Influence of the Accuracy and Coverage of Current ENCs on the Safety of Maritime Navigation

Mohsen Fekry, Refaat Rashad
Collage of Maritime Transport and Technology, Nautical Department
Abukir, Alexandria, Egypt
mohsenfekry@gmail.com; refaat.r@hotmail.com

ABSTRACT

Electronic Navigational Chart (ENC) displayed on ECDIS provided new possibilities and functions of automatic tracking of ship's situation to improve the safety and efficiency of marine navigation, and reduce the workload on the officer on watch.

The ability to display different levels of the contents of the chart that meet the requirements of navigation situation and ship's draft without having to display additional information do not fit the situation of sailing and may cause interference of ECDIS screen, and the growing capabilities of ECDIS in warning the navigator in the process of follow-up voyage when activate look-ahead function, which paint a safety zone around the vessel, this is a safety feature line after the second function (Route Check) in warning of the dangers of grounding or get close to navigational hazards and entry of the ship in special areas or areas where navigation is not allowed make the ECDIS a powerful means of navigation.

Obviously, the reliability of the data including how complete (no error), how accurate, and how current (up-to-date) can have a significant impact on the safety provided by the overall system. This is valid more for nautical charts than for land maps, since charts described the underwater regions that are usually hidden from view. While the appearance of the graphics and the ability to properly interpret the information are important ergonomic considerations, it is the quality of the data that is of primary importance in term of navigation safety.

This paper discusses the new functionality and added value of ECDIS in navigation task in the light of the current coverage and accuracy of ENCs, and its impact on the safety of navigation.

KEYWORDS: ECDIS – ENC – Accuracy – Reliable – Safety

1 INTRODUCTION

Navigators used to planning the voyage on the paper charts for a long time, the process itself was taking time in the preparation of charts and required nautical publications for the voyage as well check its corrections, and then choosing the way points and plotting it accurately on paper chart using the traditional navigation tools, then drawing routes, calculating the distances and estimated time of arrival (ETA), locating the Wheel Over Points (WOP), and ensuring that the passage of routes in the traffic separation scheme system (TSS), reviewing of nautical publications (sailing directions, list of radio stations, and tidal tables), plotting of navigational warnings on the charts and locating the changing position of machines statues to standby mode, positions of calling the master to the bridge and positions of reporting to the coastal stations. Using their personal skills to ensure the safety of the routes of navigational hazards and shallow depths, and areas where navigation is not allowed.

The planning of voyage by using the ECDIS is considered a simple process as well as it takes a short time, comparing to paper chart; which is displaying the appropriate chart to ECDIS screen, and inputs of way points either graphically using the index (Cursor) appears on the ECDIS screen or digitally by entering the coordinates of latitude and longitude, ECDIS is also drawing the routes and calculating the distances automatically. The ability of ECDS is appearing in drawing the ship courses in straight lines and curves which is connecting between the straight lines where the changing points to achieve the actual behaviour of the vessel during the manoeuvre to change the courses, In addition to the ability of ECDIS to plan the voyage in Great Circle sailing. Nowadays navigators can use ECDIS capabilities and new ways to ensure the safety of the routes of navigational hazards during voyage planning and passage execution.

2 NAVIGATION WITH ECDIS

Before the start of the planning of the voyage on ECDIS, there is a range of settings and controls which is carried out by the navigator, depending on the nature and specifications of the ship draft, such as determining the safety depths, the safe limits of water, the maximum of the safe height for passage down the bridge and the safe distance from the nearest land or navigation hazard. For these settings the utmost importance in activating ECDIS alarms during the preparation stage and voyage execution.

2.1 Route Planning

The added value of using the ECDIS in the planning of voyage is the ability to check the voyage route against the risks automatically, by using Route Check function which appears in the event that the track is safe for navigation or there is any risk to the routes or the paths exceed the safety standards that set by the navigator ' Such as the following;

- Exceeding of the routes for the safe water limits.
- Passing of the routs on shallow depths which are not appropriate to the ship draft.
- Passing down the bridge without enough height.
- Passing through unsafely distance from navigational risk.
- Entry of the ship to non-allowed navigational areas such as navigation in the opposite direction in traffic separation zones (TSS).

