TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 9 Number 1 March 2015
DOI: 10.12716/1001.09.01.14

Maritime Traffic Situations in Bornholmsgat

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ABSTRACT: Maritime traffic situations is regulated in the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs), but how well are these rules followed by officers on board vessels? When the world shipping fleet grow and the traffic becomes more intensive, the risk of collision increase.
By analysing AIS data from vessels in the traffic separation scheme Bornholmsgat during 24 hours in December 2013, 421 traffic situations were found where the passing distance between the vessels were less than 1.5 nautical miles.
The compliance with the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) seems to be good, but the average avoiding action is less than the recommended manoeuver.

1 INTRODUCTION

Due to the growth of the world shipping fleet and the increased spatial occupation of sea areas, maritime traffic becomes denser in many areas. Denser traffic could mean more complex traffic situations and vessels traveling closer to each other. One way to analyse the traffic and the consequences of denser traffic are through collision investigations, or by analyse of all traffic situations to identify incidents or potential accidents, not leading to an accident.

Today, it is possible to analyse vessels' actual track with information from the Automatic Information System (AIS), used on board almost all merchant vessel and many leisure crafts. Messages from the AIS system are sent out with short time periods of 2-360 seconds, depending on the vessel's status (moored, anchored, under way etc.), speed and course change. The accuracy and integrity of positions from AIS is discussed (Felski & Jaskólski, 2013), but used in many studies as the best possible way of measuring the track for vessels with low cost.

The aim of this study has been to identify the traffic situations that occurred in Bornholmsgat, a passage in the Baltic Sea southeast of Sweden, during 24 hours and how they relate to the rules of the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) to get a picture of the actual maritime traffic situation in the area. The result could be used as it is or as a benchmark for measurements in other areas, but the primary purpose for this study is to be used as calibration for a developed software to automatically find and measure maritime traffic situations for further research.

2 BACKGROUND

The main tasks for an officer of the watch (OOW) on board a merchant vessel are to avoid grounding and avoid collision when conning the vessel between two locations. When the spatial occupation of sea areas increase, i.e. by new wind mill parks, the space for navigation of ships decrease, resulting in denser traffic and increased risk of collision.

The marine traffic to and from the Baltic Sea is increasing and the Bornholmsgat is one of the areas with most traffic (Gucma et al., 2007). In 2006 a new traffic separation scheme (TSS) in Bornholmsgat came into force (IMO, 2006). A traffic analyse for the area has been performed by Gucma and Puszcz (2010) to find the distribution of vessels position within the traffic lanes. According to Hajduk and Montewka (2008), there are still dangerous traffic situations in the area, due to the fact that traffic to and from the Polish coast crosses the traffic flow out from the TSS in north-easterly direction.

The behaviour of maritime officers in traffic situations have been studied in different situations. Zhao, Price, Wilson, and Tan (1996) used cadets on board to gather information from 1053 different traffic situations. Their result was an average of 0.2 nautical miles (M) in original distance to the closest point of approach (CPA), an average actual passing distance of 1 M, an average course alteration of avoiding manoeuver of 20° at an average time to CPA (TCPA) of 10 minutes. Kobayashi (2006) put together data from simulator exercises from different training centres around the world, and found that the mariner's behaviour is a function of the mariner's competence, such as licence, experience, physical and mental condition, together with the navigational condition, such as own ship characteristics, water area, maritime traffic, sea state, weather and rule of road. They also found that when the crossing angle decreased (the target vessel appear more from dead ahead), the action to avoid collision starts earlier.

A study, measuring the rule following behaviour in the Dover Straits, has been performed by Belcher (2007). In the Dover Strait, mean passing distance in crossing situations was 0.58 M and 0.44 M in overtaking situations, when there were risk of collision. Situations, with risk of collision, were identified as situations where the passing distance were within 0.8 M, resulting in 175 situations during a 24 hours period.

