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RESEARCH ARTICLE

The importance of CATZOC in passage planning and prioritization of strategies for safe navigation

Ozan Hikmet Arıcan[1] • Osman Arslan[2] • Ali Umut Ünal[3*]

[1] *Kocaeli University, Maritime Faculty, Department of Maritime Transportation Management Engineering, Karamürsel, Kocaeli, Türkiye*
[2] *Kocaeli University, Maritime Faculty, Department of Marine Engineering, Karamürsel, Kocaeli, Türkiye*
[3] *Kocaeli University, Karamursel Vocational High School, Department of Motor Vehicles and Transportation Technologies, Karamürsel, Kocaeli, Türkiye*

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ABSTRACT

Maritime transport has a significant share in world trade. The unsafe operation of ships causes loss of life, loss of cargo, and marine environmental pollution. Commercial ships are equipped with advanced types of equipment. The nautical charts as aids to navigation are used on commercial ships to navigate safely between ports. The officer of the watch can see the risks in the navigation area by checking these charts. The risks indicated on the chart should be taken into account during the navigation of ships, and if the correct calculations are not made, serious accidents may occur. These calculations are based on both sufficient maritime experience and knowledge. This research studied the category zone of confidence (CATZOC) areas in ECDIS on ships, the limitations of the system, and their solutions. Recommendations received from experts for the solutions to the identified problems were determined and explained according to the priorities with the Fuzzy Analytical Hierarchy Process (FAHP) method.

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Introduction

In international trade, there are different forms of cargoes such as solids, liquids, live animals, ro-ro, containers and liquefied gas. Although the ship types are different, they all have a common purpose in navigation, which is navigational safety. Each device has a system designed to assist the master and officers of the watch during navigation. Ships are equipped with navigational equipment according to the rules regulated by the International Maritime Organization (IMO).

Ships can navigate in narrow channels and shallow waters and it is of great importance for the officers that the navigation

* Corresponding author
E-mail address: umut.unal@kocaeli.edu.tr (A. U. Ünal)

charts used are reliable. Although the depths of the berths of the ports are shown on the navigation charts, in practice, shallow areas may occur due to natural sea movements and port operations. For this reason, ship manoeuvres in port areas should be applied carefully.

As the size of the ships increases, the draft of the ships also increases. When the ship is underway, speed increases the draft of the ship. This is called the dwarfing effect and has a greater effect in shallow water and fresh water, causing the draft of ships to increase further (Chénier et al., 2019). Besides unpredictable fluctuations, the rapid increase in ship sizes in recent years and the collaborations established by global line operators force container ports to increase their physical capacities (Efecan & Temiz, 2023). This is a risk because the greater the draft of the ship, the more likely it is to run aground at shallower depths. To mitigate these risks, nautical charts should be trusted and interpreted well. It is possible to check the depth controls with echo sounder in the areas where the ships are moving. The echo sounder device measures the depth instantaneously by means of sound echoes with the help of sensors located at the bow and stern of the ship. However, it does not help to get information before reaching a dangerous point; it only provides control (Talwani et al., 1966).

Due to their nature, the seas contain many risks, such as shallows, reefs, shipwrecks, corals, offshore platforms, fish farms, and navigational aid buoys. The master can see these risks on the bridge during look-out or on the charts. It is dangerous to approach or watch such risks. For safe navigation, the information on the charts constitutes an order of importance according to the type of voyage. For example, route planning and considering currents are more important in open sea navigation, while in narrow and shallow waters, effects such as dangerous areas, buoy locations, shoreline information, and tides are more critical (Başaraner et al., 2011). Master and watchkeeping officers need to be careful and prepared for these risks for the ship's safe navigation.

Today, electronic charts that replace nautical charts, along with navigation sensors and other navigation aid devices, have become an important area of use based on the creation of an integrated bridge system that will significantly increase navigational safety (Admiralty, 2021). These technological developments are supported by international standards (Er, 2007).

The reliability of the chart-based systems used on ships is vital for the safety of navigation. The Electronic Chart Display and Information System (ECDIS) is sophisticated navigational equipment developed to "assist the seafarer in route planning and tracking and, if necessary, display additional navigation-related information" as specified in the performance standards (IMO, 2006). The history of ECDIS dates back to the 1990s when several companies offered electronic chart systems for use on ships. Recognizing the need to prepare performance standards for ECDIS, IMO adopted the ECDIS Performance standards resolution (IMO, 1995).

This decision sets out the minimum requirements that must be met for the use of ECDIS as bridge equipment on conventional ships. With the adoption of the amendments to SOLAS in 2000, it was accepted that ECDIS complies with the provisions of the SOLAS Convention (IMO, 2000). Later in 2009, IMO established the implementation timeline as shown in Table 1. Today, the implementation of ECDIS on ships has expired, making it mandatory for ships to be equipped with ECDIS equipment.

ECDIS is an integrated information system that displays a wide variety of navigation information using spreadsheets. Designed with the ship operator in mind, ECDIS is a vital resource for efficient route planning and monitoring (Matek, 2019).

Table 1. ECDIS implementation timeline (Weintrit, 2015)

Ship Types	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
New construction passenger ships >500 GT	-	+	+	+	+	+	+	+
New construction tankers >3000 GT	-	+	+	+	+	+	+	+
New construction cargo ships >10000 GT	-		+	+	+	+	+	+
Except passenger ships>500 GT	-			+	+	+	+	+
Except tankers>3000 GT	-				+	+	+	+
Except cargo ships>50000 GT	-					+	+	+
Except cargo ships>20000 GT	-						+	+
Except cargo ships>10000 GT	-							+

The CATZOC used in ECDIS is an essential instrument for safe navigation. Over a long period, these depths have been calculated with different methods and charted. In the early days, measurements were made with wire cables and beam echo methods. Then, the wire drawing method was adopted, in which a wire is dragged by two or more ships with weights submerged to a constant depth (Helmsman, 2010). Depth was determined by stretching the wire with any obstacle in the covered area. Techniques applied today use sonar multiple beam waves to record depths. The collected information is processed with data that affects the measurement, such as tides, so the depths are as accurate as possible. This method will provide more accurate depth measurements (Saltaş, 2020). Category Zone of Confidence (CATZOC) values are applied to geographic areas to indicate whether the information meets a minimum set of criteria for location, depth accuracy, and seabed coverage. The Zone of Confidence (ZOC) value depends on the data's positional and depth measurement accuracy (Admiralty, 2021).

