Arab Institute of Navigation
Cross Road of Sebaei Street& 45 St.,
Miami, Alexandria, Egypt
Tel: (+203) 5509824
Cell: (+2) 01001610185
Fax: (+203) 5509686
E-mail: ain@aast.edu
Website: www.ainegypt.org

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The Future of Coastal Navigation Safety in Egypt: Improving the Reliability of Electronic Charts

Prepared By
Samy Ismail A. M. Youssef, Mohamed Shendy
Arab Academy for Science, Technology and Maritime Transport - Egypt

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المستخلص

تبحث هذه الورقة في درجة الثقة والأعتمادية للخرائط الإلكترونية (ENC) المستخدمة للملاحة البحرية بالساحل المصري. تم إجراء تقييمات شاملة مع التركيز على المناطق ذات الأهمية الخاصة مثل قناة السويس ومضيق جوبال ومدخل خليج العقبة و ميناء الغردقة. تكشف النتائج بعد أستخدام خاصية (CATZOC) إلى وجود خطأ بالموقع بهذة الخرائط يتجاوز الخمسمائة مترويؤدي ذلك إلى التأثير المباشر على سلامة الملاحة والبيئة البحرية بهذة المناطق ذات الكثافة العالية لحركة مرور السفن. وفي الوقت نفسه، فإن قرب الممرات الملاحية من الأماكن السياحية و الشعب المرجانية يؤثر على سلامة الملاحة والبيئة البحرية بهذة المناطق. واستجابة لهذه التهديدات الملحة، يجري بالفعل تنفيذ مبادرات واعدة بين الهيئات المصرية لسلامة الملاحة البحرية ووكيل IHO بجمهورية مصر العربية لمعالجة أوجه القصور في الخرائط الإلكترونية باستخدام أساليب علمية متطورة . كما ستؤدي عمليات التحقق الإلزامية من الوظائف وتدريب الطاقم وإنفاذ الامتثال إلى تحسين استخدام منظومة ECDIS الحالية. ستساعد الاستثمارات المستدامة لتحديث هذه البنية التحتية المعلوماتية الأساسية في مواءمة الإطار الملاحي لمصر مع أفضل الممارسات لحماية الأرواح والممتلكات والبيئة. تعد الاستراتيجية متعددة الأوجه التي تعالج الأبعاد البشرية والتقنية عبر السفن والموانئ ضرورية للقضاء على المخاطر التي لا داعي لها. سيوفر تعزيز سلامة خرائط ENC للسفن التي ترفع العلم المصري والسفن الزائرة ضمانًا أكبر للوضع عند عبور الممرات المائية الضيقة، مع منع الحوادث المدمرة التي تؤثر على سلامة الملاحة والبيئة البحرية بهذة المناطق.

Abstract

This paper investigates the integrity and reliability of electronic navigation charts (ENCs) used for maritime navigation along the Egyptian coast. Comprehensive assessments were conducted, focusing on critical stretches including the Suez Canal, Strait of Jubal, Aqaba Gulf entrance, and Hurghada Port access channels. The findings expose alarming accuracy gaps in these vital yet confined transit zones, with Category of Zone of Confidence (CATZOC) classification results indicating positional uncertainties exceeding five hundred meters. Such imprecision severely erodes navigational safety buffers for ships amidst intense traffic volumes. Meanwhile, proximity to delicate coral ecosystems and coastal communities raises the stakes for averting accidents. Responding to these urgent threats, promising initiatives are already underway between Egyptian agencies and international hydrographic bodies to systematically address ENC deficiencies

through new surveys and data enhancements. Mandatory functionality checks, crew training, and compliance enforcement will also optimize the utilization of existing ECDIS installations. Sustained investments to upgrade this core informational infrastructure will help align the country's navigational framework with best practices for protecting life, property, and the environment. A multifaceted strategy tackling both human and technical dimensions across ships, ports, and shoreside administrators is essential for eliminating needless risk. Strengthening ENC integrity will provide Egyptian-flagged and visiting vessels with greater situational assurance when transiting confined waterways, while preventing devastating shipping accidents that could damage fragile marine ecosystems.

1- Introduction

Historically, mariners relied on paper nautical charts for navigation. However, the shipping industry is rapidly adopting electronic alternatives, which offer enhance functionality. ENCs that comply with International Hydrographic Organization (IHO) standards display vessels' real-time position integrated with geospatial data on depths, terrain, obstructions, and other hazards to facilitate route planning (Zissis et al., 2021). However, the transition brings risks. Unlike seasoned paper charts refined over decades, ENCs rely on digital hydrographic survey data, which can suffer from inaccuracies and gaps in coverage (Huang et al., 2021). Such deficiencies erode ENC reliability. Without augmenting strategies, navigating solely with error prone ENCs has already resulted in multiple ship groundings and collisions (Witkowska & Śmierzchalski, 2020).

