TECHNICAL REPORT

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ECDIS AND ENC COVERAGE – FOLLOW UP STUDY

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Tel:
Fax:
http://www.dnv.com

Summary:

In this report, an updated study on the effect of Electronic Navigational Chart (ENC) coverage on Electronic Chart Display and Information System (ECDIS) risk reduction is presented. Global traffic data for cargo ships has been evaluated in relation to the present and future global coverage of ENC. Eleven specific ship routes, representative for global merchant shipping, has been analysed to assess the ECDIS risk reducing potential in light of actual ENC coverage along these routes. The coverage along selected routes varied from 49% to 100%, with four of the eleven routes having 100% coverage. Currently, the global coverage of suitable ENC lie between 85% and 96%. Based on the analyses carried out in this study, and the current cost-effectiveness criteria used at IMO, the following recommendations on mandatory carriage of ECDIS have been supported and strenghtened:

Oil tankers	Other cargo ships	Passenger ships
new ships > 500 GT. existing ships > 3,000 GT if not older than 20 years. existing ships > 10,000 GT irrespective of age.	new ships > 3,000 GT. existing ships > 10,000 GT if not older than 20 years. existing ships > 50,000 GT irrespective of age.	> 500 GT

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Work carried out by: Erik Vanem, Magnus Strandmyr Eide, Gjermund Gravir and Arve Lepsøe

Work verified by: Linn Kathrin Fjæreide

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1 CONCLUSIVE SUMMARY

Electronic navigational charts (ENC) and Electronic chart display and information system (ECDIS) are tools which aid the navigator on ships. The system is in use in the world merchant fleet today, and several studies have documented that the system has a risk reducing effect, reducing the number of grounding accidents, and consequently the number of fatalities and oil spills. This has led to initiatives from several flag states to push for an IMO carriage requirement for ECDIS, in order to secure that the advantages of ECDIS will benefit as large a portion of the world fleet as possible.

The NAV subcommittee in IMO will consider a carriage requirement for ECDIS at its NAV 54 meeting. To support discussions at this meeting, this report provides a comprehensive investigation of the risk reducing potential of ECDIS, seen in light of global ship traffic distributions and updated ENC coverage data. The cost-effectiveness of ECDIS as a risk control option for cargo ships has been evaluated using updated data on global ENC coverage. As such, this study represents an update of a previous study from which results were submitted to NAV 53 [17].

Compared to the previous study, performed in 2006/2007, a notable increase in worldwide coverage of ENC has been observed. According to data received from the International Hydrographic Bureau (IHB), the number of ENCs in usage bands 3 – 6, i.e. corresponding to *coastal*, *approach*, *harbour* and *berthing* ENCs, has increased by about 33%. Based on the updated ENC coverage it has been demonstrated that between 85% – 96% of global ship traffic operates with suitable ENC coverage in coastal waters. Compared to the previous study, this represents a reduction of gaps in the global ENC coverage by about 25%.

Selected representative shipping routes have been reinvestigated in detail, and most of these have also experienced an improvement of suitable ENC coverage. With the updated ENC coverage, ECDIS was proven to become cost-effective in the near future (at least by 2012) for all selected routes (one of which was not found to be cost-effective in the previous study). This study also examined ENC coverage in the world's major ports. Accordingly, nearly 88% of the 800 largest ports worldwide were found to have suitable ENC coverage. Hence, it was demonstrated that the ENC coverage of major ports are extensive.

The study showed that:

a. The global coverage of suitable ENC for SOLAS traffic within 20 nautical miles off the coast currently lies between 85% and 96% and is expected to increase to 88 – 97% within 2012.
b. The coverage of suitable ENC along selected representative routes varies between a minimum of 49% (expected to increase to 77% by 2012) to a maximum of 100%.
c. The grounding frequency reductions achievable from implementing ECDIS vary between 19% and 38% for the selected routes. By 2012, grounding frequencies may be reduced by at least 30% on all selected routes.
d. It is expected that ECDIS may result in 1.1×10^{-2} groundings averted per shipyear on average for the merchant fleet.

The cost-effectiveness has been assessed in terms of the Gross Cost of Averting a Fatality (GCAF) and the Net Cost of Averting a Fatality (NCAF) for new as well as existing ships. It was found that GCAF would always be higher than USD 3 million for all cargo shiptypes and sizes. However, NCAF was found to be less than USD 3 million and even negative for many variations of ship age and size. Keeping in mind the criteria for cost-effectiveness consistent with current practice at IMO, i.e. that risk control options are cost-effective if GCAF ≤ USD 3 million or NCAF ≤ USD 3 million, the estimates arrived at renders ECDIS a cost-effective means of reducing risk for ships larger than a certain threshold for various shiptypes.

Basically, the recommendations and conclusions from the previous study have been supported and strengthened by this study. Notwithstanding known gaps in the global ENC coverage, this study has demonstrated that the coverage that already exists is sufficient to make ECDIS a cost-effective means of reducing the risk of grounding. Thus, the following recommendations have been substantiated with increased confidence, based on the cost-benefit assessment presented in herein:

i. ECDIS should be made mandatory for all passenger ships of 500 gross tonnage and upwards.

ii. ECDIS should be made mandatory for all new oil tankers of 500 gross tonnage and upwards.

iii. ECDIS should be made mandatory for all new cargo ships, other than oil tankers, of 3,000 gross tonnage and upwards.

iv. ECDIS should be made mandatory for all existing oil tankers of 3,000 gross tonnage and upwards.

v. ECDIS should be made mandatory for all existing cargo ships, other than oil tankers, 10,000 gross tonnage and upwards.

vi. Exemptions may be given to existing oil tankers of less than 10,000 gross tonnage and existing cargo ships, other than oil tankers, less than 50,000 gross tonnage when such ships will be taken permanently out of service within 5 years after the implementation dates given for iv) and v) above.

2 INTRODUCTION AND BACKGROUND

Electronic navigational charts (ENC) and Electronic chart display and information system (ECDIS) are tools which aid the navigator on ships. The system is in use in the world merchant fleet today, and several studies have documented that the system has a risk reducing effect, reducing the number of grounding accidents, and consequently the number of fatalities and oil spills. This has led to initiatives from several flag states to push for an IMO carriage requirement for ECDIS, in order to secure that the advantages of ECDIS will benefit as large a portion of the world fleet as possible.

As all requirements from the IMO should be based on a solid, objective and rational foundation, Formal Safety Assessment (FSA) is used to document the cost-effectiveness of proposed risk reducing measures [6]. In the case of ECDIS, several FSAs have been produced and submitted to the IMO, documenting that ECDIS is a cost-effective risk reducing measure [12, 14, 16, 17].

The NAV subcommittee in IMO will consider a carriage requirement for ECDIS at its NAV 54 meeting. To support discussions at this meeting, this report provides a comprehensive description of ECDIS and ENC (section 2.1), as well as the historic development of the ECDIS and ENC standards and the motivation behind these standards (section 2.3). Furthermore, a description of the FSA process (section 2.4) and summary of previous FSAs on ECDIS is provided (section 2.5). Finally, an update of the cost-effectiveness of ECDIS and the ENC coverage is given (section 5), using an updated catalogue of worldwide ENCs (section 3) as well as a description of the ENC coverage in the 800 largest ports in the world (section 4).

2.1 Navigational risk

Recent FSAs have concluded that navigational accidents such as collision and grounding are main risk drivers for many shiptypes [1, 2, 3]. Hence, major risk reduction may be achieved by implementing measures to prevent such accidents, e.g. related to navigation.

According to casualty data from Lloyds Register Fairplay (LRFP), grounding is the third most frequent accident type involving ships larger than 1000 GT and the fourth highest contribution to fatalities in maritime accidents. Figure 1 illustrates the breakdown of the six most important maritime accident categories in terms of number of accidents and number of fatalities for the period 1991 – 2006 according to LRFP. Grounding (or wrecked/stranded as it is labelled in Figure 1) is found to correspond to about 20% of all maritime accidents reported in this database for this period, and to account for nearly 12% of all fatalities occurring in maritime accidents. The relative ratio of groundings to all maritime accidents has remained between 20% and 25% at least for the last 30 years.

In Figure 2, the number of groundings and the grounding frequency (per shipyear) are illustrated for the period 1980 – 2005. As can be seen, groundings have occurred and continue to occur relatively frequently in international shipping, and it may be concluded from these statistics that preventing groundings and other navigational accidents have been and continue to be important for improving maritime safety.

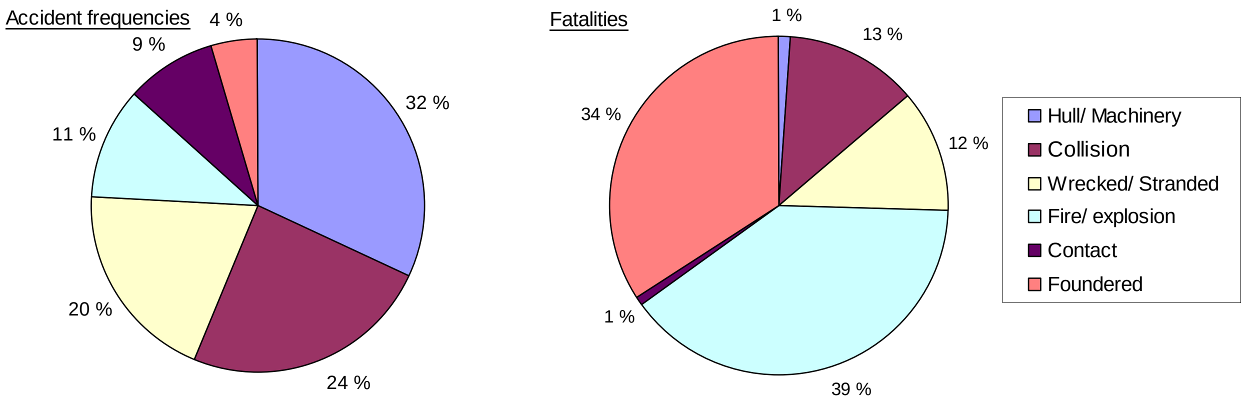

Figure 1: Main maritime accident categories according to LRFP

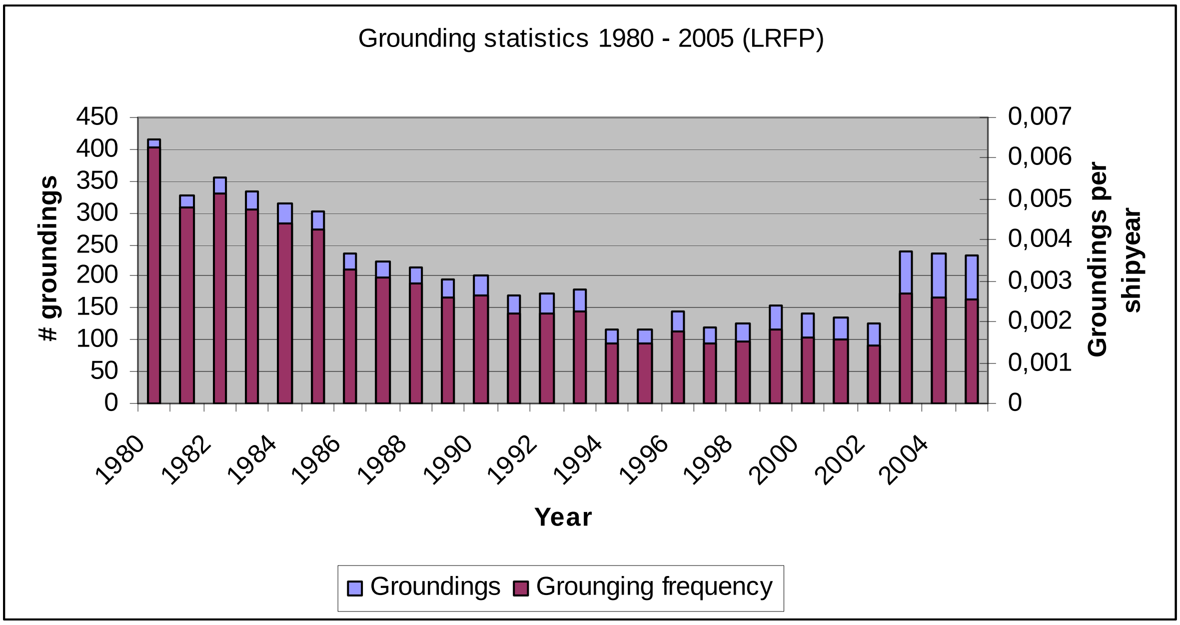

Figure 2: Grounding ratio of maritime accidents 1980 – 2005 (LRFP)

2.2 ENC and ECDIS

2.2.1 ENC

Only up to date official charts may be used to fulfil carriage requirements of ships. Other nautical charts are often referred to as private charts, and these are not accepted as the basis for navigation under the SOLAS convention. There are two kinds of official digital charts available, Electronic Navigational Charts (ENC) and Raster Navigational Charts (RNC).

RNC stands for Raster Navigational Charts and official RNCs are digital raster copies of official paper charts. These can only be issued by, or on the authority of, a national Hydrographic Office. According to the IMO performance standard, ECDIS operated in the Raster Chart Display System (RCDS) mode may be used to meet carriage requirements for areas where ENCs are not available. However, for these areas an appropriate portfolio of up-to-date paper charts (APC) should be carried on board and be readily available to the mariner.

ECDIS operation in RCDS mode is acknowledged to have limitations compared to using ENCs. Hence, in order to fully exploit the risk reducing effect of ECDIS, ENCs need to be available and for the remainder of this study, the availability of RNCs will not be considered.

ENC stands for Electronic Navigational Charts. ENCs are produced by or on the authority of a government authorised Hydrographic Office or other relevant government institution. ENCs should be the responsibility of the responsible Hydrographic Office and be based on their source data or official charts. They should be compiled and coded according to international standards and regularly updated with official update information distributed digitally. All ENCs should be referred to World Geodetic System 1984 Datum (WGS84), the world-wide datum used by Global Positioning System (GPS). For the purpose of this study, only ENCs will be considered.

ENCs are vector charts compiled from a database of individual geo-referenced objects from Hydrographic Offices' archives. IMO offer the following definition for ENC [4]: *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 (e.g. sailing directions) which may be considered necessary for safe navigation.* Being a database, ENC content may be continuously retrieved by special operational functions in ECDIS to give warnings of impending danger related to the vessel's position and its movements.

ENCs are optimized to absorb the Hydrographic object information and this structure is not adequate for fast generation of computer images on the screen. In order to get data structures that facilitate rapid display of ENC data, ECDIS first converts each ENC into an internal format called System Electronic Navigational Charts (SENC) which is optimized for creating chart images. In contrast to the ENC format that is common and uniform, SENC formats are proprietary for each ECDIS manufacturer. Presentation rules for the display of the abstract geographic entities of ENCs are contained in the presentation library as a separate ECDIS software module.

2.2.2 ECDIS

ECDIS (Electronic Chart Display and Information System) is a type of navigational electronic chart system that may be installed on the bridge of a vessel. An example of a modern ECDIS is shown in Figure 3.

Figure 3: Modern ECDIS

The IMO ECDIS Performance Standards [4] defines ECDIS equipment as follows: *Electronic chart display and information system (ECDIS) means a navigation information system which, with adequate back-up arrangements, can be accepted as complying with the up-to-date chart required by regulation V/20 of the 1974 SOLAS Convention, by displaying selected information from a system electronic navigational chart (SENC) with positional information from navigation sensors to assist the mariner in route planning and route monitoring, and by displaying additional navigation-related information if required.*

Another class of navigational electronic chart systems exist, simply referred to as Electronic Chart System (ECS). Such systems do not meet the SOLAS chart carriage requirements. Hence, the use of ENCs in a tested, approved and certified ECDIS (with appropriate back-up arrangements) is the only alternative option to paper charts for vessel navigation. Appropriate back-up systems may either be in the form of paper charts or an independent, separate ECDIS. For the purpose of this study, dual ECDIS are assumed, i.e. with a complete, independent ECDIS as the back-up arrangements.

In order to be an ECDIS, equipment must be shown to meet a number of requirements laid down by the performance standards. I.e. it must support the whole range of navigational functions that make use of the characteristics of the chart data and their specific presentation. The performance standards contain requirements related to i.a.:

- Display of SENC information
- Display of other navigational information
- Display requirements for route planning and monitoring
- Provision and updating of chart information
- Scale indication
- Colours and symbols
- Route planning, monitoring and voyage recording
- Accuracy
- Performance tests, malfunction alarms and indications
- Back-up arrangements
- Power supply

Within the ECDIS, a database of electronic nautical charts (ENC) store chart information in the form of geographic objects represented by point, line and area shapes carrying individual attributes that make each object unique. Mechanisms are built into the ECDIS system so that the data can be inquired and used to perform certain navigational tasks such as anti-grounding surveillance. The ECDIS performance standards also state that the use of ECDIS should reduce the navigational workload related to route planning, route monitoring and positioning compared to the use of paper chart. This means that navigational risks could be reduced when using ECDIS compared to traditional paper charts.

2.3 Historic ECDIS development and motivation behind ECDIS requirements

ECDIS is not new, and various aspects of ECDIS have been discussed at IMO for more than 20 years. In the following, a brief overview of the historical development of ECDIS and ENC will be provided, with a particular focus on discussions at IMO.

User requirements were the prime basis during the development of the ECDIS standards. This was made clear already during the earliest discussions in IMO during NAV sub-committees 32 meeting in March 1986. At this early stage it was emphasised, by Japan (NAV/32/6/10) that user needs should be duly investigated and considered and that the technical systems developed (both software and hardware) should be designed for supporting those user needs.