In the application of CATZOC, some deficiencies may occur. If the calculations are not performed accurately, this situation may lead to the grounding of the vessel.

Literature Review

Kusworo et al. (2019) used cross strips as independent data to test the quality of bathymetry data compared to overlay strips from Multibeam Echosounder (MBES) in the Bawean Island cases. The tests were carried out by 3 methods: 1. testing the crossing strip and the main strip overlapping the crossing strip, 2. testing the 25 crossing points between the main strip and the crossing strip, and 3. testing the overlap strip between the main strip along the crossing strip. The data obtained from the quality test were re-tested using statistical analysis methods to determine the extent to which the data can represent the data quality of the study area. As a result, it was found that testing the data of the cross lanes was more effective as the main lanes were not affected by the features.

Chénier et al. (2019) proposed a confidence level approach where a minimum number of SDB techniques is required, which must be agreed upon at a defined level to allow SDB estimates to be maintained due to the difficulty of validating Satellite Derived Bathymetry (SDB) data. The approach has been applied to a Canadian Arctic region combining four techniques. Based on International Hydrographic Organisation (IHO) guidelines, results are described, with each approach meeting the requirements of the Category of Confidence Zones (CATZOC) level C.

Acomi (2020) emphasised the effect of data accuracy on navigational safety. For this purpose, a model ship was considered in the Dover Strait bridge simulation scenario, assuming good weather conditions with no waves or currents. The Safety Contour was defined using a mathematical formula involving under keel clearance, heeling effect and tidal levels. The Safety Contour was then analysed taking into account the accuracy of the chart data. The results of this analysis contribute to a better understanding and increased awareness of CATZOC effects in determining safe waters for navigation.

Kastrisios et al. (2020) provided information on CATZOC, horizontal and vertical uncertainty of depth information, as well as seafloor coverage and feature detection. The current symbology creates visual clutter in high quality bathymetry fields. Furthermore, horizontal and vertical uncertainties cannot be adequately assessed by the user. This paper presents a research programme to develop a method to demonstrate bathymetric data quality and to integrate digitised uncertainties into ECDIS.

Chénier et al. (2020) attempted to collect the data needed by the Canadian Hydrographic Service (CHS) to produce wide-area navigational products for the Canadian coastline, the longest in the world. CHS products cover all Canadian waters, but there are gaps in the data. To prioritise these gaps, the CHS has developed a geographic information systems (GIS) tool called the CHS Priority Planning Tool (CPPT). The derived output of the CPPT helps prioritise areas that pose the highest risk to navigation.

Karström Hettman (2022) worked on extending CATZOC classifications in Swedish territorial waters by creating a model that can predict how fast the bathymetry will change at different locations from the SMA in Norrköping. Models and maps were prepared in ArcMap GIS to predict bathymetric changes of the seabed in the Baltic Sea. Factors in the models include seabed type, seabed slope and shipping corridors. The models and maps can be used to see which areas should be changed from A1 classification to a lower classification or the area should be re-measured. This study opens a new way to assess changes in the bathymetry of Swedish territorial waters without the need to re-measure surfaces and will help to know which areas to prioritise for re-measurement.

Radić et al. (2023) analysed the bathymetric data collection method. The collected depth data were compared with official data displayed on electronic navigational charts (ENC) in the United States. Four sea areas were selected where 104 depths were compared at the same positions and also categorized according to the criterion of navigational importance, namely category confidence zones (CATZOC). Official depth data from hydrographic surveys and depth data collected from public sources for the same positions were compared and correlated, and it was concluded that CSB data, despite its limitations, is a very valuable addition to the existing official data.

Gülher & Alganci (2023) aimed to produce the first optical image-based SDB map of the shallow coast of Horseshoe Island and to perform a comprehensive and comparative evaluation with Landsat 8 and Sentinel 2 satellite imagery. The research considers the performance of empirical SDB models (classical, ML-based and DL-based) and the effects of atmospheric correction methods ACOLITE, iCOR and ATCOR. These models are followed by DL-based ANN and CNN models. However, the nonlinearity of the reflectance-depth relation is significantly reduced by the ML-based models. Furthermore, Landsat 8 performed better in the 10-20 m depth ranges and the entire (0-20 m) range, while Sentinel 2 performed slightly better up to 10 m depth ranges. Finally, ACOLITE, iCOR and ATCOR provided reliable and consistent results for SDB, with ACOLITE providing the highest automation.

Dias et al. (2023) aimed to minimize human effort by automating the detection of discrepancies between nautical charts and survey data. A GIS location model was developed based on specific rules derived from three analysis criteria: depth fields, minimum soundings and bathymetric models. The model produces six outputs, two for each criterion, to support the final human decision. The model has been tested in various hydrographic surveys, such as open waters and harbour surveys, and successfully validated by comparing the results with existing manual processes and other existing methods, such as the Sea Chart Adequacy Tools (CA Tools). Potential advantages over other methods are also evaluated and discussed, confirming the usefulness of this new approach for the adequacy and completeness assessment of nautical charts.