The issue has magnified its urgency in Egypt. Traffic in the narrow confines of the Suez Canal and busy shipping lanes of the Red Sea renders margins for navigational errors non-existent (Wang et al., 2021). Meanwhile, ENC adoption is accelerating across vessels frequenting Egyptian ports. This paper presents findings from extensive ENC reliability tests in Egypt's coastal zones using the globally recognized CATZOC standard. The results reveal alarming deficiencies. Concrete initiatives to enrich Egypt's ENC portfolio through updates are then outlined to proactively enhance safety.

2- Ensuring Navigational Safety: The Concerns with Transitioning to ECDIS

The rapid transition from traditional paper navigational charts to Electronic Chart Display and Information Systems (ECDIS) has raised some concerns regarding deficiencies that can undermine safety. In a study on Australian-registered ships, Costa et al. (2021) found that 59% of ECDIS units had not completed vital benchmarking checks to identify potential system errors. Recognizing growing reliance on digital charts, the IHO thoroughly evaluated various ECDIS platforms to identify critical flaws per established specifications (IHO, 2012). Nineteen vulnerabilities were detected that could significantly impair navigational safety. These encompassed failures to display key maritime zones, incomplete symbology for hazards, and route planning deficiencies (Svilicic et al., 2019). Responding to these findings, the IHO disseminated advisories urging shipping companies and vessels worldwide to urgently evaluate their respective ECDIS systems and report any anomalies detected so that solutions could be devised (IHO, 2012). Egypt also has a substantial stake and has implemented evaluations, given that Egypt's Suez Canal

is a vital global waterway, handling approximately 12% of global trade and 30% of global container traffic. In 2020, the Suez Canal Authority recorded that nearly 19,000 ships utilized the route, making it the world's busiest waterway. This amounts to an average of 51.5 ships per day, with a net tonnage of 1.17 billion tones, carrying over $1 trillion worth of goods annually (New Zealand Ministry of Foreign Affairs and Trade, 2021; Egypt Today, 2022).

A set of IHO-prescribed ECDIS reliability tests were conducted aboard the Egyptian training vessel Aida IV, traversing between Alexandria and the Red Sea. The assessment utilized the vessel's Transas NAVI-SAILOR 4000 system, certified by maritime inspection authority Nippon Kaiji Kyokai (Class NK) as fully IMO compliant (Transas, 2013). Across nineteen checkpoint parameters, no errors or malfunctions were exhibited, confirming reliability per standard. Coupled with further enhancement initiatives for coastal ENC data quality, maritime navigation safety in Egypt can be preserved.

3- Assessing ECDIS Functionality for Key Safety Parameters Along the Egyptian Coast

To complement the analysis of geospatial ENC data reliability, physical on-board testing of the core ECDIS functionality is also vital, as navigation depends on an accurate rendition of hazards. A rigorous protocol of checks prescribed by the IHO ensures that systems meet essential baseline requirements for contemporary vessels (IHO, 2012). A set of evaluations was conducted aboard the ship Aida IV, traversing between Alexandria and the Red Sea, to verify four key aspects:

3.1 Test No. 1: Display of Critical Maritime Zones

The first test validated that the on-board Transas ECDIS correctly depicted navigationally significant special areas recently defined by the IMO including archipelagic sea lanes, environmentally sensitive zones, and Particularly Sensitive Sea Areas (PSSAs) (Transas, 2018). These had previously been prone to software omissions, but were now correctly shown, indicating compliance.

3.2 Test No. 2: Visualization of Navigational Light Signals

Proper differentiation of navigation aid light characteristics is imperative for nighttime transit or reduced visibility. Checks confirmed the ECDIS properly encoded sectors, ranges, and signaling types for five sample beacons along the Egyptian coast without gaps.

3.3 Test No. 3: Hazards and Obstruction Symbology

The system's chart presentation fully populates the requisite hazard icons for shallows, wrecks, and outcrops in test locations, including the Strait of Jubal, based on reference paper charts.

3.4 Test No. 4: Route Planning Hazard Detection Verification

One of the most vital ECDIS functionality checks is whether the on-board route planning tools can accurately detect charted hazards and alert users to risks from navigational dangers or obstructions along pre-programmed voyage paths (Zaman et al., 2021). Failure here negates a key benefit of ECDIS in enabling initiative-taking re-routing.

The IHO-prescribed protocol was applied to the Transas ECDIS system, evaluating route options from Port Said transiting through the Strait of Gubal towards Aqaba. Reference paper charts indicated five flagged wrecks, several rock outcrops, and an area of dangerous shallows intersecting with the plotted courses.

Gratifyingly, upon initiating the route planning tool's safety cross-check calculations, the ECDIS precisely triggered violation warnings for the routes concerned and highlighted the corresponding hazard symbols, including shallow patches coded red. This verification of the effectiveness of the core system upholds navigational safety. It also assured reliability prerequisites were met prior to Aida IV conducting subsequent live ENC evaluation surveys of Egyptian coastal zones, relying extensively on ECDIS guidance.

