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Navigators' Behavior in Traffic Separation Schemes

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ABSTRACT: One of the areas of decision support in the navigational ship conduct process is a Traffic Separation Scheme. TSSs are established in areas with high traffic density, often near the shore and in port approaches. The main purpose of these schemes is to improve maritime safety by channeling vessel traffic into streams. Traffic regulations as well as ships behavior in real conditions in chosen TSSs have been analyzed in order to develop decision support algorithms.

1 DECISION SUPPORTING SYSTEMS

The development of information and communication technologies (IT and ICT) creates increasing opportunities for acquiring, processing and sharing information. The need for improvement and extension of navigational equipment and systems on ships and in land-based centers results from the fact that the safe navigation and vessel traffic management require access to relevant information and its proper use. Navigational systems and devices are systematically supplemented with new functionalities. On the one hand, the operator/navigator acquires additional information, on the other hand, excess information makes the selection of relevant information more difficult and consequently hampers making the correct decision. For this reason, great emphasis is placed on human centered design of such systems.

Currently used navigational systems and devices increase the scope of support in decision-making processes by using prediction algorithms or statistical tools. More and more attention is paid to navigation decision support systems that additionally allow to generate solutions to a navigation situation, including collision situations. These solutions are presented to the navigator or operator. This is particularly important in complex decision-making situations in difficult conditions: storm, restricted visibility, high traffic. NAVDEC is an example of the navigational decision support system on seagoing ship (Pietrzykowski & Borkowski & Wołejsza, 2012). The system enables, inter alia, analysis and assessment of the navigation situation, and generation of avoidance manoeuvres in collision situations. Proposed solutions should be effective, legal and rational. The third requirement relates to navigators/operators' preferences resulting from their knowledge and experience (Pietrzykowski & Magaj & Maka, 2014). This is very important because the collision regulations leave a certain margin for interpretation and action. The creation of a rational system requires the application of complex models and computing algorithms. The automatic generation of solutions is particularly important in encounter situations in dense traffic areas. These areas, mainly port approaches and frequently used shipping routes, are often restricted (limitation of one of three dimensions). There is a whole range of constraints

which restrict ship maneuvers: ship's dimensions, ship maneuverability, shape and depth of the water area, obstacles and navigational dangers, legal regulations , other sea-going vessels, drilling platforms, wind farms and other.

The use of decision support systems in areas where TSSs are established requires that such systems should take into consideration general and TSS-specific regulations as well as navigators' expertise: experience and knowledge needed for analysis and assessment of the situation and for the determination of safe maneuvers, i.e. calculation of a safe ship trajectory. One of the possibilities is presented in (Szlapczynski, 2012).

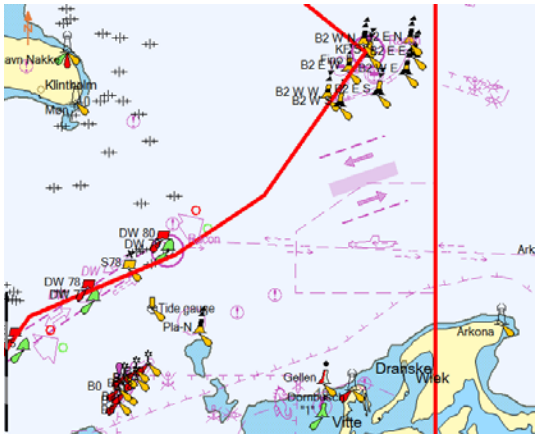

Figure 1. TSS North of Rügen

2 TRAFFIC SEPARATION SCHEMES

TSS can be described as a traffic-management route-system ruled by the IMO where the traffic lanes indicate the general direction of the traffic flow. IMO's responsibility for ships' routing is set forth in SOLAS Chapter V, which recognizes the Organization as the only international body for establishing such systems. Ships' routing systems contribute to safety of life at sea, safety and efficiency of navigation and/or protection of the marine environment. Rule 10 of the COLREGs (COLREGs, 1972) prescribes the conduct of vessels when navigating through traffic separation schemes adopted by the IMO. However, this in no way relieves vessels from compliance with other COLREGs rules. It should be noted that there are also TSS *not* governed by the IMO.