The Convention on the International Regulations for Preventing Collisions at Sea (COLREGs), 1972 as amended, regulates the behaviour of vessels in marine traffic situations. The COLREGs states that the risk of collision should be carefully assessed at an early state, and if there is a risk of collision normally one vessel is the give-way vessel and the other is stand-on vessel (except in head-on situations and in restricted visibility when both vessels are give-way vessels). This means that the officer of the stand-on vessel need to trust the officer of the give-way vessel and wait for an avoiding manoeuver. The COLREGs do not provide detailed information on when and how an avoiding manoeuver should be performed, leading to uncertainties sometimes (Belcher, 2007; Zhao, Price, Wilson, & Tan, 1995).

Habberley and Taylor (1989) found that officers initiated the avoiding manoeuver by measuring the distance to the target ship or the time to collision (TCPA). The individual behaviour was consistent in different situations, but varied between different persons.

Chauvin and Lardjane (2008) analysed 62 traffic situation in the Dover Straits with ferries crossing the traffic separation scheme between Dover and Calais. When the cargo vessel following the traffic lane was the give-way vessel, the probability that the vessel did an avoiding manoeuver increased with the speed of the cargo vessel, a slow cargo vessel only changed course in 19% of the situations, but a fast cargo vessel changed course in 91% of the situations. When the ferry was the give-way vessel, there was almost always an avoiding manoeuvre. The mean amplitude of this avoiding manoeuver was 18° at an average distance of 3.5 M to cross astern of the cargo vessel at a distance of 0.7 M or ahead of the cargo vessel at a distance of 1 M.

3 THEORY

The Convention on the International Regulations for Preventing Collisions at Sea (COLREGs), regulates the behaviour of vessels in marine traffic situations through rule 1 to 19. Situations could be categorized as head-on situation, crossing situation or overtaking situation depending on the relative bearing between vessels (figure 1). Rule 13 regulates overtaking situations and states that the overtaking vessel always is give-way vessel. An overtaking situations occur if the overtaking vessel approach the other vessel from a direction more than 22.5° abaft the beam. Rule 14 regulates head-on situations between power-driven vessels and states that both vessels should alter their course to starboard if they are meeting on reciprocal or nearly reciprocal courses. Rule 15 regulates crossing situations and states that "the vessel which has the other on her own starboard side shall keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel".

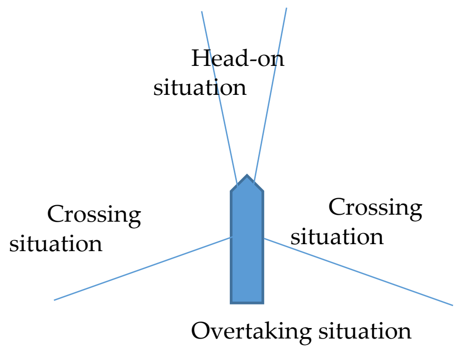

Figure 1. Categorization of situations depending on the relative bearing

The exact distance or time for an avoiding action is not stated. Rule 8 states that an avoiding manoeuver should be "positive, obvious and made in ample time", without given any specific time limits or distances. One common interpretation is that an avoiding manoeuver should be at least 30° (Cockcroft & Lameijer, 2012).

Rule 10 regulates the traffic flow in a traffic separation scheme (TSS), for example the TSS Bornholmsgat. The basic rules are that vessels should follow the traffic lanes, preferably enter the TSS at the end points and cross the lane perpendicular (if necessary). In case of a traffic situation with risk of collision, the steering rules mentioned above should be followed. The main purpose of a TSS is to split the traffic in different lanes to avoid head-on situations. As a consequence, the number of overtaking situations increases.