During the following years, IMO, strongly supported by a joint IMO/IHO harmonisation group on ECDIS (NAV-HGE), further developed the user requirements as well as draft performance standards for ECDIS. IMO adopted, on 23 November 1995, the first performance standards for ECDIS, by Resolution A.817(19). These performance standards where amended by resolution MSC.64(67), where further detailed requirements for a back-up arrangement for ECDIS where added and by resolution MSC.86(70), December 1998, which allowed the use of ECDIS in raster chart mode (RCDS mode of operation) and included requirements for such mode of operation.

The NAV sub-committee agreed, after thorough considerations, that such systems should provide added value by reducing the navigational workload as compared with using paper navigational chart. It should further enable the mariner to execute in a convenient and timely manner all route planning, route monitoring and positioning previously performed on paper navigational charts.

Bearing in mind the core functions of ECDIS;

- real-time positioning – Actual own ships position is always known and displayed on the chart in real-time,
- anti Grounding alarms – ECDIS provides automatic alerts when the route is planned without satisfactory clearance to grounding dangers and when own ship approaches areas or objects representing a danger to the ship,
- appropriate information level – ECDIS are automatically adjusting the amount of chart details to fit the selected zoom level. ECDIS furthermore allows the user to select only those chart information's needed for the operation at hand. All other information's are readily available.

There is no doubt that ECDIS is an effective tool for increasing navigational safety by reducing the workload and then also the stress level. Another workload reducing factor is that ECDIS charts are corrected by simply inserting a CD or DVD into the ECDIS computer – quite another story than correcting paper charts, which is a laborious and time consuming task for the mariner.

In later years, navigators have been requesting further developments of ECDIS in order to get maximum navigational benefit from new technological developments. Examples are:

- AIS targets displayed on the ECDIS. By this function, the navigators are able to make efficient use of the data received through the AIS system.
- Radar targets and video superimposed on the ECDIS (radar overlay). By this function the navigators are able to see the traffic picture in relation to the navigable waters and ships routing systems (TSS's) and by that foresee other ships future movement. This function is

further highly recommended for ships operating in areas where the chart geodetic datum is unknown, as the combined radar – ECDIS picture immediately shows the navigator if there is inconsistency between the geodetic datum of the GPS position and the geodetic datum of the chart.

- Weather services. ECDIS can be used for avoiding heavy weather damage if provided with weather forecasts which can be used for planning/ re-planning a route in such way to reduce the risk for heavy weather damage. Such weather-safe routes are also often the fastest and therefore environmental friendly.

After having recognised the need to improve the initial performance standards by taking into account the technological progress and experiences gained, IMO adopted, on 5 December 2006, revised performances standards for ECDIS, Resolution MSC.232(82).

In 2007, a Russian study was performed to investigate the navigator's psychophysiologic condition when using ECDIS. This study was referred to in the plenary session of NAV 53 [5]. In the study, groups of trained navigators were tasked with performing a port call at the Port of Helsinki (Finland) using a bridge simulator. The navigators performed the task both with and without ECDIS on the bridge, and the performance was monitored. Among the outcomes of the study were results showing that in a majority of cases the navigators pulse rate was lowered when ECDIS was available. The reduced pulse was explained by a decrease in the general workload on the navigator. The researchers also noted a reduction in "near miss groundings" using ECDIS. Hence, the Russian study demonstrated that ECDIS indeed is of valuable help to the navigator.

IMO Model Course 1.27 – The Operational Use of ECDIS – has been established, and this model course provides valuable assistance for preparation of training courses and training material for ECDIS training centres. Furthermore, STCW sub-committee issued interim guidance, STCW.7/Circ.10 (2001) on training and assessment in operational use of the ECDIS simulators. An increasing number of nautical schools and training centres worldwide are now offering ECDIS training based on the model course and the simulator guidance.

2.3.1 Development of electronic navigational charts - ENC

In parallel to the developments of ECDIS standards within IMO, other organisations have developed the necessary supporting standards, such as the special publications S-52, S-57 and S-61 issued by the International Hydrographic Organisation (IHO) and the IEC 61174 standards issued by the International Electrotechnical Commission.

In the early stages of electronic chart production, the production rate of the approved electronic navigational chart data (ENC) was below expectations. This resulted in the need for an interim solution, namely the use of ECDIS in RCDS mode of operation, which was allowed for areas without ENC coverage after the ECDIS standards was amended in 1998. However, there was never doubt that ECDIS in RCDS mode of operation was not equivalent to ECDIS using ENCs. The differences between ECDIS using ENC and ECDIS in RCDS mode of operation was detailed in IMO SN/Circ.207 (1999), which was revised by IMO SN.1/Circ.207/Rev.1 (2007).

After more efficient production methods was developed and used, the production has accelerated resulting in that those coastal areas with highest traffic density are currently to a large extent covered by approved electronic navigational charts (ENC's).

2.3.2 Future developments: ECDIS as a prerequisite for E-Navigation

At its 81st meeting (2006), IMO Maritime Safety Committee added a new agenda item "Development of an E-navigation strategy" to the NAV Sub-committees work programme. E-navigation was by NAV Sub-committees 53rd meeting defined to be:

> *"E-Navigation is the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment."*

The core objectives of E-navigation were defined to include aspects such as:

- *"facilitate safe and secure navigation of vessels having regard to hydrographic, meteorological and navigational information and risks;"*
- *"integrate and present information through a human interface which maximizes navigational safety benefits and minimizes any risks of confusion or misinterpretation on the part of the user;"*

It was further agreed that core element of the E-navigation was expected to include *"high integrity electronic positioning, electronic navigational charts (ENCs) and system functionality with analysis reducing human error, actively engaging the mariner in the process of navigation while preventing distraction and overburdening."*

A wide uptake of ECDIS onboard ships will consequently be a pre-requisite for efficient implementation of the E-navigation.

2.4 Formal Safety Assessment

FSA is a standard risk assessment, with the aim of developing maritime safety regulations in a structured and systematic way. The overall aim is to enhance maritime safety, including protection of life, health, the marine environment and property, using risk analysis and cost benefit assessment.

FSA can be equally useful in the evaluation of new regulations and in comparing existing and possibly improved regulations and it aims at balancing safety and environmental protection levels with costs so that the optimal effect of the resources spent on safety can be achieved. Both technical and operational issues, including the influence of the human element on shipping accidents, may be incorporated in an FSA. Guidelines for the application of FSA are issued by IMO, and these are publicly available and have recently been updated [6, 7].

The FSA methodology is described as a 5 step process, as follows:

0. Preparatory steps
1. Identification of hazards
2. Risk analysis
3. Identifying risk control options
4. Cost benefit assessment
5. Recommendations for decision-making

One of the benefits of using this approach for regulatory development is that the resulting regulations for maritime safety will be based on a sound rationale, and that pertinent costs imposed by new requirements may be defended based on achievable risk reductions.

By now, a number of FSA studies have been performed and reported to IMO according to these guidelines, and decisions have been made based on such submissions [8]. It is also realised that decisions at IMO regarding safety interventions have been surprisingly consistent when it comes to decision criteria, be they implicit or explicit. According to current practice within IMO, and according to the proposals presented in MSC 72/16 [9], which is also supported by e.g. IACS [10], the following cost-effectiveness criteria are deemed appropriate for deciding on safety interventions: A risk control measure will generally be recommended for implementation if GCAF ≤ USD 3 million or NCAF ≤ USD 3 million (note that by definition, NCAF ≤ GCAF, so if GCAF ≤ USD 3 million, NCAF will always be ≤ USD 3 million). This decision criterion is also deemed appropriate for deciding on mandatory carriage requirements of ECDIS.

Formal definitions of the Gross Cost of Averting a Fatality (GCAF) and the Net Cost of Averting a Fatality (NCAF) are provided in the equations below, where ΔC refers to the cost incurred by a risk control option (i.e. a safety requirement), ΔR refers to the risk reduction achievable from the risk control option in terms of human safety and environmental protection and ΔB refers to the additional benefits, e.g. related to more efficient operations and reduced accident costs attributable to the risk control option.

$$GCAF = \frac{\Delta C}{\Delta R} \qquad (1)$$

$$NCAF = \frac{\Delta C - \Delta B}{\Delta R} \qquad (2)$$

2.5 Previous FSA studies on ECDIS presented at IMO

Previously, studies on navigational safety have been reported to IMO where the effects of ECDIS have been evaluated in particular. The initial studies focused on large passenger ships [11, 12] and was later extended to focus on other shiptypes such as oil tankers, product tankers and bulk carriers along particular routes [13, 14, 15, 16]. The most recent study also investigated the cost-effectiveness of implementing ECDIS on existing cargo ships of various size and age [17, 18]. The conclusions arrived at in these previous studies were:

a. ECDIS is a cost-effective risk control option for large passenger ships, with a significant potential to save lives by reducing the frequency of collision and grounding
b. ECDIS is a cost-effective risk control option for all other vessel types engaged in international trade, with the exception of the smallest vessels.
c. ECDIS represents a cost-effective means of preventing oil spills close to shore for most types of cargo ships by reducing the probability of grounding accidents.
d. The potential for saving lives is small for cargo ships, but ECDIS represents a net economic benefit in itself.

e. ECDIS remains cost-effective also for a great number of existing ships, with a number of combinations of ship age and size rendering ECDIS cost-effective.

The earliest studies did not consider the coverage of ENCs in detail or the effect of this coverage on the ECDIS performance, and the simplifications and assumptions in relation to this introduces uncertainty in the conclusions. However, the most recent study was initiated in order to investigate this assumption in more detail, and to evaluate the actual effect of ECDIS given the actual coverage of ENC [17, 18]. This was done in two ways, i.e. considering the global picture and examining selected representative shipping routes in more detail. Furthermore, this was done both for the current situation (2006) and for the anticipated ENC coverage in 2010.

From the global study, mapping the global ship traffic densities with the global coverage of ENC as illustrated by Figure 4, it was found that, for the situation in 2006, between 82 – 94% of the ship traffic had suitable ENC coverage. This increased somewhat to 85 – 96% for the anticipated coverage by 2010. The coverage of ENC was also broken down on major shiptypes, and it was found that the overall coverage of ENC is greatest for container vessels and least for bulk carriers. As was demonstrated by this part of the study, the overall coverage of ENC for areas carrying a great portion of world ship traffic is already quite extensive.

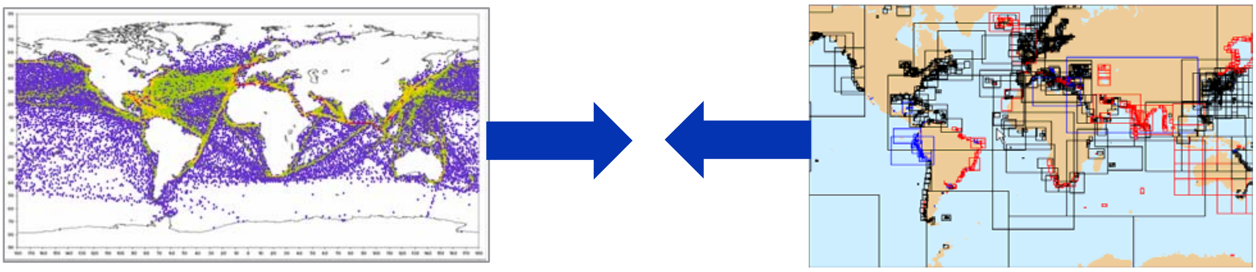

Figure 4: Global ship traffic distributions were mapped to global ENC coverage

Following the high level investigation of global coverage of suitable ENC coverage, more detailed studies were carried out on selected representative shipping routes. In all, 11 specific routes were selected, including typical routes for the major shiptypes, i.e. oil tankers, container vessels and bulk carriers as well as typical routes for general cargo vessels, chemical tankers and LNG carriers. The actual coverage of ENC along the selected routes was investigated, and the effect of holes in coverage on the risk reducing effect of ECDIS was estimated. The following observations were made:

- 4 of the 11 selected routes already have 100% ENC coverage in coastal areas (in 2006)
- 6 of the 11 routes sees no anticipated changes in the ENC coverage between 2006 and 2010
- The grounding frequency reduction due to ECDIS are between 11 – 38% for the selected routes
- The different routes have ENC coverage between 28% and 100%. The global ENC coverage for ship traffic closer to shore than 10 nm was estimated between 84% - 96%.

Consequently, the cost-effectiveness associated with installing ECDIS on particular ships operating these routes was assessed. Based on this study, the following general observations were made:

- The Gross Cost of Averting a Fatality (GCAF) associated with each route exceeds USD 3 million. This is due to the somewhat limited effect of ECDIS in terms of number of lives saved on cargo ships.
- The Net Cost of Averting a Fatality (NCAF) is negative for all routes except one. This indicates that ECDIS is a cost-effective risk control option when other benefits than the life-saving potential are taken into account (e.g. environmental and property protection).
- The NCAF value is exceeding USD 3 million for one particular route, and this was the route with the poorest ENC coverage. Hence, only on routes with poor ENC coverage will ECDIS cease to be cost-effective.
- For cargo ships, the most significant effect of ECDIS is the prevention of oil spills along the shore and the prevention of ship and cargo loss in case of grounding.
- Major differences were found between the cost-effectiveness of installing ECDIS on oil tankers compared to other cargo ships, with oil tankers being the shiptype that benefits the most.
- The observations listed above are equally true for 2006 as for 2010.

The results on ECDIS cost-effectiveness pertaining to particular routes were used as a basis for estimating the average cost-effectiveness of mandating ECDIS on SOLAS ships, and the results that could be extracted from the study are summarised in Table 1 and Table 2. The cost-effectiveness was found to be considerably better for oil tankers than for other types of cargo ships, and this is reflected in the tables below.

Table 1: Oil tanker sizes corresponding to NCAF < USD 3 million and NCAF < 0

Ship age	*Size (GT) (NCAF < USD 3 million)*	*Size (GT) (NCAF < 0)*
Newbuilding	630	700
5 years	720	780
10 years	870	920
15 years	1,200	1,200
20 years	2,000	2,100
24 years	9,300	9,300

Table 2: Other cargo ship sizes corresponding to NCAF < USD 3 million and NCAF < 0

Ship age	*Size (GT)* (*NCAF < USD 3 million*)	*Size (GT)* (*NCAF < 0*)
Newbuilding	3,800	4,200
5 years	4,300	4,700
10 years	5,200	5,500
15 years	7,000	7,300
20 years	12,000	13,000
24 years	56,000	56,000

Based on the previous studies on the risk reduction achievable from implementing ECDIS, the following recommendations were presented to IMO's sub-committee on safety of navigation at its 53rd session [18]:

i. ECDIS should be made mandatory for all passenger ships of 500 gross tonnage and upwards.
ii. ECDIS should be made mandatory for all new oil tankers of 500 gross tonnage and upwards.
iii. ECDIS should be made mandatory for all new cargo ships, other than oil tankers, of 3,000 gross tonnage and upwards.
iv. ECDIS should be made mandatory for all existing oil tankers of 3,000 gross tonnage and upwards.
v. ECDIS should be made mandatory for all existing cargo ships, other than oil tankers, of 10,000 gross tonnage and upwards.
vi. Exemptions may be given to existing oil tankers less than 10,000 gross tonnage and existing cargo ships, other than oil tankers, less than 50,000 gross tonnage when such ships will be taken permanently out of service within [2] years after the implementation dates given for iv and v above.

Basically, the main conclusions, i.e. that ECDIS represent cost-effective risk control options for a number of shiptypes, were supported by a Japanese study that was also submitted to NAV 53 [19]. The Japanese study suggested mandatory ECDIS for ships greater than 10,000 GT and a less stringent timeline for the implementation. It may also be noted that the study that investigated the effect of actual ENC coverage was referred to and supported by International Hydrographic Organization (IHO) who attested that the coverage of ENCs by 2010 will be greater than what was assumed in the study [20].

The main objections to mandatory ECDIS were related to: The availability of ENCs, the availability of ECDIS training, ENC pricing, licensing and distribution schemes and harmonisation of Flag State requirements on back-up arrangements. All things considered, it is believed that the main objections that have been raised concerning ECDIS carriage requirements thus far may easily be rebutted. Nevertheless, at NAV 53 further analyses, studies and documentation was encouraged forwarded to NAV 54, where it will be endeavoured to make a decision based on consensus. Hence, the present follow-up study on ECDIS and ENC were initiated as a response to this encouragement.

In addition to forming the basis for submissions to IMO, the latest study on the ECDIS and ENC coverage have been presented publicly at conferences and in journals [21, 22, 23], and have received considerable media coverage in other periodicals[1].

2.6 Representative shipping routes

The current study on ECDIS and ENC coverage will also assume a set of representative shipping routes, and for the purpose of simplicity, the same routes as those defined in the previous study [17] will be assumed. These routes will be outlined in the following, and it is assumed that they constitute a reasonable representation of the global ship traffic. For further discussion on the rationale behind this selection, reference is made to the original study [24].

The following 11 routes were selected, corresponding to typical trades for various shiptypes, i.e. 3 typical oil tanker routes, three typical bulk carrier routes, two typical container vessel routes, one typical general cargo route, one typical LNG carrier route and one typical chemical carrier route:

<u>Oil tankers:</u>

1. Dammam, Saudi Arabia – Yokohama, Japan
2. Yanbu, Saudi Arabia – Galveston, TX, USA
3. Yanbu, Saudi Arabia – Barcelona, Spain

<u>Container vessels:</u>

4. Singapore, Singapore – Rotterdam, Holland
5. Hong Kong, China – Long Beach, CA, USA

<u>Bulk carriers:</u>

6. Newcastle, Australia – Qinhuangdao, China
7. Vitoria, Brazil – Hamburg, Germany
8. Vancouver, Canada – Salvador, Brazil

<u>General cargo vessels:</u>

9. Helsinki, Finland – Cadiz, Spain

<u>Chemical tankers:</u>

10. Rotterdam, Holland – Savannah, GA, USA

<u>LNG carriers:</u>

11. Point Fortin, Trinidad & Tobago – Everett, MA, USA

These routes are illustrated on a world map in Figure 5. It is noted that traffic along all continents and over all oceans are represented in these routes.