As the ECDIS can identify 29 kind of special areas where navigation is not allowed, and warning the navigator that there area such risks by showing a warning report or mark the danger in the red zone. Where the route can be modified easily on ECDIS to avoid those risks by using the cursor or digitally by modifying or cancelling the way points as needed 'and then the way points and routs are to be saved for using it when the voyage is starting up or in any similar voyage.

ECDIS also allows the entry of navigator notes as text or symbols, such as wheel over point, pilot boarding position, reporting points to the coastal stations or vessel traffic service (VTS), and the position of the query about the danger. Figure (1) showing the safety limits adjustment to ensure the rout from the risks and appearing the danger in the red zone.

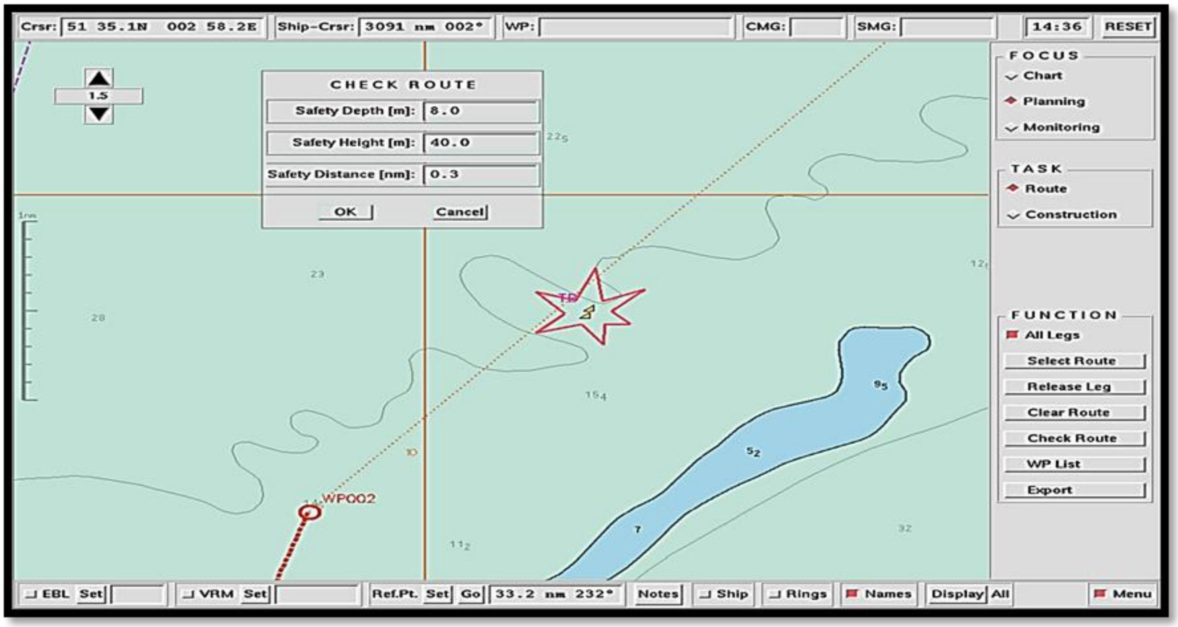

Figure 1: ECDIS Safety Settings and warning message
Source: (Hecht, et al, 2002)

2.2 Route Monitoring

The navigator has two main tasks in the ship bridge first; monitoring the ship's position from navigational risks to avoid the grounding, and making sure the ship is going on the right and safe route to arrive shortly.

Second; watching the ship's position from other ships to avoid collision, It is noted that the navigator was not capable of facing a challenges particularly in determination the ship position on the paper charts using the traditional navigation tools in which need continues observation to avoid the grounding, and using radar to monitor the risks around the ship to avoid the collision.