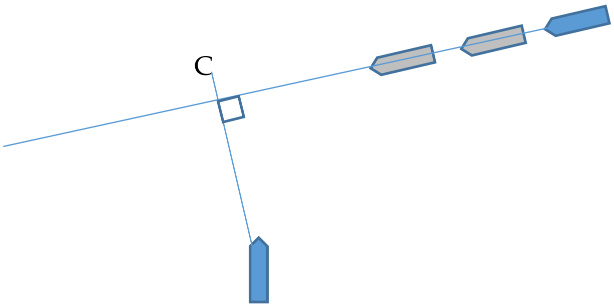

Figure 2. Definition of closest point of approach (CPA) using relative motion of vessels

In the daily work for the officer of the watch the risk of collision is measured as the distance of the closest point of approach (DCPA) and the time to the closest point of approach (TCPA), using radar- and/or AIS-information (figure 2).

4 METHOD

In this study, AIS information from December 1, 2013 has been used. The AIS information is part of the information in the HELCOM database of AIS messages, and extracted for this study by the Swedish Maritime Administration (SMA). The area used is latitude N54°29′ to N55°51′ and longitude E013°35′ to E015°46′, and during the studied 24 hours there were totally 586,518 AIS messages sent from 309 different vessels. The messages consist of the vessel's MMSI number, ship name, ship type, current position, course over ground, speed over ground, heading, navigational status, destination etc.

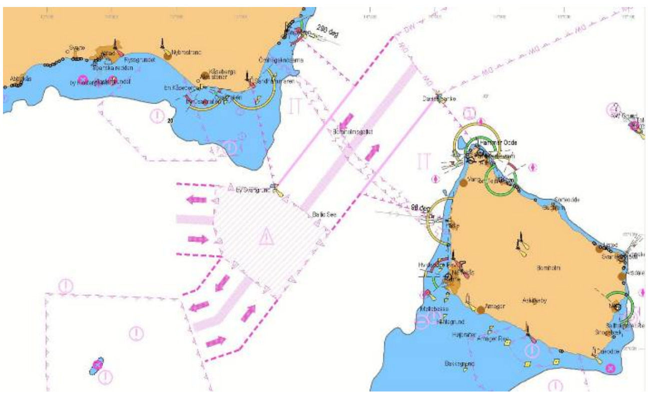

Figure 3. Overview of the TSS Bornholmsgat

In the area between the Swedish mainland and the Danish island Bornholm a TSS has been established. The TSS includes six traffic lanes, one precautionary area and two inshore traffic zones (figure 3). The traffic lanes are approximately 2.7 M wide, separated by a 0.8 M wide separation zone. (IMO, 2006)

To focus on the situations in or close to the TSS Bornholmsgat, situations south of latitude N54°45′ has been removed from the analyse.

The overall traffic situation has been identified and analysed for the area every third minute to identify three different types of situations (see table 1), head-on situations, crossing situations and overtaking situations, fulfilling criteria for minimum passing distance, CPA, TCPA, target ship aspect, relative bearing and course difference measured at a range called action range.

Table 1. Types of situations to find

		1	2	3
Type of situation		Head on	Crossing	Overtaking
Criteria	Minimum distance	<1.5 M	<1.5 M	<1.5 M
	DCPA	<2 M	<3 M	<2 M
	TCPA	<1 hour	<1 hour	<2 hours
	Target ship aspect	0-10° or	10-112,5°	>112,5°
	Relative bearing	<10°	10-112,5°	<90°
	Course difference	>160°	-	-
Assessment range		12 M	12 M	12 M
Action range		7 M	5 M	3 M

The identification and measurement of traffic situations were done in four steps.

- Step 1: Identification of possible situations
  From the analyse start time, the distance between all combinations of vessels are calculated every third minute. If the distance between the vessels is lower than a specified assessment range (in this study 12 M), the situation is stored as a possible situation for further analyse. The situation is also categorized as head on situation, crossing situation or overtaking situation depending on target ship aspect, relative bearing and course difference.
- Step 2: Check basic criteria
  When all possible situations are found, each situation is analysed in detail, checking if the situation fulfils the criteria of minimum passing distance and, at action range, the criteria of DCPA and TCPA.
- Step 3: Find all manoeuvers (change of course and/or speed)
  The third step is to find changes in course and/or speed for the involved vessels. A manoeuver is identified when a constant course/speed has been hold for at least five minutes, then a change of speed of minimum two knots or a course change of minimum three degrees, following of a new period of at least five minutes with constant course/speed. The type of manoeuver (starboard turn, port turn or speed change), order of manoeuver (change in course or speed) and the situation measures (range, CPA and TCPA) at the time of manoeuver were stored.
- Step 4: Identify avoiding manoeuver
  The fourth step is to identify which of the manoeuvers that are the avoiding manoeuver. This is first done automatically by selecting the first manoeuver occurred when the distance between