[1] The study has been discussed in i.a. Digital Ship (June/July 2007, August 2007, September 2007 and November 2007), Tanker Shipping & Trade (August/September 2007), TradeWinds (May 22. 2007), The Naval Architect (June 2007) and Fairplay Solutions (July 2007).

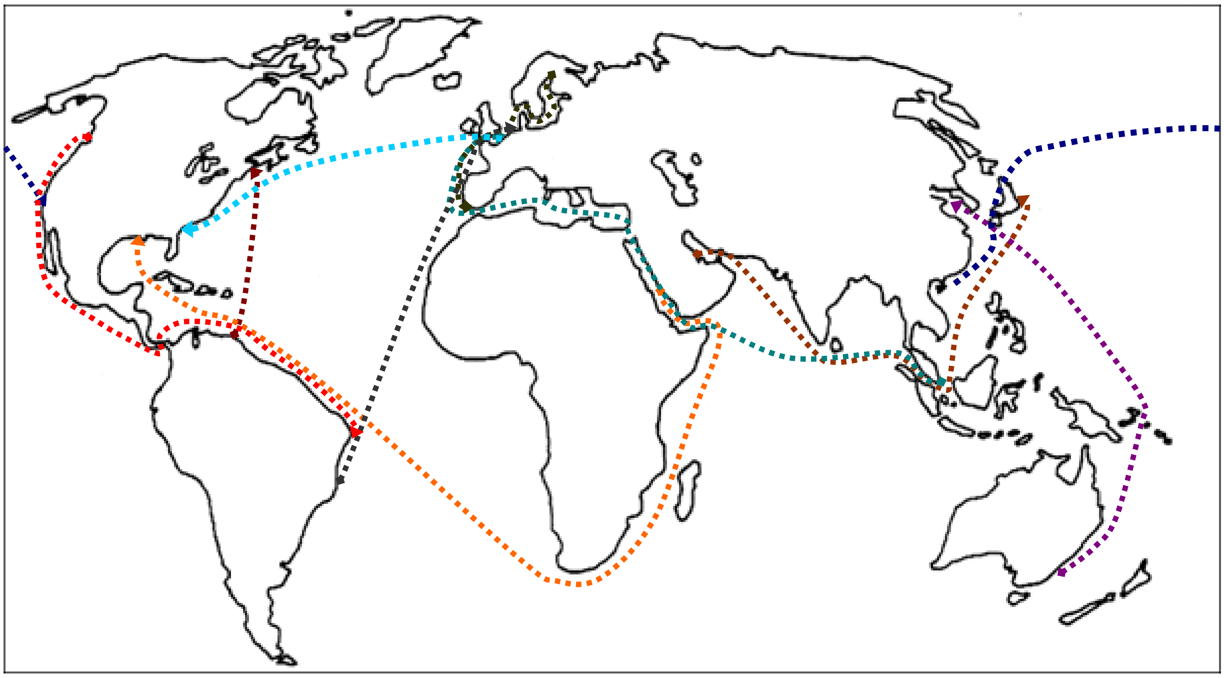

Figure 5: Selected routes representing worldwide shipping

These routes will be investigated further in the current study, and for each route it will be determined what extent of ENC coverage would be adequate along the route. This will then be compared to updated ENC coverage for 2008 as well as for anticipated coverage for 2012.

2.7 Definition of scope

The scope of the current follow-up study on the cost-effectiveness of ECDIS in light of actual ENC coverage is threefold:

1. Elaborate on the motivation behind making ECDIS mandatory under SOLAS, i.e. investigate whether there is a genuine user need for such equipment or if the motivation is technologically driven.
2. Investigate the global coverage of ENC for SOLAS ships in light of updated ENC coverage data received from the IHB.
3. To investigate the 11 selected routes in terms of what an adequate coverage of ENC along these routes would be, and compare this to an updated ENC coverage for 2008 as well as the anticipated coverage for 2012.
4. Investigate the coverage of ENC in the world's busiest ports.

One important remark regarding the scope of the current study is that ECDIS will be investigated, with due consideration on the coverage of ENC, in terms of its potential to reduce the risk of groundings. The key consideration is risk reduction, and recommendations will be based on this. Hence, the way ECDIS may influence, for example, the efficiency of ship operations will not be considered. It is noted that the number of other navigation related accidents, such as collision and contact accidents, may also be reduced by implementing ECDIS, but this has not been considered in this study, indicating conservatism.

One important implication of this is the assumption of what adequate or suitable ENC coverage should be taken to mean. For the purpose of this study, adequate coverage of ENC is related to the ENC coverage along the coast, and this is deemed reasonable given the fact that groundings cannot occur in open seas. Hence, the coverage of ENCs in open seas is not believed to influence grounding risk. Groundings obviously occur close to shore, and for the purpose of this study the probability of grounding is only assumed non-zero for ships sailing closer to land than 20 nautical miles. Presumably, this is a very conservative assumption.

At any rate, according to the assumptions made in this study, all parts of a voyage closer than 20 nautical miles to shore for which ENCs of scale coastal or larger (usage bands 3 - 6) are available will be regarded as having suitable ENC coverage.

For the open seas, overview or general ENCs (usage bands 1 and 2) are regarded to contain sufficiently detailed information and hence be suitable for safe navigation. Figure 6 illustrates the current worldwide coverage of ENCs of type overview or general, according to the current Primar chart catalogue[2], and it may easily bee seen that this coverage is quite extensive. Nevertheless, this coverage will not be considered in this study since it is not believed to contribute to reduce the risk of grounding.

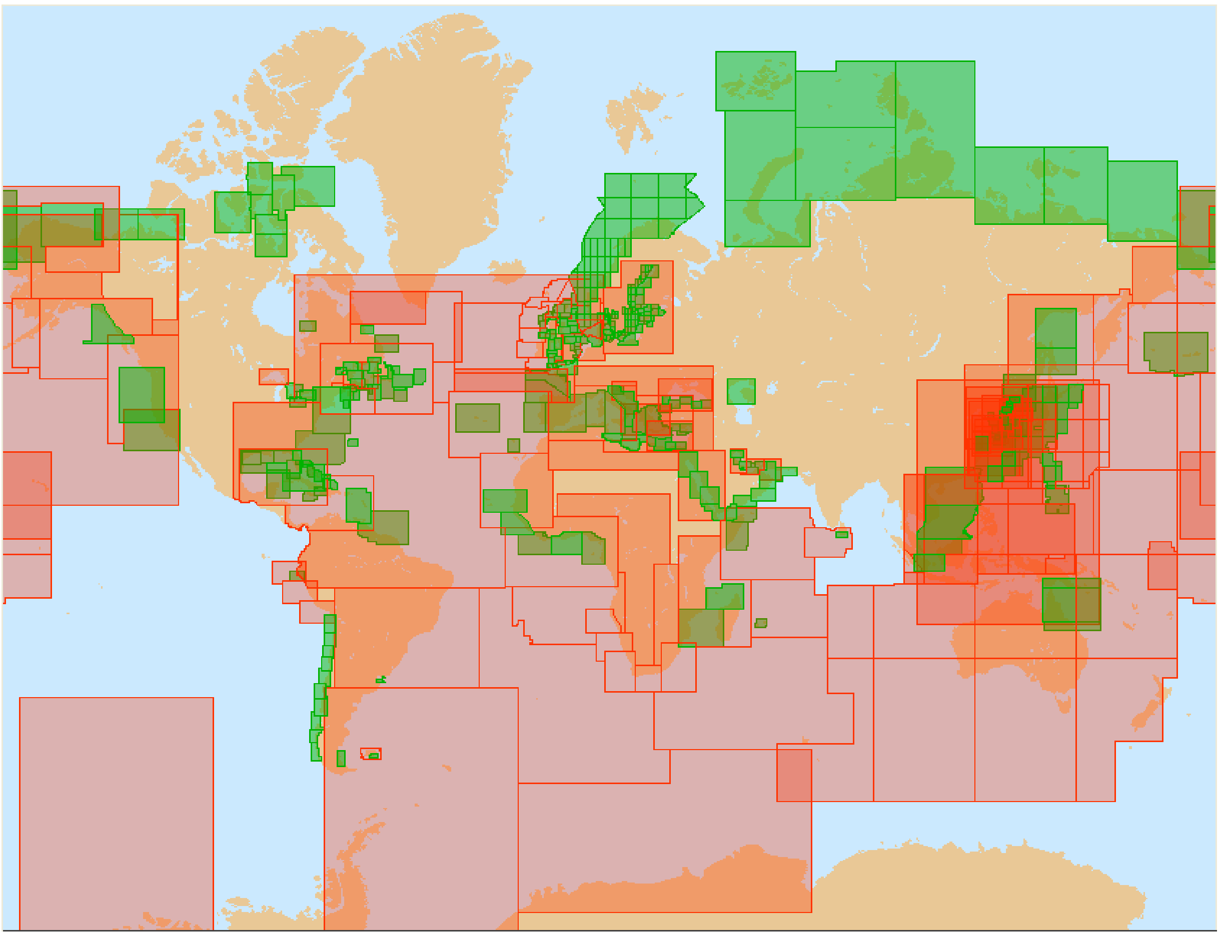

Figure 6: ENC coverage – overview and general according to the Primar chart catalogue

[2] Available from http://www.primar.org/

3 UPDATED DATA ON ENC COVERAGE

The worldwide coverage of ENC is developing continuously as new ENCs are produced. The previous study on ENC coverage was carried out using coverage data from 2006, and since then, the ENC coverage has increased significantly.

For the purpose of this follow up study, updated data on the global coverage of ENCs were collected from the IHB. Whereas the dataset from 2006 contained 5516 available ENCs within usage bands 3 - 6, the updated dataset received early 2008 contain 7315 available ENCs within the same usage bands. Furthermore, the 2006 dataset contained information about 909 ENCs within usage bands 3 – 6 than were planned for production and 701 ENCs that were issued although not commercially available. For the 2008 dataset, the number of additional ENCs that are planned or issued but not commercially available is 950.

The updated data on ENC coverage contains 1799 additional available ENCs in usage bands 3 – 6 compared to the original dataset. This represents an increase of almost 33% for ENCs available from IHB. Considering also ENCs that are planned for production or issued but not commercially available, a 16% increase in ENCs can be observed.

It is noted that the ENC coverage that has been assumed in this study has been based on data received through the IHB. Unfortunately, not all ENCs that are available were included in this dataset, and actual ENC coverage is higher than what is indicated by the dataset received from IHB. These ENCs could therefore not be included in the current study, and it is stressed that this makes the estimated coverage for SOLAS ships globally and along selected shipping routes conservative. Most notably, according to the IHB, ENCs are known to exist for the coasts of China, Cuba and Tunisia even if not included in the data received from the IHB. In addition to the ENC coverage data, the IHB defined three regions of additional ENC coverage, as illustrated in Figure 7.

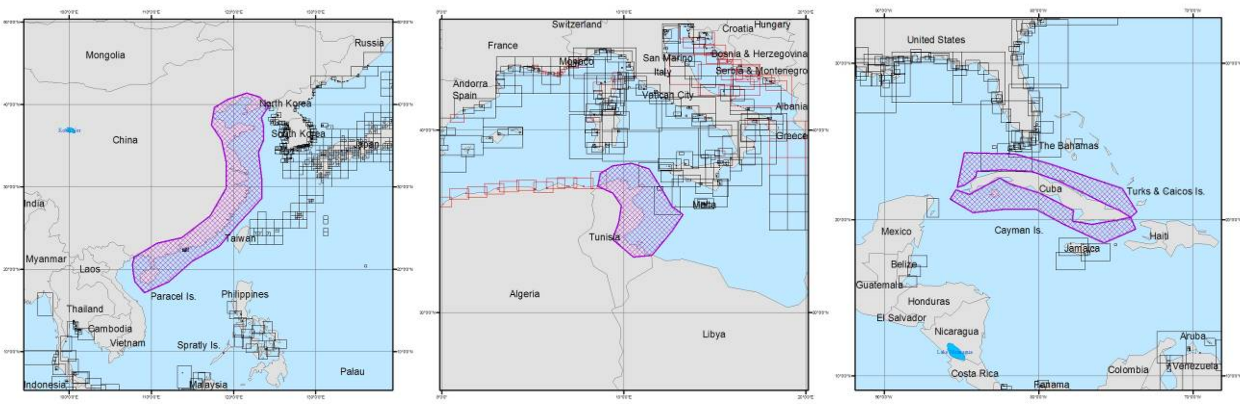

Figure 7: Other ENC regions for China, Tunisia and Cuba as suggested by IHB

Regarding ENC coverage of the Chinese coastline, which is believed to be the most important for the results of this study due to the heavy traffic in these areas, the following information is presented on the website of IC-ENC[3]: "*The Chinese Maritime Safety Administration has*

[3] IC-ENC website: http://www.ic-enc.org/page_coverage_country.asp

established an ENC centre in Shanghai which is producing a series of 290 ENC cells covering the entire Chinese coastal waters. The ENCs are available on a limited basis to some domestic customers, and the centre is presently considering options for making the data openly available to the international market. Please note that the Chinese ENCs are not shown on our graphical catalogue as we have been unable to acquire a full listing of the ENCs that have been produced."

In addition to these regions where IHB have indicated the ENC coverage, other countries are also known to have extensive coverage of ENC even if not included in the dataset received from IHB. For example, Taiwan has extensive ENC coverage according to the website of Taiwan ENC Center[4]. The coverage of usage bands 3 – 6 around Taiwan according to Taiwan ENC Center is illustrated in Figure 8, and as can be seen, the complete Taiwanese coastline is covered.

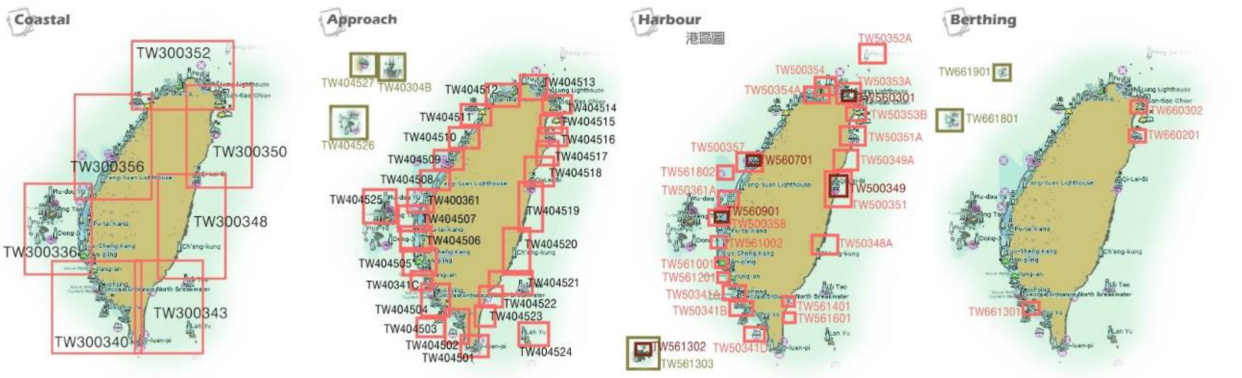

Figure 8: ENC coverage for Taiwan, from left: Coastal, Approach, Harbour and Berthing

Also the Republic of Ireland has extensive ENC coverage along its coast, but these data were also not included in the dataset received from the IHB. Indonesia is another example where a number of ENCs have been completed, but where information about ENC coverage was not included in the data used in this study. A final example could be the west coast of South America (Chile, Peru, Ecuador and Colombia). For this region, the IHB online catalogue suggests that there are or will soon be coverage of ENC (in usage bands 3 – 6) beyond what is included in the dataset used in this study. The coverage of Ireland and South America according to the IHB online catalogue is illustrated in Figure 9.

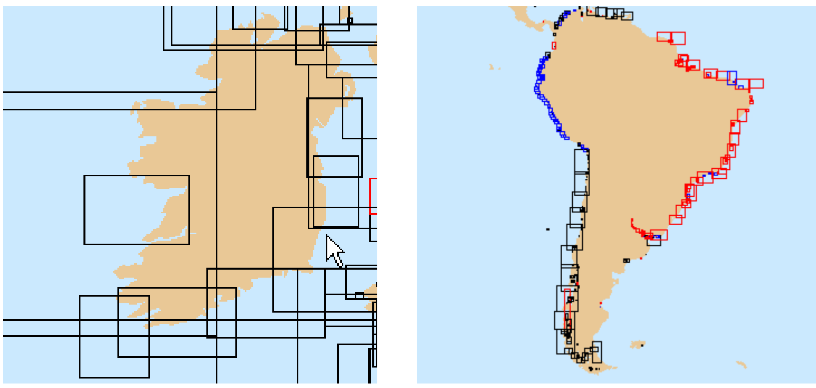

Figure 9: ENC coverage for Ireland and South America according to IHB online catalogue

[4] http://enc.ihmt.gov.tw/eng/history.asp

As for ENCs that are currently planned or exist but not yet made commercially available according to the dataset used in this study, it may be assumed that these will soon be available. The most significant of these pertain to the coasts of Australia, Papua New Guinea, Algeria and Pakistan.

