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Analysis of the IMO's Role for Safe Maritime Transport System

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Abstract : *Keeping in mind that there are only limited social, economic and administrative resources for reducing marine casualties, the result of statistical survey showed the loopholes of safe maritime transport system, and rendered that most casualties occurred in coastal waters by human errors. When the IMO Marine Casualty Investigation Code was utilized to reveal any structural vulnerability of the international measures, IMO was required to expand its roles to enhance the interface between Liveware and Environment of SHEL model. So, several risk assessment models were studied and found that Maritime Safety Audit System of the Republic of Korea could be a good example of enhancing safe interface between navigators (Liveware) and the navigational circumstances (Environment). It could be dealt with at IMO level as a tool for applying at human error enforcing waters. International cooperative research for upgrading risk assessment modes should also be future terms of reference.*

Key Words : *IMO, SHEL model, Liveware, Environment, Maritime Safety Audit*

1. Introduction

Every system, natural or artificial, is not free from failure, and the human element is considered to be a major contributor in terms of cause of marine casualties. The proportion of human error causing marine casualty varies from 65 % to 96 % according to scholars worldwide (Kim et al., 2012). Korean statistics of marine casualty agrees that about 80 % of casualties are caused by operating errors such as deficiency of sailing readiness, negligence of position fixing, violation of navigation rules and regulations, negligence of watch-keeping, negligence of safety working rules and so on (KMST, 2015). Operating errors would be equal to human errors such as slips, lapses, mistakes or violations according to classification by IMO (IMO, 1997). Therefore, human error should be primarily focused on to prevent failure of safety system because it is a principal causation factor in maritime casualties.

As shown in Table 1, around 70 % of marine casualties occurred in territorial waters including ports, approaching channels and anchorages. In terms of safety, coastal waters including ports and approaches are more important than any other waters.

Table 1. Marine casualty Area of Korea (KMST, 2015)

Area \ Year	2008	2009	2010	2011	2012	2013	2014
Ports, Approaches (A)	99	201	213	161	171	126	145
Ratio (A/D)	10.44	11.07	13.09	8.90	10.87	11.53	10.90
Territorial seas (B)	634	1,263	1,113	1,365	1,134	769	942
Ratio (B/D)	66.88	69.59	68.41	75.46	72.09	70.36	70.83
Open seas (C)	215	351	301	283	268	198	243
Ratio (C/D)	22.68	19.34	18.50	15.64	17.04	18.12	18.27
Total (D)	948	1,815	1,627	1,809	1,573	1,093	1,330

Moreover, modern ships are getting bigger and faster to achieve economy of scale, which exerts baleful influence on the confined navigable waters. In addition, artificial water facilities including mooring buoys and anchorages beside ship's routes could act as obstacles to safe navigation because they limit navigable waters. These obstacles are generally built in coastal areas, which could be risky factors that are not easily found in the high seas.

Consequently, facilities in coastal waters as hindrance to safe navigation should be scientifically surveyed and analysed to root out or mitigate potential hazards as much as possible before deciding or changing the port design or ship's routeing like Traffic Separation Scheme (TSS), one-way routes and Inshore Traffic Zone. Port zoning is also an important part of port design, which can contribute to minimizing hazards and to

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promoting safe working that lessens the possibility of accidental spillages and consequent pollution (IAPH, 1991).

This study intends to depict what IMO should address further on dealing with human error by using the method of the Casualty Investigation Code. In accordance with the SHEL Model of the Code, the interfaces between Liveware and other factors such as Software, Hardware, Liveware and Environment would be studied to search for the existence of the IMO solutions in the field of the above four interfaces. Then, it would suggest a solution to reduce or break down the possibility of marine casualties in error enforcing zones.

2. Selected approaches to human element

2.1 Review of the IMO's safety measures

IMO has adopted several conventions, resolutions and circulars for reducing human errors which are root causes of marine casualties. Most of the significant IMO conventions were originated by serious marine casualties as shown in Table 2.

The grounding and oil spill of the tanker *Torrey Canyon* contributed to consider human element. The first development was the STCW for training and education of seafarers on an international level. It contains manning, qualification, and licensing.

