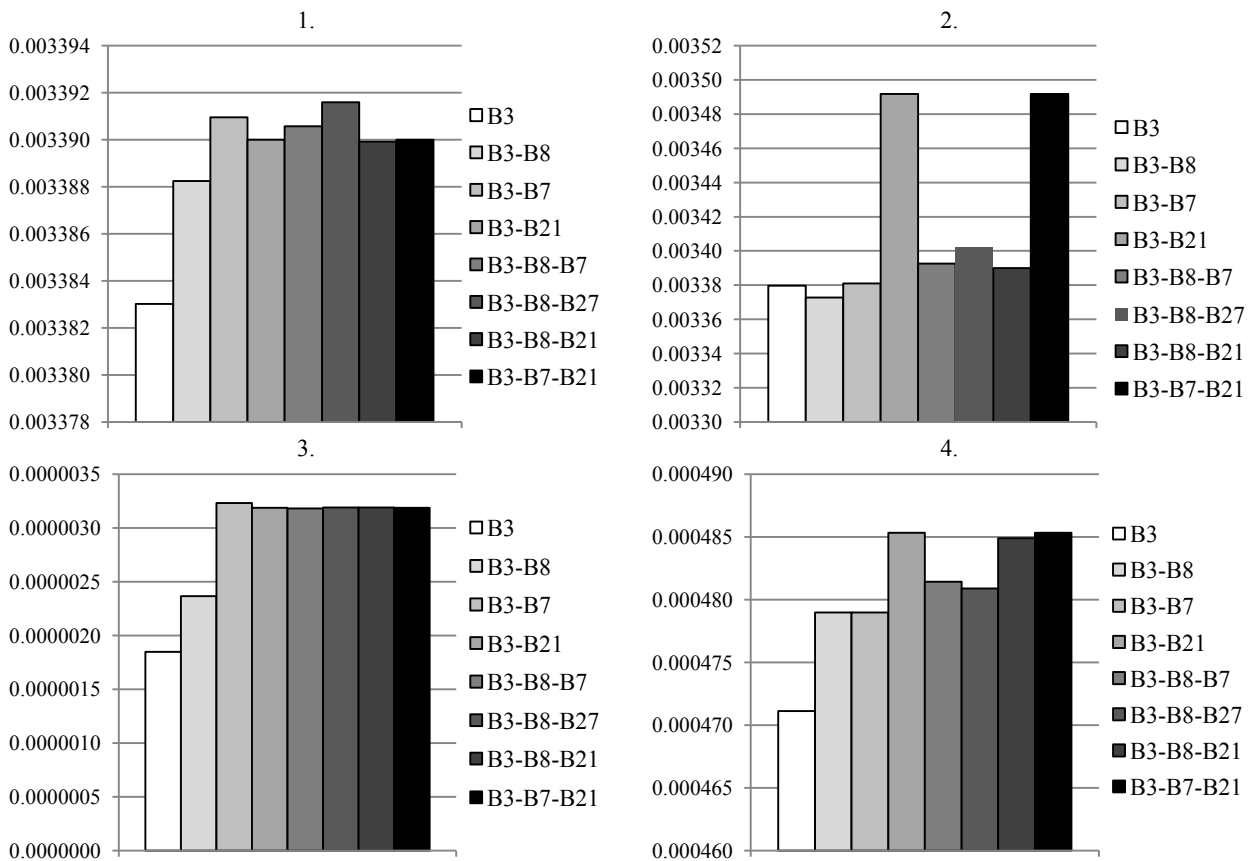


Fig. 13. Probability of collision with vessels supplying the platforms operating in fields B-3, B-8, B-7, B-21, B-27 depending on the type of encounter: 1. on opposite courses, 2. overtaking, 3. crossing courses, and 4. on convergent courses