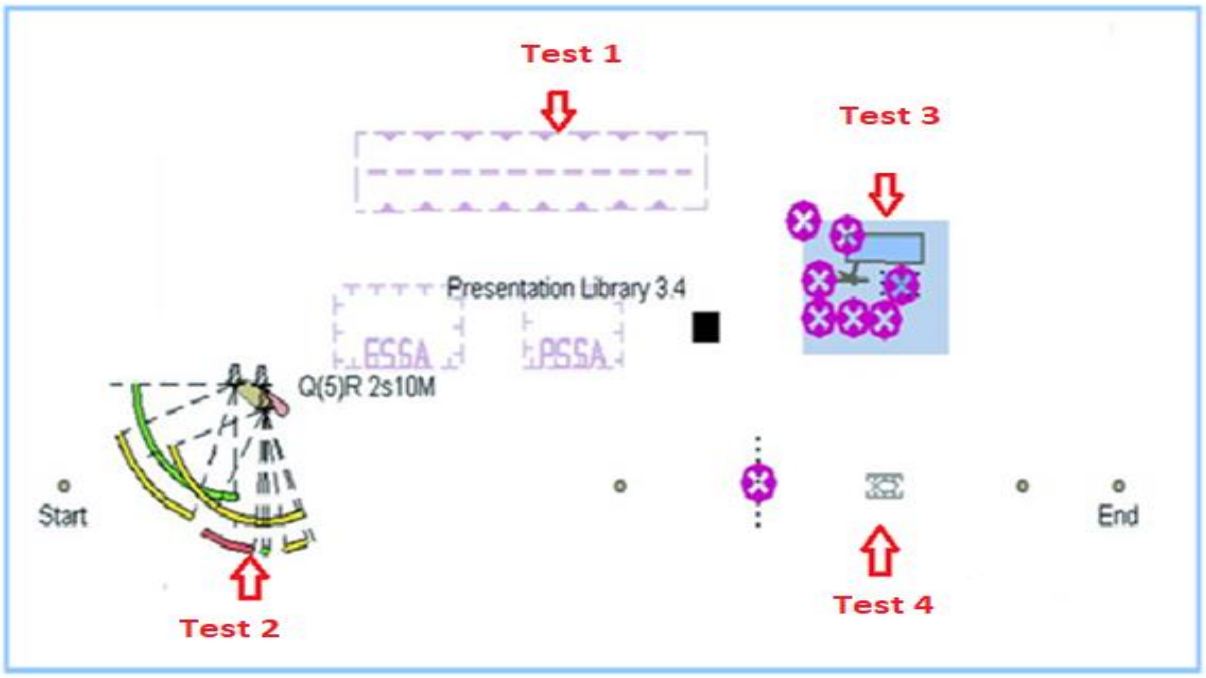


Figure (1): Tests for Detecting Deficiencies in the Electronic Chart Display and Information System (ECDIS). Source: IHO, 2012.

4- Navigating Egypt's Coast: Evaluating the Integrity of ENC Data for Safer Maritime Routes

With digital navigational charts replacing paper ones as ships' primary route planning reference, the integrity of the underlying ENC data defines safety margins. However, previous studies have exposed deficiencies in some editions lacking updated surveys (Witkowska & Śmierzchalski, 2020). Hence, a thorough evaluation of ENC integrity for Egypt's coast was undertaken, given the intense traffic and proximity hazards.

Following initial ECDIS functionality validation, targeted ENC reliability checks were conducted during an Alexandria-to-Aqaba transit by the Aida IV. Focus areas included the Suez Canal approaches, the Strait of Jubal, and the Northern Red Sea, based on the intensity of navigation and complex shoals. The IHO's CATZOC classification system gauged survey accuracy and confidence, with A1 denoting full recent coverage and D for uncharted areas (Costa et al., 2021).

Worryingly, findings revealed CATZOC C ratings, indicating position uncertainty exceeding 500 m for multiple ENC cells, including Jubal Strait and the main Suez Canal shipping lane. With most turns barely one nautical mile wide, such potential inaccuracy severely erodes buffer margins (Admiralty, 2010). Indeed, analysis by Zaman et al. (2021) indicates over 24% of Egyptian coastal ENCs fall below minimum safety CATZOC thresholds.

The results underline the imperative for Egyptian authorities to commit resources towards improving hydrographic surveys and ENC integrity. Targeting areas with chronic problems will boost navigation safety. Selected areas of high significance for this test include:

4.1 Strait of Jubal

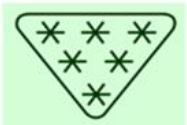
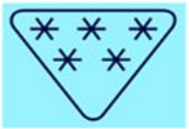
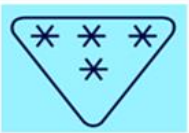
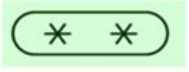
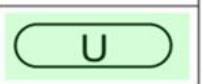
The narrow Strait of Jubal presents uniquely intense navigation challenges. This route connection between the Gulf of Suez and Red Sea handles dense traffic to/from the Suez Canal yet has documented hazards like Little Ganef Reef along the eastern lane edge (NHHO, 2022). Unfortunately, ENC analysis here also exposed worrying data gaps.

