Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2016, 45 (117), 196–201
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/106

Received: 31.08.2015
Accepted: 17.02.2016
Published: 25.03.2016

Factors influencing grounding probability in the Baltic Sea area – quantitative assessment

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Key words: vessels grounding causes, grounding probability coefficient, navigational safety, quantitative assessment, research area, internal factors

Abstract

This paper presents the process of quantitative assessment of selected factors influencing the probability of grounding. All grounding accidents that occurred during one year (2013) in the Baltic Sea area were analysed. The research area was chosen because of very high traffic intensity and a large number of narrow passages that make it difficult for navigation. The research period was limited by the latest data reported by HELCOM up to the year 2013. The Method of Grounding Probability Coefficient (GPC) calculation is proposed to reach the assumed goal. Either internal factors such as the ships size and ship type or external factors such as time of day, wind force and season were taken into account. As a result the values of coefficients describing the impact of various factors on the probability are evaluated. This coefficients, taking into consideration coupling effect, can be used in future in the navigational safety simulation models based on the assumed value of accident probability.

Introduction

The Baltic Sea is one of the busiest sea areas in the world. Statistical data based on the AIS records gathered by HELCOM shows that in some places the intensity of traffic is higher than 50,000 passages per year, which gives on average more than 5 passages per hour. Intensity and spatial distribution of ship traffic in the Baltic Sea during 2013 is shown in Figure 1.

High traffic intensity and navigational obstacles such as sandbanks, narrow passages etc. make the Baltic Sea a navigationally difficult area, with a relatively high number of accidents. According to the reports from the HELCOM Contracting States the average number of accidents per year equals c.a. 130 for the last 10 years. The number of reported accidents in the years 2004–2013 are shown in Figure 2.

According to data from HELCOM the most frequent type of accidents are groundings, contacts defined as striking any fixed or floating object other than ships or underwater objects (wrecks etc.) and collisions. The share of types of accidents in 2013 is shown in Figure 3.

Causes of accidents

According to HELCOM report (HELCOM, 2014) the main cause of accidents in 2013 was human element (28%). Technical failure accounted for 19%, 9% were due to external causes and 1% due to structural failure. In 2013 the cause of the accidents was reported as unknown for 43% of the accidents. The percentage share of accident causes for 2013 is comparable to average values for the Baltic Sea area. The causes of accidents for years 2004–2013 are given in Table 1 (HELCOM, 2004–2013).

The classification of accident causes presented in the HELCOM reports is very simplified, more detailed lists of factors influencing probability of grounding can be found in literature.

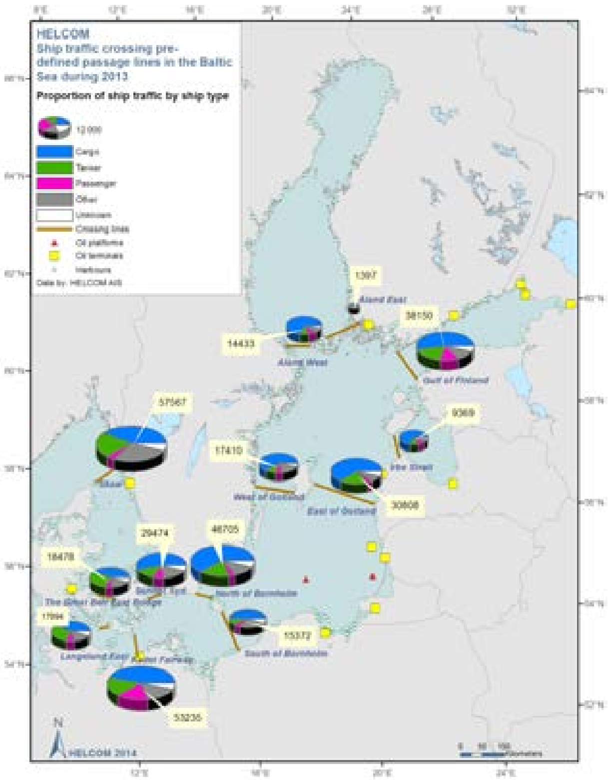

Figure 1. Spatial distribution of ships traffic in the Baltic Sea during 2013 with proportion by ship type (HELCOM, 2014)