Figure 2. TSS Adlergrund

The traffic lanes in TSS are demarcated by virtual boundaries. This means that boundary violation does not imply directly a risk of grounding or collision with the shore. In many cases vessels simply sail across a TSS. In such situations, the ship shall cross on a heading 'as nearly as practicable at right angles to the general direction of traffic flow'. The regulations also allow a ship to join or leave a traffic lane at the termination of the lane, but when joining or leaving from either side ships 'shall do so at as small an angle to the general direction of traffic flow as practicable'.

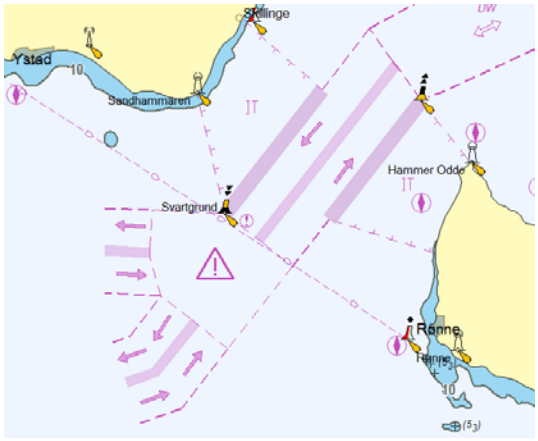

Figure 3. TSS Bornholmsgat

Such wording leaves room for interpretation (tolerance range) by decision-makers. Both the navigator and the decision support system should take such interpretation margin into account in the analysis and assessment of the situation and in determining a maneuver to solve a collision situation.

In this connection, the authors have analyzed vessel traffic in selected regions of the Baltic Sea where TSSs are established: TSS Adlergrund, TSS Bornholmsgat, TSS North of Rügen and TSS Słupska Bank (Figures 1-4). The analysis makes use of AIS data registered during one day in June 2011. Individual ship encounter situations and vessel traffic flows have been analyzed.

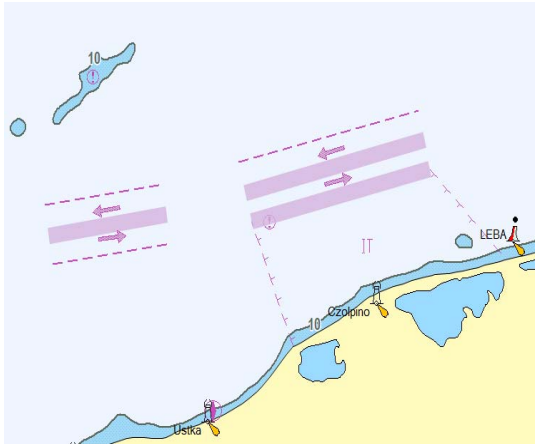

Figure 4. TSS Słupska Bank

The analysis is aimed to develop and test the methodology to be used in further research.

3 NAVIGATORS BEHAVIOUR

This section provides examples of proper and improper conduct of ships in Traffic Separation Schemes (TSS).

The case study was performed using two ships' passages in TSS Bornholmsgat. In both cases ship encounter situations with other targets are taken into consideration and are presented graphically. The examined ship is placed in the center of the screen.

Case 1. The chosen ship heading south came into south-west traffic lane of Bornholm TSS at a slight angle (Figure 5), which is in accordance with rule 10 (Traffic Separation Schemes of COLREGs, point b / iii:

b/ A vessel using a traffic separation scheme shall:

iii/ normally join or leave a traffic lane at the termination of the lane, but when joining or leaving from either side shall do so at as small an angle to the general direction of traffic flow as practicable.