Horn (2023), used SDB for recursive mapping of Stono Inlet at large spatial and large temporal (2001-2022) scales. SDB methods summarized in the IHO-IOC GEBCO Cook Book: LANDSAT 8 Satellite Derived Bathymetry is used to derive bathymetric surfaces using the algorithm of Stumpf et al. (2003). Extinction depths are estimated to be between 5 and 10 feet in the Inlet. NOAA vDatum, ArcGIS Pro, Fledermaus, and ArcGIS Online (AGOL) were used for analysis and visualization. The results show that the high-resolution, high-quality WorldView 02/03 imagery data used for the 2016 to 2022 analysis years are necessary to obtain bathymetric surfaces in Stono Inlet that are useful only for visual bathymetric assessments.

Carreras Ruiz (2023) examined and analysed the principles of transition planning throughout onboard training. The voyage from Sakai (Japan) to Point Fortin (Trinidad and Tobago) is detailed and followed step by step to encourage deck officer candidates to acquire these competencies. The study also contributes to the assessment of the ship's performance in safety issues and its economic and environmental costs.

When the previous researches are examined, it is seen that the subject research has not been conducted before. The subject research both contributes to the literature and as new research, it will be an example for other researches in the future.

Material and Method

Material

Category Zone of Confidence

Table 2 shows the types of CATZOC symbols. By gaining a deeper understanding of the accuracy limitations of the data within the system, ships can manage risk levels while navigating a specific area. Based on errors in measurements in position and depth, accuracy data is divided into 6 ZOC.

The Zones of Confidence (ZOC) chart shows position accuracy, depth measurement sensitivity, and seabed for each of these values to help manage risk levels while navigating.

ECDIS displays these CATZOC values in Electronic Nautical Charts (ENC) using a triangle-shaped symbol pattern. The number of stars inside these symbols indicates the CATZOC value. For example, six stars indicate the highest data quality (A1) and two stars the lowest level (D). For CATZOC, unevaluated areas are shown as a symbol (U) (Teledynecaris, 2016). The maximum possible errors in each confidence zone depth and the positions marked in the charts are given. If for a graph or ENC, CATZOC is 4 stars (ZOC B), this means that the location of the depths and dangers marked in the ENC can have a margin of error of about 50 meters (Matek, 2019). Depths may have an error of up to 1 meter + 2%. If anywhere the graph shows depth of 20 meters, the error here could be 1.4 meters.

CATZOC is not a guide recently released with ECDIS. In fact, it was used in nautical charts before. Nautical charts contain source diagram. For example, the source diagram of the chart on the British Admiralty is shown in Figure 1.

As can be seen, the depths in the "c and d" areas are circled with a red line in Fig. 1. Depths in this area can have significant errors. The master and watchkeeping officers should be careful of these errors. Depth and position categories on charts are shown in the information part of the chart, as in Figure 2.

It is necessary to consider the risk levels of this error percentage, which should be considered. Nautical charts do not include error rates for these depth measurements. The master and watch keeping officers should decide on the information in the diagram given in Figure 3.

The ECDIS user can visually transfer the CATZOC settings to the screen from the device's settings menu. The user has the opportunity to quickly analyse the system from the screen shot in Figure 4.

For the correct use of the CATZOC system, it is necessary to take precautions against possible errors everywhere. If entering a dangerous area while navigating, a safe distance must be maintained, taking into account the CATZOC category in that area. ZOC, passage planning, safety depth setting and UKC under ship depth need to be safely calculated. Maximum draft is the sum of the actual draft and the ship's squad at maximum speed.

Table 2. CATZOC table (Mavraeidopoulos et al., 2017)

CATZOC ECDIS Symbols	Position Accuracy (meter)	Depth Accuracy
A1 (6-star notation)	5 m	0.5 m + depth %1
A2 (5-star notation)	20 m	1.0 m + depth %2
B (4-star notation)	50 m	1.0 m + depth %2
C (3-star notation)	500 m	2.0 m + depth %5
D (2-star notation)	500 m over	2.0 m over + depth %5
U (U letter notation)	Not evaluated	Not evaluated

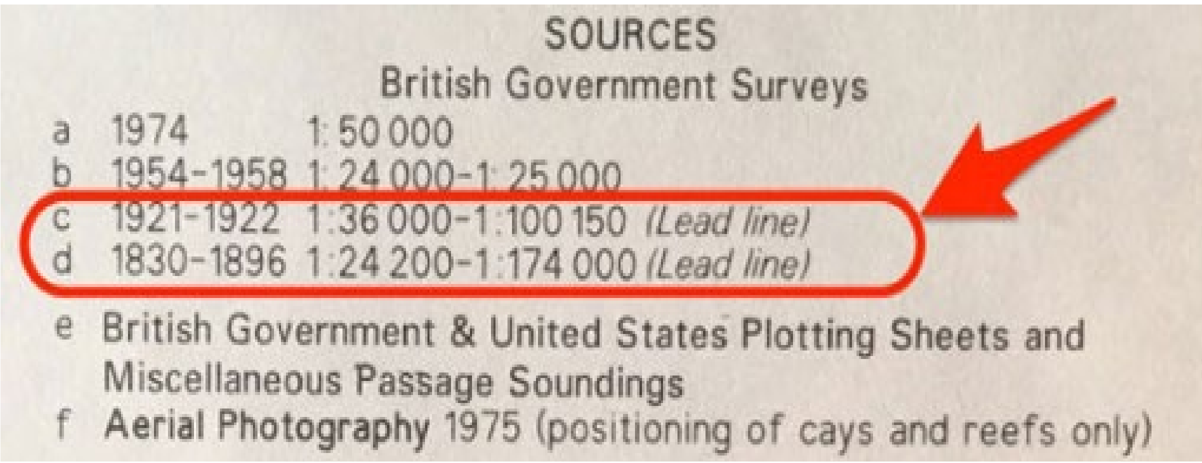

Figure 1. Depth and position categories indicated on the British admiralty nautical chart (Jassal, 2017)

