Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2016, 48 (120), 153–158
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/189

Received: 29.04.2016
Accepted: 18.09.2016
Published: 15.12.2016

The ship safety zones in vessel traffic monitoring and management systems

Mirosław Wielgosz

Maritime University of Szczecin, Faculty of Navigation, Institute of Navigation
1–2 Wały Chrobrego St., 70-500 Szczecin, Poland, e-mail: m.wielgosz@am.szczecin.pl

Key words: navigational danger, safety, safety frame, safety zone, ship domain, traffic monitoring

Abstract

This paper presents the problem of the "know-how" needed by the operators of vessel traffic supervision, monitoring, advisory and safety zone management systems required and maintained by marine navigators on their ships. The problem of the proper and correct interpretation of these systems is raised. Different types of ship safety zones, concerning both anti-collision and navigational purposes are presented, introducing the concept of hydrographic ship domain. Anti-collision and hydrographic domains were compared in order to establish mutual dependence. The factors influencing the two types of ship domains were analysed. The author proposed their merging and replacement with one universal domain, discussing its advantages and disadvantages. The analysis of the factors influencing the shape and size of such ship safety zones in conducted. The results in the different phases of research were presented and conclusions were drawn.

Introduction

Monitoring and management of vessel traffic in narrow channels and in proximity of ports is usually performed by shore based centres known as VTS (Vessel Traffic Service) or VTMS (Vessel Traffic Management Service). They are engaged in control, advisory, information services and direction of movement of vessels in the subordinate waters (IALA, 2016, Wawruch, 2001).

At its simplest, the main objectives of a VTS are to (IALA, 2016):

- aid the mariner in the safe and efficient use of navigable waterways;
- allow unhindered access to pursue commercial and leisure activities while respecting any restrictions that may exist;
- contribute to keeping the seas and adjacent environment free from pollution.

Their tasks, depending on the specific service provided, may also include, but are not limited to:

- monitoring the traffic of vessels;
- monitoring of compliance to rules and regulations;
- advice on passing the supervised area;
- guiding ships by:
  - passing information about position relative to the fairway centre;
  - advising about course and speed changes;
  - information about other traffic in the area.

For the operator of such a system to issue advice, instructions or recommendation to change course or sail along specified routes, knowledge is required regarding at least the approximate size of the zones that the navigator wants to keep free from other objects – domains or ship safety zones. This involves responsibility for the decisions taken. Although not all the transmitted commands and recommendations are mandatory, navigators generally trust the information and willingly submit to and expect the recommendations of the operator, who has experience and knowledge of the area and the specifics of local traffic.

When sending information, recommendation or advice, the VTS operator should take into account the movement of other vessels, the presence of navigational hazards (such as wrecks and fishing nets),

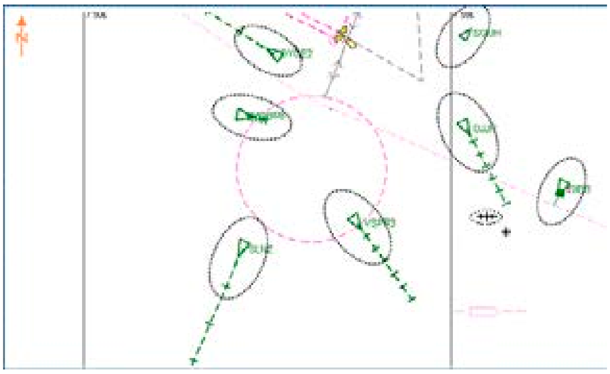

Figure 1. Pre analysed anti-collision domains on ECS screen

and areas that are restricted or well-known for their special conditions. At the same time, they should understand the degree of risk they represent for individual ships, depending on the size, type, speed, and other specific characteristics of the vessel in question.

Safety zone – domain from VTS operator point of view

The expression "ship domain" was introduced for the first time in the 1970s (alternatively, one can use the term "safety zone") and refers to the safety zones in terms of collision avoidance. By definition, this is an area in which the navigator wants to keep, or keeps, free from other objects (Goodwin, 1975; Śmierzchalski & Weintrit, 1999; Pietrzykowski & Uriasz, 2009).