The ECDIS ability of displaying ship position automatically and in real-time makes it possible for the officer of watch to follow up the ship position on its correct route and as well as keep the ship away from the navigational risks with no need to manual plotting of ship's positions. Also the ECEDS can display the ship's vector with a suitable length of chart scale and its range of matching to the drawn route on the chart or entrance of navigational channels that assigned by buoyage system, Which is considered as a new tool for ship's route safety, in addition to the alarming in case of crossing the Track Limits.

The importance of the ECDIS is highly growing to warn the navigator in voyage execution and manoeuvring phase by activating the look-ahead function, which paint a safe zone around the ship position that may be formed in a circular sector with a notable colour like an "Orange". This function makes the electronic chart an effective tool to prevent wrongdoing or grounding. Figure (2) illustrates the form of a safety zone around the ship position, and warning from entering the danger zone

Figure 2: Look-ahead function and appearance of safety zone on ECDIS screen
Source: (Hecht, et al, 2002)

In addition, ECDES gives off a number of extra warnings to those of GPS or in case of not receiving position from GPS system. ECDES also shows a number of available satellites in the observer sky and the number of satellites used to determine the position of the ship and HDOP number, which reflects the accuracy of the ship position and its appropriateness to sailing. ECDES also gives an alarm when the GPS Coordinates Reference differs from the electronic chart used by ECDES, as well as when geodetic datum system differs from the world geodetic system (WGS-84).

ECDES also shows the Radar image and ARPA data to be integrated with the electronic chart on one screen, which enables the navigator to follow up the ship position from any possible risks, and keeping the ship on its route, and watching the detected Radar targets and their ARPA data on ECDES screen to combine between two navigational tasks; grounding and collision preventions. Also the matching of Radar image and coast line on the electronic chart can be monitored as proof of accuracy of ship position from the GPS system; If the two images were not matched, it could be an error on GPS position, but if the Radar image was inclining with an angle on the electronic chart, this could be an error in GYRO compass.

The navigator's ability to do asses situations, and decrease the collision risks is increased when the data of the Automatic Identification System (AIS) is showed on the ECDES Screen since the Guard Zone of ARPA works as Guard Zone of AIS targets on ECDS screen, this type of display counteract some of the Radar limitation about the inability of radar to detect some targets.

The showing of ship symbol on ECDES screen is representing a new way of the monitoring methods of ship position from the any navigation risks , where the ECDES shows the ship symbol as an movable point on the screen upon showing the electronic chart with small scale, and when the ship approaches from the coast, the narrow channels or entering the ports then the chart could be displayed with a large scale , in this case the ship symbol could be displayed with dimensions (length, width) that appropriating with the actual ship size and chart scale. This kind of presentation is useful during manoeuvres in the narrow channels or mooring the ship to dock or ligament on the buoy especially in the case of poor visibility or when there are strong winds where the navigator can check the safety of the ship manoeuvre and distance off from navigational hazards, if the accuracy of the position within a few meters.

One of the new tools which follows the ship position in the narrow navigational channels is the Prediction Function which is the ability of ECDIS to predict ship movement for a short period of time, 1-3 minutes, and for any number of predictions as per navigator‘s requirements by showing the position of ship symbol during these periods on the ECDS screen by the use of positioning sensors (GPS), the heading, rate of turn, and actual ship speed. This function shows in a typical pre-calculated future of a ship during a course change in navigational channels. But all these capabilities and functions need an official electronic chart with high level of accuracy and reliability.

3 OFFICIAL ENC

"The Electronic Navigational Chart (ENC) means the database, standardized as to content; structure and format, issued for use with ECDIS on the authority of government authorized Hydrographic Offices. The ENC contains all the chart information necessary for safe navigation and may contain supplementary information in addition to that contained in the paper chart such as (sailing directions) which may be considered necessary for safe navigation." (IMO – ECDIS PS, 1995)

From above IMO definition, ENC considered official data when issued by authorized national government agency, normally the national Hydrographic Office (HO), and meets the specifications of the International Hydrographic Organization (IHO). The chart data can be authorized only by the national authorities that are responsible for creating, collecting, and update the chart information. The IHO has defined a uniform data exchange format called IHO S-57 as amended, containing the ENC product specification, and requested member states to produce and distribute electronic charts in this format. Figure (3) shows the status of official ENC.

