

# The model of oil spills due to ships collisions in Southern Baltic area

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**ABSTRACT:** The paper presents implementation of probabilistic ships collision model to evaluation of possible oil spills in the Southern Baltic Sea area. The results of the model is time, place and size of the oil spill due to ships collision. The results could be used for oil spill response action plans. The paper will open the discussion about validation of achieved results and will try to answer the question about verification of Baltic Sea oil spills data in comparison to worlds statistics.

## 1 INTRODUCTION

The collision between ships, grounding and fire on board are most contributing factor in ship accident. The consequences of this three kind of accidents especially on coastal waters due to possibility of oil spill could be catastrophic. The paper presents methodology of ships accident probability evaluation in different conditions with use of complex stochastic safety model and real statistical data.

To achieve the aims of the paper stochastic model of ships traffic was developed and applied on the Southern Baltic Sea area. The model is capable to assess the risk of large complex system with consideration of human (navigator) behaviour models, ship dynamics model, real traffic streams parameters and external conditions like wind current visibility etc (Fig. 1). The model works in fast time and could simulate large number of scenarios.

In the second step the statistical data of real collision accidents was collected. With the number of collision situations, assessed, in previous step, the collision probability in different scenarios was evaluated. This probability of collision in different encounter situations was estimated.

In the third stage of researches calibrated model was run with the traffic data estimated at level 2010 and routing schemes introduced in 2006. The output from model as collision place, ships involved,

navigational conditions could be useful for further risk assessment.

## 2 STOCHASTIC MODEL OF SHIPS ACCIDENTS

One of the most appropriate approach to assess the safety of complex marine traffic engineering systems is use of stochastic simulation models [Gucma 2005, Gucma 2003]. The model presented on Figure 1 could be used for almost all navigational accidents assessment like collisions, groundings, collision with fixed object [Gucma 2003], indirect accidents such as anchor accidents or accidents caused by ship generated waves [Gucma & Zalewski 2003]. The model could comprise several modules responsible for different navigational accidents.

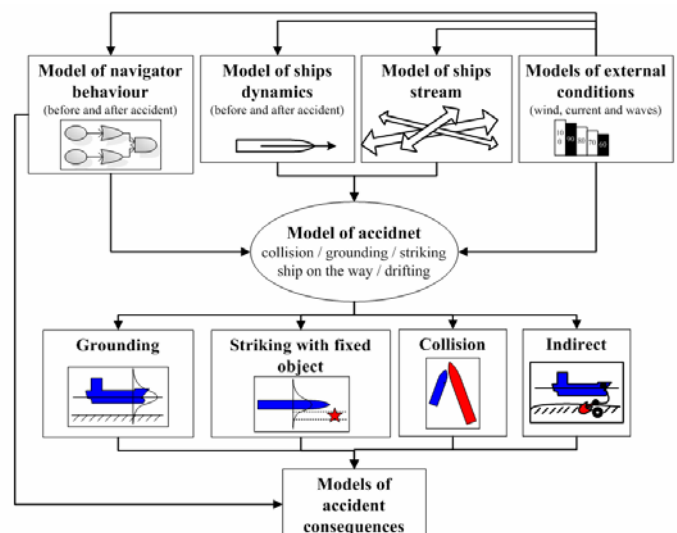


Fig. 1. Diagram of fully developed stochastic model of navigation safety assessment

This methodology was used already by several authors before with different effect [Friis-Hansen & Simonsen 2000, Merrick et al. 2001, Otay & Tan 1998]. In presented studies the model was used to assess the probability of oil spills in the Baltic Sea area.

## 2.1 Traffic data

There are several sources of data necessary for the running of simulation model. The data of traffic was obtained by analysis of AIS records [Assessment 2005] Polish national AIS network studies, and statistics of ships calls to given ports. The weather data was obtained from Polish meteorological stations and extrapolated in order achieve open sea conditions [Risk 2002]. The navigation data was obtained from navigational charts, guides and own seamanship experience.