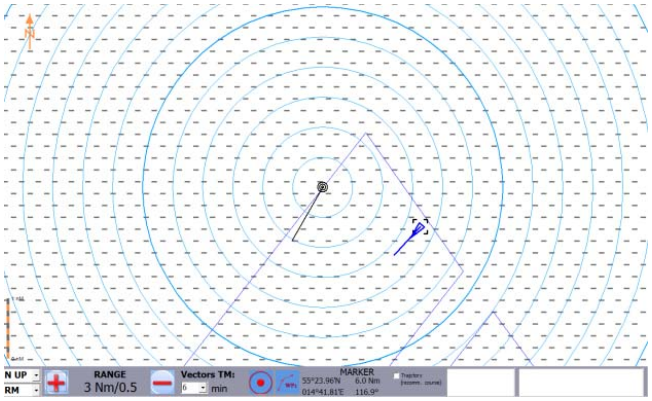

Figure 5. Joining a traffic lane.

The ship sailed almost the entire length of the traffic lane, but the direction of its motion was not in line with the direction of the lane. Meanwhile, Rule 10 point b/i reads:

b/ a vessel using a traffic separation scheme shall:

i/ proceed in the appropriate traffic lane in the general direction of traffic flow for that lane.

After about 80 minutes the vessel reached its port side of the lane, and then entered a separation zone (Figure 6), breaking another rule:

b/ A vessel using a traffic separation scheme shall:

ii/ so far as is practicable keep clear of a traffic separation line or separation zone.

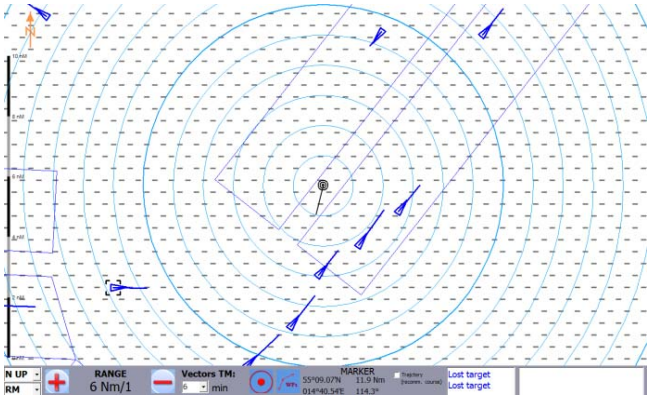

Figure 6. Entering a separation zone.

The crossing of the zone at this point is not allowed. This is stated in point e/:

e/ a vessel, other than a crossing vessel or a vessel joining or leaving a lane shall not normally enter a separation zone or cross a separation line except:

i/ in cases of emergency to avoid immediate danger;
ii/ to engage in fishing within a separation zone.

The conditions described in the section i/ and ii/ are not applicable in this situation, so another rule was broken.

Meanwhile, the vessel continues to travel through the separation zone on a course close to the zone direction, subsequently entering the opposite lane and cutting it at a small angle, which is not in accordance with Rule 10 point c/:

c/ a vessel, shall so far as practicable, avoid crossing traffic lanes but if obliged to do so shall cross on a heading as nearly as practicable at right angles to the general direction of traffic flow.

In addition, the rule of point **b**/i/ is broken:

b/ a vessel using a traffic separation scheme shall:

i/ proceed in the appropriate traffic lane in the general direction of traffic flow for that lane;

The vessel brings about (Figure 7) a collision situation (CPA less than 1 Nm and TCPA less than 10 minutes) with two targets that proceed on the proper lane, in accordance with the rules.

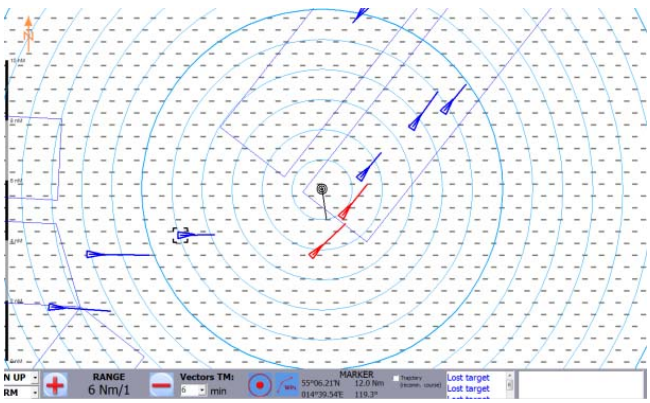

Figure 7. Collision situation.