the vessels are within action range. The real world is not so simple, some avoiding manoeuvers are performed in very good time and some changes are very small, so all situations have been checked and updated manually.

Data for all identified traffic situations were exported to Microsoft Excel and analysed statistically with the Add-in "Analysis ToolPak".

5 RESULT

In the studied area, there were 421 traffic situations fulfilling the criteria at December 1, 2013. 48 of these were head-on situations, 84 were crossing situations and 289 were overtaking situations. There were also 48 situations discarded due to lack of information (situation occurred very close to the area limit or very early in the time period) or by other reason (i.e. situation occurred in a port area or pilot boat approaching a larger vessel). The average passing distance in head-on situations was 1.01 M, in crossing situations 1.03 M, and in overtaking situations 0.79 M.

5.1 *Head-on situations*

It was only in one of the 48 head-on situations were both vessels did an avoiding manoeuver. In 12 situations one of the vessels changed course and in 35 situations there were no avoiding manoeuver.

The situation when both vessels did manoeuvers were between two tankers with a DCPA of 0.32 M. at a distance of 7 M (TCPA 19 minutes). Both changed their courses to starboard, one with 4° at a distance of 4.8 M and the other with 8° at a distance of 4.5 M. The passing distance was 0.82 M.

In the 12 situations were one of the vessels changed course, the average passing distance was 0.90 M. Three vessels changed their course to port and nine vessels changed their course to starboard. The average order of manoeuver was 8° performed at an average distance of 7.2 M. The distribution of passing distances could be found in figure 4.

In the remaining 35 situations were no avoiding manoeuver identified, the average passing distance was 1.05 M, with a minimum passing distance of 0.54 M. The distribution of passing distances could be found in figure 5.

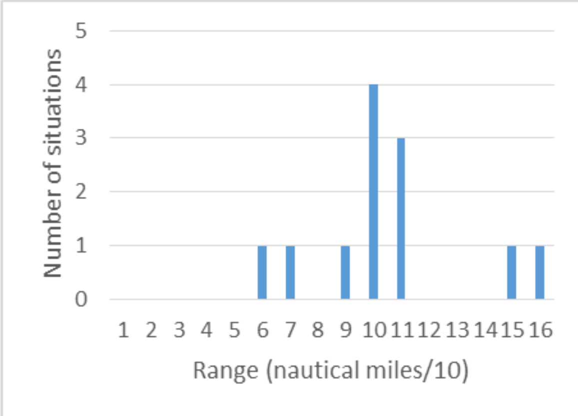

Figure 4. Passage distance between vessels in head-on situations when avoiding maneuver has been performed

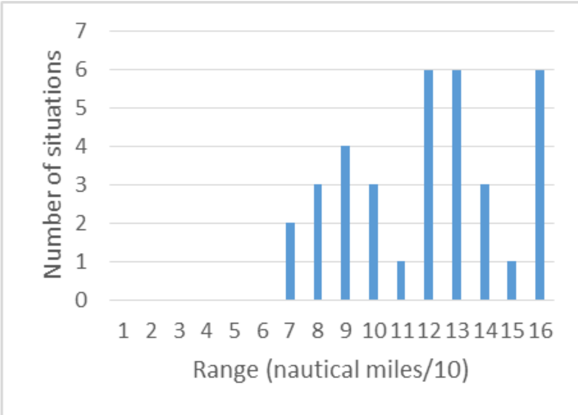

Figure 5. Passage distances between vessels in head-on situations when no avoiding manoeuver could be identified

5.2 *Crossing situations*

In three of the 84 crossing situations, both vessels performed an avoiding manoeuver. In 31 situations one of the vessels changed course and in 50 situations there were no avoiding manoeuver.