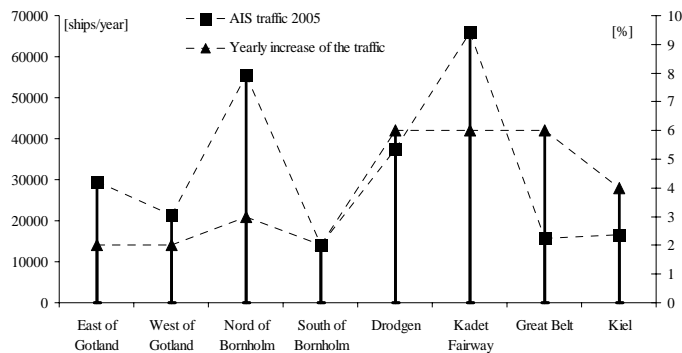


Fig. 2. Traffic of ships and its increase on analyzed part of the Baltic Sea

## 2.2 Collision accident models

To model the collisions simplified statistical model is used. The model neglects several dependencies but because it is based on real statistical data the achieved results are very close to reality. The most unknown parameter necessary for collision probability assessment on large sea areas is number of ships encounter situations. In complex systems with several traffic routes this number could be evaluated only by traffic streams simulation models such as the one presented in this study.

The traffic of ships is modelled by nonhomogenous Poisson process where actual intensity of traffic is evaluated on the basis of real AIS (Automatic Identification System) data from the Helcom network which is operated since mid 2005. The collected AIS data is used also for determination of ships routes, types, length and draught distribution. The variability of mean ships routes is modelled by two-dimensional normal distribution which parameters were estimated by

AIS data and expert-navigators opinion. New ships routings were considered. Routes are presented on Figure 7. Ships traffic and its annual increase in different Baltic Sea regions is presented on Figure 2.

After collecting necessary input data the simulation experiment was carried out and the expected number of encounter situation was calculated. The critical distance where navigators perform anti-collision manoeuvre was assumed on the base of expert opinion separate for head on (heading difference  $\pm 170^\circ$ ), crossing and overtaking situations (heading difference  $\pm 10^\circ$ ). These distances called minimal distances of navigators reaction were estimated by expert opinion and real time non-autonomous simulation experiment performed on ARPA simulator. The mean distances of reaction were estimated to 0,35; 1,0; 0,45 Nm for head on collision avoidance, crossing and overtaking [Kobayashi 2006].

The overall number of encounter situation estimated by simulation model are around 140000 per year where 30% of them are head on situations, 40% of crossing and 30% of overtaking (Figure 3).

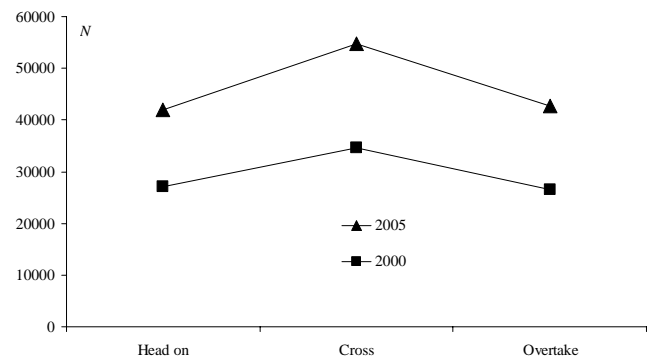


Fig. 3. Simulated number of encounter situations N (the influence of traffic increase)

Statistical data from southern part of the Baltic Sea accidents were used for evaluation of mean intensity of ship collision accidents in the Southern Baltic. The number of accidents significantly increase mostly due to traffic increase. Only the accidents on the open sea area was considered. Figure 4 presents number of accidents per year on the investigated area.