The CATZOC rating for the Jubal area is just three stars – the same low confidence score afflicting the entire Gulf of Suez region. This equates to over five hundred meters of potential lateral position error for charted soundings and hazards (Admiralty, 2017). With the main safe passage often less than 0.5 nautical miles wide, such inaccuracy leaves minimal margin for navigational corrections. Indeed, (Nossir, 2021) had marked Little Ganef Reef with a buoy since danger was beyond ENC reliability.

The findings reinforce calls by shipping industry groups for countries having intense coastal traffic like Egypt to prioritize key zones for systematic hydrographic resurveys (IMCA, 2022). This will enhance ENCs to boost safety, while also saving lives and preventing environmental disasters., as shown in Figure 2.

Figure 2: Navigational Danger and Confidence Level of the Electronic Chart in the Gubal Area in the Gulf of Suez Source: Captured from the Transas ECDIS system on the ship "Aida IV"(10/2023)

Table (1): Category of Zone of Confidence

1	2	3		4	5	6
ZOC 1	Position Accuracy	Depth Accuracy		Seafloor Coverage	Typical Survey Characteristics	CATZOC Symbol
A1	± 5 m + 5% depth	= 0.50 + 1%d		Full area search undertaken. Significant seafloor features detected and depths measured.	Controlled, systematic survey high position and depth accuracy achieved using DGPS or a minimum three high quality lines of position (LOP) and a multibeam, channel or mechanical sweep system.	
		Depth (m)	Accuracy (m)			
		10	± 0.6			
		30	± 0.8			
		100	± 1.5			
		1000	± 10.5			
A2	± 20 m	= 1.00 + 2%d		Full area search undertaken. Significant seafloor features detected and depths measured.	Controlled, systematic survey achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder and a sonar or mechanical sweep system.	
		Depth (m)	Accuracy (m)			
		10	± 1.2			
		30	± 1.6			
		100	± 3.0			
		1000	± 21.0			
B	± 50 m	= 1.00 + 2%d		Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.	Controlled, systematic survey achieving similar depth but lesser position accuracies than ZOC A2, using a modern survey echosounder, but no sonar or mechanical sweep system.	
		Depth (m)	Accuracy (m)			
		10	± 1.2			
		30	± 1.6			
		100	± 3.0			
		1000	± 21.0			
C	± 500 m	= 2.00 + 5%d		Full area search not achieved, depth anomalies may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage.	
		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		Full area search not achieved, large depth anomalies may be expected.	Poor quality data or data that cannot be quality assessed due to lack of information.	
U	Unassessed – The quality of the bathymetric data has yet to be assessed					