The data on global ENC coverage in usage band 3 – 6 that has been used in this study is illustrated in Figure 10. In this figure, black cells represent ENCs that are currently available, and red cells represents ENCs that are expected to become available soon (at least prior to 2012). This data is what the analyses presented herein has been based on, but it is stressed that it is known that this dataset is not presenting a complete picture of current ENC coverage, as there are several regions that have not been included in the data. Thus, it should be kept in mind that the estimates that are obtained in this analysis of ENC coverage will be conservative.

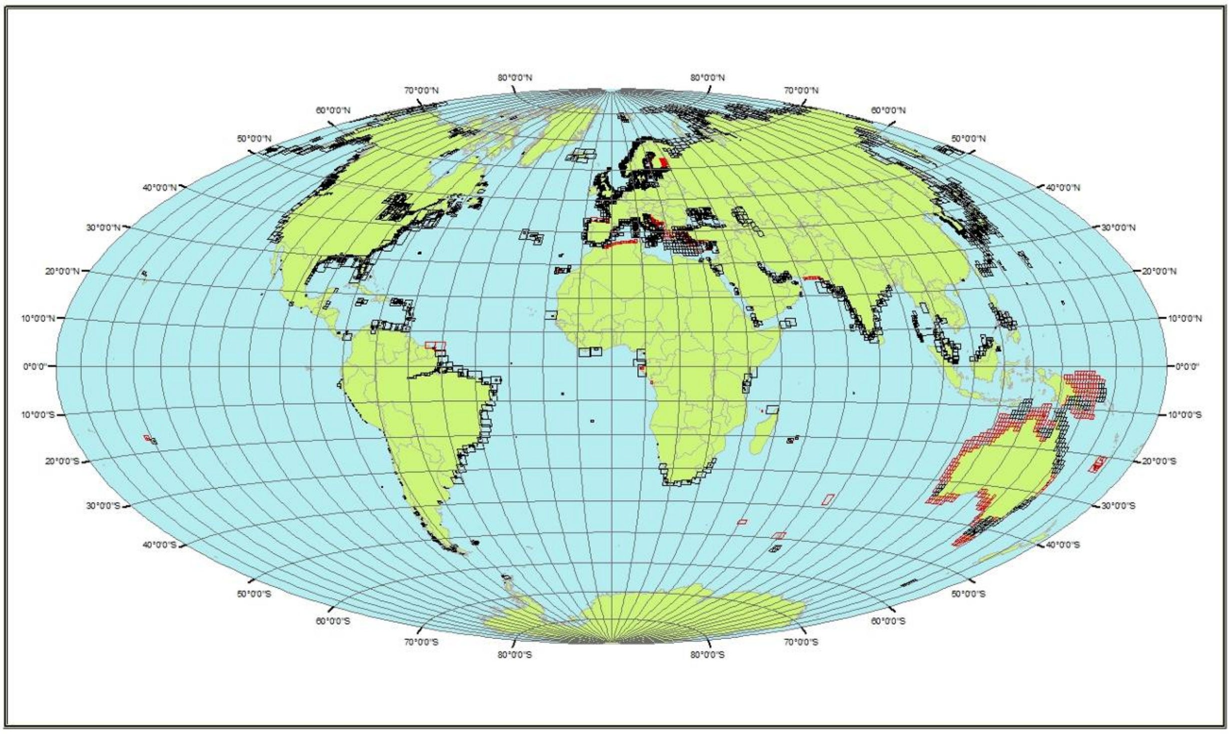

Figure 10: Global coverage of ENC in usage bands 3 – 6 (Coastal or better) according to dataset received from IHB (red cells denote charts that will soon become available)

3.1 ENC coverage for SOLAS ships

In the previous study on ENC coverage a methodology was developed to estimate the percentage of worldwide ship traffic in coastal waters for which coverage of ENC was available. The method was to count ship observations within 20 nm from the coastline contained in the AMVER/COADS dataset, and overlay the ENC chart data supplied by the IHB. This method is distinctly separate from other methods counting coverage on a set of sea lanes or ocean area. The reason for applying the chosen methodology is to analyse the effect of ECDIS on grounding risk, for which only coast-near traffic is relevant.

Counting all ship types, the previous study concluded that in 2006, the global coverage of suitable ENC lie between 82% and 94% (depending on the automated counting techniques for ship traffic and ENC overlay applied).

The updated global ENC portfolio from IHB has been used to re-evaluate the coverage in 2008. The results show that the global coverage of suitable ENC lie between 85% and 96%. It should be noted that this is the same coverage level that was estimated in the previous study for the anticipated future coverage in 2010. This indicates that ENCs are becoming available earlier than foreseen in the previous study.

The development from the previous estimate is perhaps best seen by considering the percentage of traffic without suitable coverage. The figures for the previous study, between 18% and 6%, have been reduced to 15% and 4%. In other words, the traffic without coverage in coastal areas has dropped by the order of one fourth between 2006 and 2008, due to increased coverage of ENC.

When ENCs which are currently in production or planned for production are included in the analysis, to estimate the anticipated coverage in 2012, the global coverage of suitable ENC lie between 88% and 97%. This implies that only about one in ten ship observations in coastal waters are expected to lack suitable ENC coverage in 2012. The resulting coverage figures for both the current and the previous study is summarised in Table 3.

Table 3: Percentage of world traffic within 20nm of shore with sufficient ENC coverage

Study	Year	Lower estimate (%)	Upper estimate (%)
Previous study	2006	82,1	94,4
	2010	84,7	96,3
Current study	2008	85,1	96,4
	2012	88,2	97,1

3.2 Updated ENC coverage on representative shipping routes

Eleven representative shipping routes were selected and investigated in detail in the previous study [17]. In the following, these routes will be revisited, and it will be investigated how the ENC coverage has increased for each of these routes. It should be kept in mind that the coverage estimates refers to coverage of suitable ENC (coastal or better) on stretches of the route closer than 5 nautical miles from shore. For a further description of the routes, reference is made to the previous study [17].

3.2.1 Dammam, Saudi Arabia – Yokohama, Japan

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 11. The most notable increase in ENC coverage along this route between these datasets is in the Straights of Malacca. In addition, ENCs for the coast of India that was not available in the 2006 dataset have now become available. In the previous study a suitable ENC coverage of 65% was assumed by 2010, and it can now be seen that this coverage has already been surpassed. I.e. the coverage of suitable ENCs along this route is currently at least 65%.

The data indicate that currently, 50% suitable coverage of the Straits of Malacca and Singapore are in place, and the current suitable coverage of ENCs along this route would be estimated to 82%.

Remaining gaps to be filled in order to obtain full coverage of suitable ENCs along this route would be complete coverage in the Straights of Malacca as well as some East Malaysian Island.

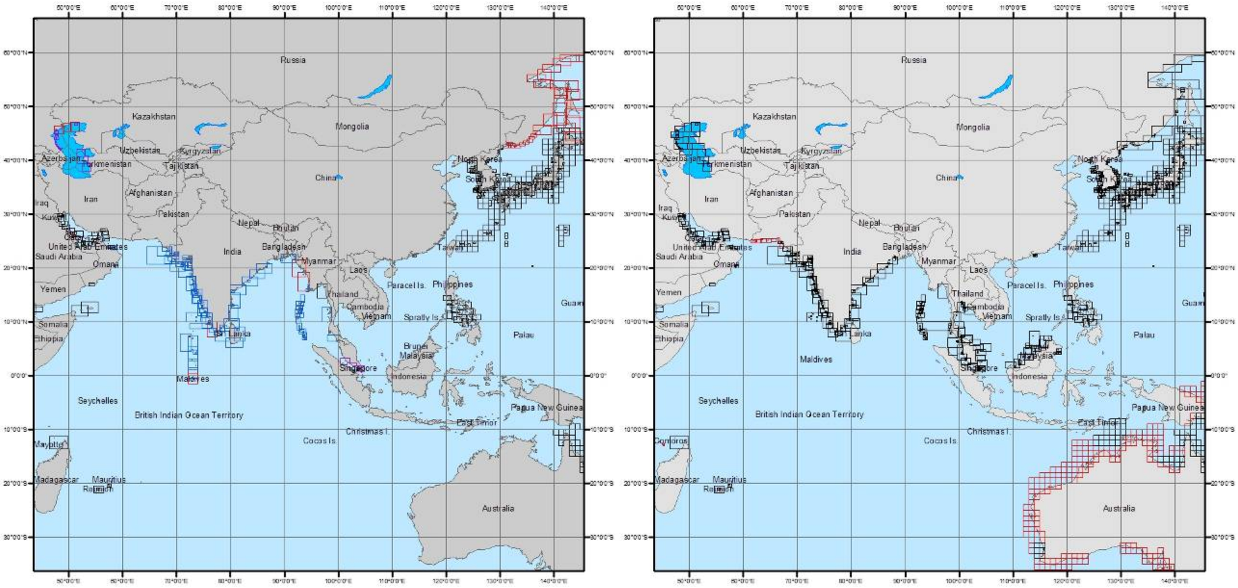

Figure 11: ENC coverage (usage bands 3 – 6) between Dammam and Yokohama according to data from 2006 (left) and 2008 (right)

3.2.2 Yanbu, Saudi Arabia – Galveston, TX, USA

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 12. The most significant difference between the two datasets for this route is that ENCs that were assumed to be available by 2010 in the previous study is now marked as available in the 2008 dataset. It is also noted that neither of the datasets included Cuban ENCs, although these are now know to exist (see section 3). Therefore, the actual ENC coverage is somewhat higher than what the analysis indicates. Hence, the current suitable coverage of ENCs along this route is estimated to be at least 77%, which is what was estimated for 2010 in the previous study.

Remaining gaps to be filled in order to obtain full suitable ENC coverage along this route would be along the East African coast (most notable, for Somalia and Mozambique) and in the Caribbean Sea (most notably, considering that Cuban ENCs are known to exist, for the waters of the Dominican Republic and Haiti).

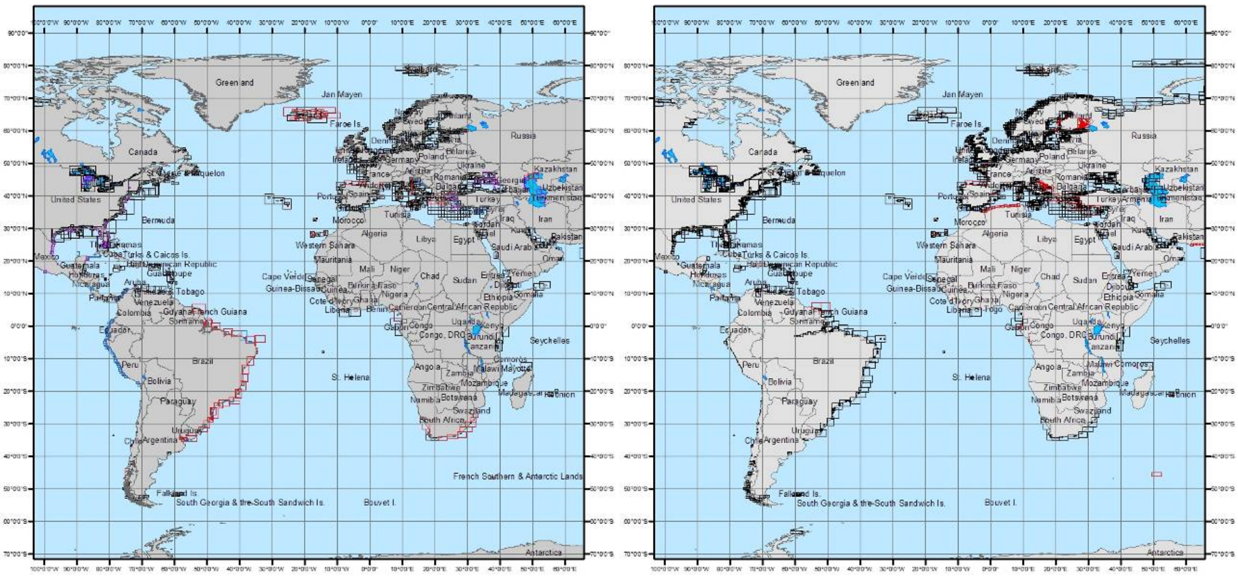

Figure 12: ENC coverage (usage bands 3 – 6) between Yanbu and Galveston according to data from 2006 (left) and 2008 (right)

3.2.3 Yanbu, Saudi Arabia – Barcelona, Spain

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 13. There are no notable changes in ENC coverage between the two datasets for this particular route. Hence, the estimate from the previous study (for both 2006 and 2010) is assumed to be valid, i.e. a coverage of suitable ENCs of 94%.

Remaining gaps to be filled in order to achieve full suitable coverage for this route would be for short distances along the Mediterranean coast of Egypt.

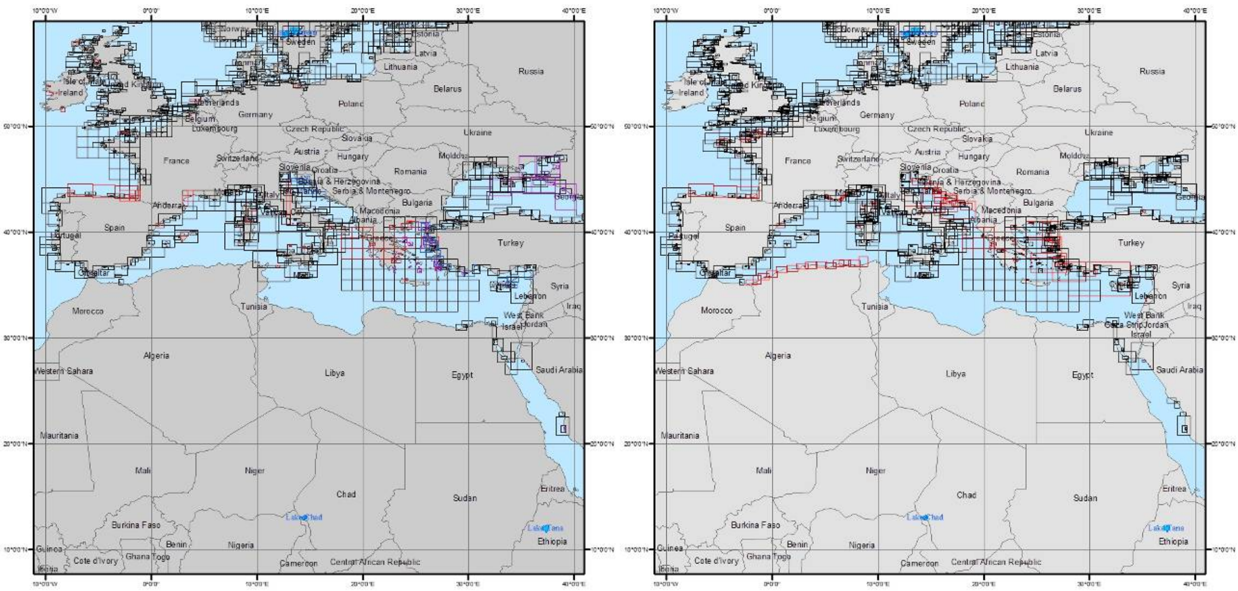

Figure 13: ENC coverage (usage bands 3 – 6) between Yanbu and Barcelona according to data from 2006 (left) and 2008 (right)

3.2.4 Singapore, Singapore – Rotterdam, Holland

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 14. The main difference between the datasets from 2006 and 2008 pertaining to this route is that ENC coverage in the Straits of Malacca is available in the latter. In addition, the coverage along the Indian coast that was assumed in place by 2010 in the previous study has now become available. The previous study estimated the coverage of adequate ENC to be 68% by 2010, and this coverage has been surpassed by now. Assuming that 50% coverage has been obtained in the Straits of Malacca, current ENC coverage along this route is now estimated to 81%.

Furthermore, it is known that ENC coverage exists for Tunisia, and that ENC coverage covering the coast of Algeria will soon be available which was not included in the 2006 dataset. Taking these into account, the coverage of suitable ENCs will reach 87% along this route, and it is assumed that this coverage will be reached at least by 2012.

Remaining holes to be filled along this route in order to obtain full suitable coverage would be to cover the whole of the Straights of Malacca with suitable ENCs.