After passing at a distance of about 0.6 Nm and leaving the lane, the ship moves ahead of two other ships and comes too close to another ship (Fig. 8).

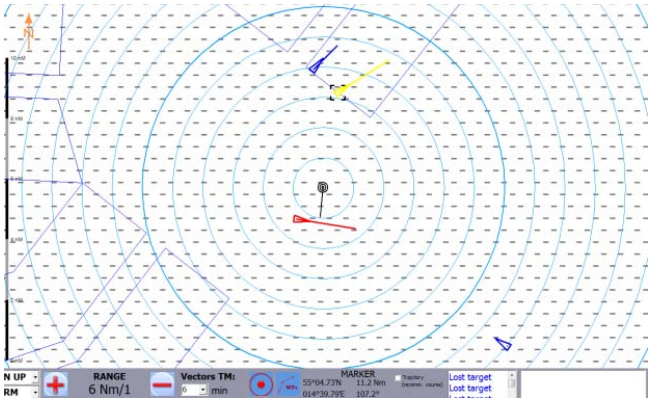

Figure 8. Close quarters situation.

Case 2. The examined ship (in the middle of the screen) heading north-east entered and followed (Fig. 9) the east lane in accordance with rule 10 point **b**/i/:

b/ a vessel using a traffic separation scheme shall:

i/ proceed in the appropriate traffic lane in the general direction of traffic flow for that lane.

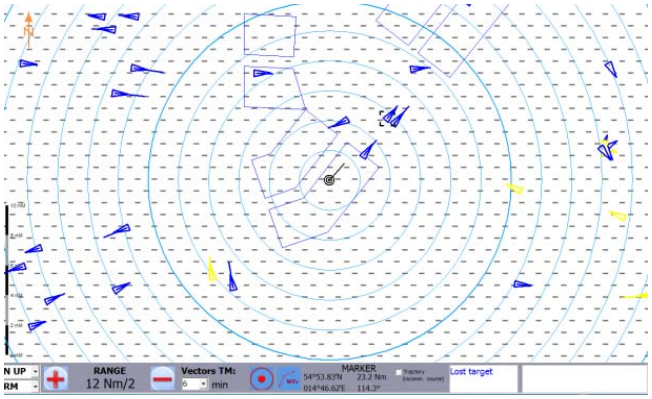

Figure 9. Proper target course on the traffic lane.

The vessel went through the first section of the traffic separation scheme in the normal direction. Then she proceeded to overtake slower ships leaving all targets on her port side (Figure10).

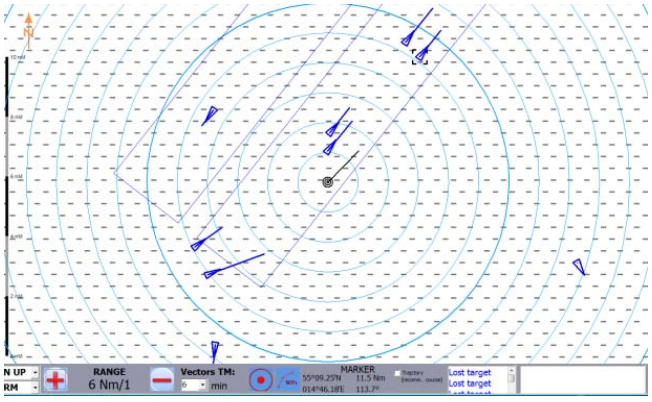

Figure 10. Overtaking.

After about 3 hours, the vessel left the system in the proper place (Figure 11), in accordance with point **b**/ii (see case 1): she leaves from one side at a small angle to the general direction of traffic flow.