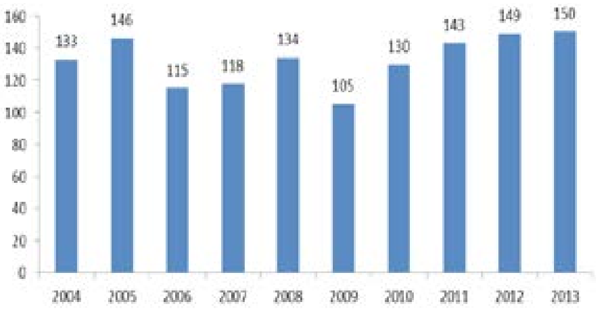

Figure 2. Number of reported accidents in the Baltic Sea (HELCOM, 2014)

A comprehensive classification is proposed e.g. by Gucma (Gucma, 2009), Stornes (Stornes, 2015):

- external:
  - area: width, depth, shape, etc.;
  - positioning systems: accuracy, availability, number, etc.;

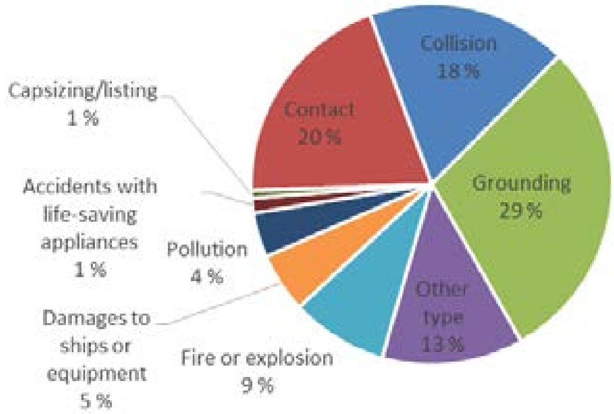

Figure 3. Distribution of types of accidents in the Baltic Sea in 2013 (HELCOM, 2014)

  - hydro meteorological conditions: wind, current, visibility, etc.;
  - other ship traffic: size, intensity, speed etc.;
  - vessel traffic systems and aids to navigation: VTS service, pilotage, AIS etc.;
- internal:
  - vessel: dimensions, propeller, steering devices, cargo, manoeuvring parameters, etc.;
  - equipment: navigational systems, ECDIS, ARPA, radar, communication, positioning, bridge ergonomics, etc.;
  - management: ships procedures, emergency procedures, route planning, publication correction, etc.;
- human factor:
  - master, pilot, OOW: education, fatigue, experience, stress, fear, self-confidence, amount of information, etc.;
  - external and internal communication: language problems, misunderstandings, etc.;
- other.

Factors which impact can be assessed quantitatively on the basis of gathered statistical dataset were selected for further research. Wind speed, season, time of day, size of vessel, type of vessel and partly human factor are taken into account.

Grounding Probability Coefficient

To assess the relationship between selected factors and a frequency of groundings, Grounding

Table 1. Percentage share of accidents causes for years 2004–2013 in Baltic Sea area

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean
Human factor	39%	42%	36%	32%	47%	52%	30%	50%	43%	28%	40%
Technical factor	20%	26%	15%	20%	13%	20%	20%	22%	17%	19%	19%
External factor	6%	6%	9%	12%	18%	15%	9%	17%	4%	9%	11%
Other factor	8%	19%	5%	4%	7%	8%	5%	5%	0%	1%	6%
No information	27%	7%	35%	32%	15%	5%	36%	6%	36%	43%	24%

Probability Coefficient (GPC) is proposed. The value of this coefficient can be calculated by the following general formula:

$$GPC = f_A / f_F \quad (1)$$

where:

f_A – percentage share of groundings occurred in the presence of factor;

f_F – percentage share of factor.