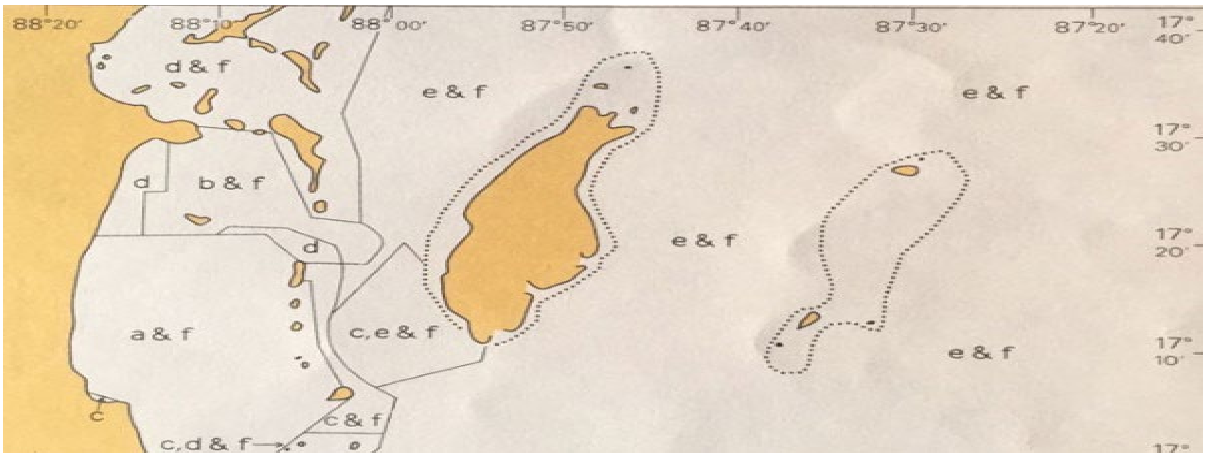

Figure 2. Depth and position categories indicated on the chart (Azuike et al., 2012)

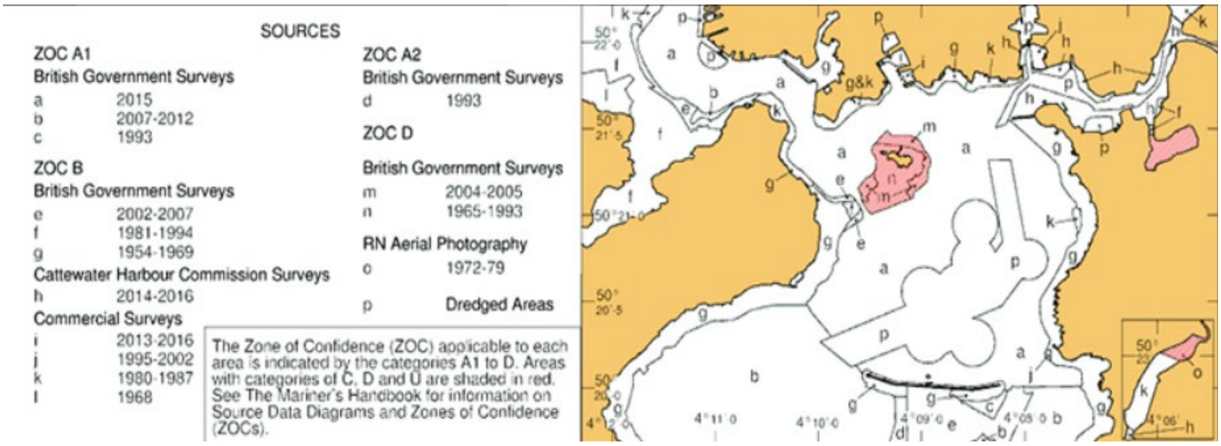

Figure 3. Nautical chart CATZOC information display (Azuike et al., 2012)

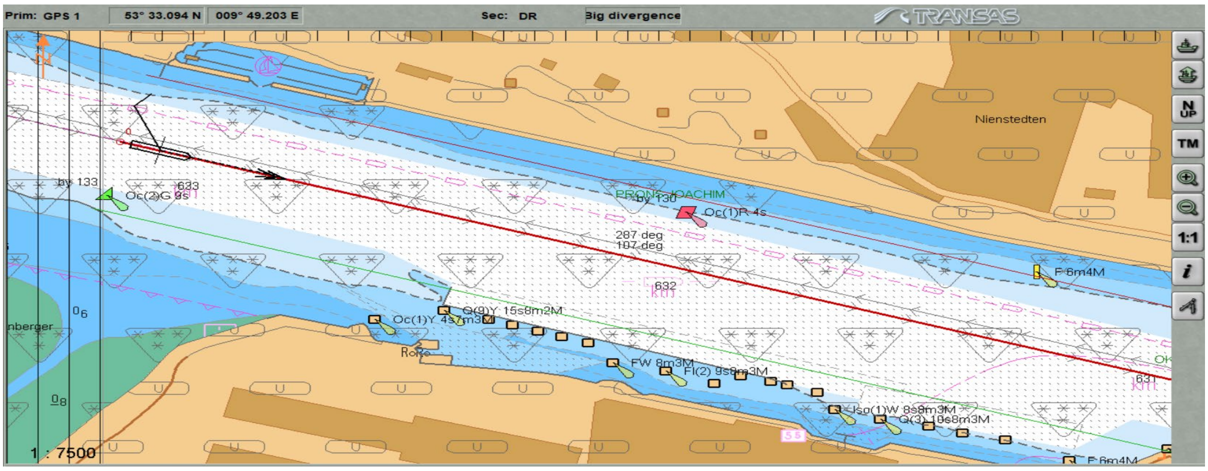

Figure 4. CATZOC display on ECDIS screen (Transas, 2020)

UKC means underwater opening and expresses the depth of water below the ship's keel line. Wind, tides, waves, seabed movement, and even continental movements can change the water depth, especially in coastal areas. On top of that, the squat effect of the ship also reduces the UKC. In this case, the water depth you read on the chart and the actual water depth will not be the same (Zadeh, 1965). UKC is calculated before entering narrow waterways, shores, and ports to eliminate the risk of stranding.