Table 2. Casualties causing International Instruments (Kim, 2012)

Ship's Name	Year/Place of casualty	Abstract	International Instrument
Titanic	1912 North Atlantic	Sinking. Loss of 1,503 lives	SOLAS
Torrey Canyon	1967 UK Dover Strait	Grounding. Oil spill of 119,000 tons	MARPOL STCW
Herald of Free Enterprise	1987 Begium Zeebrugge	Capsizing. Loss of 193 lives	ISM Code
Scandinavian Star	1990 North Sea	Fire. Loss of 158 lives	Accelerating ISM Code

A highly important resolution on the human element was triggered by the capsizing of passenger ferry *Herald of Free Enterprise* in 1987. It was the International Safety Management (ISM) Code which officially put managerial levels ashore in the maritime transport system. It linked liveware aboard to software ashore.

The cause of the *Herald of Free Enterprise* casualty was related not to the design of the ship but to fatigue of seafarers. No matter how IMO has continuously improved ship's hardware, certain marine casualties like the *Herald of Free Enterprise* and the *Scandinavian Star* cases were not linked to hardware but it was related to mistakes of human.

Within this context, every shipowner should establish safety policies in the first place, then develop, implement and maintain the safety management system for ensuring adequate management, safe operation for ships and environmental protection.

It could be evaluated that IMO developed conspicuous instruments regarding the combination of human elements aboard and ashore with safe navigation and management matters.

2.2 User-Centered Design

'User-centered design' (UCD) is a broad term to describe design processes in which end-users influence how a design takes shape (Abras et al., 2005). UCD is adopted by the International Standardization Organization (ISO, 2010). So, the ISO standard of human-centered design for interactive systems (ISO 9241-210) would be beneficial in the maritime community concerning design of ship's equipment and machinery.

When IMO decides to introduce the UCD for the navigational equipment and machinery, the Quality Assurance System (QAS) should be considered to check compliance of the UCD. When it comes to the QAS to check the adaptation of the ISO standards concerned, there are already several known tools even in the maritime community. For instance, the ISM Code is a type of QAS tools. ISM auditors could check documents in compliance with the ISO standards for the target equipment, machinery or factories. It is expected that the concept of the UCD could be realized by e-navigation project of IMO.

Conclusively, human error could partly be avoided by the introduction of the UCD.

2.3 SHEL model

Human elements dealt with in IMO are complex and multi-dimensional matters related to every factor which affects human-system interface including social, legal, human ability, cultural and health and design factors (Kim et al., 2012).

Therefore, IMO set up guidelines for providing practical support of the systematic investigation into human elements in marine casualties and to let the development of effective analysis and preventive action be achieved (IMO, 1999). The SHEL Model was introduced to get assistance in analysing the contribution of human elements to errors. Table 3 shows summary of Appendix 2 of Casualty Investigation Code for reviewing at a glance.

Table 3. Components of SHEL Model

Title	Sub-title	Contents
Software	Non-physical parts	Organizational policies, procedures, manuals, checklist layout, charts, maps, advisories, computer programs, etc.
Hardware	Equipment	Design of work, stations, tools, displays, controls, seats, etc.
Environment	Surroundings	Internal & external climate, temperature, visibility, noise. vibration, etc.
Liveware (central)	Each person	Physical, physiological, phychological, psychosocial, etc.
Liveware (peripheral)	Workgroup	Management, supervision, teamwork, crew interactions, communications, etc.

Figure 1 based on SHEL Model shows safety measures between central liveware and others. To summarize four interfaces related to the central human:

- First, Liveware - Liveware Interface could be controlled by the STCW.
- Second, Liveware - Software Interface could be adjusted by the implementation of the ISM Code of the SOLAS.
- Third, Liveware - Hardware Interface could be addressed by the UCD. This sector needs further discussion for QAS by the IMO approval.
- Last but not least, instruments of Liveware - Environment Interface (LEI) are not found in the IMO level.

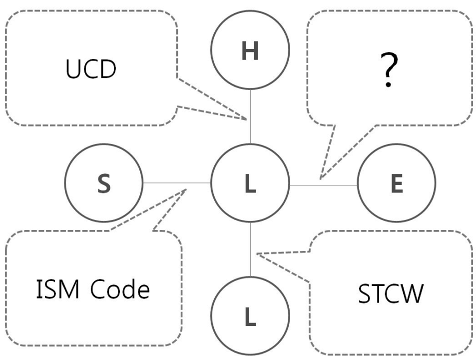

Fig. 1. International Measures in relation to the centered Liveware (Kim, 2012).