Nowadays, with the new electronic equipment implemented and installed on board ships, it seems to be reasonable to distinguish between the "anti-collision domain", which refers to floating objects such as other ships, and the "hydrographic domain", defined in the following subchapter.

By observing the image of navigational situation in the supervised waters, the operator keeps track of vessels in accordance with the distance and range of automatic identification system (AIS) and ARPA/radar equipment. In general, the navigational situation is reported in accordance with the requirements (if applicable), so that the operator has enough information about the object. If not reported, detailed data is read and obtained from the AIS.

When information about the size and current speed of ship is available, it is possible to generate on-screen a chart system of the ship's domain. Generally, VTS systems are established in restricted areas, where physical and legal restrictions exist (proximity to the land and navigational hazards as well as special areas). It is thus possible to introduce (Figure 1) and input the ship domain described in the author's previous research works and publications (Rutkowski, 2010; Wielgosz & Pietrzykowski, 2012; Wielgosz, 2016).

The VTS operator must not only take into account the navigator's anti-collision domains, but also consider their safety zones in hydrographic terms.

Anti-collision domain

The term "anti-collision domain" refers to a ship domain taking into consideration floating objects only and excludes underwater objects and fixed navigational hazards.

Research works conducted by the author and other researchers allow assigning to a ship of known size and speed an individual elliptic domain of predefined size (Pietrzykowski, Wielgosz & Siemianowicz, 2012; Hansen et al., 2013).

The mathematical model of a ship's domain in the restricted area, taking into account its size and the speed, is shown below (1, 2, 3, 4, 5, 6) (Wielgosz, 2015a; 2015b).

The parametric equation of the ellipse for the mean effective domain of such a ship, taking into accounts its size and speed, takes the form:

$$x(t) = x_0 + a \cdot \cos(t) \tag{1}$$

$$y(t) = y_0 + b \cdot \sin(t) \tag{2}$$

where:

$$a = \left(a_{1L} \cdot L^{b_{1L}} + c_{1L}\right) + a_{1v}\left(v^{b_{1v}} - 2^{b_{1v}}\right) \tag{3}$$

$$b = \left(a_{2L} \cdot L^{b_{2L}} + c_{2L}\right) + a_{2v}\left(v^{b_{2v}} - 2^{b_{2v}}\right) \tag{4}$$

$$x_0 = p_x \cdot L + q_x \cdot v + r_x \tag{5}$$

$$y_0 = p_y \cdot L + q_y \cdot v + r_y \tag{6}$$

where:

L – ship's length [m];

v – ship's speed;

$a_{1L}, b_{1L}, c_{1L}, a_{2L}, b_{2L}, c_{2L}$ – length influence coefficients;

a_{1v}, b_{1v}, c_{1v}, a_{2v}, b_{2v} – speed influence coefficients;

t – relative bearing;

p_x, q_x, r_x – X-axis centre displacement coefficient;

p_y, q_y, r_y – Y-axis centre displacement coefficient.

Function coefficients for different domains are available as groups of coefficients relating to the length of semi-axes and displacement of ellipse centre (Wielgosz, 2015a).

The process of generating and visually presenting such a domain on the VTS operator's electronic chart system screen should be very simple – comparable to the automatic acquisition zones used in the ECDIS and ARPA systems.

This will, according to the author, improve decision-making and increase the safety level of both life and the environment.

The VTS operator, when making a decision and advising the navigator, should take into account the problem (known from the practice and literature) of partially overlapped ship domains. Figure 2 illustrates a situation (in this case overtaking), where the domain of a smaller ship (ship A), with a smaller domain, remains intact, while the bigger ship domain (ship B) has been breached. Later in time, ship B may require action by ship A or undertake its own action.