The importance of the UKC in the voyage plan can be explained as follows.

The Master shall ensure that there is an adequate under-keel allowance at all stages of the voyage and at all times while transiting in port or while at anchorage or at berth. The estimation of the smallest bottom clearances the vessel may encounter during the voyage and during port operations, which will permit the Master to identify possible manoeuvring constraints and decide on proper risk reduction measures, is therefore an essential part of passage planning that should never be neglected.

The under-keel allowance necessary for a safe bottom clearance varies with the specific local conditions and the size and handling characteristics of the ship and consists for practical purposes of two main elements:

1) A minimum Under-Keel Clearance (UKC) which should be maintained between the ship and the sea, river or canal bottom, and
2) An allowance for other variable factors that may be present as follows: The effects of squat, State of sea and swell, Past weather impact on water depths, Tidal and current conditions, particularly the range and stand of tide, Variation in water level due to barometric pressure or tidal surges, Changes in water density, Stability of the sea bed (sand wave phenomena), Accuracy of soundings, tidal information and predictions, Accuracy of ship's draught observations or calculations, including provision for hogging or sagging.

Vessel's size and handling characteristics, and increase of draught due to trim or heel, which is particularly important where vessels have a large beam, Reduced depths over pipelines or other known/charted obstructions.

The Equation (1) shows how to calculate the safety degree concept used in the calculations

$$Degree\ of\ Safety = Max\ Draft + Required\ UKC \quad (1)$$

First of all, the uncertainties in the depth errors given in the graphics should be eliminated. Calculations are made according to the information in Table 4 regarding depth accuracy. While navigating the ship's route passes through ZOC A1, and if the depth is assumed to be 15.7 meters, the minimum depth should be close to the passage route and necessary corrections should be made in these areas.

One of the components of the required UKC is the ZOC clearance. The CATZOC application for ZOC, A1 is expressed in Table 4 by the Equation (2):

$$ZOC\ (A1) = 0.5 + 0.01 \times DEPTH \quad (2)$$

$$ZOC\ permission\ (A1) = 0.5 + 0.01\ x\ 15.7 = 0.657 \approx 0.7m$$

On the other hand, when calculations related to position accuracy are made according to the Deep Accuracy in Table 3, it is interpreted as follows.

If the depth position accuracy for ZOC A1, A2 and B is relatively high (position error less than 50 m for ZOC B), this value is 500 m and greater for ZOC C and D. In this case, not only the ZOC permission for the UKC needs to be accessed, but also the depth locations when plotting the fields in the table.

Transas type 5000 series bridge simulation program was used. Opinions about the problem that emerged as a result of the CATZOC implementation were received from the experts who worked on ships. The opinions received from the experts were prioritized by weighting them with the Fuzzy Analytical Hierarchy Process (FAHP). With the results obtained, alternative solutions were presented for the CATZOC implementation problem.

Method

Fuzzy Analytic Hierarchy Process (FAHP)

Fuzzy logic was emerged by the scientist Zadeh based on the concept of fuzzy set. Zadeh's (1965) fuzzy set theory is a mathematical theory created to eliminate uncertainty in human cognitive processes (Zadeh, 1965). Fuzzy logic, with people's most developed sense organs interprets the information obtained from the beginning of people's lives with the perspective and understanding style that they have developed under the influence of their environment (Yılmaz & Şahin, 2023). When the problems in daily life are evaluated, it can be said that there are many situations that do not show certainty and this situation arises from the fuzzy, uncertain and non-linearity of the real world (Sanca et al., 2022). According to this theory, the value obtained from the judgments of the people participating in the evaluation is a fuzzy number defined as the membership function (Başlıgil, 2005).

In fuzzy set logic, the degree of belonging to the cluster varies between 0 and 1, and 1 definitely belongs to the cluster, while 0 means that it does not belong to the cluster. Cluster belonging degrees can be defined with functions such as trapezoid, triangle, gaussian curve (Özdağoğlu, 2008).

It would be more appropriate for decision makers to give their opinions about the study in verbal expressions instead of a definite number. These verbal assessments are triangular fuzzy numbers that indicate the range of verdict (Soltani & Morandi, 2008) Triangular fuzzy numbers are represented by triple values such as (l, m, u). With $l < m < u$, the fuzzy number is in the interval [l, u] and the maximum value that can take is m.

In this study, Saaty's (1988) five-point scale is transformed into triangular fuzzy numbers scale, as the following 3 shows.

Table 3. Fuzzification of Saaty's scale (Soltani & Morandi, 2008)

Saaty Scale	Definition	Fuzzy Triangular Scale
1	Equally important	(1, 1, 1)
3	Weakly important	(2, 3, 4)
5	Fairly important	(4, 5, 6)
7	Strongly important	(6, 7, 8)
9	Absolutely important	(9, 9, 9)

Numerous the multi-criteria decision making (MCDM) approaches have been applied to tackle complex decision-making problems in many fields. AHP is sensitive to inputs and results can be unreliable if input data is biased (Singh et al., 2023). The FAHP method was used to determine the criterion weights. It was preferred to be implemented as it significantly reduces the subjectivity of the decision maker (Pavlov et al., 2023). In addition, there are many qualitative criteria supporting the application of this method. In this study, Chang's extended analysis method was used to determine the weights of the most ideal reactions related to CATZOC implementation.