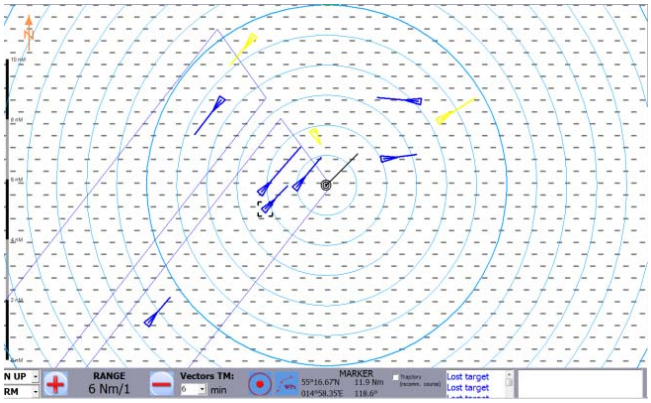

Figure 11. Leaving traffic lane

4 TRAFFIC FLOWS

Vessel traffic in the chosen Baltic Sea TSSs was analyzed using AIS data recorded within one day. The ships trajectories are shown in Figures 12-15.

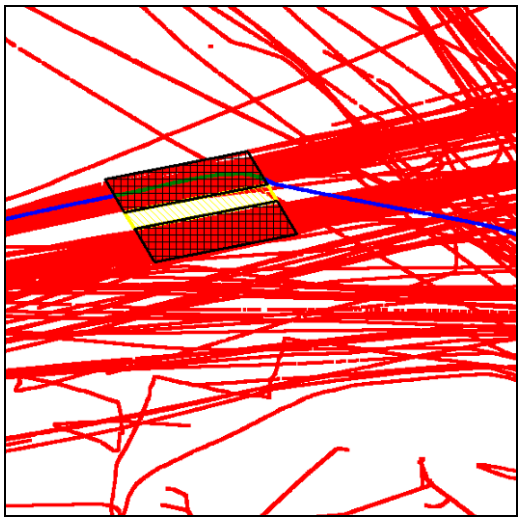

Figure 12. Vessel traffic in TSS North of Rügen

Figure 13. Vessel traffic in TSS Adlergrund

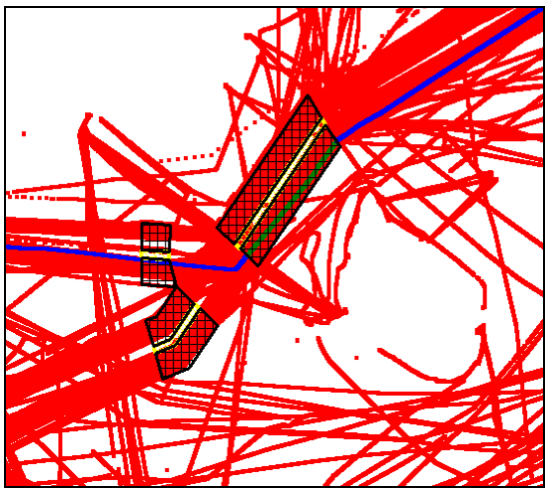

Figure 14. Vessel traffic in TSS In Bornholmsgat,

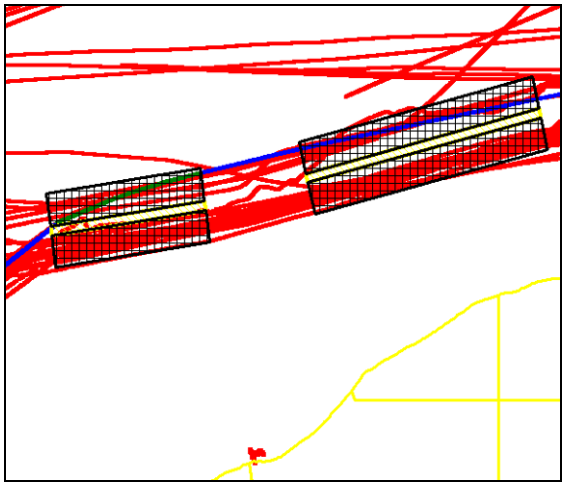

Figure 15. Vessel traffic in TSS Słupska Bank

On this basis, a more detailed analysis of traffic flows has been carried out for each of the TSS (Tables 1 and 2).