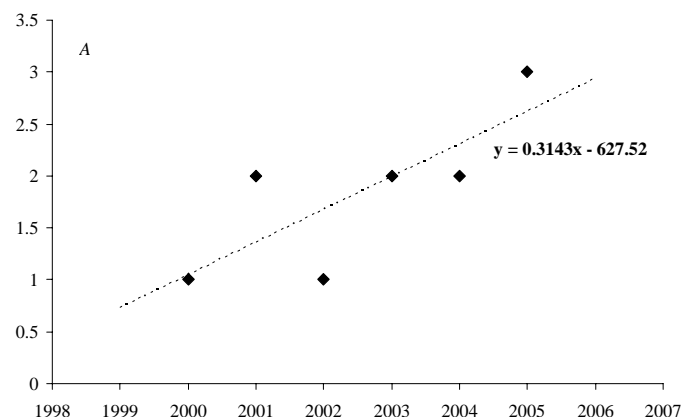


Fig. 4. Number of collision accidents per year (A) located at the open sea of the Southern Baltic

Data presented on Figure 4 and the simulation results of ships encounter situation (Figure 3) have been used for estimating the number of collisions. To simplify the calculations it was assumed that probability of collision is equal in all considered situations. The existing databases of real accidents scenarios justify this assumption.

The calculated probability of collision in single encounter situation (Figure 5) is higher than  $1 \cdot 10^{-5}$  which is the typical mean value of probability used in safety of collision assessment. The difference between probability in 2000 and 2005 can be justified only by the error of estimation and simplicity of applied model. Normally minor decrease of collision probability could be expected due to better navigational and positioning systems, traffic regulations, better training of navigator.

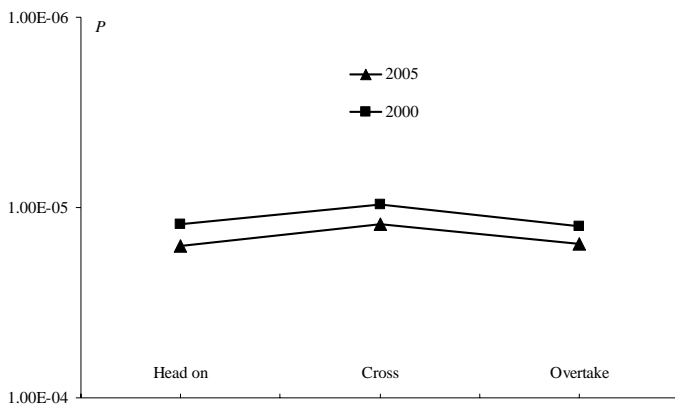


Fig. 5. Probability of collision accident (P) in different encounter situations in 2000 and 2005

### 3 OIL SPILLS

The collision, grounding and fire on ship accident could be followed by the oil spills. The conditional probability is used and finally the probability of oil spill accident ( $P_S$ ) is calculated as follows:

$$P_S = P_A P_{A/OS}$$

where:  $P_A$  = probability of accident;  $P_{A/OS}$  = conditional probability of oil spill if accident occur.

Several databases [MEHRA 1999, ITOPF 1998, MAIB 2005, LMIS 2004, HECSALV 1996, IMO 2001] was used to find the conditional probability of oil spills if given accident occurs. Fig. 6 shows conditional probability of oil spills in different accidents.

Oil spills due to collision is estimated with the double bottom tankers with relation to ships size expressed in DWT. Identical procedure was followed to find probability of oil spill after grounding and fire. Fire on ships is highly unlikely to

be the result of oil spill. Only about 10% of such accident is ended with oil spill.

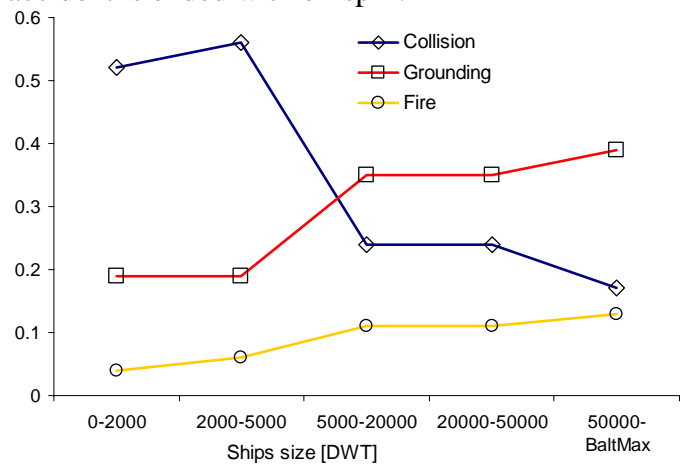


Fig. 6. Conditional probability of oil spill if given kind of accident occurs

#### 3.1 Estimation of size of oil spill after collisions

To evaluate the probability oil spill size after ships collision several databases and another study results was used [MEHRA 1999, ITOPF 1998, MAIB 2005, LMIS 2004, HECSALV 1996, IMO 2001]. The simplified statistical model is used. The model assumes that the size of oil spill is dependant only of ships size expressed in DWT in tons. The results are presented on Figure 7.