Results

Category A 38,000 dead weight tonnage (DWT) liquid petroleum gas (LPG) tanker in loaded condition was chosen for ECDIS simulation practice. The maximum draught of the ship was 9.43 meters. Elbe Channel in Germany was selected as the navigation area, which is presented in Figure 8. The channel's lowest chart depth on the route was 12.6 meters. As can be seen in Figure 7, the ZOC category of the navigation area was category B.

Step 1: Based on Table 3, the depth accuracy for this scenario was calculated as approximately 1.3 meters by Equation (3).

This result means that the actual depth for ZOC (B) area can be between 11.3 meters and 13.9 meters within a 50 meters diameter area.

Step 2: Safety parameters were entered into ECDIS, as can be seen in Figure 8.

Step 3: The squat value was calculated by using Equation (4).

Step 4: The vessel information was entered into Ship Manager Stability 2020 software. When the tidal height was taken as 0.6 meters, the minimum available depth was calculated as 12.6 meters. The results indicated that the ship was expected to squat 1.66 meters at 15 knots. The planned route that the ship was expected to follow is given in Figure 9.

Step 5: It was tried to explain in this scenario implementation whether it is possible for the ship to pass through this route line safely.

Discussion

Two approaches can be followed in calculating the UKC used in the voyage plan. The first one is CATZOC calculation on ECDIS, and the second option is to use a simple UKC calculation formula according to shipping company requirements.

Option 1:

Some shipping companies require the water depth below the ship to be ten percent higher than the maximum draft of the ship (Equation 6). Detailed information is given in Table 4.

Table 4. Final draught calculation according to option 1

Item	Values
Draught	9.43 m
Squat (15 knt)	1.66 m
Company Requirement (%10 of ship draught)	0.09 m
Final Draught	12.09 m

Option 2:

ZOC category of the navigation area was category B. It means there may be an error of up to 1 meter + 2% in depth, according to Table 3.

First, Equation (7) is used to find the Maximum Sufficient Water Depth in ZOC B. The calculation results according to Equation (7) showed that the ship could pass through this area. However, it would be correct to check it according to the CATZOC calculation. The calculation details are explained in Table 5 and Table 6.

It can be thought that the value found as a result of the calculation in Table 7 may be inaccurate up to 1.3m, considering the Depth Accuracy for ZOC (B) found in the 1st step.

When the calculation results of Option 1 and Option 2 were compared, it can be seen that the difference is 0.19 m. Such a difference increases the grounding risk of the ship. It will cause an officer of the navigation to reach an erroneous result of up to 1.3 meters when applying the formula in option one. In this situation, the safe navigation of the ship cannot be mentioned. In the case of the implementation of the two options, a difference of 0.19 meters puts ships navigating in shallow waters at risk.

Since the ship is not safe to pass through this route line, solution methods will be presented with expert opinions.

$$Depth\ Accuracy\ for\ ZOC\ (B) = \pm[1.0 + (0.02 \times 12.6)] = 1.252 \approx 1.3\ m \tag{3}$$

$$Squatmax\ in\ meters = K\ x\ Block\ Coefficient\ x\ (Speed\ through\ water)2\ x\ 0.01 \tag{4}$$

$$\text{where; } K = \frac{Shallow\ water\ depth}{Stable\ draft\ of\ the\ ship} \tag{5}$$

$$Final\ Draft = Actual\ Draft + Squat + Company\ UKC\ Requirement \tag{6}$$

$$Maximum\ Sufficient\ Water\ Depth = Charted\ Depth - (1 + 2\%\ Charted\ depth) + Tide \tag{7}$$

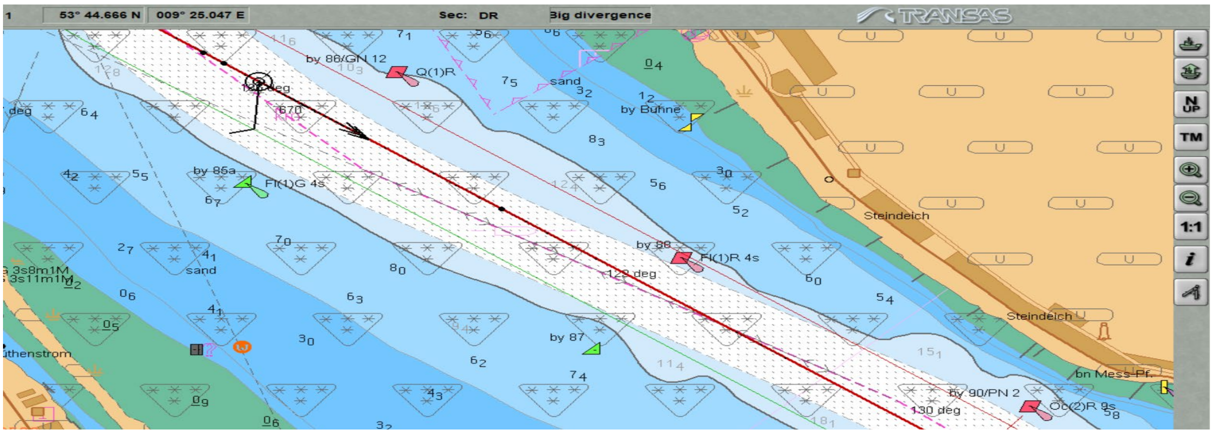

Figure 7. Navigation area of case analysis (Transas, 2020)