The analyzed data included the number of vessels entering the system, the number of ships crossing the TSS and their direction, the number of vessels joining or leaving a traffic lane at the termination of the lane.

Ships which violated the regulations were identified - some of them violated the separation zone.

Table 1. Vessel traffic flows in analyzed TSS. Part 1

TSS	No of ships	No of maneuvers	
		speed changes *	crossing TSS / angle [°]
Rügen	93	1	1 / 24
Adlergund	19	-	1 / 64
Bornholmsgat			
Main part	56	3	3 / 53, 38, 98
West part	95	-	-
South-west part	57	1	-
Słupska Bank			
West part	30	1	-
East part	25	-	-

* speed change more than 3 kn

Table 2. Vessel traffic flows in analyzed TSS. Part 2

TSS	No of join or leave a traffic lane / angle [°]	No of intersec-tios of traffic separation zone	proceeding in opposite direction
Rügen	-	2	-
Adlergund	2 / 17, 30	-	-
Bornholmsgat			
Main part	2 / 18, 8	1	2*
West part	-	-	-
South-west part	-	-	-
Słupska Bank			
West part	2 /26, 21	1	1
East part	1 / 24	-	3*

* fishing vessels

Additionally, the density distributions of ships for each of traffic lanes were calculated (Fig. 16).

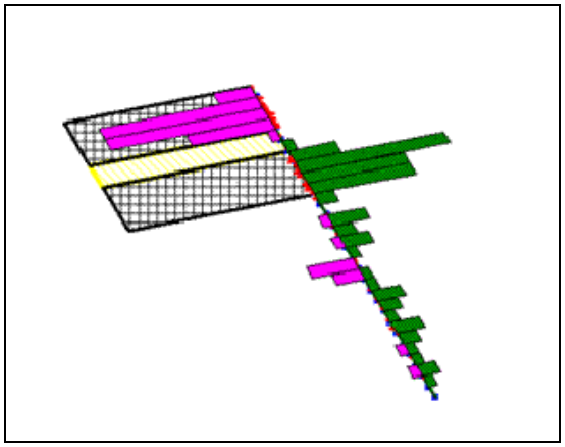

Figure 16. TSS North of Rügen. Traffic density in traffic lanes and adjacent areas.

5 CONCLUSIONS

Traffic separation schemes are virtual areas, generally marked by buoys. Our investigation has established that most ships proceed in accordance with regulations concerning TSSs. Despite relatively denser traffic in these areas, there exists increased navigation safety resulting from high predictability of the navigators' (ships) behavior.

If the vessel traffic control system is not restrictive, or does not exist, there are often violations of the law, as was the passage of vessel analyzed in Case 1. The reason for such behavior of the navigator could be the fact that the traffic separation system impedes voyage planning, therefore, it was ignored by the navigator.

On the other hand, the provisions of Rule 10 are not strict, thus their interpretation may vary. Point b/ is an example of this: 'a vessel using a traffic separation scheme shall' [...] followed by recommendations, expressed by the word “should” in the text of this point.

Another such "imprecise" wording is a provision on ships joining or leaving from either side of the track. Rule 10 refers to a maneuver at a possibly small angle to the general direction of movement, without specifying the size of the angle, which can lead to divergent interpretations.

This imprecise wording may also include the texts of points i/ or j/, referring to fishing and sailing ships. The points including the phrase "not impeding" safe passage of a power-driven ships use the verb "should not", which is frequently used by fishing or sailing ships to force action by motor driven ships that go on the right lane. Such wording should be avoided as much as possible. Also, there is need to train crews of ships engaged in fishing operations or sailing ships in the correct interpretation of relevant COLREGs.

This article presents research into traffic flows in selected Baltic Sea TSSs. The idea behind the research is to develop methodology for the identification of navigators behavior in TSSs in real conditions and, further, to develop decision support algorithms for TSS areas.

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