The SHEL model discloses loose interface between a navigator and navigational circumstances.

If it has been strongly insisted on to sketch an instance of LEI measures from the IMO instruments, TSS could be an example. TSS plays a role in reducing risky conditions between a navigator (Liveware) and navigational circumstances (Environment) considering that TSS separates head-on situations of ships in narrow channels or dense traffic routes. However, the design of TSS depends totally on individual states. IMO has not given any instructions or guidelines yet for how to draw the TSS, how to audit it or how to maintain it.

Conclusively, LEI should be a new agenda of IMO and the international maritime community.

3. User-friendly navigational circumstance

3.1 Ship's routeing and Port zoning Audit Scheme

Several coastal states put risk assessment models into effect for enhancing safety of navigation at ports and approaches. It could be good examples for IMO to adopt risk assessment method as official recommendation for enhancing LEI.

3.1.1 The United Kingdom

The UK enforced the Port Marine Safety Code of 2009 that applied to all harbour authorities. The Code is generally interested in harbour authorities' performance and plan. The meeting for assessment opens once every three years.

Basically it uses the Formal Safety Assessment techniques to identify risks in harbours and approaches. It aims at maintaining marine safety management system and it is to ensure that all risks are controlled - the identified risks must be eliminated or kept as low as reasonably practicable (UKD, 2009).

In the matter of assessment model or technic, the Code does not supply any specific guidelines for auditing the safety system of the target waters.

3.1.2 The United States of America

The United States Coast Guard (USCG) operates the Port and Waterways Safety Assessments (PAWSA) under authorities of 33 USC. 1221 - Port and Waterways Safety Act of 1972, as amended by the Port and Tanker Safety Act of 1978. The PAWSA aims at providing specific results and measures for optimal routeing of ships to, in and from major ports in conjunction with all other marine activities occurring in that area. For instance, it is to confirm that every fairway and anchorage in fairways might be designated or established to provide unobstructed approaches for ship (USCG, 2012).

As shown in Figure 2, the PAWSA process is made up of two-day teamwork whose members are composed of maritime safety experts, waterway users, stake holders, and the agencies/entities responsible for implementing selected risk mitigation measures because it is to survey major waterway safety hazards, estimate the level of risk related to fairways, evaluate potential mitigation measures, and set the stage for enforcement of selected preventative measures to decrease risk (USCG, 2012).

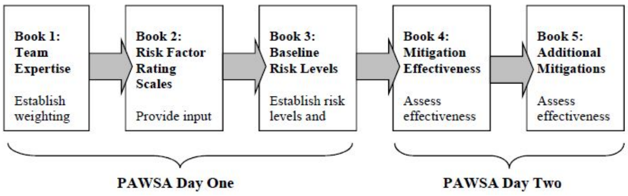

Fig. 2. Simplified Overview of the PAWSA Process (NC, 2005).

To sum up, the PAWSA could be classified into the expanded harbour board of the UK. Although the PAWSA results are collected by a quantitative method using spreadsheets for the data collected from each book, the convened group members use a qualitative method to fill in the books because they depend on their expertise and experience. Computer simulations are not involved in the process.

3.1.3 Canada

Canada enforced the Navigable Water Protection Act (NWPA) in 1985. It was lastly amended on 12 March 2009. It is composed of 5 parts and has 5 subsidiary regulations for safe navigation.

The NWPA only aims at navigational safety at navigable waters, and the target of the law includes most work including construction at sea. The minister in charge of maritime safety holds the power of approval in every case of work at sea.

The Canadian system is much similar to Korean system as compared in Table 4.

However, Canadian scheme does not have specific guidelines on the audit process and technical parts such as simulation standards which Korea and Japan have.