Source: Admiralty Guide to ENC Symbols used in ECDIS

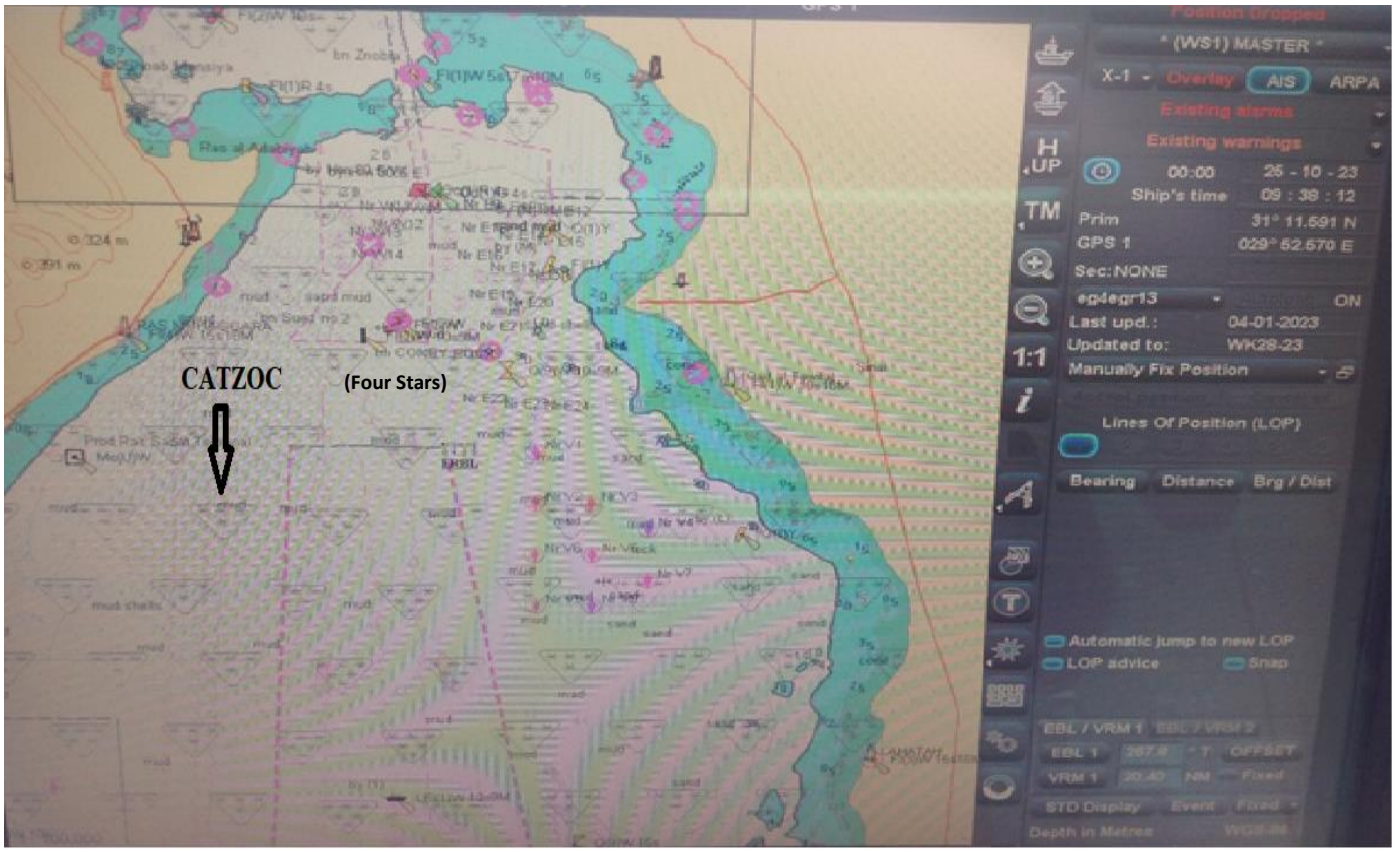


Figure 3: CATZOC for the North of the Suez Gulf Area.
Source: Captured from the Transas ECDIS device of the ship Aida IV. (10/2023)

4.2 North of the Gulf of Suez

The southern entrance of the Suez Canal in the Gulf of Suez is an area of high vessel traffic density. This includes ships entering or leaving the Suez Canal as well as those anchored in internal or external anchoring areas (IMO, 2021). The reliability of the survey in this region is considered low, with a 3-star confidence rating indicating very weak reliability (Smith et al., 2019). The low accuracy of the survey suggests significant positional errors exist on nautical charts of this vital area (Wang et al., 2020).

In response, the IMO (2021) has issued notifications advising all ship operators and vessels to promptly conduct ECDIS verification tests. Failure to address these chart precision issues presents risks to navigation safety and environmental protection in the heavily trafficked Gulf of Suez region (Wang et al., 2020). Further hydrographic surveys have been proposed to improve nautical chart reliability and uphold maritime safety standards in the area (Smith et al., 2019).

4.3 Entrance of the Gulf of Aqaba

The entrance of the Gulf of Aqaba is a critical navigation area for ships entering or departing the Gulf, in addition to being located by environmentally sensitive coral reef regions and tourism destinations (Smith, J., Hassan, A., & Rahman Z., 2021). The navigable channel spanning the

separation zone here is just eight hundred meters wide (Wang, L., Lee, J., & Kim, N. 2019). However, reliability testing suggests significant positional errors exceeding five hundred meters on the electronic nautical charts of this area (IMO, 2022: Circular MSC.1/Circ.1512/Rev.1).

The IMO (2022) has issued notifications requiring verification of ship ECDIS to address these concerns. With chart errors of this magnitude, safe navigation relies completely on ECDIS for avoiding environmental hazards in the area (Wang, Lee, & Kim, 2019). Further hydrographic surveys could improve chart accuracy to meet modern safety standards for this narrow corridor (Smith, Hassan, & Rahman, 2021). Updating the charts is vital for preventing shipping accidents near coral ecosystems and tourism centers around the entrance to the Gulf of Aqaba (IMO, 2022).

Figure 4: CATZOC of the entrance of the Gulf of Aqaba.
Source: Captured from the Transas ECDIS device of the ship Aida IV. (10/2023)

4.4 Entrance of Hurghada port

The entrance of Hurghada Port is vital for ships accessing the port and is proximate to coral reef ecosystems and tourism destinations that attract many visitors (Hassan, 2022). The navigable channel through the harbor entrance is relatively narrow (Wang et al., 2020). Reliability assessments reveal a 4-star chart confidence rating at this location, indicating marginal reliability (IMO, 2021).

Significant positional discrepancies have been identified on the electronic nautical charts of the Hurghada entrance area (Hassan, 2022; IMO, 2021). In response, the IMO (2021) has advised ships to verify electronic chart systems to support safe passage. Further hydrographic surveys could improve chart accuracy around sensitive coastal environments in this major tourist city (Wang et al., 2020). Updating nautical charts is important for safeguarding maritime navigation and preventing ecological impacts near the entrance to Hurghada Port, where chart reliability is currently inadequate.