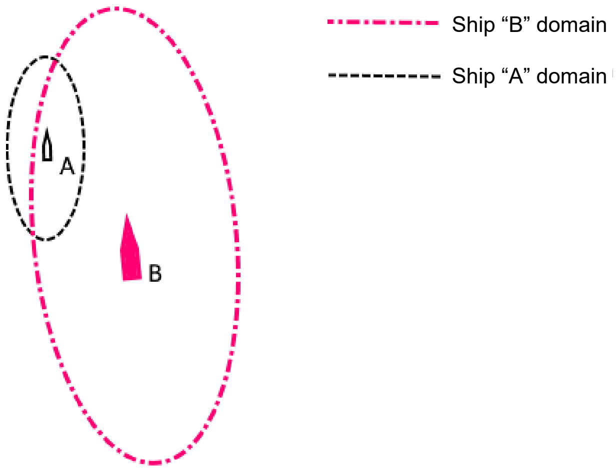

Figure 2. Partially overlapped domains

A useful solution would be the introduction in VTS systems of applications that are already known as navigational decision support systems, e.g. NAVDEC. These systems have the possibility to input the domain as a criterion for assessing the safety of navigation. Such a system will allow planning the manoeuvres of two or more ships in the area considering their domains (Pietrzykowski et al., 2011).

Hydrographic domain

The concept and term "hydrographic domain" is still not known in literature. It can be defined, based on the other anti-collision domains, as the area around the ship that navigators want to keep or keep free from all kinds of navigational hazards that may be identified on an electronic navigational chart encoded in vector format. The possibility to use such domain appeared with the implementation of systems, such as ECDIS and ECS (Electronic Chart System), working with vector format charts. Such systems are able to read and interpret navigational chart content. The extra task remaining to the navigator is the selection and activation of corresponding alarms and, setting safety parameters appropriate to the situation.

In the situation shown in Figure 3, the VTS operator is going to order ship with call sign ABCD to leave the fairway and give way to ship with call sign IJKL, yet he will not be able to quickly and precisely determine the limits – the safety zone in hydrographic terms.

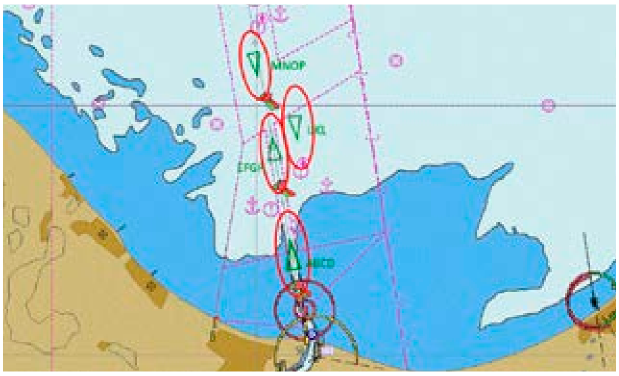

Figure 3. Proposed ship domain on VTS operator screen

Research work

The scope of research was setting the safety parameters in standard tools used in ECDIS systems. The research has been conducted in two forms: questionnaire research and recording of a/m parameters set by ECDIS course participants.

One of such tools is the "Safety Frame", introduced in their systems by several ECDIS manufacturers (Figure 4). This frame is a rectangle, set by a navigator, containing the ship's position and giving the ability to detect, with the necessary advance:

- user defined safety contour and safe depth;
- underwater navigational hazards (wrecks, rocks);
- special areas selected for the detection by navigator (military area, restricted area, etc.);
- user inserted objects on the chart, which have been given the attribute "danger".

They can vary in technical details in systems of different manufacturers, but the task is always the same: to detect in advance the above mentioned navigational dangers and obstructions.

Figure 5 presents the frame, as designed by the company Transas, that gives the possibility to set