Calculated coefficients can be used in future to improve the navigational safety simulation models based on the assumed value of accident probability e.g. a stochastic model for navigational safety assessment SMOB developed in IMTE Szczecin (Przywarty, 2012). However it has to be underlined that the calculated GPC values cannot be directly used into an accident prediction model, because of the coupling effects which should be taken into consideration. In this case, Bayesian Theorem can be a good support to describe the conditional probability which may be a good interpretation for the contribution to the grounding (Yin, Mou & Wen, 2010).

Results

Wind speed

Heavy weather conditions and especially strong wind can be a cause of groundings because of a drifting vessel with technical problems or an anchor dragging. On the other hand during the heavy weather the watch is carried out with increased attention, which can reduce the probability of mistakes. Information about wind speed during the groundings was gathered from accident reports available via internet databases (MAIB, GISIS, and HELCOM) or from weather databases. Parameters of distribution of wind speed were evaluated on the basis of data form Admiralty Sailing Directions, Baltic Pilot vol. I–III (UKHO NP18, 2012; UKHO NP19, 2014, UKHO NP20, 2013).

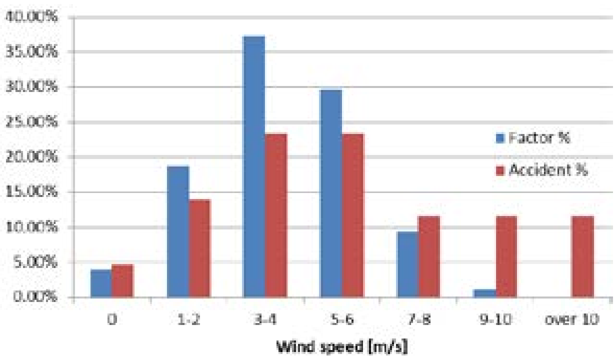

Figure 4. Percentage distributions of wind speed and groundings occurred in the presence of given wind speed

Table 2. Calculated values of GPC according to wind speed

Wind speed [m/s]	Share	Number of groundings	Share	GPC
0	4.01%	2	4.65%	1.16
1–2	18.66%	6	13.95%	0.75
3–4	37.21%	10	23.26%	0.63
5–6	29.56%	10	23.26%	0.79
7–8	9.34%	5	11.63%	1.24
9–10	1.16%	5	11.63%	9.98
over 10	0.06%	5	11.63%	201.51

The percentage shares of wind speed and groundings are presented in Figure 4. The calculated values of GPC are shown in Table 2. The results show high correlation of speed of wind and grounding frequency.

Season

In order to assess the effect of the season on the frequency of the groundings, monthly distribution of accidents were determined. Results of the analysis are presented in Figures 5 and 6. The results show higher frequency of groundings during late autumn, winter and at the beginning of spring (October – April).

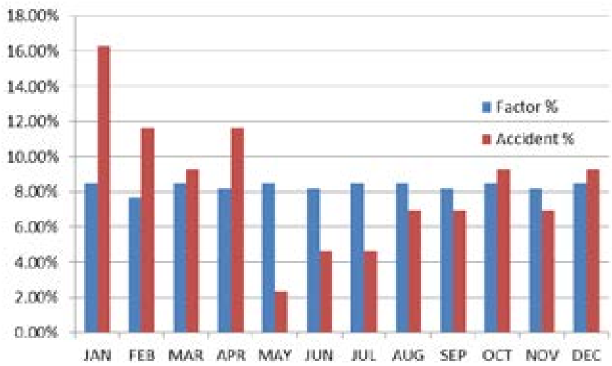

Figure 5. Percentage distributions of days of month and groundings according to months