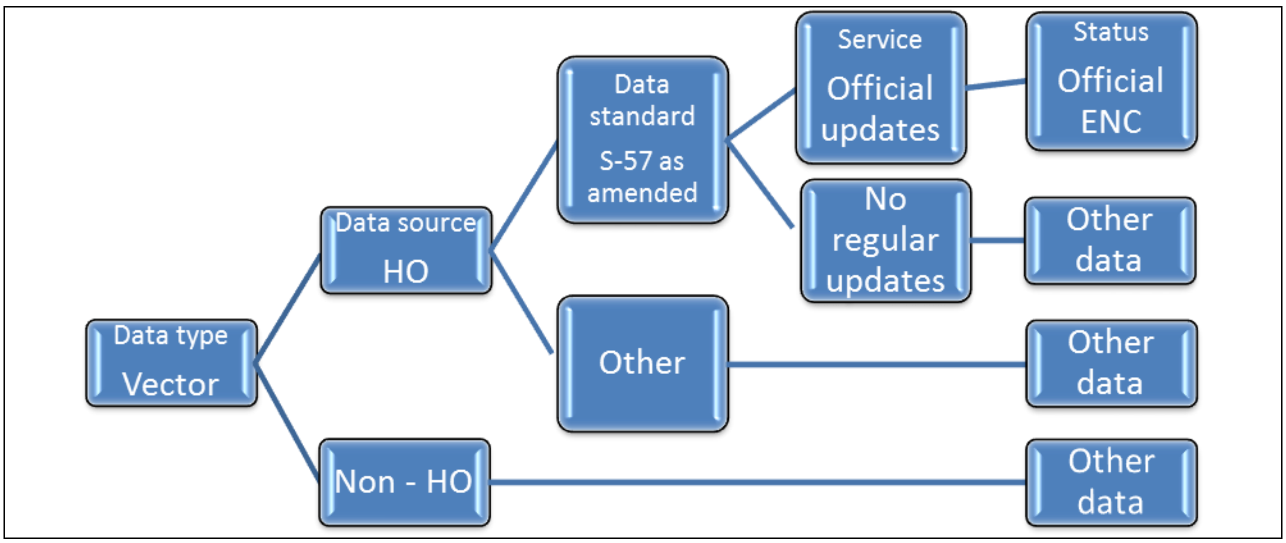

Figure 3: Status of official ENC

3.1 Identification of ENCs

Each ENC is identified by an 8-character identifier for example GB105030. The first two characters indicate the producer; GB for Great Britain. A complete list of producer codes is included in the IHO standard (S-62). The third character indicates the navigational purpose band (a number from 1 to 6). The last five characters are alpha- numeric and provide a unique identifier. Table (1) shows the Navigational Purpose band to Scale Range and cell size

Table 1: The Navigational Purpose band to Scale Range

Navigational Purpose	Name	Scale Range	Cell Size
1	Overview	< 1:1 499 999	200 – 1000 NM
2	General	1:350 000 – 1:1 499 999	60 – 100 NM
3	Costal	1:90 000 – 1:349 999	24 – 48 NM
4	Approach	1:22 000 – 1:89 999	8 – 18 NM
5	Harbor	1:4000 – 1:21 999	2 – 6 NM
6	Berthing	> 1:4000	0.1 – 1.5 NM

Source: (PRIMAR, et al, 2007)

3.2 Hydrographical Source Information

The Hydrographic Offices the source of official chart data. All information associated with either paper and electronic charts are initially collected or even produced by, or under the authority of, a national Hydrographic Office (HO). It is the responsibility of a HO to conduct hydrographic surveys in national waters to ensure safety of navigation. This includes measuring the water depth wherever navigation takes place, and to investigate the area for any underwater obstacles (wrecks, rocks and reefs)

In addition, a Hydrographic Office (HO) also compiles information about aids to navigation, traffic regulations issued by the relevant maritime authorities, reporting requirements, Vessel Traffic Systems (VTS), pilot stations and coastal radio stations. (Hecht, et al, 2002)

3.3 Quality of the Hydrographic Data

Individual nations are responsible for conducting hydrographic survey in the area consisting of the coastal sector of the territorial waters (normally 12 nm from the coastline) and of the Exclusive Economic Zone (EEZ) reaching up to 200 nm from the coast. The actual borders of these regions are determined in accordance with the United Nation Convention on the Law of the Sea (UNCLOS).

