TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 14
Number 2
June 2020

DOI: 10.12716/1001.14.02.19

# Impact of Chart Data Accuracy on the Safety of Navigation

N. Acomi
*Constanta Maritime University, Constanta, Romania*

ABSTRACT: Conducting navigation by using electronic charts is not an option anymore. With few exceptions, vessels shall carry on board electronic navigational charts and Electronic Chart Display and Information Systems. The official electronic charts are issued by or on behalf of the authority of a Government, authorized Hydrographic Office or other relevant government institutions. These nautical charts are compiled from multiple data sources, some modern and very comprehensive, while others older. The accuracy of data, named "Category Zones of Confidence – CATZOC", differs among various navigation areas. The navigation officers of the watch rely on the chart data to calculate the safety parameters and to plan the route in advance for the intended voyage. The aim of this paper is to emphasize the impact which the data accuracy has on the safety of navigation. For this purpose, a model vessel was considered in a Strait of Dover bridge simulation scenario, assuming good weather conditions without swell or current. The Safety Contour was defined using a mathematical formula which incorporated the under keel clearance, the squat effect and the tide levels. Then, the Safety Contour was examined considering the chart data accuracy. The results of this analysis contribute to increasing awareness and better understanding of CATZOC influences on the identification of safe waters during navigation.

## 1 INTRODUCTION

Electronic Chart Display and Information System (ECDIS) is a complex navigation tool developed "to assist the mariner in route planning and route monitoring and display additional navigation-related information if required", as specified in the Performance Standards for ECDIS [IMO, 2006].

The history of ECDIS started in the 1990s when a couple of companies offered electronic chart systems to be used on board vessels. Recognizing the need to prepare performance standards for ECDIS, the International Maritime Organization (IMO) adopted the resolution Performance standards of ECDIS [IMO, 1995]. This resolution set out the minimum levels of requirements to be met in order to use the ECDIS as bridge equipment on board conventional ships. In year 2000, with the adoption of amendments to the International Convention for the Safety of Life at Sea, the ECDIS was accepted as complying with the provisions of the SOLAS Convention [IMO, 2000].

Later on, in 2009, the IMO established the implementation timeline as depicted in Figure 1. Nowadays, the period of implementation of the ECDIS on board vessels came to the end, making mandatory the fitting of vessels with ECDIS equipment.

With few exceptions, every vessel shall carry ECDIS equipment in accordance with the IMO performance standards and the Safety of Life at Sea

Convention (SOLAS). Ships which will be permanently taken out of service within two years of a trigger date from the implementation timeline may be exempted by the Flag States. There is no provision for cargo ships (other than tankers) of less than 10,000 GT to be fitted with ECDIS.

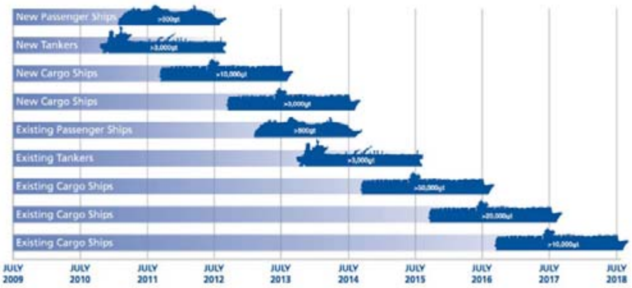


Figure 1. ECDIS implementation timeline [IMO, 2008].

The 1st of July 2018 marked symbolically that the ship navigation has accomplished the shift from paper charts to the era of digital chart navigation [Weintrit, 2018a].

There were six years of transition, from July 2012 to July 2018, while the ship-owners fitted the ships with ECDIS system in compliance with the international requirements [IMO, 1995]. Within this period, various ECDIS equipment manufacturers went beyond the performance standards and provided systems with additional functionalities able to support the officers in the process of decision making. The functionalities come together with software design solutions which differ from one provider to others, and sometimes from one version to an updated one. The complexity of functions and the apparent easiness of operating the system seem to increase the risk of overreliance on ECDIS.