The situations when both vessels did manoeuvers were in two cases between two tankers and in the third case between two cargo vessels. In the cases between tankers, both vessels turned to starboard with an average change of course of 5° at an average distance of 5.8 M. In the third case one of the vessels turned to port 49° at distance 2.1 M entering the northeast-bound traffic lane, but not crossing ahead of the other vessel which changed course 5° to starboard at a distance of 3.1 M to give more space. The average passing distance was 0.74 M.

In the 31 situations were one of the vessels changed course, the average actual passing distance was 1.02 M. Eleven vessels changed their course to port and 20 vessels changed their course to starboard. The average order of manoeuver was 16° performed at an average distance of 5.7 M. The distribution of passing distances could be found in figure 6.

In the remaining 50 situations were no avoiding manoeuver identified, the average passing distance was 1.06 M, with a minimum passing distance of 0.43 M. The distribution of passing distances could be found in figure 7.

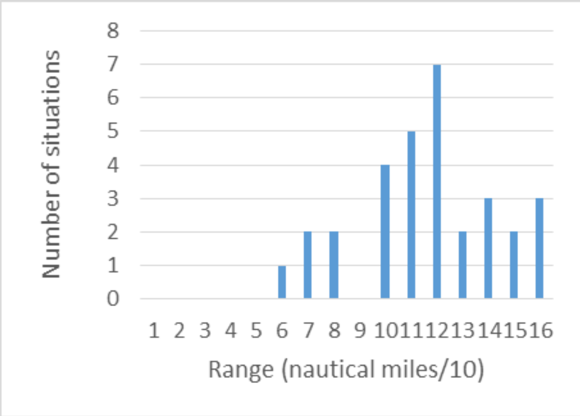

Figure 6. Passage distance between vessels in crossing situations when avoiding maneuver has been performed

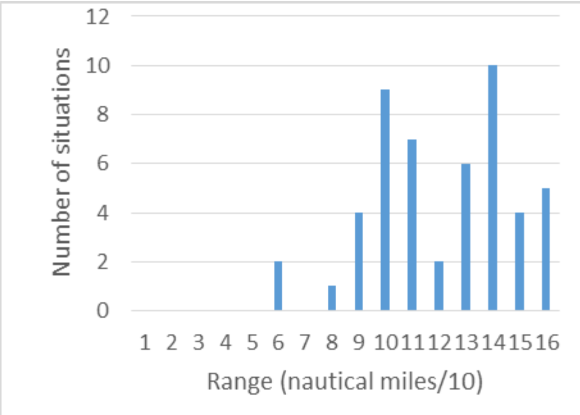

Figure 7. Passage distances between vessels in crossing situations when no avoiding manoeuver could be identified

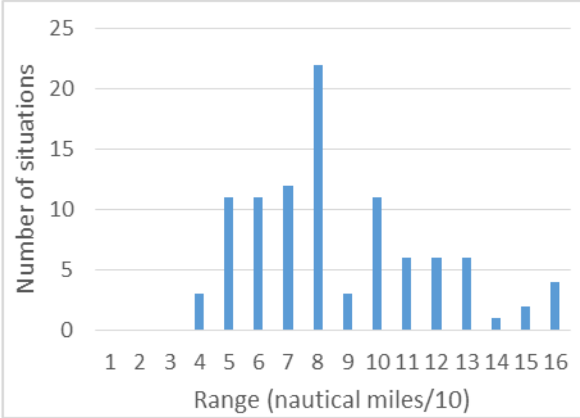

Figure 8. Passage distance between vessels in overtaking situations when avoiding maneuver has been performed