For instance, Germany is responsible for a relatively small sea area of 57000 Km². however, for countries like USA, Australia or Indonesia with sea area of 6 million Km² or more, it is almost impossible to meet the requirements of accurate and up-to-data surveys for the entire area. In most cases, hydrographic surveys are primarily conducted in areas that are important in terms of safety of navigation. Outside these areas, charts may be based on survey data from over a hundred years ago. (Hecht, et al, 2002)

The northern entry to the North Sea between Great Britain and Norway was last surveyed at the beginning of the 20th century. Obviously, these earlier surveys could not match the accuracy of sounding or positioning provided by today’s equipment, such as (the echo sounder and GPS). If you sail along the north coast of Norway using a GPS for positioning, you may notice that there is a 400 m difference between the GPS fix and the charted position of the rocks and islands.

Problem areas exist even along short coastline of highly-developed countries. For instance in Germany strong currents in the North Sea and in some regions of the Baltic cause continuously changes of the sandy bottom. In some cases, these changes cannot be fully monitored by periodic surveys. For example, the fairways in the Elbe estuary the Elbe leading from the North Sea to the biggest German port (Hamburg) has shifted over 800m to the north during only five years, changing the depth in some place by up to 10 meters. Many small North Sea ports also cope with severe sand shoaling of their entrances after every storm. It is not always possible to maintain up-to-date surveys in such areas. Control soundings are conducted at the entrance to several important North Sea ports every month. In other areas these surveys must be conducted at least once a year. Naturally, regular updating of the database for the electronic charts is an imperative in such shallow areas. (Hecht, et al 2002)

United States produce 1000 paper charts to cover their own territorial waters and to have 670 NOAA ENCs to cover all the 40 major ports, over 50 % of the depth information found on NOAA charts is based on hydrographic surveys conducted before 1940. Surveys conducted with lead lines or single-beam echo sounders. Due to technological constraints, hydrographers were unable to see between the sounding lines. Depending on the water depth, these lines may have been spaced at 50, 100, 200, or 400 meters (Web-1).

On the other hand, there are many regions do not have hydrographic office, for example in Africa there are no hydrographic services except along the Mediterranean coast and in South Africa. As a result, the information presented on the many charts of the Africa coastal waters is unreliable.

4 DEVELOPMENT OF ENC COVERAGE

ECDIS is the heart of modern navigation systems and electronic chart is the heart of ECDIS which have enabled range of capabilities and functions to prevent grounding and increase the safety of navigation. For this, ENCs coverage and accuracy play an important role in activating the anti-grounding functions and achieve the safety of navigation. In response to these drives, the IHO recognized the need to improve ENC coverage, and encouraged national hydrographic offices to produce and distribute ENCs that will improve maritime and environmental safety. Normally, a member state produce ENCs within their national waters; however, they can delegate responsibility for the production of ENCs, completely or in part, to another country. The designated country then becomes the producing country in the considered area.

Examine the coverage and the source of hydrographic data of ENCs for the Mesoamerica and Caribbean Sea region, extending approximately from central Mexico to Belize, Guatemala, El Salvador, Honduras, Nicaragua, and northern Costa Rica, including adequate ENC coverage for all usage bands, which only correspond to the paper chart coverage for the routes between the ports, as well as the port areas themselves, for the Atlantic side and pacific side. The table (2) shows the total number of ENC cells as required to achieve adequate coverage as per the World-wide Electronic Navigational Chart Data Base (WEND) Principles, the cells available by July 2012 and the producing authors.