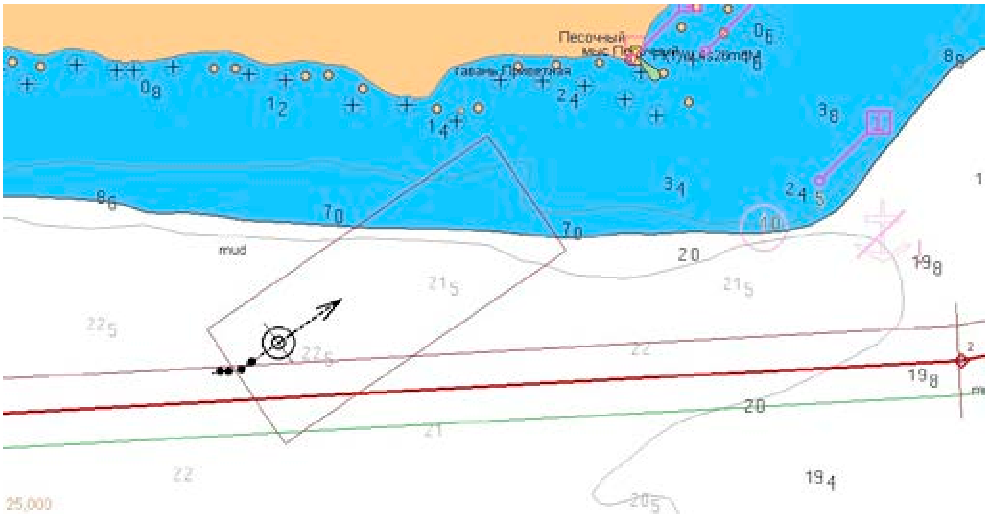

Figure 4. Safety frame in ECDIS system (Transas ECDIS NS 4000)

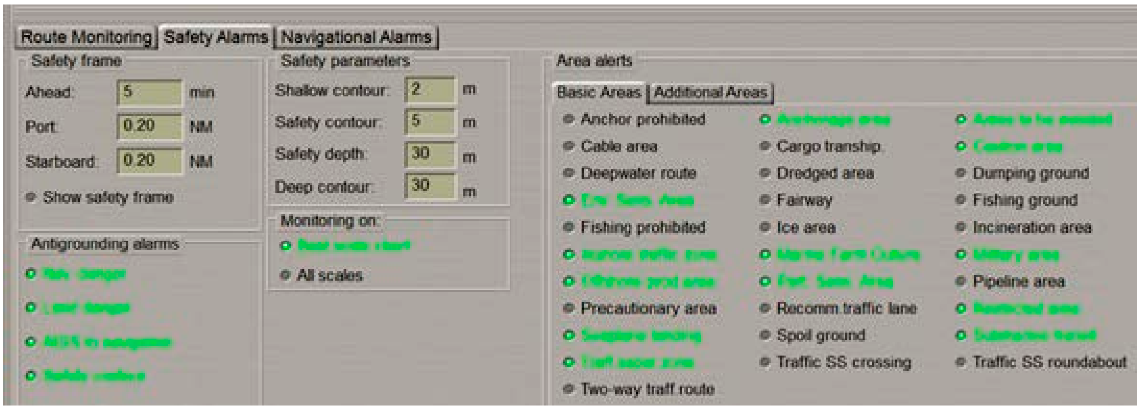

Figure 5. Route monitoring window (Transas ECDIS NS 4000)

detection time to 0–15 min (representing the ship's motion at current COG and SOG). The width of the frame, both of the port and starboard side of the ship, is set in nautical miles. The stern distance is associated with a lower value set on the side of the ship (Transas ECDIS NS4000), as it is not very important when the ship is moving forward. Figure 5 shows the "Safety Alarms"/"Route monitoring" window, with the possibility of editing the parameters of the frame and selecting items to detect.

Such a tool is not present in the electronic chart system used by VTS operators. VTS operators giving instructions or sending information or recommendation and analysing the collision domain only, may suggest to the navigator an incorrect execution of course alternation or deviation from the course.

It was therefore decided to introduce the concept of hydrographic domain, in all aspects known to both parties, and conduct research works concerning its size. Suggested hydrographic domains are

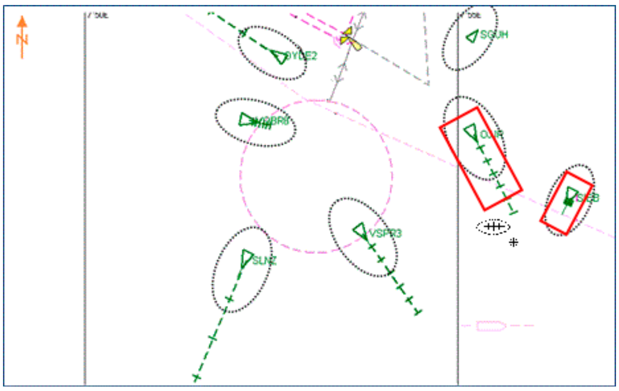

Figure 6. Electronic chart system screen with anti-collision and proposed hydrographic domains

shown as red rectangles in Figure 6, together with the anti-collision domains shown as black dotted ellipses.