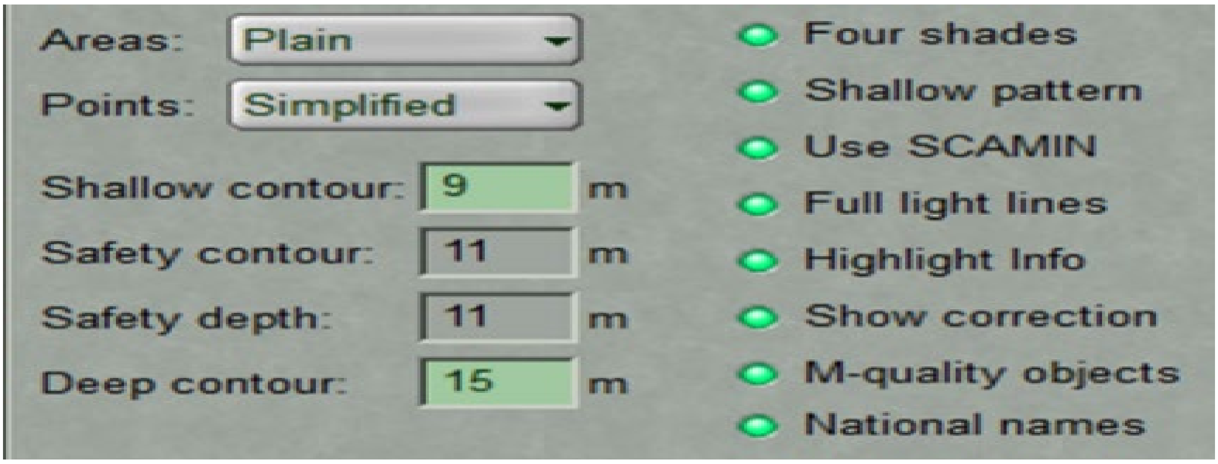

Figure 8. Safety parameters entered into ECDIS

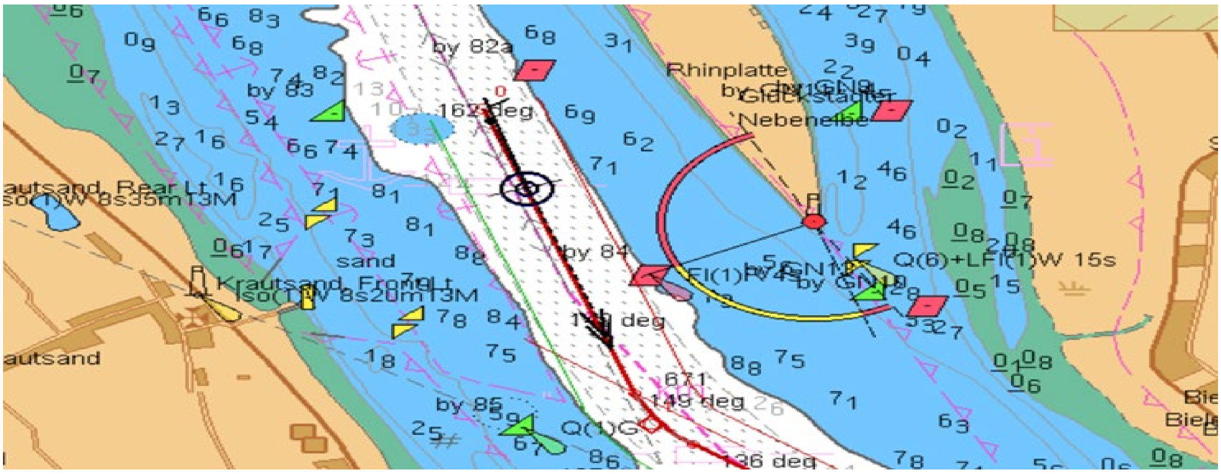

Figure 9. Scenario application area ECDIS screenshot (Transas, 2020)

Table 5. Calculation steps for depth

Depth on the Chart	A	Meter
Tidal Height at Ship's Crossing Time (Always Positive Effect)	B	meter
Sea Condition / Swell / Wind (Always Negative Effect)	C	meter
Chart Information Accuracy / CATZOC Value, If Any	D	meter
Maximum Sufficient Water Depth	E	meter

Table 6. Letters and distances

Letter	Values
A	12,6 m
B	0,6 m
C	N/A
D	-1,3 m
E	11,9 m

Determination of Alternative Decisions

Alternative options may need to be applied by ships related to the deficiency resulting from the implementation of CATZOC. Expert opinion was used to determine the alternatives. The number of experts consulted was ten. All the experts held Ocean Going Master certificates and served at sea for at least ten years. The ship type information that the experts worked on is given in Table 7.

The problem that occurred in the CATZOC implementation was shared with the experts in detail. Open-ended questions were asked to determine alternative options to follow to ensure navigational safety. The experts advised five options which are presented in Table 8.

Table 7. Expert specifications

Experts	Ship Type	Experience (Years)
Expert 1	Chemical Tanker	12
Expert 2	LPG Tanker	13
Expert 3	Chemical Tanker	14
Expert 4	Dry Cargo Ship	11
Expert 5	Container Ship	10
Expert 6	Chemical Tanker	12
Expert 7	Ro-Ro Ship	15
Expert 8	Bulk Carrier	12
Expert 9	Dry Cargo Ship	12
Expert 10	Oil Tankers	13

Pairwise comparison matrix established according to expert opinion. The data obtained from the experts were converted into fuzzy triangular numbers in Table 3. Then a single comparison matrix, which is given in Table 9, was created by taking the arithmetic means of the answers. The normalized weights of the criteria were calculated and presented in the same table.