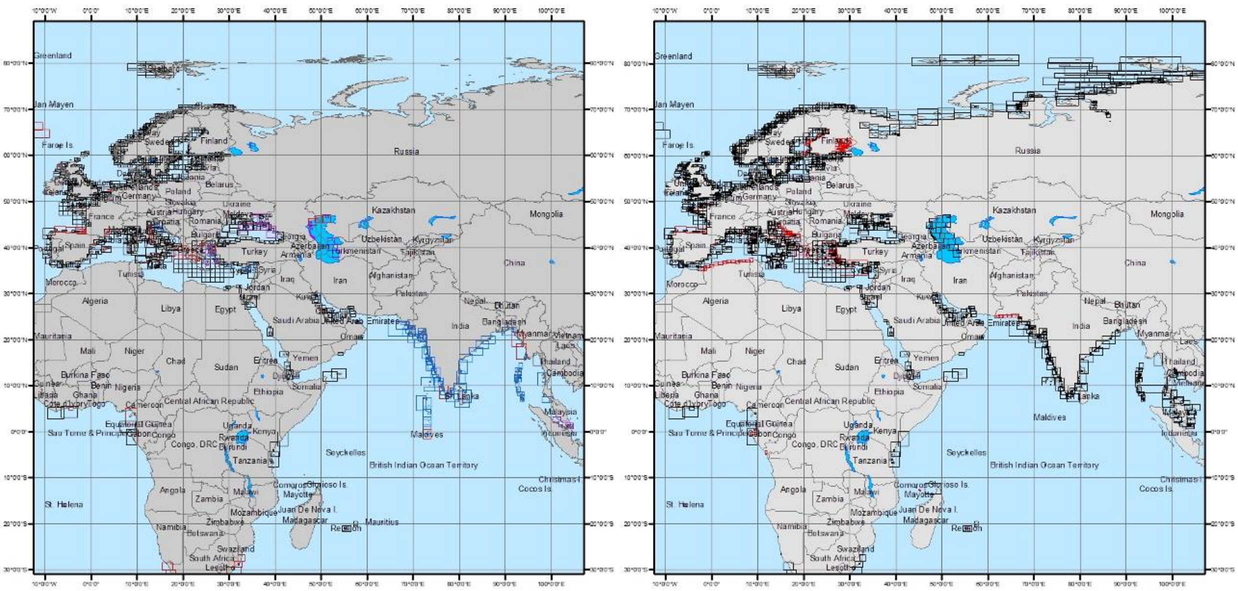

Figure 14: ENC coverage (usage bands 3 – 6) between Singapore and Rotterdam according to data from 2006 (left) and 2008 (right)

3.2.5 Hong Kong, China – Long Beach, CA, USA

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 15. There are no significant changes in the ENC coverage between the different datasets, and 100% suitable coverage was also estimated for this route in the previous study. Thus, the estimate of suitable coverage for this particular route remains 100%.

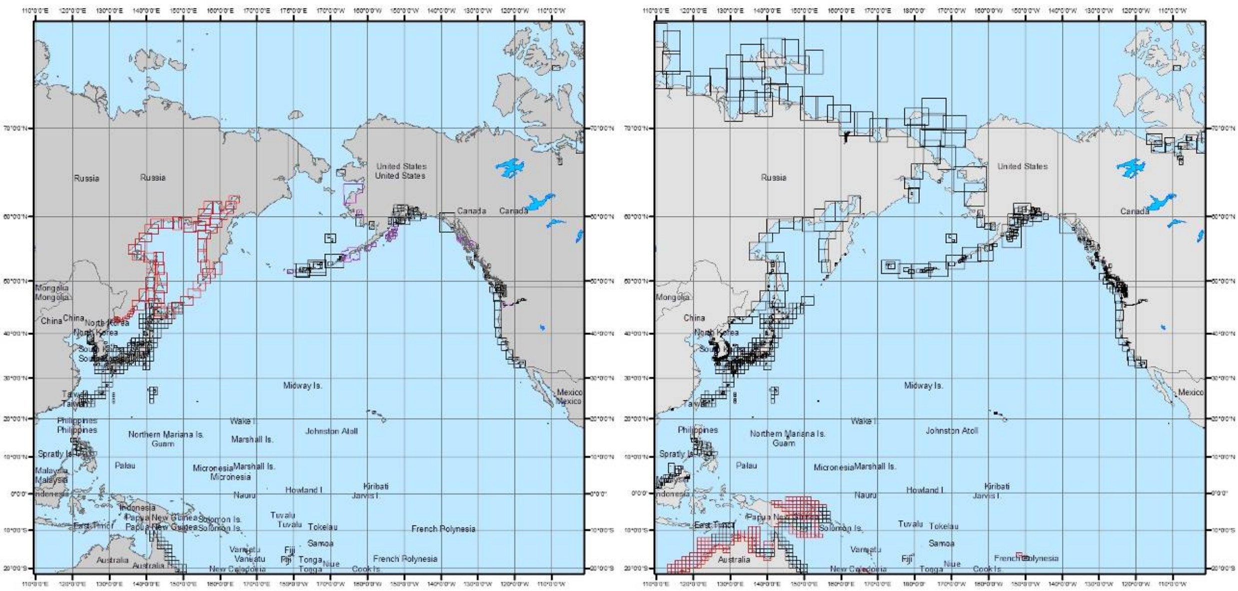

Figure 15: ENC coverage (usage bands 3 – 6) between Hong Kong and Long Beach according to data from 2006 (left) and 2008 (right)

3.2.6 Newcastle, Australia – Qinhuangdao, China

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 16. In the previous study, this route was the one with poorest ENC coverage (28%), and as such perhaps the most interesting to investigate with the updated dataset. Indeed, significant changes are observed for this route between the 2006 and 2008 datasets. First, an increase of available Australian ENCs is observed, and if this is taken into account, the coverage of suitable ENCs along this route would increase to about 49%. This is assumed to be the current coverage of suitable ENCs along this route.

Moreover, a further significant increase in ENC coverage along the complete Australian coast as well as for Papua New Guinea and nearby islands is anticipated, as included in the 2008 dataset. In addition, Chinese ENCs are known to exist even if not included in the dataset. Considering all this, the anticipated coverage of suitable ENCs for this particular route is 100% by 2012.

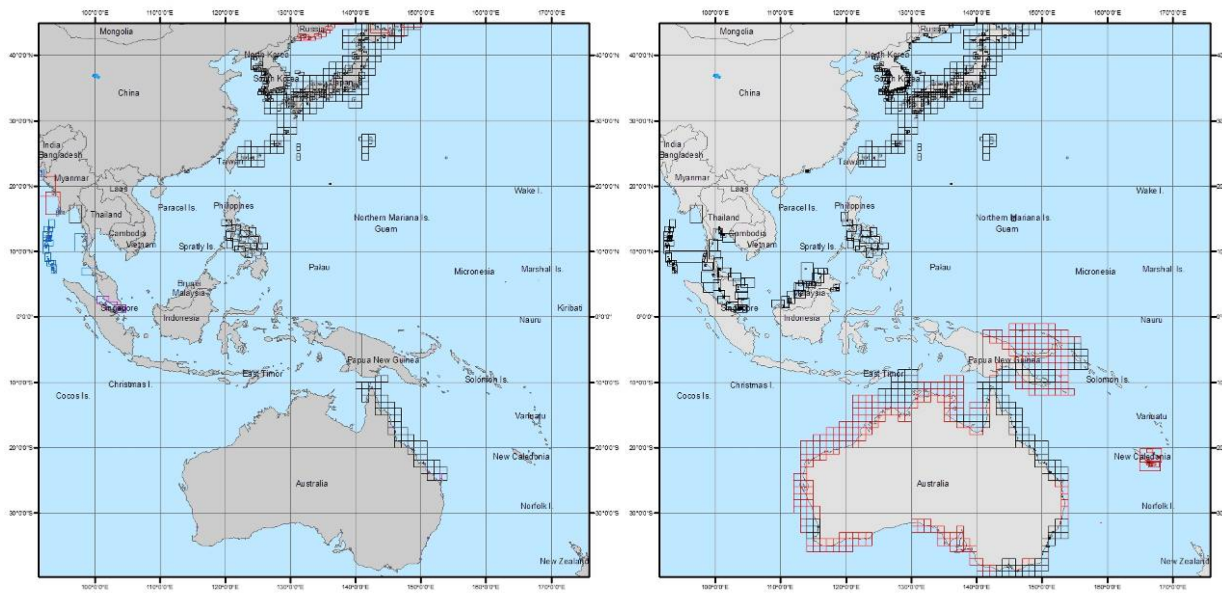

Figure 16: ENC coverage (usage bands 3 – 6) between Newcastle and Qinhuangdao according to data from 2006 (left) and 2008 (right)

3.2.7 Vitoria, Brazil – Hamburg, Germany

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 17. The most significant different between the 2006 and 2008 datasets relevant for this particular route is that additional ENCs along the coast of Brazil has now become available. In the previous study, some ENCs were anticipated by 2010, and these have now become available. Furthermore, additional ENCs for Brazil than the ones foreseen in the 2006 dataset are now available, so that the entire part of this route along the Brazilian coast now has suitable ENC coverage. With this updated ENC coverage, this route is now estimated to have coverage of suitable ENC of 94%.

No further increase of coverage is currently foreseen for this route, and remaining holes to be filled to obtain full coverage of suitable ENCs along this route would be around Cape Verde and Madeira islands.

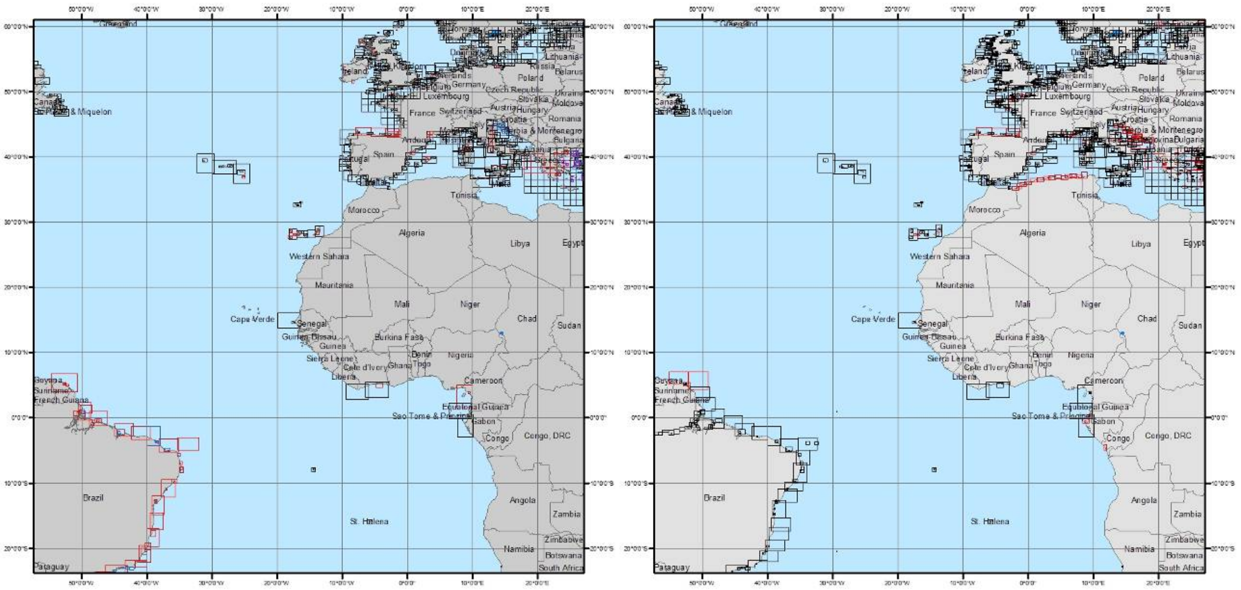

Figure 17: ENC coverage (usage bands 3 – 6) between Vitoria and Hamburg according to data from 2006 (left) and 2008 (right)

3.2.8 Vancouver, Canada – Salvador, Brazil

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 18. The most notable increase in ENC coverage relevant to this route is along the coast of Brazil. ENCs that were anticipated by 2010 in the dataset from 2006 are now available as well as additional coverage along the Brazilian coast. Considering that the Brazilian coast currently has full suitable ENC coverage, the coverage for this route is increased to 88%. No further increase is anticipated for this route according to the 2008 data.

Remaining gaps to be filled in order to obtain full coverage of suitable ENCs for this route would be along the west coast of Mexico as well as well as some areas on the west coast of Costa Rica and Panama.

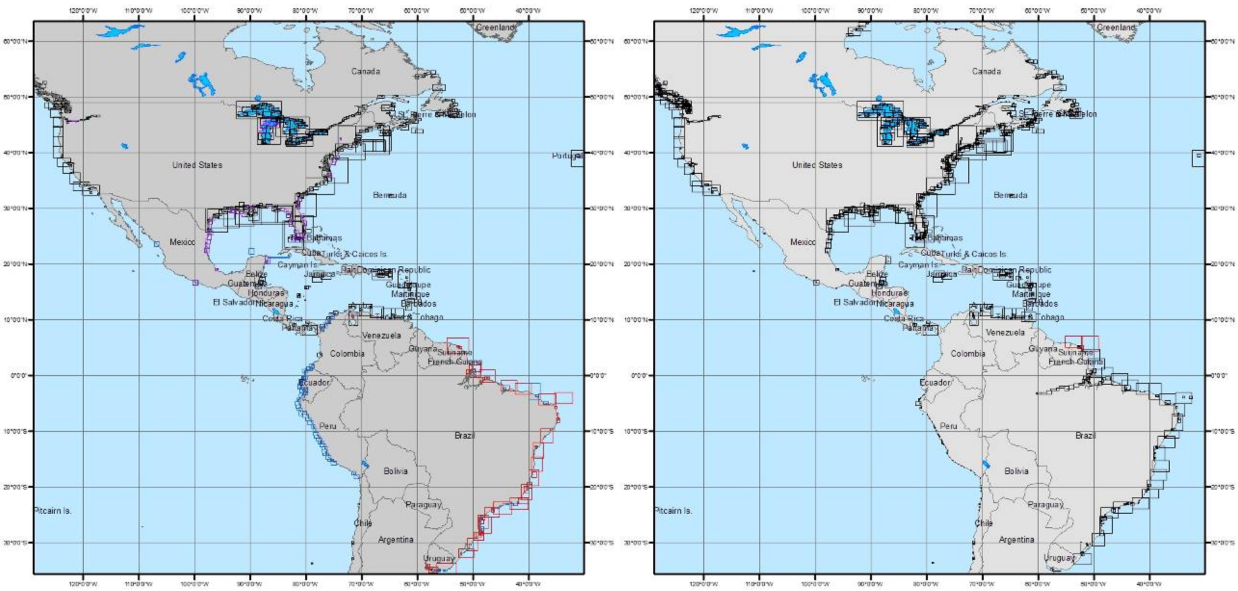

Figure 18: ENC coverage (usage bands 3 – 6) between Vancouver and Salvador according to data from 2006 (left) and 2008 (right)

3.2.9 Helsinki, Finland – Cadiz, Spain

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 19. No significant changes since the 2006 dataset are observed for this route, and this route was also found to have 100% coverage in the previous study. Hence, this route is still assumed to have full coverage of suitable ENCs.

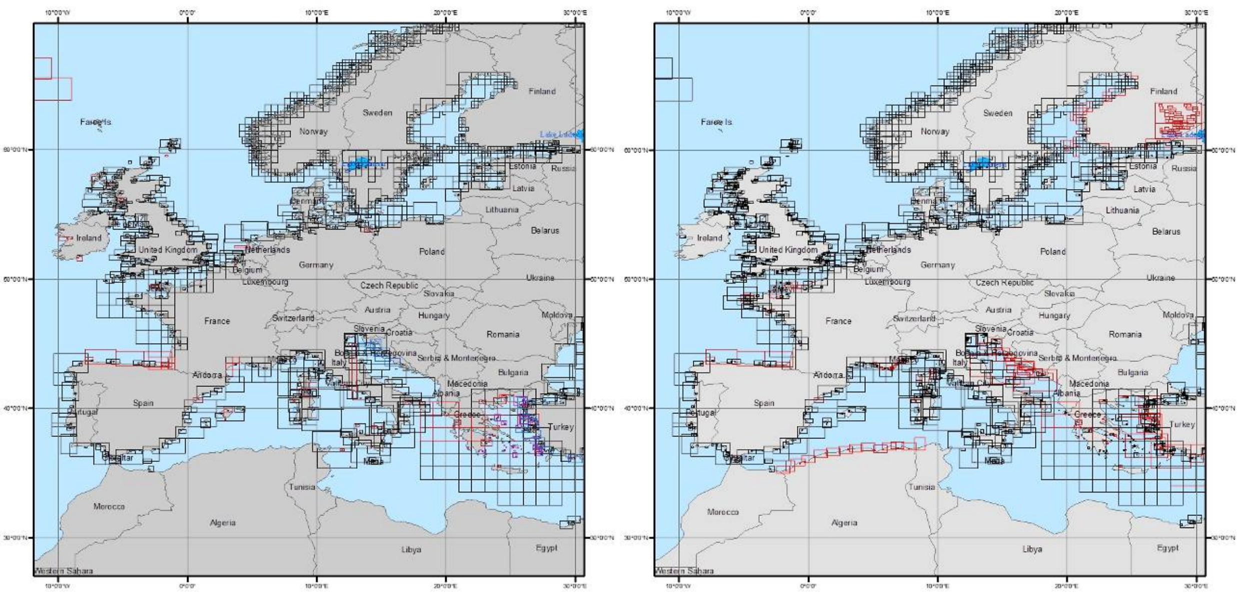

Figure 19: ENC coverage (usage bands 3 – 6) between Helsinki and Cadiz according to data from 2006 (left) and 2008 (right)

3.2.10 Rotterdam, Holland – Savannah, GA, USA

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 20. No significant changes since the 2006 dataset are observed for this route, and this route was also found to have 100% coverage in the previous study. Hence, this route is still assumed to have full coverage of suitable ENCs.