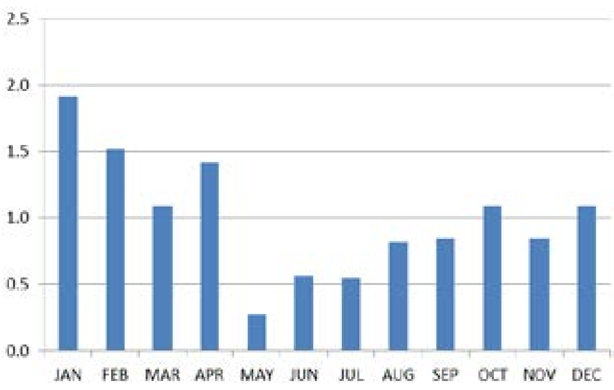

Figure 6. Values of GPC according to month

Time of day

To assess the effect of time of day on grounding frequency first the distribution of grounding percentages were determined in a two-hour period. The results are presented in Figures 7 and 8. They show an increase of the frequency of grounding in the afternoon and evening (12:00–22:00).

In the second stage, on the basis of the evaluated time of sunrise and sunset for each accident, the percentage distribution of groundings that occurred during a given time of day were calculated. Day (24 hrs) was divided into three parts:
- day – from sunrise to sunset;
- twilight – from half an hour before sunrise to half an hour after sunset;
- night – from half an hour after sunset to half an hour before sunrise.

Results are presented in Figures 9 and 10. The results do not show a significant dependence between grounding frequency and time of day.

In the third stage the possible effect of improper handling / taking over a navigational watch was studied. In order to calculate the GPC values the navigational watch was divided into two parts:

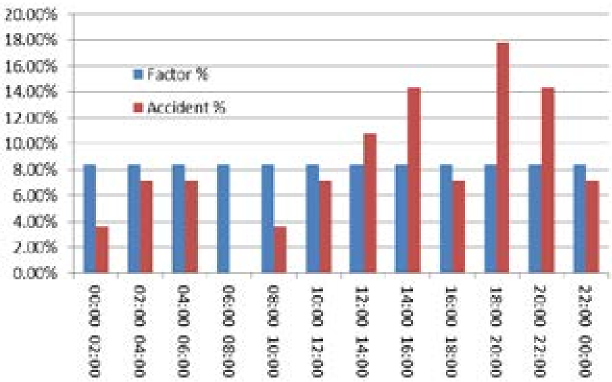

Figure 7. Percentage distribution of groundings according to hour

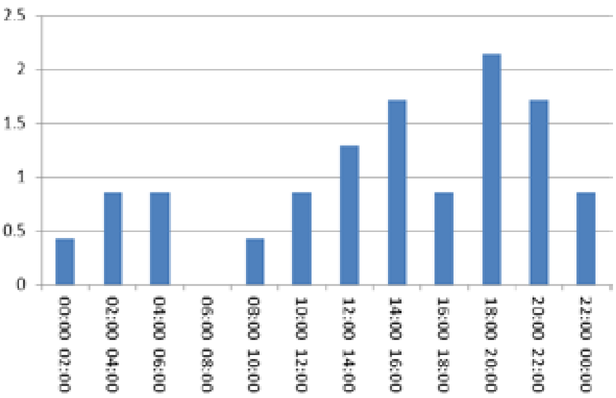

Figure 8. Values of GPC according to hour

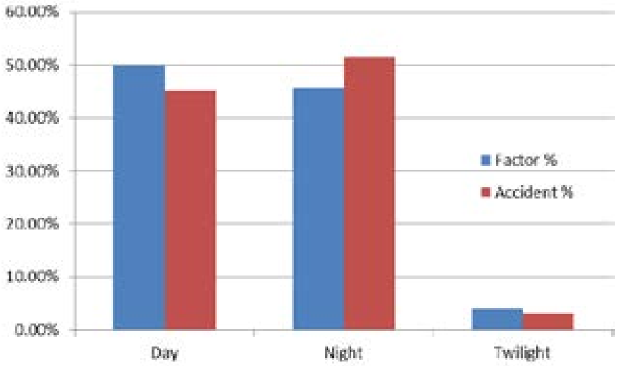

Figure 9. Percentage distributions of day parts and groundings according to time of day