Certainly, if properly used by well-prepared officers, there are many benefits of ECDIS use on board. Nevertheless, we cannot deny the fact that ECDIS complexity might make things to go wrong. For example, if wrong settings are put in place, the information provided to navigators will not be accurate. Feeding in wrong parameters for the safety critical settings such as the Safety Depths and Safety Contours can give a false sense of safety [Weintrit, 2018b].

The value of Safety Contour, calculated on board by the deck officer and set on the ECDIS, rapidly separates the safe waters from the unsafe waters on the electronic navigational chart.

The main question arising is: how safe is the safe water?

The officer must know the answer. Recommendations were formulated [Bhuiyan, 2012] for assisting the deck officer to understand the values for Safety Contour and to consider data source while determining the safety settings. These are of assistance on properly setting the ECDIS to achieve a sensible and well thought-out implication.

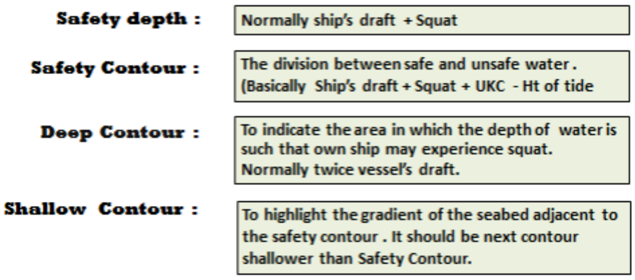
It has been noted [Weintrit, 2018c; Rutkowski, 2018] that many navigators have a tendency to put much reliance on ECDIS. This may contribute to accidents rather than preventing them. From accident analyses Chhabra [2014] concluded that the main causes are not ECDIS system failures, but more likely operational failures. One of these types of failures is the improper use of source data.

In this context, the subject of this paper is represented by the source data used for creating electronic navigational charts. The ECDIS provides navigators with a facility to examine reliability and quality of source data presented on the chart by means of Category Zone of Confidence (CATZOC).

The electronic charts for various areas are generated using data of different accuracy levels. The purpose of the following sections is to emphasize the impact of the data accuracy on the safety parameters. Taking into consideration the category zones of confidence CATZOC, this case study highlights the differences in Safety Contour values obtained with or without considering the chart data accuracy, all other variables remaining equal.

## 2 DETERMINING THE SAFETY CONTOUR

“Appropriate safety settings are of paramount importance for the safety of navigation” [Bhuiyan, 2010]. Because several variable factors are influencing ship’s behaviour (e.g. environmental, topographic, loading, ships nautical qualities) and because all these contribute to the safety of navigation, there is no all-inclusive mathematical formula for calculating the Safety Contour. Instead, a couple of recommendations were formulated by Bhuiyan [2010] and several papers from marine professionals agreed with these [Mukherjee, 2018]:



**Safety depth :** Normally ship’s draft + Squat

**Safety Contour :** The division between safe and unsafe water. (Basically Ship’s draft + Squat + UKC - Ht of tide

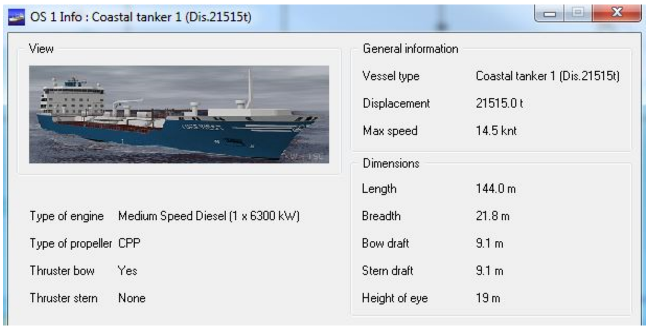
**Deep Contour :** To indicate the area in which the depth of water is such that own ship may experience squat. Normally twice vessel’s draft.

**Shallow Contour :** To highlight the gradient of the seabed adjacent to the safety contour. It should be next contour shallower than Safety Contour.