Table 8. Definition of criteria

C_1: Reducing Speed	After detecting the risky part of the depth, it minimizes the squat by taking the speed on the ship to the lowest value when approaching that area.
C_2: Draft Adjustment	Adjusting the maximum draft of the ship at the port of departure before reaching the danger zone.
C_3: Information Exchange with Port Authority	It is to communicate with the relevant port authority before the ship enters the port limits, to obtain information about that region and to confirm that it is accessible.
C_4: Not Entering the Zone	If a risk analysis is made with the charterer and shipowner officials and a result that will pose a danger to the ship, it is decided not to enter the port of the ship. If this is done before the affreightment, it will not cause economic damage.
C_5: Tide Height Confirm	It includes receiving tide information from pilotage services located in this area and confirming whether there is sufficient depth underwater.

Table 9. Pairwise comparison matrix of criteria

C_1	C_2	C_3	C_4	C_5	Normalized W.
(1,1,1)	(2,3,4)	(3,4,5)	(4,5,6)	(2,3,4)	0.457
(1/4,1/3,1/2)	(1,1,1)	(2,3,4)	(4,5,6)	(1/4,1/5,1/6)	0.162
(1/5,1/4,1/3)	(1/4,1/3,1/2)	(1,1,1)	(1/4,1/3,1/2)	(2,3,4)	0.103
(1/6,1/5,1/4)	(1/6,1/5,1/4)	(2,3,4)	(1,1,1)	(1/6,1/5,1/4)	0.078
(1/4,1/3,1/2)	(6,5,4)	(1/4,1/3,1/)	(4,5,6)	(1,1,1)	0.201

Table 10. Sorting the criteria by weight

Criteria	Criterion Weights	Ranking
Reducing speed (C1)	0.45	1
Draft adjustment (C2)	0.16	3
Information exchange with port authority (C3)	0.10	4
Not entering the zone (C4)	0.07	5
Tide height confirmation (C5)	0.20	2

Conclusion

Navigation planning of merchant ships is very important and should be done carefully and in accordance with the rules for the safety and security of the ship and personnel. In the navigation planning of the ship, the safety issues of the ship should be followed regularly by the master and watch officers and should be at the top in terms of priority. After the completion of the ship's departure from the port, before the departure operation, the responsible officer of the watch on watch should make the necessary navigation plan and obtain the approval of the master. Maritime publications and navigational technical equipment and auxiliary equipment on board should support the correct use of the data used at each stage of the navigation plan.

According to today's maritime conditions, navigation plans, which were previously made on nautical charts, are now prepared on technologically advanced electronic nautical charts. With this development, route changes can be followed instantly and mistakes made can be seen more quickly. The drawing of the routes of the navigation plans, the navigation course points of the ship and all other necessary information are prepared on digital nautical charts. Depending on how the data in the nautical charts are measured and when they are measured, various errors may occur. The older the data in the nautical charts, the greater the existing error rate. The accuracy level is divided into six categories known as "CATZOC". For each CATZOC, the maximum error value is given for the depths and location shown in Table 2.

As seen above, the greatest risk occurs in shallow waters. The grounding of ships occurs not only on sandy bottoms but also on rocky bottoms and the structure of the ship is seriously damaged on rocky bottoms compared to sandy bottoms. In addition, depending on whether the ship is loaded or unloaded, the changes in the draft should be treated very carefully, especially where the A1, A2 and B symbols are located. Depths of shallow waters can change with tides depending on natural conditions. In addition, serious changes may have occurred in the existing depths with the recent natural events.

The application of CATZOC becomes mandatory when calculating UKC in shallow waters or when approaching a distress signal shown on ECDIS. For the navigational safety and security of the ship, the master and other officers of the watch are required to activate the CATZOC application. If the depths and position distances during the navigation of the ship are not calculated correctly, dangers such as grounding of the ship in the navigation area and damage to the ship's hull may occur. After determining the arrival route of the ship for navigation, the existing charts should be examined one by one, and if it is necessary to pass through risky areas according to the CATZOC category table, the affiliated marine management company should be informed. The marine management company may be requested to make a risk analysis of the ship related to the subject passage or information may be requested from the port state authorities about the reliability of the chart depths of the subject area. In this study, the opinions of the ship masters were taken on the measures related to the solution alternatives to be considered. The most important solution alternative obtained from the opinions of the masters was determined that the ship should continue its voyage at minimum speed.

The second critical solution option is determined that the conditions and times of the tide height in the sea in the area where navigation is carried out and the hazardous area is located should be confirmed from the units providing navigation pilotage services in that region. In this way, support should be received in a region that is unknown to the ship's crew and the safety and security of the ship should be ensured by acting according to the data and recommendations obtained. The solution options obtained in this study are presented as suggestions. Compliance or non-compliance with these suggestions is left to the preferences of other watchkeeping officers, especially the master of the ship. It is also important that the calculations carried out in the study are tried to be made accurately and completely and that the alternative options specified in this study are taken into consideration. Another suggestion obtained as a result of the study is that it would be important to prepare a separate section under "Trust Zone" in the bridge manuals prepared by the maritime companies for the ships under their management and it would be a supportive and guiding situation in the decision-making phase of the ship personnel. It is thought that it will help and guide the master and officers of the watch in making navigation planning in risky areas.

It is hoped that the subject study will be an example and shed light on future studies. In addition, in the future studies, it is planned to carry out studies on navigation planning in the Marmara Sea, which is very busy and risky in terms of ship traffic, and what the ships should pay attention to in navigation planning.

Compliance With Ethical Standards

Authors' Contributions

OHA: Conceptualization, Methodology, Validation, Formal Analysis, Resources, Writing - Original Draft, Writing-Review and Editing, Data Curation, Software, Visualization, Supervision, Project administration, Funding acquisition.

OA: Conceptualization, Methodology, Validation, Formal Analysis, Resources, Writing - Original Draft, Writing-Review and Editing, Data Curation, Software, Visualization, Supervision, Project administration, Funding acquisition.

AUU: Writing - Original Draft, Writing-Review and Editing.

All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

Data Availability Statement

All data generated or analyzed during this study are included in this published article.

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