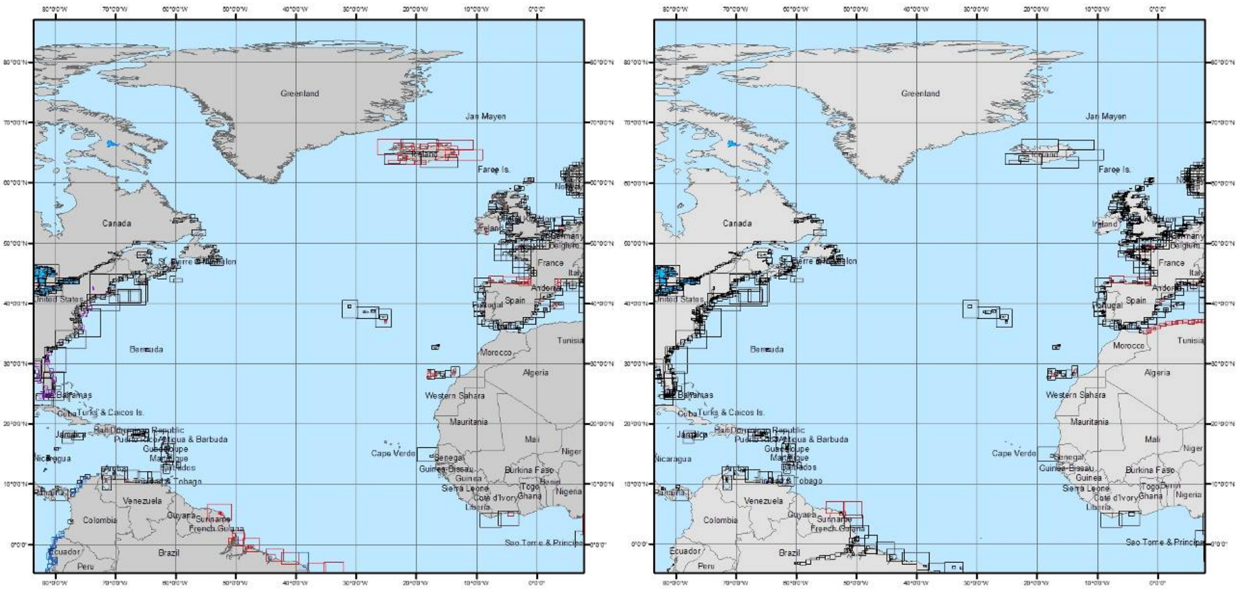

Figure 20: ENC coverage (usage bands 3 – 6) between Rotterdam and Savannah according to data from 2006 (left) and 2008 (right)

3.2.11 Point Fortin, Trinidad & Tobago – Everett, MA, USA

The coverage of ENCs along this route according to the dataset from 2006 and 2008 respectively is illustrated in Figure 21. No significant changes since the 2006 dataset are observed for this route, and this route was also found to have 100% coverage in the previous study. Hence, this route is still assumed to have full coverage of suitable ENCs.

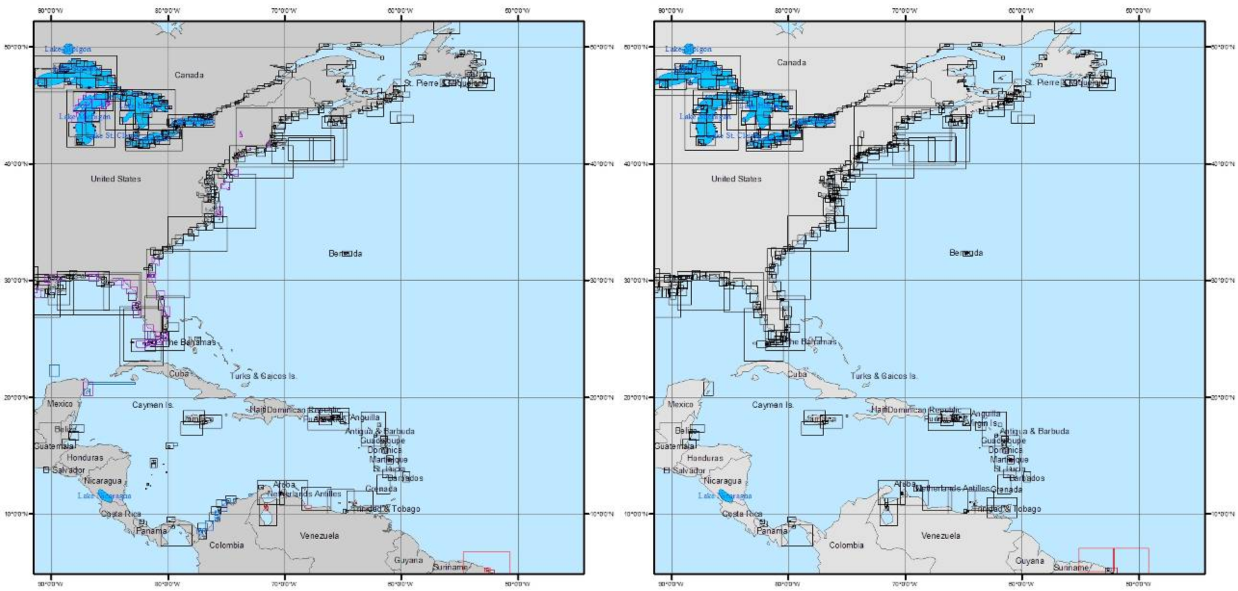

Figure 21: ENC coverage (usage bands 3 – 6) between Point Fortin and Everett according to data from 2006 (left) and 2008 (right)

3.3 ENC coverage and grounding risk reduction on selected routes

The results from the above examination of representative shipping routes may be synthesized in Table 4, where the current and near-future coverage of suitable ENCs are summarized. If this table is compared to the estimates from the previous study, a significant increase can be observed for almost all of the routes. Most notably, the route with poorest ENC coverage from the previous study is now estimated to reach full coverage by 2012 due to planned ENCs around Australia and Papua New Guinea. It is observed that 5 of the 11 selected routes will have full coverage of suitable ENCs by 2012, and that all of the selected routes will have suitable ENC coverage of more than 77% by this time.

Table 4: Suitable ENC coverage along selected routes

Route	*Suitable ENC coverage*	
	2008	*2012*
Dammam – Yokohama	82%	82%
Yanbu – Galveston	77%	77%
Yanbu – Barcelona	94%	94%
Singapore – Rotterdam	81%	87%
Hong Kong – Long Beach	100%	100%
Newcastle – Qinhuangdao	49%	100%
Vitoria – Hamburg	94%	94%
Vancouver – Salvador	88%	88%
Helsinki – Cadiz	100%	100%
Rotterdam – Savannah	100%	100%
Point Fortin – Everett	100%	100%

Considering the 11 selected routes, some particular areas can also be identified where additional ENCs would be needed in order to provide full coverage of suitable ENCs along these routes. These areas are:

- Extended coverage of the Straights of Malacca
- East African coast, most notable along the coast of Somalia and Mozambique
- West coast of Mexico
- West coast of Costa Rica and Panama
- Caribbean sea, most notably around the Dominican Republic and Haiti
- Mediterranean coast of Egypt
- Coverage of some East Malaysian islands
- Coverage around the Cape Verde and Madeira islands

Based on the potential for grounding risk reduction achievable from ECDIS, as established by previous studies [11, 12], the anticipated grounding frequency reduction and the number of statistical groundings that may be averted per shipyear for each of the selected routes are summarized in Table 5. It can be observed that by 2012 all of these routes will achieve a grounding risk reduction of at least about 30% from implementing ECDIS.

Table 5: Grounding frequency reduction and averted groundings due to ECDIS for selected routes and for ENC coverage in 2008 and 2012 respectively

	Grounding frequency reduction		*Groundings averted (per shipyear)*	
Route	*2008*	*2012*	*2008*	*2012*
Dammam – Yokohama	31%	31 %	1.5×10^{-2}	1.5×10^{-2}
Yanbu – Galveston	29%	29%	2.4×10^{-3}	2.4×10^{-3}
Yanbu – Barcelona	36%	36%	2.6×10^{-2}	2.6×10^{-2}
Singapore - Rotterdam	31%	33%	1.9×10^{-2}	2.0×10^{-2}
Hong Kong – Long Beach	38%	38%	3.1×10^{-3}	3.1×10^{-3}
Newcastle – Qinhuangdao	19%	38%	2.3×10^{-3}	4.6×10^{-3}
Vitoria – Hamburg	36%	36%	1.2×10^{-2}	1.2×10^{-2}
Vancouver – Salvador	33%	33%	1.4×10^{-2}	1.4×10^{-2}
Helsinki – Cadiz	38%	38%	1.2×10^{-2}	1.2×10^{-2}
Rotterdam – Savannah	38%	38%	8.9×10^{-3}	8.9×10^{-3}
Point Fortin – Everett	38%	38%	8.1×10^{-3}	8.1×10^{-3}

In the previous study, representative ships were assumed for each of the selected routes, and a generic risk model was applied to estimate accident costs and statistical fatality rates for grounding accidents. Based on this, the cost-effectiveness of implementing ECDIS was estimated for each route. Accordingly, ECDIS were found to be a cost-effective risk control option for all routes except one already in the previous study. The one route where ECDIS was not found to be cost-effective in the previous study will be further investigated in the following, to see whether this route would also be cost-effective in light of the updated ENC coverage data. All other factors remain the same, and the route in question is the route between Newcastle, Australia and Qinhuangdao, China.

For the route Newcastle (Australia) – Qinhuangdao (China), notable increase of ENC coverage has been observed since the 2006 dataset. Hence, the number of averted groundings along this route from implementing ECDIS has increased from 1.3×10^{-3} in the previous study to 2.3×10^{-3} for the current situation and even further to 4.6×10^{-3} by 2012. The GCAF and NCAF values for ECDIS on this route according to the updated ENC coverage, compared to the estimates for 2006/2010 from the previous study is presented in Table 6. All estimates are in million USD. As can be seen from this table, ECDIS is currently just on the border of being cost-effective for this route as well (with an NCAF close to USD 3 million per averted fatality), and will surely be cost-effective by 2012 with a negative NCAF.

Table 6: Cost-effectiveness of ECDIS along Newcastle – Qinhuangdao route

2006/2010		*2008*		*2012*	
GCAF	*NCAF*	*GCAF*	*NCAF*	*GCAF*	*NCAF*
118	54	66	3.2	33	< 0

ECDIS was demonstrated to be cost-effective for all other routes in the previous study. Hence, with the updated ENC coverage it can now be established that ECDIS represents a cost-effective risk control option for all the 11 selected routes that has been investigated.

4 PORT COVERAGE OF ENC

The main focus of this study is to evaluate the effectiveness of ECDIS as a risk control option to prevent grounding of ships. In this regard, the coverage of ENC within ports may not be the most important aspect, as serious groundings are normally not occurring within ports. However, the approach and departure to and from ports is relevant for grounding. At any rate, a brief overview of the current coverage of ENC in the most important ports of the world has been made, as will be outlined in the following.

4.1 The World's busiest ports

A limited number of ports are responsible for a large portion of maritime trade. For the purpose of this study, the 800 biggest ports in terms of total deadweight in or out have been selected for an investigation of ENC coverage, based on information from Lloyd's port statistics, and these are responsible for about 90% of all trade by tonnage. The list of ports that have been investigated is presented in appendix 1 to this report.

It is noted that this list contain some items that are not normally considered ports, but rather calling points along a route. Examples of such point are Gibraltar, Panama canal, Straight of Bosporus and Suez. Furthermore, some of the items in this list are offshore terminals and not ports ashore. Examples of such offshore terminals in the list of ports are Aasgard field and Draugen field in the Norwegian Sea and Balder field in the North Sea.

These calling points and offshore terminals have been included in the study of ENC coverage in the world's busiest ports. However, it is noted that the same degree of ENC coverage may not be necessary for such places, and this means that the estimates arrived at in this study are conservative. I.e. if such places had been removed from the list, the ENC coverage would have been improved. Nevertheless, the complete list of 800 ports has been kept unchanged for the purpose of this study.

4.2 ENC coverage in major ports

In order to investigate coverage of ENC in the world's major ports, it is assumed that adequate coverage should be ENCs in usage bands 3 - 6. I.e. ENCs of type *Coastal*, *Approach*, *Harbour* or *Berthing*.

Considering only the 100 most important ports (in terms of deadweight tonnage), it was found that only 13 of these were without ENC coverage in usage bands 3 – 6. Of these, 6 ports are in China and 4 are in Taiwan. As has been discussed previously in this report, ENCs are known to exist in Chinese waters, although information about these could not be obtained from the IHB at the time of carrying out this study. Furthermore, Taiwan is known to be completely covered by ENCs of scale *Coastal*, and a number of additional ENCs of type *Approach*, *Harbour* and *Berthing* are also available for Taiwan[5]. Hence, these ports are assumed to be covered by ENC, even though they are not included in our data. Thus, of the 100 major ports worldwide, only 3 have been found to be without appropriate ENC coverage.

[5] Taiwan ENC center, homepage: http://enc.ihmt.gov.tw/eng/history.asp

If the top 200 ports are investigated for ENC coverage, only 13 additional ports without ENC coverage are discovered, many of which are believed to actually have ENC coverage that was not included in the dataset used in this study.

Considering the whole list of the 800 most important ports of the world, 193 of these are found to be without adequate ENC coverage. The 800 major ports, as investigated in this study, are illustrated in Figure 22. In this figure, ports that were found to have adequate ENC coverage are green, whereas ports where adequate ENC coverage was not found are in red. It is noted that some of the ports where ENC coverage was not found may actually be covered by ENCs since the dataset that was used in this study was missing ENCs from some countries.

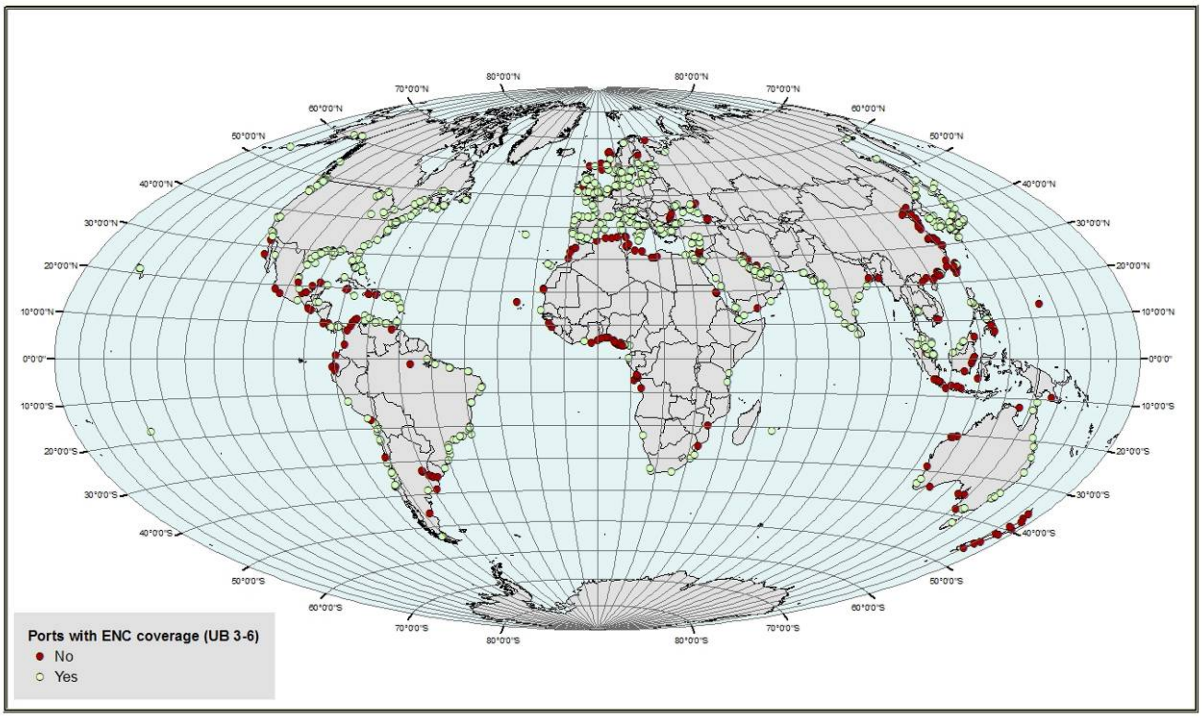

Figure 22: ENC coverage for the world's top 800 ports.

However, some of the 193 ports that were not found to be covered by ENC may actually have ENC coverage, even though these ENCs are not included in the dataset from IHB. For instance, 30 of the major ports without ENC coverage are in China, which are believed to be covered by ENCs even if not included in the data used for the analysis. Some other countries where ENCs are known to exist even if not included in the dataset used for this study could be identified. Furthermore, for some other countries with ports without ENC coverage ENCs are known to soon become available (e.g. Australia, Algeria). In addition, some of the ports without ENC coverage are actually offshore terminals or oil or gas fields where ENC coverage would not need to be of usage bands 3 – 6. For example six offshore terminals off the Norwegian coast are included in the list of ports that do not have adequate ENC coverage. Looking at individual ports that are marked as without adequate ENC coverage, one can also finds ports that actually have coverage, for example Dublin in the Republic of Ireland which is known to have ENC coverage.

All countries with more than one out of the 800 most important ports without ENC coverage according to the dataset used are presented in Table 7. However, as argued above, many of these should be removed since actual ENC coverage is believed to exist and since some of these are actually not ports requiring ENC coverage of usage bands 3 – 6.

Table 7: Countries with two or more major ports without ENC coverage

Country	*Number of ports without ENC coverage*
China	30
Indonesia	16
New Zealand	10
Australia	9
Mexico	9
Nigeria	9
Argentina	7
Colombia	6
Norway	6
Libya	6
Taiwan	5
Tunisia	5
Morocco	5
Algeria	4
Angola	4
Ecuador	4
Islamic republic of Iran	4
Israel	4
Vietnam	3
Bulgaria	2
Cayman Islands	2
Costa Rica	2
Ghana	2
Guinea	2
Mauritania	2
Mozambique	2
Philippines	2
Republic of Georgia	2
Russian Federation	2
Sudan	2
The Congo	2

Considering the ports where ENC coverage is believed to exist and offshore terminals where ENC coverage in usage bands 3 - 6 is believed to not be required, what remain are about 100 of the 800 most important ports that have not been found to have adequate ENC coverage. Thus, 700 of the 800 most important ports of the world currently have adequate ENC coverage, or will obtain this in the near future. I.e. nearly 88% of the major ports of the world have adequate ENC coverage. It is therefore deemed that current ENC coverage of the world's busiest ports are quite extensive, although it is recommended that further efforts should be made in order to increase this coverage, in particular for the countries listed in Table 7.