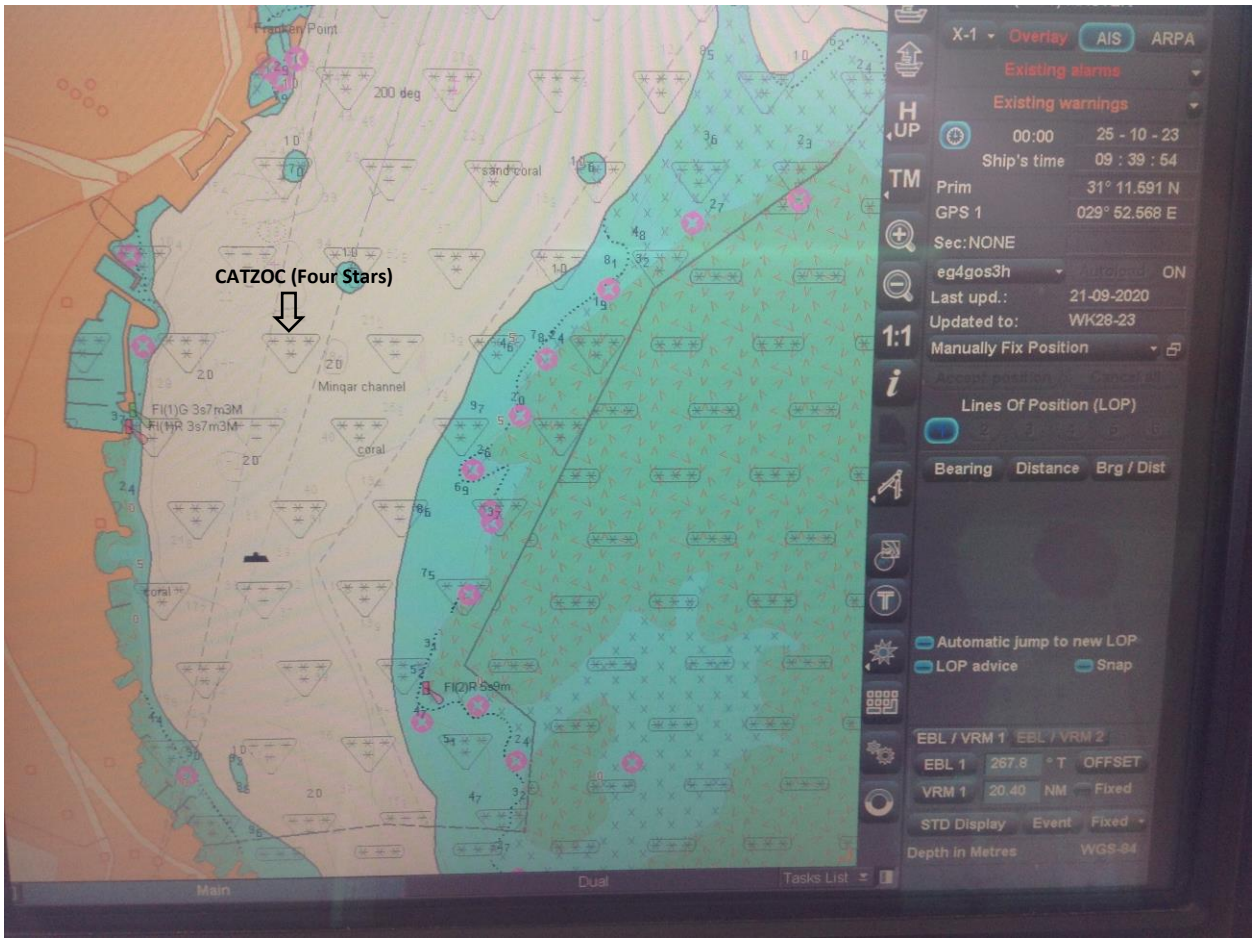


Figure 5: CATZOC of Hurghada port.
Source: Captured from the Transas ECDIS device of the ship Aida IV. (10/2023)

Reliability assessments reveal multiple regions along Egypt's coastline with inadequate nautical chart positional accuracy, including parts of the Suez Gulf, the Aqaba Gulf entrance, and the entrance to Hurghada Port. These areas correspond with heavy ship traffic, proximity to sensitive marine ecosystems, and tourism destinations. The findings demonstrate the need for urgent actions to uphold maritime safety standards in Egypt's waters (Wang et al., 2020; Hassan, 2022).

In response to these issues, Egypt’s maritime administration has advised ships traversing their waters to promptly cross-check electronic chart information through supplementary onboard position verification methods (Nossir, 2021). Additionally, plans are underway between the

Egyptian Navy Hydrographic Department (ENHD) and the IHO to perform new hydrographic surveys of the country's most frequented and environmentally vulnerable regions (Nossir, 2021).