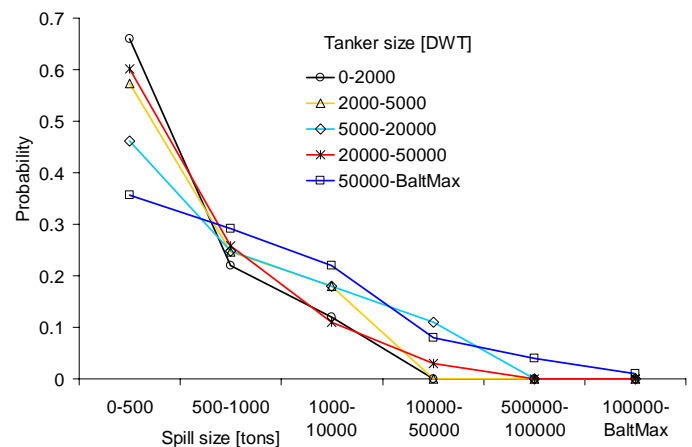


Fig. 7. The probability of given oil spill size for different size of tankers in collision accident

### 4 BUNKER SPILLS

Bunker spills was estimated with use of accident databases [MEHRA 1999, ITOPF 1998, MAIB 2005, LMIS 2004, HECSALV 1996, IMO 2001]. The following formula is used for finding the bunker spill accident probability:

$$P_{BS} = P_A P_{A/BS}$$

where:  $P_A$  = probability of accident;  $P_{A/BS}$  = conditional probability of bunker spill if accident occur.

It was found that the conditional probability of bunker spill is dependant only of kind of accident and for collision equals  $P_{BS/C}=0.125$  for grounding  $P_{BS/G} = 0.12$  and the for fire accidents  $P_{BS/F} = 0.017$ .

To find the size of bunker spill the mean capacity of bunker tanks in different ships was used. It was assumed that only 50% to 30% of bunker could be spilled after accident. This value is dependant of ships size. The results as mean bunker spill can was fitted to exponential function (Fig. 8).

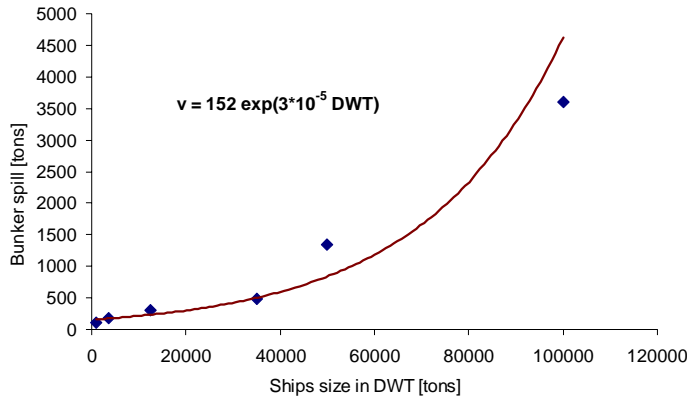


Fig. 8. The model of bunker spill size

## 5 RESULTS

New routing measures in South Baltic are adopted in July 2006. Traffic separation scheme established north of Bornholm significantly changed the traffic layout in the Southern Baltic Sea. The most reliable accident database is carried out by Maris database of Helcom. The accident statistics between 2000 and 2005 are presented on Figure 9.