5 COST-EFFECTIVENESS OF ECDIS IN LIGHT OF UPDATED ENC COVERAGE

In the previous study [17], some globally applicable estimates of average grounding risk reduction achievable from implementing ECDIS were made based on the 11 representative shipping routes. The same approach will be followed in the following, updated according to updated ENC coverage data. Hence, the following average risk reduction will be assumed attributable to global implementation of ECDIS:

2008: 1.12×10^{-2} groundings averted per shipyear

2012: 1.15×10^{-2} groundings averted per shipyear

The cost of implementing ECDIS is assumed unchanged since the previous study [17]. Furthermore, the same average accident costs and fatality rates will be assumed for grounding accidents, i.e. [17]:

Oil tankers:	720 USD/GT
Other cargo ships:	120 USD/GT
All cargo ships:	0.01 fatalities

5.1 Cost-effectiveness for new cargo ships

Using the average estimates above and the grounding frequency reduction estimated in light of updated ENC coverage, the GCAF value associated with ECDIS is estimated to:

GCAF = USD 25 million

The NCAF value will be a function of the ship size, and will be different for oil tankers and other cargo ships.

It can be shown that for oil tankers of 500 GT and above, NCAF will be less than USD 3 million. For ships greater than 570 GT, NCAF will be negative. Hence, ECDIS is cost-effective for all oil tankers bigger than 500 GT. Compared to the previous study where only ships greater than 630 GT were found to be cost-effective, this represents an improvement that may be ascribed to the increased coverage of ENCs.

For other cargo ships, NCAF will be about 21 million for ships of 500 GT. However, for other cargo ships greater than 3000 GT, NCAF will be less than USD 3 million. For ships greater than 3500 GT, NCAF will be negative. Hence, ECDIS is demonstrated to be cost-effective for other cargo ships bigger than 3000 GT. Compared to the previous study where only ships greater than 3800 GT were found to be cost-effective, this represents an improvement that may be ascribed to the increased coverage of ENCs.

To summarize, for existing ships, ECDIS has been proven to be a cost-effective risk control options for the following new cargo ships:

Oil tankers greater than 500 GT

Other cargo ships greater than 3000 GT

5.2 Cost-effectiveness for existing cargo ships

For existing ships, the size limits for cost-effectiveness will vary with ship size for both oil tankers and other cargo ships. Table 8 and Table 9 give the ship size for which ECDIS has a negative NCAF for different ship ages, for oil tankers and other ships respectively. The tables show that ECDIS is cost-effective for oil tankers above 7700 GT irrespective of ship age. For other ship types, ECDIS is cost-effective for ships above 46200 GT irrespective of age. Compared to the results from the previous study (also given in Table 8 and Table 9), ECDIS can now be shown to be cost-effective for smaller vessels for all age groups.

Table 8: Ship size (GT) corresponding to negative NCAF – Oil Tankers

Ship Age	*Previous study*	*Current study*
Newbuilding	700	570
5 years	780	650
10 years	920	760
15 years	1200	1010
20 years	2100	1750
24 years	9300	7700

Table 9: Ship size (GT) corresponding to negative NCAF – Other cargo ships

Ship Age	*Previous study*	*Current study*
Newbuilding	4200	3500
5 years	4700	3700
10 years	5500	4600
15 years	7300	6100
20 years	13000	10500
24 years	56000	46200

Assuming an average service life of 25 years, it may be seen that for ships with less than 5 years remaining service ECDIS is a cost-effective risk control option for all oil tankers larger than 2000 GT and for other cargo ships larger than 10,000 GT. Comparing these estimates with the recommendations that were formulated based on the previous study [18], it is found that the present study supports the previous recommendations.

5.3 Cost-effectiveness for passenger ships

The cost-effectiveness of ECDIS as a risk control option for passenger ships has not been investigated in this study, as previous studies have demonstrated that ECDIS is indeed cost-effective for such ships [25]. In fact, the comprehensive study on the navigational safety of large passenger ships, submitted to IMO in [11, 12], identified ECDIS as one of the most promising risk control options, with a considerable potential for risk reduction. Two configurations of ECDIS were examined as risk control options, i.e. with or without track control, and the GCAF and NCAF values for these are reproduced in Table 10, as pertaining to passenger ships. From this table, is can be seen that both GCAF and NCAF criteria renders ECDIS highly cost-effective for passenger ships.

Table 10: Cost-effectiveness of ECDIS for passenger ships

Risk Control Option	*GCAF (USD)*	*NCAF (USD)*
ECDIS	2000	< 0
ECDIS (no track control)	3000	< 0

Previous recommendations to IMO, based on the abovementioned study, have been that ECDIS should be mandatory for all passenger ships of 500 gross tonnage and upwards, and it is suggested to uphold this recommendation.

6 CONCLUSIONS AND RECOMMENDATIONS

The cost-effectiveness of ECDIS as a risk control option for cargo ships has been evaluated in light of updated data on global ENC coverage. As such, this study represents an update of a previous study from which results were submitted to NAV 53 [17].

Compared to the previous study, performed in 2006/2007, a notable increase in worldwide coverage of ENC has been observed. According to data received from IHB, the number of ENCs in usage bands 3 – 6 has increased by about 33%. Based on the updated ENC coverage it has been demonstrated that between 85% – 96% of global ship traffic operates with suitable ENC coverage in coastal waters. Compared to the previous study, this represents a reduction of gaps in the global ENC coverage by about 25%.

Selected representative shipping routes have been reinvestigated in detail, and most of these have also experienced an improvement of suitable ENC coverage. With the updated ENC coverage, ECDIS was proven to become cost-effective in the near future (at least by 2012) for all selected routes (one of which was not found to be cost-effective in the previous study). This study also examined ENC coverage in the world's major ports. Accordingly, nearly 88% of the 800 top ports worldwide were found to have suitable ENC coverage. Hence, it was demonstrated that the ENC coverage of major ports are extensive.

The cost-effectiveness has been assessed in terms of GCAF and NCAF for new as well as existing ships. It was found that GCAF would always be higher than USD 3 million for all cargo shiptypes and sizes. However, NCAF was found to be less than USD 3 million and even negative for many variations of ship age and size. Basically, the recommendations and conclusions from the previous study have been supported and strengthened by this study. Notwithstanding known gaps in the global ENC coverage, this study has demonstrated that the coverage that already exists is sufficient to make ECDIS a cost-effective means of reducing the risk of grounding. Thus, the following recommendations have been substantiated with increased confidence:

i. ECDIS should be made mandatory for all passenger ships of 500 gross tonnage and upwards.

ii. ECDIS should be made mandatory for all new oil tankers of 500 gross tonnage and upwards.

iii. ECDIS should be made mandatory for all new cargo ships, other than oil tankers, of 3,000 gross tonnage and upwards.

iv. ECDIS should be made mandatory for all existing oil tankers of 3,000 gross tonnage and upwards.

v. ECDIS should be made mandatory for all existing cargo ships, other than oil tankers, 10,000 gross tonnage and upwards.

vi. Exemptions may be given to existing oil tankers of less than 10,000 gross tonnage and existing cargo ships, other than oil tankers, less than 50,000 gross tonnage when such ships will be taken permanently out of service within 5 years after the implementation dates given for iv) and v) above.

7 ABBREVIATIONS

AMVER	Automated Mutual-assistance Vessel Rescue
APC	Appropriate portfolio of up-to-date paper charts
COADS	Comprehensive Ocean-Atmosphere Data Set
DWT	Deadweight tonnes
ECDIS	Electronic Chart Display and Information System
ECS	Electronic Chart System
ENC	Electronic Navigational Charts
FSA	Formal Safety Assessment
GCAF	Gross Cost of Averting a Fatality
GPS	Global Positioning System
GT	Gross Ton
IHB	International Hydrographic Bureau
IHO	International Hydrographic Organization
IMO	International Maritime Organization
NCAF	Net Cost of Averting a Fatality
NM	Nautical mile (1 nm = 1.852 km)
NPV	Net Present Value
RCDS	Raster Chart Display System
RENC	Regional Electronic Navigational Chart Coordinating Centre
RNC	Raster Navigational Charts
SENC	System Electronic Navigational Chart
SOLAS	International Convention for the Safety of Life at Sea

APPENDIX 1: MOST IMPORTANT PORTS WORLDWIDE

#	PORT	COUNTRY
1	Singapore	Singapore
2	Gibraltar	Gibraltar
3	Hong Kong	China
4	Istanbul	Turkey
	Fujairah	United Arab
5	Anchorage	Emirates
6	Rotterdam	Netherlands
7	Port Said	Egypt
8	Kaohsiung	Taiwan
9	Busan (Pusan)	Republic of Korea
10	Suez	Egypt
11	Panama Canal	Panama
12	Antwerp	Belgium
13	Houston	USA
14	Hamburg	Germany
15	Shanghai	China
16	New York	USA
17	Yokohama	Japan
18	Nagoya	Japan
19	Juaymah Terminal	Saudi Arabia
20	Port Klang	Malaysia
21	Ningbo	China
22	Ras Tanura	Saudi Arabia
23	Long Beach	USA
24	Tubarao	Brazil
25	Le Havre	France
26	Santos	Brazil
27	Kharg Island	Iran
	Jebel Ali	United Arab
28		Emirates
29	Tokyo	Japan
30	Kobe	Japan
31	Qingdao	China
32	Ponta da Madeira	Brazil
33	Brunsbuttel	Germany
34	Novorossiysk	Russian Federation
35	Yantian	China
36	Keelung	Taiwan
37	Sidi Kerir Terminal	Egypt
38	Vancouver	Canada
39	Port Hedland	Australia
	Ain Sukhna	Egypt
40	Terminal	
41	Port Arthur	USA
42	Chiba	Japan
43	Algeciras	Spain
44	Gwangyang	Republic of Korea
45	Bremerhaven	Germany

#	PORT	COUNTRY
46	Ulsan	Republic of Korea
47	Newcastle	Australia
	Jebel Dhanna	United Arab
48	Termina	Emirates
49	Los Angeles	USA
50	Taichung	Taiwan
51	Durban	South Africa
52	Felixstowe	United Kingdom
53	Oakland	USA
54	LOOP Terminal	USA
55	Shekou	China
56	Mizushima	Japan
57	Incheon	Republic of Korea
58	Hay Point	Australia
59	Savannah	USA
60	Osaka	Japan
61	Kawasaki	Japan
62	Richards Bay	South Africa
63	Barcelona	Spain
64	Gladstone	Australia
65	Laem Chabang	Thailand
66	Brixham	United Kingdom
67	Valencia	Spain
68	Charleston	USA
69	Gioia Tauro	Italy
70	Genoa	Italy
71	Xingang	China
72	Haldia	India
73	Colombo	Sri Lanka
74	San Francisco	USA
75	Xiamen	China
76	Yanbu	Saudi Arabia
77	Visakhapatnam	India
78	Las Palmas	Canary Islands
79	New Orleans	USA
80	Delaware Bay	USA
81	Al Basra Terminal	Iraq
82	Port de Bouc	France
83	Kashima	Japan
84	Dalian	China
85	Texas City	USA
86	Mina al Ahmadi	Kuwait
87	Tees	United Kingdom
88	St Petersburg	Russian Federation
89	Mina al Fahal	Sultanate of Oman
90	Augusta	Italy
91	Piraeus	Greece

#	PORT	COUNTRY
92	Immingham	United Kingdom
93	Amsterdam	Netherlands
94	Corpus Christi	USA
95	Constantza	Romania
96	Paranagua	Brazil
97	Mai-Liao	Taiwan
98	Seattle	USA
99	Mumbai	India
100	Brisbane	Australia
101	Arzew	Algeria
102	Taranto	Italy
103	Dunkirk	France
104	Pohang	Republic of Korea
105	Rio de Janeiro	Brazil
106	Primorsk	Russian Federation
107	Trieste	Italy
108	Chiwan	China
109	Dampier	Australia
110	Fos	France
111	Pulau Bukom	Singapore
112	Manzanillo	Panama
113	Jeddah	Saudi Arabia
114	Zirku Island	United Arab Emirates
115	Oita	Japan
116	Pasir Gudang	Malaysia
117	Cape Town	South Africa
118	Jubail	Saudi Arabia
119	Melbourne	Australia
120	Wilhelmshaven	Germany
121	Mongstad	Norway
122	Salalah	Sultanate of Oman
123	Tanjung Pelepas	Malaysia
124	San Lorenzo	Argentina
125	Norfolk	USA
126	Marcus Hook	USA
127	Khor Fakkan	United Arab Emirates
128	Bandar Abbas	Iran
129	Dubai	United Arab Emirates
130	Yokkaichi	Japan
131	Sikka	India
132	Botany Bay	Australia
133	Sao Sebastiao	Brazil
134	Jawaharlal Nehrul	India
135	Tacoma	USA
136	Rio Grande	Brazil
137	Kiire	Japan
138	Port Everglades	USA
139	Valdez	USA
140	Venice	Italy
141	Das Island	United Arab Emirates
142	Cartagena	Colombia
143	Sepetiba	Brazil
144	Miami	USA
145	Southampton	United Kingdom
146	Leghorn	Italy
147	Hovensa	American Virgin Island
148	Karachi	Pakistan
149	Philadelphia	USA
150	Rizhao	China
151	Apapa-Lagos	Nigeria
152	Vancouver Anchorage	Canada
153	Sakai	Japan
154	Fremantle	Australia
155	Tarragona	Spain
156	Baltimore	USA
157	Alexandria	Egypt
158	Santa Cruz de Teneri	Canary Islands
159	Milford Haven	United Kingdom
160	Chennai	India
161	Jakarta	Indonesia
162	Kisarazu	Japan
163	Port Walcott	Australia
164	Bilbao	Spain
165	Mobile	USA
166	Santa Marta	Colombia
167	Surabaya	Indonesia
168	Callao	Peru
169	New Mangalore	India
170	Marsaxlokk	Malta
171	Freeport(Texas)	USA
172	Guayaquil	Ecuador
173	Lake Charles	USA
174	Cayo Arcas Terminal	Mexico
175	Abidjan	Ivory Coast
176	Yosu	Republic of Korea
177	Fukuyama	Japan
178	Richmond(CA)	USA
179	Muuga	Republic of Estonia
180	Liverpool	United Kingdom
181	Buenaventura	Colombia
182	Halifax	Canada
183	Duluth	USA
184	Sepetiba Terminal	Brazil
185	Tampa	USA

#	PORT	COUNTRY
186	Qinhuangdao	China
187	Gothenburg	Sweden
188	Ruwais	United Arab Emirates
189	Damietta	Egypt
190	Mormugao	India
191	Shimizu	Japan
192	Kingston	Jamaica
193	Freeport	Bahamas
194	Ventspils	Republic of Latvia
195	Fujairah	United Arab Emirates
196	Fawley	United Kingdom
197	Ravenna	Italy
198	Montevideo	Uruguay
199	Balboa	Panama
200	Bangkok	Thailand
201	Dammam	Saudi Arabia
202	Haifa	Israel
203	Coatzacoalcos	Mexico
204	Buenos Aires	Argentina
205	Qua Iboe Terminal	Nigeria
206	Port Kembla	Australia
207	La Spezia	Italy
208	Huangpu	China
209	Hakata	Japan
210	Gdansk	Poland
211	Quebec	Canada
212	Zhanjiang	China
213	Paradip	India
214	Tilbury	United Kingdom
215	March Point	USA
216	Murmansk	Russian Federation
217	Port Angeles	USA
218	Bonny	Nigeria
219	Puerto Cabello	Venezuela
220	Marlim Field	Brazil
221	Daesan	Republic of Korea
222	Kerteh Terminal	Malaysia
223	Manzanillo	Mexico
224	Jacksonville	USA
225	Mesaieed	State of Qatar
226	Bahia Blanca	Argentina
227	Sullom Voe	United Kingdom
228	Skikda	Algeria
229	Thursday Island	Australia
230	Thessaloniki	Greece
231	Ambarli	Turkey
232	Portsmouth(VA)	USA
233	Saint John	Canada
234	Lianyungang	China

#	PORT	COUNTRY
235	Map Ta Phut	Thailand
236	Naples	Italy
237	Ymuiden	Netherlands
238	Salvador	Brazil
239	Riga	Republic of Latvia
240	Penang	Malaysia
241	Odessa	Ukraine
242	Portland(ME)	USA
243	Lisbon	Portugal
244	Zeebrugge	Belgium
245	Sines	Portugal
246	Mersin	Turkey
247	St Eustatius	Netherlands Antilles
248	Algiers	Algeria
249	Puerto Jose	Venezuela
250	Limassol	Cyprus
251	Thamesport	United Kingdom
252	Aqaba	Jordan
253	Izmir	Turkey
254	Santa Panagia	Italy
255	Balikpapan	Indonesia
256	Puerto Limon	Costa Rica
257	Saldanha Bay	South Africa
258	Leixoes	Portugal
259	Casablanca	Morocco
260	Cilacap	Indonesia
261	San Vicente	Chile
262	Tema	Ghana
263	Madre de Deus	Brazil
264	Klaipeda	Republic of Lithuania
265	Tuapse	Russian Federation
266	Forcados Terminal	Nigeria
267	Kandla	India
268	Savona	Italy
269	Puerto Bolivar	Colombia
270	Bejaia	Algeria
271	Yuzhnyy	Ukraine
272	Montreal	Canada
273	Puerto la Cruz	Venezuela
274	Sture	Norway
275	Ashdod	Israel
276	Puerto Quetzal	Guatemala
277	Hound Point	United Kingdom
278	Chittagong	Bangladesh
279	Kakogawa	Japan
280	Aden	Yemeni Republic
281	Port Elizabeth	South Africa
282	San Antonio	Chile
283	Tauranga	New Zealand
284	Ghent	Belgium