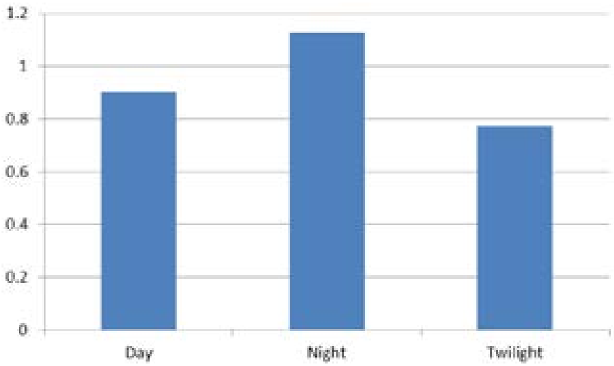

Figure 10. Values of GPC according to time of day

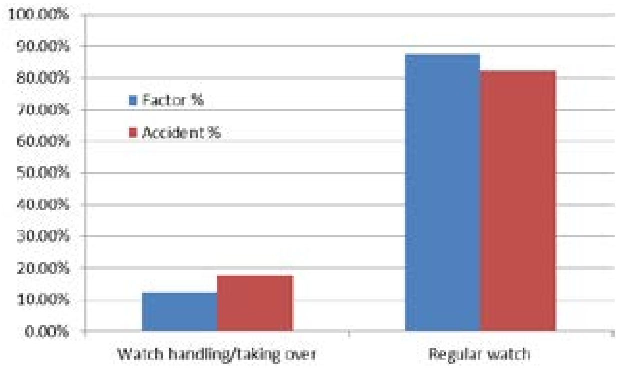

Figure 11. Percentage distributions of watch parts and groundings according to part of watch

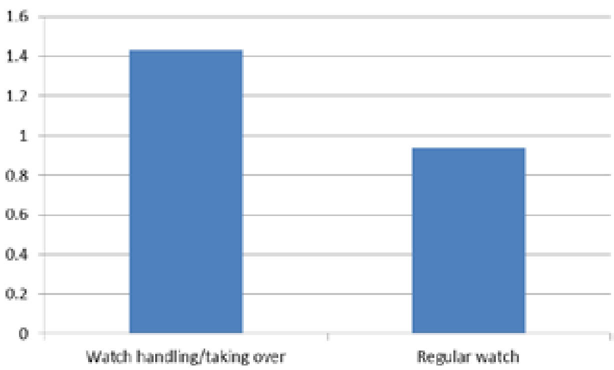

Figure 12. Values of GPC calculated for watch handling/taking over and regular watch

watch handling/taking over (half an hour after watch end/beginning) and rest of the watch. Due to a lack of more detailed information a typical distribution of navigational watch was assumed (00:00–04:00, 04:00–08:00, 08:00–12:00, 12:00–16:00, 16:00–20:00, and 20:00–24:00). Results (Figures 11 and 12) show a higher frequency of groundings during or just after (half an hour) the watch handling/taking over.

Type of vessel

In order to assess the influence of the vessel type on the grounding frequency the percentage shares of ship types and the grounded ship types were evaluated. Analysis was carried out on the basis of data gathered from internet databases of sea traffic and accidents (HELCOM, MAIB, and GISIS). No significant relationship between the type of vessel and frequency of grounding can be stated (Figures 13 and 14). The relatively high frequency of grounding calculated for the passenger ship can be caused by no sufficient number of case scenarios and should be verified in future research.

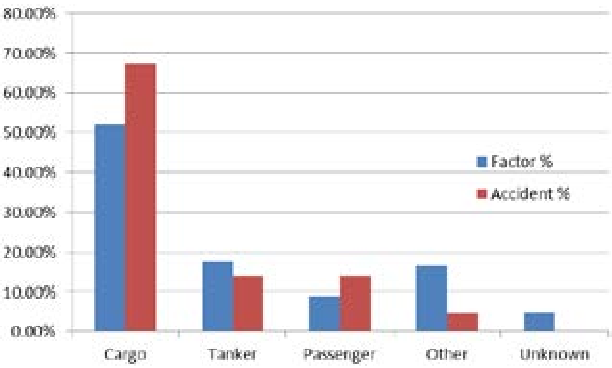

Figure 13. Percentage distribution of types of vessel and groundings according to type of vessel