3.1.4 Japan

According to the article 27 of Port Act, all construction and development work in port and approaches should be authorized by port authorities. In addition, the port authorities ask the opinion of the Japanese Coast Guard though it is not a

Table 4. Scheme Comparison b/w Korea and Canada (Kim, 2012)

Categories	Korea	Canada
Regulation	Maritime Safety Act Enforcement Decree Enforcement Rule Ordinance of Minister	Navigable Water Protection Act Five sub-regulations
Enactment	2009	1985
Purpose	Professionally to inspect, measure, evaluate any risk factors of the navigation safety which may affect to maritime traffic safety and be happened by the designated marine businesses (Maritime Safety Act article 2.16)	No work shall be built or placed in, on, over, under, through or across any navigable water without the Minister’s prior approval of the work, its site and the plans for it (NWPA 5.(1)).
Character	Specific target business, fixed audit items and evaluation method	Comprehensive target work, unspecified audit process
	Weighing on independent and impartial audit reports on the business according to specific guidelines	Weighing on navigational safety during and after the business instead of the business itself
	No works can be begun without the Minister’s approval	Minister’s decision for work is imperative
	Informing related authorities and business owners of the audit result	Publicizing the approved business to local newspapers

Table 5. Scheme Comparison b/w Korea and Japan (Kim, 2012)

Categories	Korea	Japan
Regulation	Ordinance of the Ministry of Maritime Affairs (Compulsory)	Guidelines of Marine Casualty Prevention Association(Recommendation)
Aim	To secure navigational safety by removing risky factors caused by business in navigable waters	To secure navigational safety by quantitative analysis of effects caused by business on vessel traffic
Target business	Port construction, water zoning. Traffic Separation Scheme, etc.	Port management plan, Facility construction, Maritime traffic system, etc.
Evaluation Target	Business outline, Environmental elements, Navigational circumstances, Traffic survey, Diagnosis of traffic characteristics, Users' opinion	Environmental elements, Navigational circumstances, Existing facilities, Navigational aids, Model vessel
Evaluation Method	Simulations of Ship handling, Berthing/ unberthing, Traffic congestion	Simulations of Ship handling, Traffic congestion
Assessment	Assessment Committee	Consultative Committee

compulsory step. Then the Japanese Coast Guard summons the Marine casualty Prevention Committee whose members are experts of the maritime community.

The auditing process and simulation guidelines are much similar to the Korean system as shown in Table 5, but the Japanese guidelines are on a voluntary basis.

3.2 Background of maritime safety audit scheme of Korea

3.2.1 Collision near main routes

At 07:06 (LT) on 7 December 2007, a crane barge *Samsung No.1* being towed by two tug boats collided with the anchored tanker *Hebei Spirit*, carrying 260,000 tonnes (290,000 short tons) of crude oil. The barge was floating free after the cable linking it to the tug snapped short in the heavy weather.

The collision occurred near the port of *Daesan*. It was 252° (T), 5.1 miles off from the nearest the light house as shown in Figure 3.

Fig. 3. Ships' Main Routes and Collision Site (Kim, 2012).

The collision caused the most serious oil pollution in the history of the Republic of Korea. However, the marine casualty could have been prevented if there were safe anchorages within harbour limits.

The port of *Daesan* was constructed beside the main route to the ports of *Inchoen* and *Pyeongtaek*. If the port planner reviewed the whole maritime traffic system of the region, the port zoning including inner harbour anchorage might be differently designed.

Because of the collision, Maritime Safety Act of Korea was revised to include a compulsory audit scheme for analysing navigational conditions around ship's route and port (Cho et al., 2010).

3.2.2 Controversy over the span of harbour bridges

The day before the oil pollution of the *Hebei Spirit*, the collided barge *Samsung No.1* was engaged in lifting the longest deck between the main pillars of the *Incheon daegyo* that crosses approaching channels to *Incheon* harbour. The lifting work was televised nationwide, but the barge was shown again on TV next day because it struck a VLCC *Hebei Spirit*.

Construction work of *Incheon* harbour bridge took two years for deciding the reasonable span of the main pillars before finalizing the blue print. Although the Ministry of Construction and Transport was interested in fast construction with an economic budget, the Ministry of Maritime Affairs and Fisheries did not agree on the span of the bridge because it could be an obstacle to safe navigation (Kim, 2009).

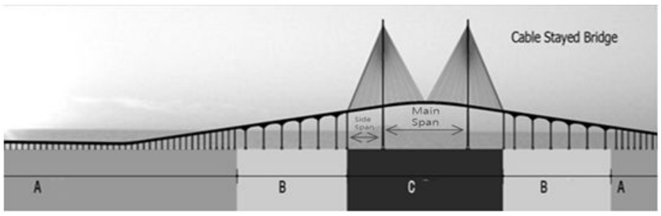

Fig. 4. Outline of the *Incheon daegyo* (Incheon Bridge, 2009).