#	PORT	COUNTRY
285	Martinez	USA
286	Veracruz	Mexico
287	Dos Bocas	Mexico
288	New Tuticorin	India
289	Seven Islands	Canada
290	Quintero	Chile
291	Valparaiso	Chile
292	San Juan	Puerto Rico
293	Flushing	Netherlands
294	Itajai	Brazil
295	Tobata	Japan
296	Tomakomai	Japan
297	Portland(OR)	USA
298	Gijon	Spain
299	Bandar Imam Khomeini	Iran
300	Manila	Philippines
301	Cherry Point	USA
302	Wakayama	Japan
303	Ilichevsk	Ukraine
304	Skoldvik	Finland
305	Honolulu	USA
306	El Segundo	USA
307	Suape	Brazil
308	Escombreras	Spain
309	Dakar	Senegal
310	Rouen	France
311	Milazzo	Italy
312	Cagliari	Italy
313	Fredericia	Denmark
314	Samchonpo	Republic of Korea
315	Jamnagar Terminal	India
316	Koper	Republic of Slovenia
317	Vancouver	USA
318	Sakaide	Japan
319	Vostochnyy	Russian Federation
320	Bourgas	Bulgaria
321	Moji	Japan
322	Adelaide	Australia
323	Ras Lanuf	Libya
324	Huelva	Spain
325	Kochi	India
326	Altamira	Mexico
327	El Dekheila	Egypt
328	Aliaga	Turkey
329	Gunsan	Republic of Korea
330	Bremen	Germany
331	Wilmington(NC)	USA
332	Galveston	USA
333	Kinuura	Japan

#	PORT	COUNTRY
334	Brofjorden	Sweden
335	Galveston light. are	USA
336	Rosario	Argentina
337	Beirut	Lebanon
338	Tanjung Bara	Indonesia
339	Ho Chi Minh City	Vietnam
340	Sao Francisco do Sul	Brazil
341	Ko Sichang	Thailand
342	Mina Saqr	United Arab Emirates
343	Rio Haina	Dominican Republic
344	Port Muhammad Bin Qa	Pakistan
345	Haugesund	Norway
346	Geelong	Australia
347	Setubal	Portugal
348	Praia Mole	Brazil
349	Benicia	USA
350	Auckland	New Zealand
351	Coryton	United Kingdom
352	Corunna	Spain
353	Donges	France
354	Malaga	Spain
355	Falmouth	United Kingdom
356	Mombasa	Kenya
357	Paulsboro	USA
358	Mariupol	Ukraine
359	Dublin	Republic of Ireland
360	Delaware City	USA
361	Nakhodka	Russian Federation
362	Aarhus (Arhus)	Denmark
363	Kakinada	India
364	Es Sider Terminal	Libya
365	Guangzhou	China
366	Salerno	Italy
367	Pyeongtaek	Republic of Korea
368	Lome	Togo
369	Kaliningrad	Russian Federation
370	Mina Saud	Kuwait
371	Aratu	Brazil
372	Castellon	Spain
373	Newport News	USA
374	Vitoria	Brazil
375	Brass Terminal	Nigeria
376	Kalundborg	Denmark
377	Djeno Terminal	The Congo
378	Masan	Republic of Korea
379	Vila do Conde	Brazil
380	Pascagoula	USA

#	PORT	COUNTRY
381	Kuantan	Malaysia
382	Lazaro Cardenas	Mexico
383	Shimotsu	Japan
384	Vladivostok	Russian Federation
385	Ferndale	USA
386	Narvik	Norway
387	Fazendinha	Brazil
388	Pecem	Brazil
389	Gullfaks Terminal	Norway
390	Bintulu	Malaysia
391	Vigo	Spain
392	Fushiki-Toyama	Japan
393	Varna	Bulgaria
394	Davao	Philippines
395	Talcahuano	Chile
396	Cotonou	Republic of Benin
397	Nantong	China
398	Trombetas	Brazil
399	London	United Kingdom
400	Gdynia	Poland
401	Westville	USA
402	Colon	Panama
403	Bristol	United Kingdom
404	Semangka Bay Termina	Indonesia
405	Iquique	Chile
406	Point Tupper	Canada
407	Banias	Syria
408	Yingkou	China
409	Lyttelton	New Zealand
410	Belawan	Indonesia
411	Statfjord Terminal	Norway
412	Sharjah	United Arab Emirates
413	Ama Anchorage	USA
414	Covenas	Colombia
415	Bunbury	Australia
416	Nemrut Bay	Turkey
417	Muroran	Japan
418	Panjang	Indonesia
419	Tampico	Mexico
420	Rijeka	Republic of Croatia
421	Port Dickson	Malaysia
422	Tutunciftlik	Turkey
423	Cork	Republic of Ireland
424	Mohammedia	Morocco
425	Ponta do Ubu	Brazil
426	Escravos Terminal	Nigeria
427	Itaqui	Brazil
428	Batumi	Republic of Georgia
429	Shuaiba	Kuwait

#	PORT	COUNTRY
430	Agioi Theodoroi	Greece
431	Sarroch	Italy
432	Diliskelesi	Turkey
433	Pipavav	India
434	Ras al Khafji	Saudi Arabia
435	Sydney	Australia
436	Onahama	Japan
437	Port Sudan	Sudan
438	Kotka	Finland
439	Kalama	USA
440	Barbers Point	USA
441	Niigata	Japan
442	Ras Laffan	State of Qatar
443	Batangas	Philippines
444	Lattakia	Syria
445	Napier	New Zealand
446	Barranquilla	Colombia
447	Terneuzen	Netherlands
448	Cayman Brac	Cayman Islands
449	Halul Island Termina	State of Qatar
450	Mokpo	Republic of Korea
451	Eleusis	Greece
452	Amuay Bay	Venezuela
453	Marseilles	France
454	Belfast	United Kingdom
455	Douala	Cameroon
456	Kalbut	Indonesia
457	Boston	USA
458	Tartous	Syria
459	Hamilton	Canada
460	Iskenderun	Turkey
461	Fateh Terminal	United Arab Emirates
462	Rostock	Germany
463	Bashayer Terminal	Sudan
464	Odudu Terminal	Nigeria
465	Hachinohe	Japan
466	Townsville	Australia
467	Cadiz	Spain
468	Puerto Miranda	Venezuela
469	Puerto Cortes	Honduras
470	Constantza Roads	Romania
471	Port Talbot	United Kingdom
472	Reserve	USA
473	Fortaleza	Brazil
474	Ceuta	Spain
475	Astoria	USA
476	Come by Chance	Canada
477	Yoho Terminal	Nigeria
478	Kure	Japan

#	PORT	COUNTRY
479	Fraser River Port	Canada
480	Vung Tau	Vietnam
481	Zhangjiagang	China
482	Fangcheng	China
483	Ras Isa Terminal	Yemeni Republic
484	La Guaira	Venezuela
485	Yantai	China
486	Brindisi	Italy
487	Jorf Lasfar	Morocco
488	Zhoushan	China
489	Vadinar Terminal	India
490	Grangemouth	United Kingdom
491	Two Harbors	USA
492	Semarang	Indonesia
493	Szczecin	Poland
494	Ashkelon	Israel
495	Port of Spain	Trinidad & Tobago
496	Helsinki	Finland
497	Gela	Italy
498	Valletta	Malta
499	Acajutla	El Salvador
500	Maputo	Mozambique
501	Bergen	Norway
502	Santo Tomas de Casti	Guatemala
503	Bontang	Indonesia
504	Port Cartier	Canada
505	La Pallice	France
506	Montoir	France
507	Pointe Noire	The Congo
508	Port Sultan Qaboos	Sultanate of Oman
509	Zawia Terminal	Libya
510	Baton Rouge	USA
511	Point Comfort	USA
512	Weipa	Australia
513	Djibouti	Republic of Djibouti
514	Longview	USA
515	Hodeidah	Yemeni Republic
516	Wellington	New Zealand
517	Salina Cruz	Mexico
518	Antofagasta	Chile
519	Villanueva	Philippines
520	Turbo	Colombia
521	Cristobal	Panama
522	Superior	USA
523	Asaluyeh Terminal	Iran
524	Mundra	India
525	Civitavecchia	Italy
526	Wakamatsu	Japan
527	Hull	United Kingdom

#	PORT	COUNTRY
528	Gemlik	Turkey
529	Stavanger	Norway
530	Nassau	Bahamas
531	Samarinda	Indonesia
532	Kamsar	Guinea
533	Abu Dhabi	United Arab Emirates
534	Sheerness	United Kingdom
535	Vysotsk	Russian Federation
536	Hunterston	United Kingdom
537	Marsa el Brega	Libya
538	Davant	USA
539	Lirquen	Chile
540	El Palito	Venezuela
541	Point Central	Mauritania
542	Launceston	Australia
543	Puerto Bolivar	Ecuador
544	Luanda	Angola
545	Brake	Germany
546	Bandar Mahshahr	Iran
547	Al Shaheen Terminal	State of Qatar
548	Fuzhou	China
549	Point Lisas	Trinidad & Tobago
550	Dumai	Indonesia
551	Nanaimo	Canada
552	Maceio	Brazil
553	Reunion	Reunion
554	Ube	Japan
555	Heidrun Field	Norway
556	Thunder Bay	Canada
557	Mishima-Kawanoe	Japan
558	Slagen	Norway
559	Pointe a Pitre	Guadeloupe
560	Omisalj	Republic of Croatia
561	Jiangyin	China
562	St Rose	USA
563	Wilmington(DE)	USA
564	Owendo	Gabon
565	Kolkata	India
566	Santander	Spain
567	Esperance	Australia
568	Ash Shihr Terminal	Yemeni Republic
569	Oslo	Norway
570	Megara	Greece
571	Hazira	India
572	Aasgard Field	Norway
573	Tallinn	Republic of Estonia
574	Nanjing	China
575	Suralaya	Indonesia
576	Dunedin	New Zealand

#	PORT	COUNTRY
577	Detroit	USA
578	Fort de France	Martinique
579	Supsa Terminal	Republic of Georgia
580	Tuzla	Turkey
581	Hadera	Israel
582	Portocel	Brazil
583	Zhenjiang	China
584	Takoradi	Ghana
585	Huasco	Chile
586	Suao	Taiwan
587	Donghae	Republic of Korea
588	Zhuhai	China
589	St James	USA
590	Campana	Argentina
591	St Martin	Guadeloupe
592	Providence	USA
593	Zueitina Terminal	Libya
594	Haiphong	Vietnam
595	Vendovi Island	USA
596	Geraldton	Australia
597	Porto Vesme	Italy
598	Ferrol	Spain
599	Necochea	Argentina
600	Porsgrunn	Norway
601	Stockton	USA
602	Cozumel	Mexico
603	Pointe a Pierre	Trinidad & Tobago
604	Mejillones	Chile
605	Copenhagen	Denmark
606	Hiroshima	Japan
607	Shuidong	China
608	Port Jerome	France
609	Dutch Harbour	USA
610	Subic Bay	Philippines
611	La Skhira	Tunisia
612	Portland	Australia
613	Tramandai	Brazil
614	St Thomas	American Virgin Island
615	Changshu	China
616	Dar es Salaam	Tanzania
617	Moerdijk	Netherlands
618	Puerto Ordaz	Venezuela
619	Cabinda	Angola
620	Miri	Malaysia
621	Kavkaz	Russian Federation
622	Karimun Island	Indonesia
623	Punta Cardon	Venezuela
624	Camden(NJ)	USA
625	Swinoujscie	Poland
626	Vanino	Russian Federation

#	PORT	COUNTRY
627	Sungei Pakning	Indonesia
628	New Haven	USA
629	Nouadhibou	Mauritania
630	Eregli	Turkey
631	Naantali	Finland
632	Nelson	New Zealand
633	Volos	Greece
634	Alicante	Spain
635	Hualien	Taiwan
636	Prince Rupert	Canada
637	La Libertad	Ecuador
638	Seria Terminal	Sultanate of Brunei
639	Ingleside	USA
640	Kikuma	Japan
641	Aviles	Spain
642	Chalmette	USA
643	Caldera	Costa Rica
644	Nikolayev	Ukraine
645	Oxelosund	Sweden
646	Archangel	Russian Federation
647	Conakry	Guinea
648	St Michael's	Portugal
649	Misurata	Libya
650	Rayong	Thailand
651	Gebze	Turkey
652	Banjarmasin	Indonesia
653	Shiogama	Japan
654	Brownsville	USA
655	Esmeraldas	Ecuador
656	Toyohashi	Japan
657	Malongo Terminal	Angola
658	Tokuyama	Japan
659	Rauma	Finland
660	Sriracha	Thailand
661	Karlshamn	Sweden
662	Rodeo	USA
663	Pasajes	Spain
664	Tangshan	China
665	Xinhui	China
666	Recife	Brazil
667	Ensenada	Mexico
668	EA Field	Nigeria
669	Agadir	Morocco
670	Coronel	Chile
671	Lumut	Malaysia
672	New Plymouth	New Zealand
673	Apra Harbour	Guam
674	Kuching	Malaysia
675	San Diego	USA
676	Port Hawkesbury	Canada

#	PORT	COUNTRY
677	Limay	Philippines
678	Mariveles	Philippines
679	Sfax	Tunisia
680	Whangarei	New Zealand
681	Kokura	Japan
682	Beilun	China
683	Ancona	Italy
684	Sete	France
685	Arica	Chile
686	Kizomba Ainal Termin	Angola
687	Beira	Mozambique
688	Cartagena	Spain
689	Palma(Maj)	Spain
690	Portsmouth	United Kingdom
691	Niihama	Japan
692	Monfalcone	Italy
693	Annapolis Anchorage	USA
694	Porto Torres	Italy
695	Walvis Bay	Republic of Namibia
696	Yorktown	USA
697	Nansha	China
698	Everingen	Netherlands
699	Lanshan	China
700	Shenzhen	China
701	Bizerta	Tunisia
702	Sirri Island	Iran
703	Tuxpan	Mexico
704	Papeete	French Polynesia
705	Maracaibo	Venezuela
706	Port Manatee	USA
707	Safi	Morocco
708	Cigading	Indonesia
709	Morro Redondo	Mexico
710	Guayanilla	Puerto Rico
711	Okono Terminal	Nigeria
712	Silver Bay	USA
713	La Goulette	Tunisia
714	Izmit	Turkey
715	Helsingborg	Sweden
716	Alumar	Brazil
717	Schiehallion Field	United Kingdom
718	Brest	France
719	Sandakan	Malaysia
720	Cebu	Philippines
721	Falconara	Italy
722	Fiumicino	Italy
723	Matarani	Peru
724	Hamina	Finland
725	Port au Prince	Haiti

#	PORT	COUNTRY
726	Chios	Greece
727	Ambes	France
728	Rostov	Russian Federation
729	Piombino	Italy
730	Little Cayman	Cayman Islands
731	Timaru	New Zealand
732	Punta Arenas	Chile
733	Caleta Patache	Chile
734	Chesapeake	USA
735	Squamish	Canada
736	Stenungsund	Sweden
737	Gove	Australia
738	Seville	Spain
739	Elnesvagen	Norway
740	Sevastopol	Ukraine
741	San Ciprian	Spain
742	Antan Terminal	Nigeria
743	Balder Field	Norway
744	Liepaja	Republic of Latvia
745	Kokkola	Finland
746	Sendai-Shiogama	Japan
747	Dahej	India
748	Gabes	Tunisia
749	Shimonoseki	Japan
750	Tagonoura	Japan
751	Chiriqui Grande	Panama
752	Norrkoping	Sweden
753	Mantyluoto	Finland
754	Nikiski	USA
755	Tanjung Uban	Indonesia
756	Crofton	Canada
757	Draugen Field	Norway
758	Makassar	Indonesia
759	Bordeaux	France
760	Coquimbo	Chile
761	Kaarsto	Norway
762	Larnaca	Cyprus
763	Guaymas	Mexico
764	Port Moresby	Papua New Guinea
765	Kushiro	Japan
766	Karwar	India
767	Cleveland	USA
768	Kagoshima	Japan
769	Glensanda	United Kingdom
770	St Vincent	Cape Verde
771	Progreso	Mexico
772	Imbituba	Brazil
773	Port Harcourt	Nigeria
774	Umm Qasr	Iraq
775	Sakaiminato	Japan

#	PORT	COUNTRY
776	Portsmouth(NH)	USA
777	Kerch	Ukraine
778	Wismar	Germany
779	Port Canaveral	USA
780	Kristiansand	Norway
781	Gary Harbour	USA
782	Ilo	Peru
783	Havana	Cuba
784	Gloucester(NJ)	USA
785	Bedi	India
786	Poti	Republic of Georgia
787	Three Rivers	Canada
788	Hirohata	Japan
789	Port Hueneme	USA
790	Nordenham	Germany
791	Okpo	Republic of Korea
792	Nanao	Japan
793	Jinhae	Republic of Korea
794	Caleta Cordova	Argentina
795	Port Lincoln	Australia
796	Motril	Spain
797	Marina di Carrara	Italy
798	La Plata	Argentina
799	Kanda	Japan
800	Shibushi	Japan

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