The values set by navigators were researched through questionnaires and practical settings of safety frame parameters in the ECDIS system.

Three different types of ships, considered as representative ships, were analysed: large, medium, and small (Table 1).

Table 1. Particulars of the researched ships

Parameter	Ship's size		
	Large	Medium	Small
Length (LOA) [m]	261.3	173.5	95.0
Breadth (B) [m]	48.0	23.0	13.0
Draft (T) [m]	9.0	8.1	3.7
Displacement (D) [t]	63 430	19 512	3 510
Speed (v) [knots]	16.3	18.9	11.1

A total of 35 course participants have been questioned, each of them setting parameters for three above mentioned ships. Example results for "Ahead" parameter settings are shown in Figure 7 in histogram mode.

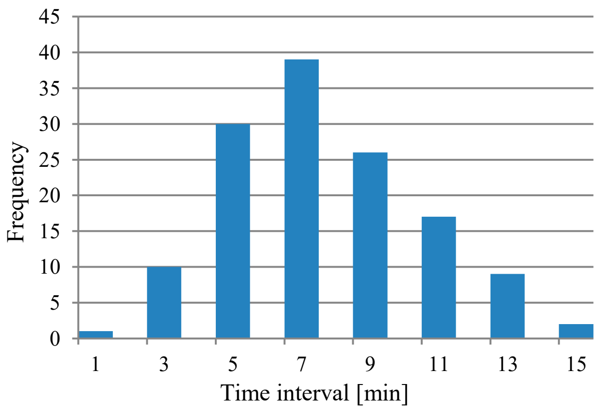

Figure 7. "Ahead" settings of safety frame in histogram mode

All detailed results for safety frame parameters settings are presented in Tables 2, 3 and 4 below. Column 5 – "Ahead [NM]" contains "Ahead' value recalculated in nautical miles for corresponding ship speed.

Table 2. Large-sized ship

	Ahead [min]	Starboard [NM]	Port [NM]	Aft [NM]	Ahead [NM]
Min	3	0.5	0.25	0.25	0.82
Mean	8.47	1.24	0.88	0.88	2.30
Max	15	2	2	2	4.08

Table 3. Medium-sized ship

	Ahead [min]	Starboard [NM]	Port [NM]	Aft [NM]	Ahead [min]
Min	2	0.25	0.15	0.15	0.63
Mean	8.22	1,11	0.74	0.74	2.59
Max	15	1,5	2	2	4.73

Table 4. Small-sized ship

	Ahead [min]	Starboard [NM]	Port [NM]	Aft [NM]	Ahead [min]
Min	1	0.25	0.10	0.10	0.19
Mean	8,05	0.76	0.48	0.48	1.49
Max	15	1	1	1	2.78

Concept of universal, total domain

Operating with two independent types of domains may lead to serious misunderstandings, mistakes and even cause serious dangerous situations in navigation. The question arises is then whether it is possible to substitute two different, independent domains with one universal, total domain containing both of their features.

The answer, until now, has been very ambiguous. The two proposed domains are shown together in Figure 8. It is easily understood that it is very difficult to substitute them with one geometric figure and further research is necessary. The hydrographic domain is significantly shorter behind the ship because the fixed object has already been passed and is no longer considered dangerous, contrarily to the target ship manoeuvring behind the ship's own stern.

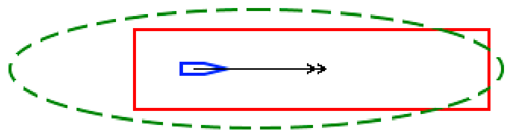

Figure 8. Proposed anti-collision and hydrographic domains

The overlapping and comparison of the two domains raises the question of whether it is more convenient to substitute the rectangle with the ellipse. Theoretically, for some reasons it may be the case, but further research is required for navigators to accept it. It should be, for example, more practical to automatic plan and check the route.