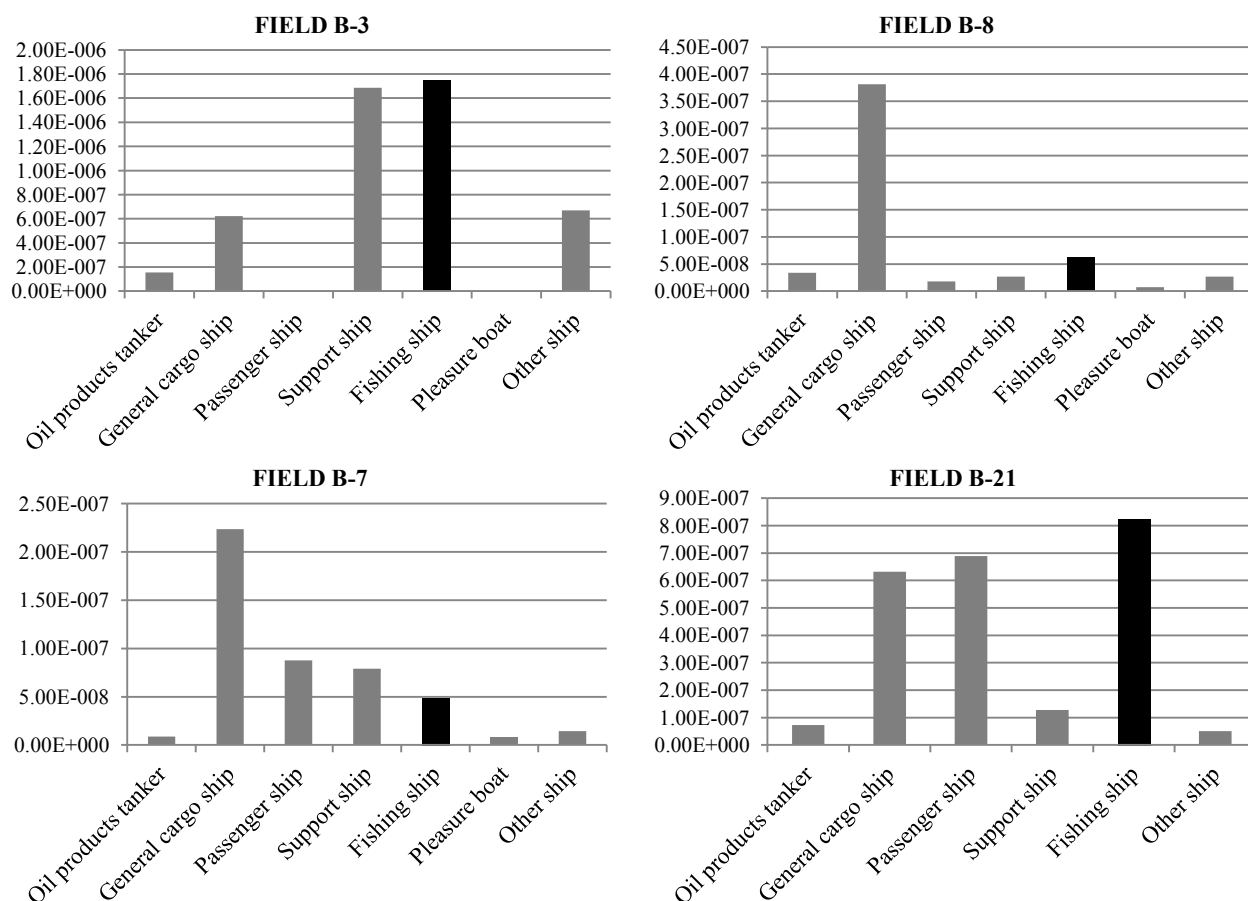


Fig. 14. Probability of collision of various type ships with vessels located in fields B-3, B-8, B-7 and B-21 including fishing vessels

The platforms and gas pipeline are situated in the fishing areas, which entails a risk of damage to the installation.

Collisions are caused due to high density of vessel traffic in the examined area and other factors: human error, variable weather conditions, technical reasons, low quality of voyage planning, insufficient update of navigational information.

Analyses based on AIS data do not provide completely true probabilities of collisions with fishing craft as vessels or boats less than 15 metres in length are not obliged to carry an AIS system. It seems imperative that fishing vessels regularly participating in marine traffic should be fitted with AIS system. Further research shall be based on VMS data.

In the future, a probabilistic model of collisions will also be based on expert and simulation tests.

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