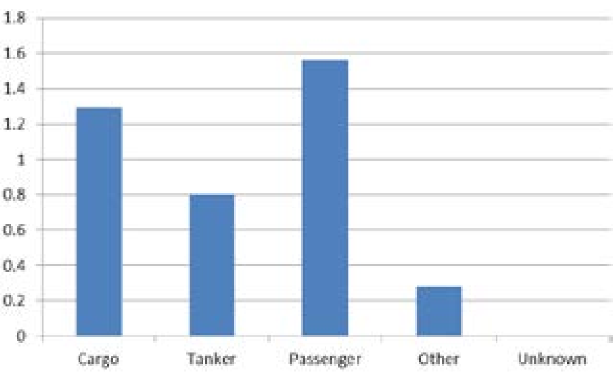

Figure 14. Values of GPC according to type of vessel

Draft

According to common sense the probability of grounding should increase with the draft of the vessel. On the other hand the bigger the draft is the more carefully navigation is. To assess the influence of draft on the grounding frequency the percentage distributions of vessel draft and groundings according to draft were evaluated (Figure 15). In the next stage the values of GPC according to draft of vessel (Figure 16) were calculated. No significant relationship between draft of vessel and frequency of grounding can be stated.

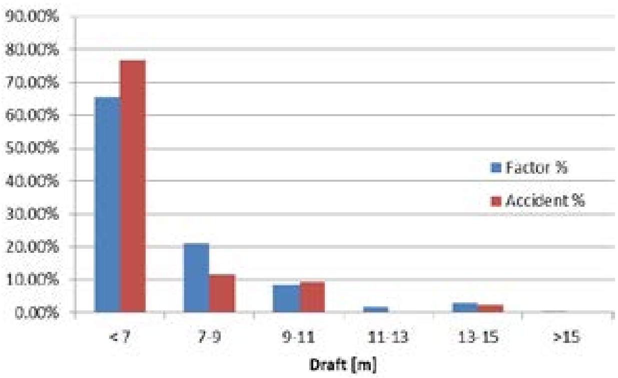

Figure 15. Percentage distributions of drafts of vessel and groundings according to draft

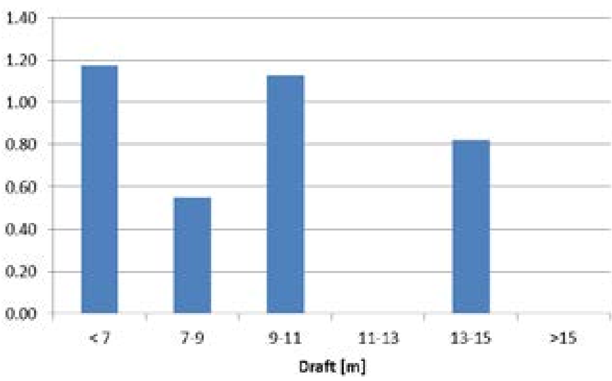

Figure 16. Values of GPC according to draft of vessel

Conclusions

In this paper the method of quantitative assessment of selected factors influencing the probability of grounding in the Baltic Sea area were proposed. It has been proven that the use of the proposed coefficients (GPC), calculated on the basis of statistical data, allows for assessing the impact of internal and external factors on the frequency of groundings. The most significant dependence was noticed for wind speed. Clear correlation has also been found for the handling/taking over of the navigational watch, season of the year and time of grounding. No correlation or unclear correlation was noticed for the draft and type of vessel. In order to verify identified dependences further then studies for longer periods are necessary. Research for other sea areas will be also be considered for verification of similarities in different conditions.

Acknowledgments

This article is a part of a study inside the RepSail project and has been co-founded by EraNET in decision: ENT III/Future_Traveling/2/2014.

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