Figure 2. Recommended Safety Settings on ECDIS [Bhuiyan, 2010].

Safety Contour value will be calculated for a model vessel and analysed from the perspective of various CATZOC features.

This study is based on the characteristics of a Coastal tanker model vessel of 21,515 DWT, 144.0m length between perpendiculars, at even keel with 9.1m draft (Figure 3). The navigation area for this scenario is the English Channel.



| | |
|---|---|
| Vessel type | Coastal tanker 1 (Dis.21515t) |
| Displacement | 21515.0 t |
| Max speed | 14.5 knt |
| Length | 144.0 m |
| Breadth | 21.8 m |
| Bow draft | 9.1 m |
| Stern draft | 9.1 m |
| Height of eye | 19 m |
| Type of engine | Medium Speed Diesel (1 x 6300 kW) |
| Type of propeller | CPP |
| Thruster bow | Yes |
| Thruster stern | None |

Figure 3. Coastal tanker model vessel, TRANSAS simulator.

### 2.1 *Under keel clearance*

The minimum Under Keel Clearance (UKC) is required by the internal procedures of shipping companies. The procedure of a Romanian company which remains anonymous requires the vessels to maintain minimum of 0.5m at all times alongside, 0.65m below deepest draft (including expected squat) while underway in confined waters, and 15% of deepest draft in exposed or open waters. In the given scenario, the model vessel navigates in the confined water of the Strait of Dover and therefore the minimum UKS is considered 0.65m (including expected squat).

### 2.2 *Squat effect calculation*

For the purpose of this scenario, the most conservative ship conditions were considered, i.e. maximum speed and draft.

The .xlsx squat effect calculation sheet and formulas for confined waters (eq. 1) and for open waters (eq. 2) follow bellow:

$$\text{Squat confined waters} = (C_b \times V2)/50 \text{ m} \tag{1}$$

$$\text{Squat open waters} = (C_b \times V2)/100 \text{ m} \tag{2}$$

where:
$C_b$ –block coefficient (eq. 3)
V – speed through the water in knots (14.5 knots in confined waters)

$C_b$ = displacement/(L x B x D x W.D.) (3)

where:
L-length, B-breadth, D-draft of the ship and W.D. is water density of 1.025Kg/l.

For the given scenario, the ship's characteristics were taken from the general information given at Figure 3. The resulting squat effect is 3.25m for the vessel in confined waters.

The current scenario did not consider any current, which would otherwise be expected in the Strait of Dover. However, according to the above formulas (1) and (2), the squat is dependent on the ship's speed through the water. Therefore, the presence of the current in the Strait of Dover is not expected to introduce significant changes to the calculated squat value.

### 2.3 *Tide levels*

The tide in the Strait of Dover is also a factor influencing the safety of navigation in confined water. While the chart depth depicts the Mean Lowest Low Water, higher tide water give additional depth available for the ship. Therefore, the Safety Contour may incorporate the tide evolution, but would be limited for the respective time of strait transit.

If it were necessary or desired to consider the tidal gains and set the Safety Contour to smaller water depth, the time constraint shall be clearly stated and followed up.

For the purpose of this study, the most conservative scenario was considered, i.e. with the vessel transiting the Strait of Dover at Low Water.

### 2.4 *Safety Contour calculation*

Considering the conservative scenario for the tide, the Safety Contour is set at the water depth which is depicted by the sum between the ship's draft, the minimum under keel clearance and the squat:

$$S_c = D + UKC + Squat \tag{4}$$

where:
$S_c$ – Safety Contour

The resulting Safety Contour is 13.0m.

It worth mentioning that other company procedures may give instructions and/or formulas for fresh water allowance, heel allowance and swell, which were not included in the current scenario.

## 3 THE CHART DATA ACCURACY

The chart data accuracy is known as category zones of confidence, CATZOC. The data is obtained from a range of sources and methods included below, from the highest to the lowest precisions:
- DGPS;
- Minimum three lines of position;
- Multi beam channel or mechanical sweep system
- Echo sounder and sonar or mechanical sweep system;
- Echo sounder but no sonar or mechanical sweep system;
- Soundings.