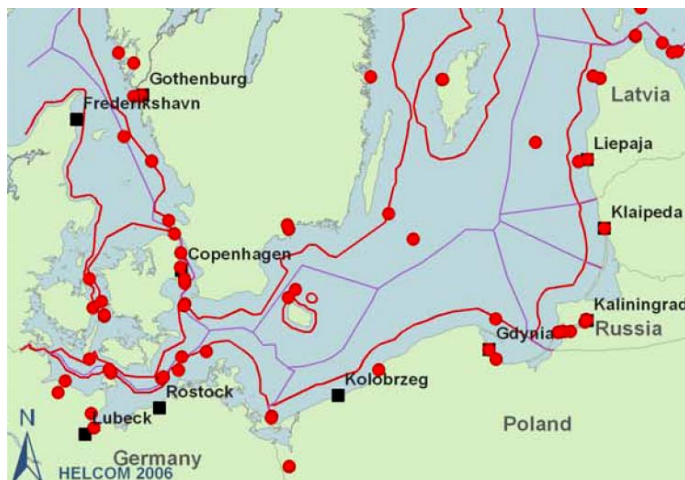


Fig. 9. Statistical data of collision accidents on the Southern Baltic Sea (2000-2005) [Helcom 2006]

The real oil spill accident are presented in Table 1. Mean intensity of oil spill accidents in Southern Baltic Sea equals **0.20** oil spill per year which gives mean time between accidents equals **5.0** years.

Table 1. The major oil spill accidents on whole Baltic Sea

Year	Name of ship	Oil spill [t]	Location
2003	Fu Shan Hai	1,200	Bornholm, Denmark/Sweden
2001	Baltic Carrier	2,700	Kadetrenden, Denmark
1998	Nunki	100	Kalundborg Fjord, Denmark
1995	Hual Trooper	180	The Sound, Sweden
1990	Volgoneft	1,000	Karlskrona, Sweden

In the further step the presented simulation model was applied for the Southern Baltic Sea region to assess the expected number of collision. The following assumptions have been made:

- traffic of ships with new routing measures applied;
- traffic on estimated level in 2010 year applied according to Figure 2;
- time of simulation: >1000 years until stabilization of parameters is achieved;
- the mean encounter reaction distances same as for probability of collision evaluation;
- no influence of weather for simplification reasons.

The results of simulation are presented on Figure 10. The simulated intensity of collision is 2.33 per year (mean time between accidents 0.42 years) and the intensity of collision ended with oil spill is **0.36** per year (mean time between accidents **2.76** years).

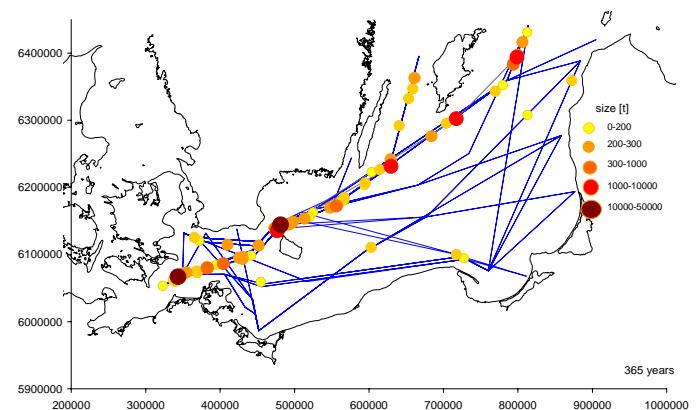


Fig. 10. Simulated collision accidents with constant traffic estimated at 2010 year (within 365 years of simulation 77 collision with oil spill observed)

## 6 CONCLUSIONS

Stochastic model of navigational safety was applied to assess the safety of Southern Baltic in respect of

oil spills. The traffic on expected at 2010 level and new routing schemes on the Baltic Sea was applied. As it was expected the number of accidents will increase significantly.

The collision probability in different conditions (meteorological, traffic, navigational) evaluated in this researches will be used in the further step as the input value in navigational risk assessment models on large costal areas. The evaluation of ships traffic influence on environment due to possible oil spills after collision is also presented.

The comparison of simulation results with real data of oils spills are little surprising. As it was presented the simulated time between oil spills accidents is almost twice as high as real data. It should be clearly stated that oil spill accidents are very rare events and high uncertainty in presented simulation should be considered. The results achieved in this paper should be considered as hazardous and all necessary precautions against accident should be taken into account.

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