Table 2: ENC coverage of Mesoamerica and Caribbean Sea region by usage bands and producing authors

Usage Band	Name	Total cells	Cells available by July 2012	Producing authors	
				NHOs	Delegated
1	Overview	13	12	5	8
			92 %	38 %	62 %
2	General	41	36	8	32
			88 %	20 %	80 %
3	Costal	113	84	59	54
			74 %	52 %	48 %
4	Approach	208	176	74	134
			84 %	36 %	64 %
5	Harbor	291	240	111	180
			82 %	38 %	62 %
6	Berthing	17	14	12	5
			82 %	71 %	29 %
All Usage Bands		683	562	269	414
			82 %	39 %	61 %

Source: (MACHC, 2012)

Where such data have been compiled from official reports of Mesoamerica and Caribbean Sea Hydrographic Commission's (MACHC) submitted to the IHO. (MACHC, 2012)

An analysis of these data found that the coverage ratio reaches the 82%, 39% produced by HOs, While 61% produced a mandate for the offices of other countries (UKHO, NOAA, and French hydrographic office).

Most HOs are focusing their efforts on producing data for important harbours and waterways. As a result of this shortage of official data, 61% or more of vector electronic chart data that is currently available throughout the region, as well as the world is produced and supplied by digitizing official paper nautical charts. However, not because the paper chart was used in the digitizing process was official, means that the ENC data is as well. It is conceivable that the original data fed into the chart is inaccurate due to technological constraints. For instance, data shown on the ECDIS display originates from surveys done, sometimes in bygone era, without multi-beam and DGPS

In problematic areas the hydrographic information shown on the best electronic chart system (ECDIS) may be no better than what can be obtained from paper chart. It would be imprudent for a mariner to totally rely on a computer-based system for navigation in these areas. It is not the computer that is the problem: it is the quality of the available data. If the electronic chart data is based on surveys that are out of date or of questionable accuracy, then the user should be warned.

5 ACCIDENTS RELATED TO INACCURATE CHARTS AND SURVEYS DEFICIENCIES

- **Grounding of Octopus Barge on an Uncharted Sandbank**

A case in point involved the jack up barge Octopus. A 2007 report by the Marine Accident Investigation Bureau into this incident, which took place off the Scottish coast, found that the cause of the accident was attributable to out of date charts. The barge "Octopus" was under towed by a tug. Due to strong tidal streams, the vessels changed course to a route unusual for deep drought vessels. The jack up barge was subsequently grounded on an uncharted sandbank. According to the area's applicable Admiralty chart, the draught should have been above 20 m. but the barge, with legs extended to 13 m. found itself stuck on the sandbank which had depth of 7.1 m. the source data for the chart was found to be over 150 years old.

The responsibility for chart surveys in United Kingdom (UK) waters lies with the Maritime Coast Guard Agency (MCA). The MCA has US$ 8.6m budget annually to hydro-map the UK's coastal waters. The funds would be enough to survey a sea area of around 10,000 sq km. but this figure should be set against a total sea area of 720,000 sq km. In this situation, the agency will prioritize which parts of the seabed are in urgent need of surveying and which are not. Essentially, it is an approach based on risk. Shipping lanes in continual use by the same ship types tend to be left alone. But where there have been changes, a new edition to an accepted route or where ship's draught have increased, these areas will be prioritized. The case is: base data of some surveys remains hundreds of years old. (Web-2)

- **Grounding of Pacific Challenger on an Uncharted Reef**

Another accident the grounding of the German-flagged, container vessel, Pacific challenger on an uncharted reef in April 2008 while en route from Rabaul, New Britain, to Oro Bay, Papua New Guinea, in the South Pacific.

- **Grounding of Sanko Harvest on an Uncharted Reef**

Also the Panama registered bulk carrier Sanko Harvest grounded on an uncharted reef, 19 miles South East of Esperance port while on passage from Tampa, USA, to Esperance, Australia, in 1991, loaded with 30791 tones of fertilizer and caused what was then the country's biggest oil spill.