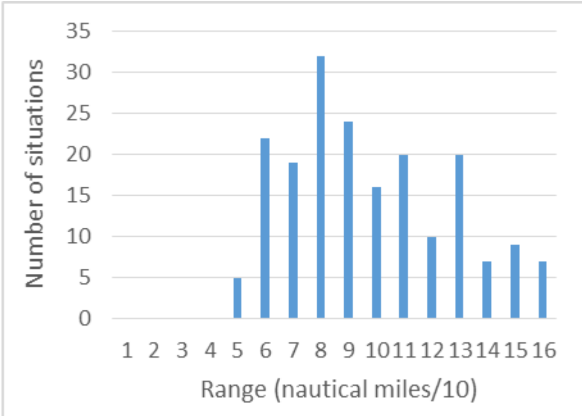

Figure 9. Passage distances between vessels in overtaking situations when no avoiding manoeuver could be identified

5.3 *Overtaking situations*

There were 98 overtaking situations with an avoiding manoeuver and 191 situations without avoiding manoeuver.

In the situations with an avoiding manoeuver, the average passing distance was 0.72 M. The average order of manoeuver was 7° at a distance of 3.22 M. 14 vessels changed course by a turn to port (average course change of 11°) and 84 vessels turned to starboard (average course change of 6°). The distribution of passing distances could be found in figure 8.

In the remaining 191 situations were no avoiding manoeuver identified, the average passing distance was 0.83 M, with a minimum passing distance of 0.31 M. The distribution of passing distances could be found in figure 9.

6 DISCUSSION

The traffic in the area in and around the traffic separation scheme Bornholmsgat is very intense and there are a lot of traffic situation on a single day. In this study a day in December 2013 were selected randomly, primarily to minimize the impact of leisure boats without AIS transponders causing manoeuvers in traffic situations which could not be seen by use of AIS data only.

The aim of a traffic separation scheme is to avoid head-on situations, and it is clear that there are few head-on situations compared to overtaking situations in the area. Many of the head-on situations are between vessels travelling between Sweden and Poland or north of the island Bornholm well clear of the TSS.

The passing distance between vessels is a key parameter for safe maritime traffic. In this study the average passing distance in head-on situations was 1.01 M, in crossing situations 1.03 M, and in overtaking situations 0.79 M, this could be compared to Zhao et al. (1996) with an average passing distance of 1 M, Belcher (2007) measured 0.58 M in crossing situations and 0.44 M in overtaking situations in the Dover Strait. The reason Belcher (2007) measured a smaller value could be that he only looked at situations with a passing distance of less than 0.8 M.

The average course alteration of avoiding manoeuvers has earlier been found to be 20° (Zhao et al., 1996) and 18° (Chauvin & Lardjane, 2008) in crossing situations, in this study the average course alteration was 8° in head-on situations, 16° in crossing situations and 7° in overtaking situations. In all studies the average course of alteration is well below the recommended alteration of at least 30° (Cockcroft & Lameijer, 2012).

An avoiding manoeuver should be made in ample time. Zhao et al. (1996) measured an action point at an average time to CPA (TCPA) of 10 minutes, and Chauvin and Lardjane (2008) measured an average action point at 3.5 M. In this study the average distance between vessels when an avoiding manoeuver was commenced was 7.2 M in head-on situations, 5.7 M in crossing situations and 3.22 M in overtaking situations.

One uncertainty by using only AIS data is that the local visibility in the area is hard to measure. If the vessels are out of sight and only discovered by radar, both vessels are give-way vessels. In this study, both vessels performed avoiding manoeuvers in less than 1% of the situations.

7 CONCLUSIONS

The maritime traffic in the traffic separation scheme Bornholmsgat is very intense and 421 traffic situations were found during one day. The average passing distance was measured to be 1.01 M in head-on situations, 1.03 M in crossing situations and 0.79 M in overtaking situations. The average course alteration was 8° in head-on situations, 16° in crossing situations and 7° in overtaking situations and performed at an average distance of 7.2 M in head-on situations, 5.7 M in crossing situations and 3.22 M in overtaking situations.

The compliance with the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) seems to be good, but the average avoiding action is less than the recommended manoeuver, in line with studies in other areas.

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