The resulting level of accuracy is represented by values assigned to geographical areas. The position and depth accuracy is indicated for each navigation area.

Depending on the characteristics of the survey, the accuracy is provided to the user through six types of quality indicators: A1, A2, B, C, D and U. The accuracy of the position may vary from +/-5m to more than +/- 500m, while the accuracy of depth may vary from less than 0.5m to 2m or more, as depicted in Table 1.

Depending on the ECDIS manufacturer and model, various safety settings are available: safety depth, Safety Contour, deep contour and shallow contour. If properly calculated and set, these parameters would provide indication and alarm. This would assist the nautical officer in conducting a safe navigation watch.

In order to properly set the safety parameters, the user is required to check and interpret the CATZOC values. The accuracy of these values shall be considered while setting the chart Safety Contour that distinguish safe from unsafe water.

Table 1. Category Zones of Confidence

| Zone of confidence | Position accuracy | Depth accuracy | |
|---|---|---|---|
| A1 | +/- 5m + 5% depth | =0.50 + 1% depth | |
| | | Depth (m) | Accuracy (m) |
| | | 10 | +/- 0.6 |
| | | 30 | +/- 0.8 |
| | | 100 | +/- 1.5 |
| | | 1000 | +/- 10.5 |
| A2 | +/- 20m | =1.00 + 2% depth | |
| | | Depth (m) | Accuracy (m) |
| | | 10 | +/- 1.2 |
| | | 30 | +/- 1.6 |
| | | 100 | +/- 3.0 |
| | | 1000 | +/- 21.0 |
| B | +/- 50m | =1.00 + 2% depth | |
| | | Depth (m) | Accuracy (m) |
| | | 10 | +/- 1.2 |
| | | 30 | +/- 1.6 |
| | | 100 | +/- 3.0 |
| | | 1000 | +/- 21.0 |
| C | +/- 500m | =2.00 + 5% depth | |
| | | Depth (m) | Accuracy (m) |
| | | 10 | +/- 2.5 |
| | | 30 | +/- 3.5 |
| | | 100 | +/- 7.0 |
| | | 1000 | +/- 52.0 |
| D | Worse than ZOC C | Worse than ZOC C | |
| U | Unassessed | | |

## 4 DISCUSSION

In order to highlight the safe (white) and unsafe waters (blue) on the electronic chart, the deck officer would set the value of the Safety Contour in the monitoring window. This case study considered good weather conditions without swell or current. This assumption would allow the comparison of CATZOC impact on the safety parameters.

Default Safety Contour
UTC 02 - 05 - 18
12 : 00 : 00
Prim 51° 41.794 N
DGPS 1 001° 27.133 E
Sec:NONE
gb301975
Last upd.: 09-10-2015
Updated to: WK49-15
System information
Drift 000.0° - 0.0 kn
Current 239.5° - 1.3 kn
SF CNT 15.0 m
True wind 000.0° - 2.6 m/s
Rel. wind 138.0°(S) - 2.6 m/
Water t° 7.8 °C
Depth ECHOSOUNDER 1 9.4 m
Tide height

Figure 4. Safety parameters, TRANSAS simulator.

For the Strait of Dover navigation area considered in the current scenario, according to the category zones of confidence, the possible values of the depth were determined. CATZOC varies from 6-star in the A1 area to 5-star in A2 and 4-star in the B navigation area, Figure 4. This might impact the value of the safety parameters as presented in Table 2.