- **Grounding of ROCKNES on an Uncharted Rock**

The stone-carrier ROCKNES hit a rock and capsized off Norway with the loss of 18 crew member on January 2004, following the disaster there was much press speculation about whether or not the rocks upon which the vessel grounded were charted. It would appear that a new shoal depth of 9.2m had been found during a recent survey but had not been specifically marked on a new edition of the Norwegian chart covering the area and the ship's electronic chart was a raster chart which, not forming part of the official navigation chart folios and was not required to be kept up to date. The Norwegian pilots also had an electronic chart system for their home computers but the correction contract had expired so these were also not corrected to include the latest data.

Whatever the exact situation over the charting of this passage (which is only 297m wide) following the disaster was, the pilot confirmed in his statement that had the buoy been in place at the time of the Rocknes' transit, the grounding would not have occurred (Web-3)

6 CONCLUSION

ECDIS achieve safe navigation for its ability to connect to other bridge navigational systems, and reduces the workload to the officer on watch in the planning and follow-up voyage, if ENCs with accurate, updated, and reliable hydrographic data are available.

On the other hand, ENCs produced and supplied by digitizing paper nautical charts, based on hydrographic surveys conducted before DGPS and multi-beam echo sounder age, in this case, ECDIS may be contributed to increase grounding incidents due to navigational chart errors over the next few years. The predication is based on more vessels, especially passenger vessels, entering poorly surveyed areas, and overconfidence in ECDIS displays. Actually, ECDIS isn't necessarily going to be more accurate than paper charts.

ECDIS must give clear indication and alarm about the reliability of data by displaying the surveyed date on the main navigation screen to warn mariners of the presence of risk in those areas despite the presence of ECDIS in Bridge

Attention must be paid to these issues in the courses offered by the nautical institutes to marine captains and navigation officers.

REFERENCES

Hecht, H. (2000). WEND and RENC Keywords for IHO's Distribution System for ECDIS Data – an Evaluation of Terminology and Concept, International Hydrographic Review, Vol. 1, No. 1, pp. 81-84.

Hecht, H., Berking, B., Buttgenbach, G., Jonas, M., and Alexander, L. (2002). The Electronic Chart Functions, Potential and Limitations of New Marine Navigation System, GITC bv, Lemmer, The Netherlands.

IHO S-52 (1996). Specification for Chart Content and Display Aspect of ECDIS, International Hydrographic Organization, Monaco.

IHO S-57 (2000). Transfer Standard for Digital Hydrographic Data, International Hydrographic Organization, Monaco.

IMO (1995). Performance Standards for Electronic Chart Display and Information System (ECDIS), IMO Resolution A.817(19), International Maritime Organization, London

MACHC (2012). Report of the MACHC Electronic Chart Committee, ENC Coverage for the MACHC region, Mesoamerican and Caribbean Sea Hydrographic Commission's.

Norris, A. (2010). ECDIS and Positioning Vol. 2 Integrated Bridge Systems, The Nautical Institute, London.

Perugini, N. (2001). Behind the Accuracy of Electronic Charts – What Every Mariner Should Know about Electronic and Paper Charts, available on line, www.nauticalcharts.noaa.gov/mcd/electronic_accuracy.html, cited on 20/12/2010

Weintrit, A. (2008). Operational Requirements for Electronic Chart Display and information system (ECDIS) Procedural and Organizational Considerations, Gdynia Maritime University, Gdynia, Poland.

Web sites:
Web-1: http://www.nauticalcharts.noaa.gov/staff/headline-ecdis-issue.html, consulted 23 Dec. 2011
Web-2: http:// www.theartofdredging.com/ecdisupdate.htm, consulted 9 Feb. 2012.
Web-3: http:// www.pilotmag.co.uk/2004/10/15/rockness-disaster/, consulted 9 Feb. 2012.
Web-4: http:// www.ecy.wa.gov/pubs/98254.pdf. Washington State Department of Ecology, Focus on Voyage Planning, consulted 1 March 2012.
Web-5: http://www.ic-enc.org/page_coverage.asp, consulted 1 August 2012.
Web-6: https://www.primar.org/enc-coverage, consulted 1 August 2012.