The main problem is visible when the two discussed domains are shown for the same vessel (Figure 9). The hydrographic domain presents an

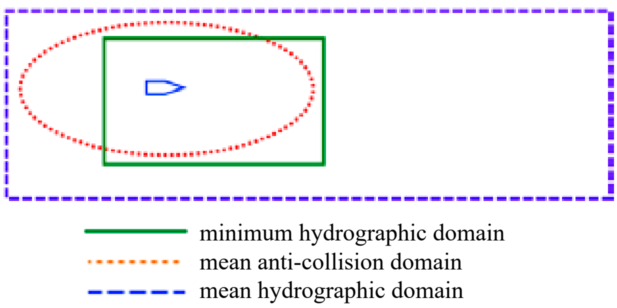

Figure 9. Anti-collision and hydrographic domains

unexpectedly large size. This observation only leads to the conclusion that researched domains are declarative only, and similarly to anti-collision domains, smaller effective hydrographic domains exist and need to be identified by simulation and research (Wielgosz, 2015a).

Conclusions

The problem of determining the shape and size of the ship safety zones is complex for navigators. The problem increases for someone who is not on board the ship and is using the standard electronic chart system, which is not pre-set for individual ship dangers (e.g. specific safety contour).

Research carried out by the author allows to draw the following conclusions:

- implementation of the proposed hydrographic domain will increase safety in VTS monitored areas;
- the domains described are to be considered as declarative only;
- further, detailed research on effective hydrographic domain is necessary.

Analysing the two domains together it is possible to determine whether the major risk for the navigator is a fixed wreck or the manoeuvring target ship.

The wreck is fixed and won't move, but the target ship, although it is also monitoring the situation, could perform the wrong manoeuvre.

A single, universal domain should find a compromise solution to this problem.

Acknowledgments

This research outcome has been achieved under the research project No. 1/S/ITM/2016 financed from a subsidy of the Ministry of Science and Higher Education for statutory activities of Maritime University of Szczecin.

References

1. Goodwin, E.M. (1975) A Statistical Study of Ship Domain. *Journal of Navigation* 28. Cambridge
2. Hansen, M., Jensen, T., Lehn-Schiøler, T., Melchild, K., Rassmussen, F. & Ennemark, F. (2013) Empirical Ship Domain Based on AIS Data. *Journal of Navigation* 66. Cambridge.
3. IALA (2016) *Vessel Traffic Services Manual*. Digital Publication, Edition 6.
4. Pietrzykowski, Z. at al. (2011) *The Navigational Decision Support System on a Sea – going Vessel*. Szczecin: Maritime University.
5. Pietrzykowski, Z. & Uriasz, J. (2009) The Ship Domain – a Criterion of Navigational Safety Assessment in an Open Sea Area. *Journal of Navigation* 62. Cambridge.
6. Pietrzykowski, Z., Wielgosz, M. & Siemianowicz, M. (2012) Ship domain in the restricted area-simulation research. *Scientific Journals Maritime University of Szczecin* 32 (104) z. 2. pp. 152–156.
7. Rutkowski, G. (2010) Wykorzystanie przestrzennego modelu domeny do oceny bezpieczeństwa nawigacyjnego kontenerowca typu post-panamax podczas manewrów podchodzenia do terminalu DCT Gdańsk Port Północny. *Prace Wydziału Nawigacyjnego Akademii Morskiej w Gdyni* 24. Gdynia.
8. Śmierzchalski, R. & Weintrit, A. (1999) *Domains of navigational objects as an aid to route planning in collision situation at sea*. Proceedings of 3rd Navigational Symposium, Gdynia.
9. Wawruch, R. (2001) *Assumptions decision-making automated control system of maritime traffic*. Proceedings of the International Scientific Conference "Transport XXI century", Warsaw University of Technology, 2001.
10. Wielgosz, M. (2015a) *Domena statku w ocenie bezpieczeństwa żeglugi*. Unpublished Phd theses [in Polish]. Szczecin: Maritime University.
11. Wielgosz, M. (2015b) Efektywna domena statku na akwenie ograniczonym i jej zastosowanie w systemach statkowych [in Polish]. *Technika Transportu Szynowego* 12. Radom.
12. Wielgosz, M. (2016) Declarative ship domain in restricted area. *Scientific Journals of the Maritime University of Szczecin* 46 (118). pp. 217–222.
13. Wielgosz, M. & Pietrzykowski, Z. (2012) Ship Domain in the Restricted Area – Analysis of the Influence of Ship Speed on the Shape and Size of the Domain. *Scientific Journals Maritime of the University of Szczecin* 30 (102). pp. 138–142.