For the 13.0m value of the Safety Contour obtained from (eq. 4), the CATZOC depths are tabulated as follows:

Table 2. Depth possible values

| CATZOC – Category zones of confidence | Depth from the ENC - Electronic Navigational Chart (m) | Possible values of the depth according to the CATZOC (m) |
|---|---|---|
| A1 | 13.0 | 12.37 – 13.63 |
| A2 | 13.0 | 11.74 – 14.26 |
| B | 13.0 | 11.74 – 14.26 |

The results depicted in the right side column of Table 2 above show positive and negative variations of the depth. Setting the Safety Contour to 13.0m would introduce delusive confidence while the actual depth may vary from 11.74m, in A2 and B CATZOC to 14.26m in B CATZOC area of navigation.

Thus, even though the Safety Contour had previously been determined at 13.0m, that depth may be unsafe for the vessel if the conditions of maximum squat effect and minimum CATZOC depth for A1, A2 and B category zones of confidence were met. Moreover, while in case of A1 the vessel would be close to aground (by 0.02m, given the UKC of 0.65m which was considered), in the A2 and B cases the vessel would be aground by 0.61m.

Therefore, it may be prudent for the officer of the watch to consider the above by setting the Safety Contour to a minimum given by the maximum of CATZOC depth. Furthermore, because the CATZOC depth value is often a decimal number, the round value of the next bathymetric line available for that area (15.0m or greater) shall be chosen for the Safety Contour.

The above analysis clearly indicates the importance of CATZOC, which should be considered for the safety of navigation.

## 5 CONCLUSIONS

The correct setting of safety parameters is essential for the safety of navigation. Being aware of the accuracy of the data allows the officers of the watch to properly evaluate the situation and to consider negative variations for depth. The results of this study are intended to increase the awareness of nautical officers regarding the limitations of ECDIS systems with regards to the Safety Contour, as well as the importance of the chart data.

In addition to the above, further area of study in the field of CATZOC may include the position accuracy, which was not factored into the current analysis.

Moreover, future studies may analyse in further depth the influence of CATZOC while the ship being in more complex and realistic conditions such as draft restrictions during low and high tide, current, fresh water allowance, heel allowance and swell.

## REFERENCES

[1] IMO MSC.232(82), (2006). Revised Performance Standards for Electronic Chart Display and Information Systems (ECDIS). International Maritime Organization, London, 5 December.

[2] IMO Resolution A.817(19), (1995). ECDIS Performance Standards.

[3] IMO MSC 73rd session, (2000) Proposed amendments to SOLAS Convention

[4] IMO Circ. letter 2916, (2008) SOLAS Amendments

[5] Chhabra, Y. (2014) A little learning: examining ECDIS education. *The Navigator.* 06 The Nautical Institute, pp. 4.

[6] Bhuiyan, Z. (2012). ECDIS Display, Safety Settings and Alarm Management *Proc of the 14th IAIN Congress, Egypt.* pp. 1-6.

[7] Bhuiyan, Z. (2010). Implementing ECDIS training for navigation officers. *Seaways Nautical Institute's international journal*

[8] Mukherjee, P. (2018) *Proper Use of ECDIS Safety Settings* www.marineinsight.com

[9] Rutkowski, G. (2018). ECDIS Limitations, Data Reliability, Alarm Management and Safety Settings Recommended for Passage Planning and Route Monitoring on VLCC Tankers. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, Vol. 12, No. 3, doi:10.12716/1001.12.03.06, pp. 483-490.

[10] Weintrit, A. (2018a). Clarification, Systematization and General Classification of Electronic Chart Systems and Electronic Navigational Charts Used in Marine Navigation. Part 1 - Electronic Chart Systems. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, Vol. 12, No. 3, doi:10.12716/1001.12.03.05, pp. 471-482.

[11] Weintrit, A. (2018b). Accuracy of Bathymetric Data in Electronic Navigational Charts. *Scientific Journals of the Maritime University of Szczecin*, No. 55 (127), doi:10.17402/302, pp. 60-69.

[12] Weintrit, A. (2018c). Clarification, Systematization and General Classification of Electronic Chart Systems and Electronic Navigational Charts Used in Marine Navigation. Part 2 - Electronic Navigational Charts. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, Vol. 12, No. 4, doi:10.12716/1001.12.04.17, pp. 769-780.