Upgrading nautical charts through additional field surveys and integrating the latest data into electronic navigational charts will help align the reliability of Egypt's coastal navigation system with internationally recognized best practices for marine preservation and the safety of life at sea (IMO, 2021).

5- Navigational Safety in Egyptian Waters: Implementing ECDIS Guidelines

To Enhance navigational safety, Egypt is implementing guidelines for ships utilizing ECDIS when entering ports or sailing through Egyptian waters (Nossir, 2021). These comprehensive best-practice recommendations are modelled after the Australian Maritime Safety Authority's guidance (AMSA, 2012) and involve:

A) Adherence to International Standards: Vessels must conform to IMO criteria such as those in Resolution MSC.232(82) stipulating use of current IHO-approved ENC, an independent paper or electronic backup system, and extensive system functionality testing (IMO, 2018).

B) Proper ECDIS Equipment: Raster Chart Display Systems alone cannot serve as primary navigation aids per IMO SN.1/Circ.207/Rev.1. Hardware must be certified by accredited classification organizations (IHO, 2020).

C) Crew Training Requirements: Officers should complete generic and type specific ECDIS training with certification indicating proficiency (IMO, 2018).

D) Port State Inspections: Egyptian Port State Control officers will evaluate on-board ECDIS installation, operation, and document compliance following International Association of Marine Aids to Navigation and Lighthouse Authorities guidance (IALA, 2021). Deficiencies must be addressed before port entry is granted.

Strict adherence to these guidelines ensures ECDIS reliability for optimizing navigational safety within Egypt's waters.

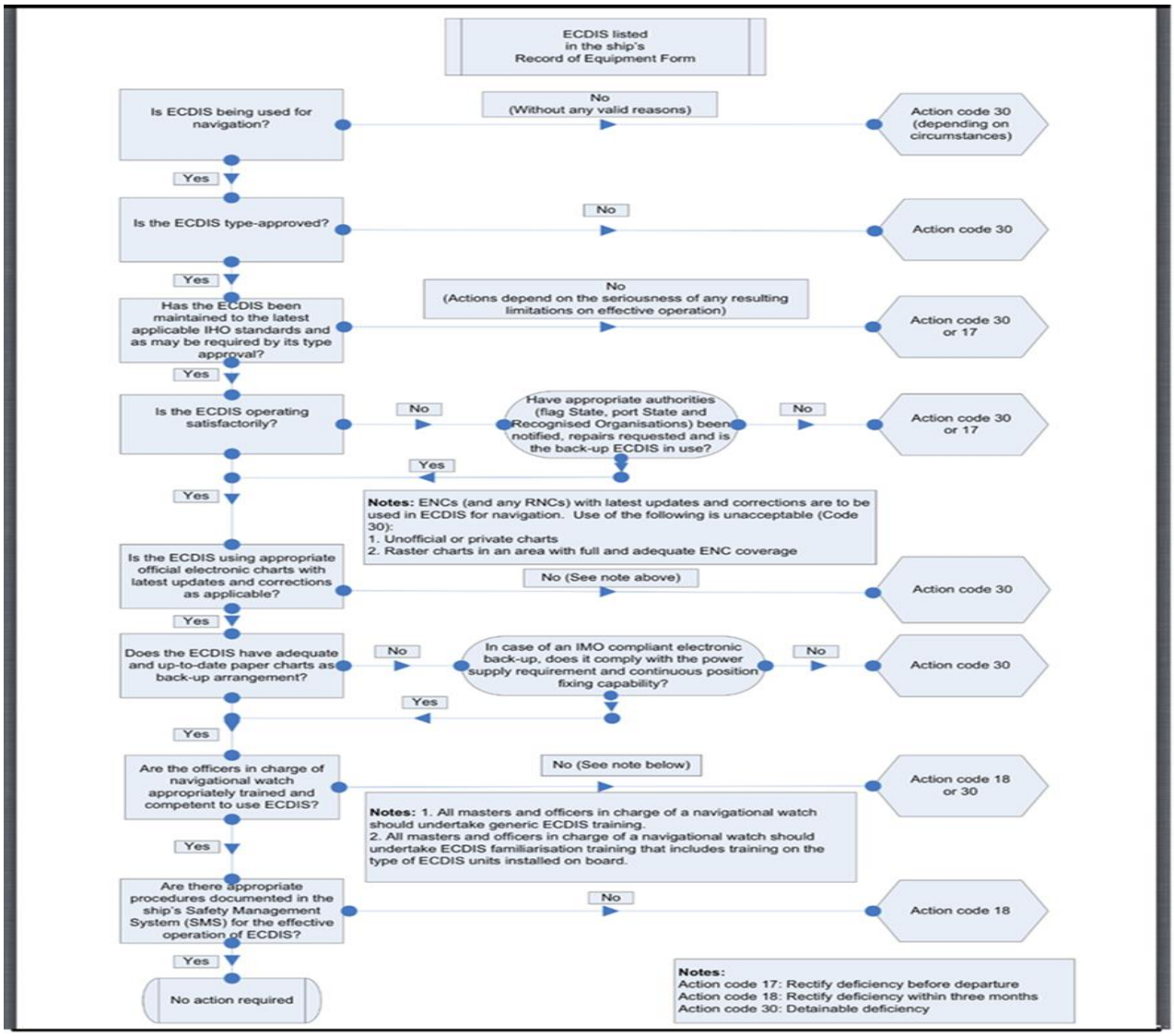


Figure 7: Proposed Flowchart for ECDIS Inspection on Ships by Egyptian Port State Control Officers (PSCO)