In order to decide the span between the main pillars as shown in Figure 4, more than four well-known institutions home and abroad were involved in the ship handling simulations for the bridge passing. They used sophisticated simulators, but the results of studies were different from one another. Each institution used its own standard for simulation input data. If wind speeds were strong, the ship would be more pushed to the leeward side. When current directions were abeam to the ship's side, the ship would easily deviate from the planned course. Considering that simulators are a kind of numeric model calculator which renders output based on input data, the standardized input data is as much important as the simulator itself.

Therefore, every input factor of simulation needs scientific verification for the reliability of the result. The Maritime Safety Act includes specific standard for analyzing traffic system and ship handling simulations

3.3 Overview of Overview of maritime safety audit

3.3.1 Concept of the Scheme

The Maritime Safety Audit is a professional survey, measurement and evaluation of the hazards that may occur at sea by the following type of work:

- Setting up or modification of water zone;
- Construction or maintenance of bridges, tunnels or cables in water;
- Development and redevelopment of harbours and ports; and
- Any projects designated by the Minister of Oceans and Fisheries as remarkably sensitive to maritime traffic.

The Scheme is a compulsory assessment measure for maritime traffic safety, and a systematic process for estimating and identifying potential risks associated with marine development. It provides opportunities to improve traffic safety system. Therefore, the task is practically to identify potential hazards from the early stage of design which might affect safe navigation, and to suggest all possible measures to eliminate or mitigate those risks (Cho et al., 2009).

3.3.2 Review of the audit result

The Assessment Committee are convened when the audit report is submitted to the Minister of Oceans and Fisheries.

The Committee is composed of over 20 experts such as delegates from the Marine Officers' Association, the Pilots' Association, the Ship owners' Association and the Ship Classification Societies, professors who teach nautical science or port management, government officials in charge of maritime traffic or port operations, marine casualty investigators. Stake holders are not permitted to join the Committee.

The evaluation results made by the Committee should be notified to the project owner with a review opinion. When the assessment result is decided as a poor audit, the audit institution should replenish the final report of audit to supplement deficiencies with safety measures for eradicating circumstantial factors of potential maritime casualties. Also, the target business like bridge construction cannot be launched until the final report passes the Committee.

Table 6 shows assessment items that have to be performed in detail by auditors. It means that the Committee would check whether the auditors carried out the assessment items regarding business types in the vertical axis of Table 5. The upright axis presents the target business of audit, and the horizontal axis lists the scope of the audit. The mark "●" in the table should be performed for each target business.

Table 6. Assessment Items regarding Business Types

Audit item / Target business		Survey of traffic state	Measure of traffic state	Ship handling simulation				Safety measures
				Navigational Safety	Berth/ Unberth	Mooring	Traffic Flow	
Water zone	Designation	●	●	●	△	—	△	●
	Change	●	●	●	△	—	—	●
Facility in water zone	Construction	●	●	●	△	△	●	●
	Repair	●	●	●	—	—	—	●
Harbor /Port	Development	●	●	●	●	●	△	●
	Redevelopment	●	●	●	●	●	—	●
Other business appointed by the Minister		●	●	●	△	△	△	●

● : Mandatory, △ : Recommendable on occasion

3.3.3 Advantages of the Scheme

The Scheme is evaluated as reasonable procedure in the project of marine development of Korea. Furthermore, it is expected that the Scheme contributes not only to maritime safety but also to efficient port management and economic construction, which may bring great benefits to the whole maritime industry concerned.

Conclusively, it is expected that well designed sea routes, where the emergent cases are anticipated, could diminish potential risks, and would result in enhancement of maritime safety. The advantages and potential benefits obtained by the implementation of the maritime safety audit scheme are as follows.