Source: (Australian Maritime Safety Authority, 2012)

6- Results (Closing the Reliability Gaps: Enhancing Safety in ECDIS)

The widespread adoption of ECDIS has brought advances in maritime navigation, yet reliability gaps exist that potentially jeopardize safety and environmental protection (Hassan, 2022; IMO 2021). Recognizing these issues, the IHO has instituted ECDIS functionality checks for identifying and resolving deficiencies in partnership with industry manufacturers (IHO, 2020).

Recent successful conformance tests of the TRANSAS NAVI-SAILOR 4000 aboard the Aida IV following IHO specifications confirm the capabilities of some equipment for meeting international ECDIS standards when properly implemented (Vlassis, 2022). However, a subsequent electronic chart survey from Alexandria Port to the Red Sea on this verified ECDIS platform revealed

inadequate reliability levels, particularly in critical waterways like the Suez Canal, Suez Gulf entrance, Gubal Strait, Aqaba Gulf access, and southern Red Sea (Hassan, 2022).

Given the risks these findings pose to navigation and ecologically sensitive regions, Egyptian Authority for Maritime Safety (EAMS) is prioritizing actions to improve safety assurances. These include enacting ECDIS testing regulations for all vessels by the EAMS, with Central Maritime Inspection Authority oversight (Nossir, 2021). Additionally, plans are progressing to upgrade unreliable electronic charts via new hydrographic surveys by the IHO-approved Egyptian Navy Hydrographic Department (Nossir, 2021).

Implementing mandatory checks on ship ECDIS installations while replacing deficient charts will help Egypt align its coastal navigation framework with best practices for protecting life, property, and the environment.

7- Recommendations

To address identified gaps in electronic chart reliability and uphold navigational safety standards, the following actions are advised:

- Implement mandatory verification procedures for ship ECDIS installations overseen by the EAMS (Nossir, 2021).
- Prioritize new hydrographic surveys by the IHO-accredited Egyptian Hydrographic Division to improve ENC navigational data quality along the country's coast (Nossir, 2021).
- Expedite the release of ECDIS guidelines detailing Egyptian PSCO inspection protocols to assist visiting vessels in achieving compliance (Rambabu et al., 2021).
- Leverage satellite communication resources to disseminate ECDIS advisories ensuring maritime domain awareness for ships transiting regional waters (IALA, 2020).
- Encourage frequent ENC updates from the ENHD to incorporate the latest chart notifications (Smith et al., 2021).
- Urge mariners to cross-check ECDIS information against multiple navigational data sources for critical safety redundancies (Wang et al., 2019).
- Reinforce best practices in ECDIS operation through enhanced international coordination and training programmes (IMO, 2021).

These recommendations can assist in optimizing Egypt's coastal navigation framework to protect life, property, and delicate marine ecosystems.

8- Conclusion

This research analyzed major deficiencies afflicting the reliability of ENCs along critical stretches of the Egyptian coast. Targeted assessments exposed alarming accuracy gaps in vital maritime transit zones, including the Suez Canal, Strait of Jubal, Aqaba Gulf entrance, and Hurghada Port access channels.

With vessel traffic intensity escalating, the implications of these findings are severe. Relying on imprecise charts erodes safe navigation buffers in restricted corridors, threatening collisions, or

groundings. The consequences could prove catastrophic given their proximity to delicate coral reef systems, beaches, and coastal communities. Decisive action is imperative.

Promising initiatives are already underway between EAMS and international hydrographic bodies to systematically address the ENC integrity crisis through new surveys and data Enhancements. Sustained investments to upgrade core informational infrastructure will help align the country's navigational framework with best safety practices.

Meanwhile, mandatory functionality checks, crew training, and compliance enforcement will optimize the utilization of existing ECDIS equipment. A multifaceted strategy tackling both human and technical dimensions across ships, ports, and shoreside administrators is essential for eliminating needless risk.

The rewards of these collaborative endeavors will be substantial. Strengthening ENC integrity will provide Egyptian-flagged vessels and visiting ships with greater situational assurance when transiting narrow passages. In parallel, averting shipping mishaps preserves fragile marine ecosystems.

Through continued hydrographic and technological progress, Egypt is charting a course towards a more secure and sustainable maritime future—one that simultaneously upholds efficiency for coastal shipping while preventing devastating accidents. The nation's seafaring prosperity depends on it.

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