- Ship's passage becomes safer, and the efficiency of port management could be maximized by reducing or eliminating risky factors.
- The overall risks that the safety authority should confront could be decreased. It would induce savings of administrative burden such as casualty-related efforts and expenditure.
- Port designers will pay active attention to the safety of navigation, and the design technology considering maritime safety could be improved in self-governing market.
- Project owners would not hesitate to accept the new audit system because the whole duration of business could be pre-estimated and audit institutions would make alternative proposals to shorten the business duration and change design with minimum additional expenditure

3.3.4 Shortcomings of the Scheme

The Scheme was inaugurated successfully on 28 November

2009, as one of the most scientific and objective measures. However, several shortcomings were analysed.

First of all, the Scheme does not have the concept of post-construction audit. The result of the audit depends generally on computer simulations based on numeric models, but the simulations could not perfectly reflect real sites from time to time. Therefore, it would be helpful to introduce the post-construction audit to verify the similarities and differences between the simulated virtual environment and constructed real site, which might enhance the simulation conditions in the long run. In the process of the post-audit, the navigators' opinion who participated in the preliminary audit should be gathered and reflected regularly. The feedback would be helpful for the enhancement of the maritime safety audit scheme.

Second, specific outset timing for audits has not been stated in the Maritime Safety Act. Therefore, it is not certain when the audit should begin. It could cost beyond the allotted budget for change of blue print just before the construction phase. That is, it would be more beneficial to edit blue the print through a feasibility study in the pre-design or design stage.

The sooner the audit is carried out, the safer the results are taken, and the less it costs (USDT, 2006). It should be the principle to perform an audit before detailed design because the earlier the audit is carried out, the more efficient and economic it can be in terms of safety and cost.

Last but not least, international cooperation is strongly required. Even though the simulation method is a scientific tool, many other assessment skills can be utilized for identifying risk factors in coastal waters. International meeting would be beneficial to improve auditing skills. In addition, the ship handling or port design societies of the world could be invited to share their knowledge and techniques.

Reminding that the international routeing has been dealt with by the IMO's NCSR, the NCSR might require the audit result of the proposed routeing for approval. In this case, the technical guidelines of the maritime safety audit scheme would contribute to devising the IMO guidelines for auditing of ships' route.

4. Conclusion

The result of statistical survey implied that maritime safety measures for reducing human error in coastal waters should be the main concerns of international maritime society including IMO, because about 80 % of the causes of marine casualties were human errors. In addition, over 70 % of mishaps occurred in coastal waters like ports and its approaches. Moreover, feasibility of marine casualties became higher in coastal waters as the increasing traffic, continuing port development and marine facility constructions.

Traditionally, IMO has approached maritime safety issues from a predominantly technical point of view. The conventional solutions have been to apply engineering and technological answers to promote safety and to minimize the consequences of marine casualties. Accordingly, safety standards have primarily addressed ship's strength, stability and equipment requirements. Despite these technical innovations, very serious marine casualties have continued to occur. Hence, IMO has shown interest in adequate training and certification of seafarers in order to address the contribution of the human element to marine casualty. In addition, the ISM Code became a conspicuous instrument regarding the combination of human element with safe navigation and management matters because it required systematic approaches on risky working conditions. The UCD could also be one more solution to reduce the possibility of casualties caused by operators' mistake because the UCD is a consideration of an end-user friendly design from the beginning of the product.

To verify that the aforementioned safety measures are corresponding to all categories of human errors, the Marine Casualty Investigation Code was referred to because it was developed to identify the categories of human errors. It was found that IMO could contribute further to preparing any appropriate measures to deal with the loose interface between liveware and environment, in other words, navigators and navigational circumstances.

In detail, it was analysed that recurrence of marine casualties would be irresistible consequences when artificial circumstances of navigation such as ship's routeing and port zoning were designated without scientific consideration to safe navigation.

Several examples of maritime safety audit scheme was studied because it could be an useful tool to fix the loopholes between liveware and environment.

The latest safety audit scheme was entered into force in Korea, which includes merits of the other states' audit schemes. The characteristics of the Scheme lies in the fact that it is a mandatory set of rules and regulations including specific guidelines for audit procedure, simulation process and technical details, which enable the system to work independently in a self-governing market. Hence, the deviation of audit reports might be minimized, and the final report would be objective and reliable.

It is worthy to note that the Maritime Safety Audit might be a turning point in dealing with the human element in the maritime transport system because it does not focus on the competency and ability of seafarers who are not free from human error, but aims at enhancing safety margins between navigators and the navigational environment that require urgent safety concerns of IMO.

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