E-NAVIGATION STRATEGY IMPLEMENTATION PLAN

A study on ship operator centred collision prevention and alarm system

Submitted by the Republic of Korea

SUMMARY

Executive summary: Collision accidents at sea have been continuously occurring despite the development in the performance of navigational equipment. As a result, the need to quantify the level of collision risk and to develop a system to prevent collision has been emerging. In response, the Republic of Korea studied a model and a system that evaluates the degree of collision risk from the perspective of ship operators. This document contains information on a ship operator centred system that prevents collision at sea and its research results.

Strategic direction: 5.2
High-level action: 5.2.6
Planned output: 5.2.6.1
Action to be taken: Paragraph 9
Related document: NAV 59/INF.2

Introduction

1 Ships make a voyage by using all available means such as RADAR, ECDIS and other navigation equipment that consistently develop in terms of their level of performance and convenience. Nevertheless, collision accidents continue to occur around the world, bringing forward the need to develop a system to prevent and quantify such risk of collision.

2 There are many additional researches being performed on the development of navigation-related decision-making systems. At NAV 59, Poland presented its navigation-related decision-making system (NDSS-NAVDEC) to improve navigational safety.
The Republic of Korea has developed an evaluation model that would quantitatively set the degree of danger on the basis of their existing research results. The model will categorize the level of danger when the ship has encountered other vessels and present such level of danger from the perspective of the ship's operator. Furthermore, we continued our research to confirm the validity of our system that provides collision prevention data to the ship's operator.

**Research details**

The research to quantify the risk of collision has been implemented mostly based on the "fuzzy theory" that could help evaluate marine traffic situations. However, the theory has its limitation for utilization as a model to support the decision-making process of a ship operator since the level of risk felt by the operator is not reflected.

In order to reflect the psychological perception of the degree of danger, we divided the consideration factors into internal and external factors. Internal factors are the factors that affect the degree of danger at sea and external factors are those that affect the ship during navigation, such as kind of ships, the own ship encounters and the angle of encounter. Using such factors, a survey was conducted on ship operators and simulations were run to quantify and evaluate a numerical value on ships that navigate the coastal waters of the Republic of Korea to develop a model based on such information (annex 1).

Based on the evaluation model, the risk of collision between own ship and other ship, as well as other ship and other ship, was analysed by using AIS information (GPS, LOA, Breadth, SOG, Ship's type). A system was also developed to distinguish and display such data by each ship and waters. Finally, a test on the system was conducted in actual waters (annex 2).

**Research result and factors to be considered**

Through the research, we were able to confirm that the degree of danger should be at the centre of focus for safe navigation in the e-navigation harmonization concept. The need to assess the level of risk of collision in a qualitative manner from the perspective of ship operator and the validity of the evaluation model has been confirmed, as well.

The quantitative level of collision risk should be considered as a support factor in the integrated decision-making system for navigation.

**Action requested of the Sub-Committee**

The Sub-Committee is invited to note the information provided.
ANNEX 1

Model and system summary

Evaluation model for risk of collision

1 Due to the increased volume of transported goods around the world, including the Republic of Korea, the number of arrivals and departures has been on the rise. As a result, encounters with other vessels in coastal areas have become more frequent, escalating the potential of maritime accidents. Although navigation equipment has been evolving, collision accidents continue to occur due to the limitation of ship manoeuvre by experience and information provided to avoid collision.

2 In order to ensure safe navigation by providing appropriate information to ship operators, the Republic of Korea researchers developed the Potential Assessment of Risk Model in 2011. The model is an evaluation model that assesses the degree of collision risk between ships. It reflects the unique characteristics of Korean coastal areas.

3 The development basis of the model is a survey that was conducted on internal and external factors that affect the ship operators’ recognition of degree of danger. Internal factors are tonnage, LOA, breadth, career, license factor and position. External factors are encounter situation, direction, inner harbour, outside harbour, speed and distance. The survey used a seven-point-criteria as seen in figure 1, with which respondents assessed the level of danger for different situations such as encounter angle 045, 090, 135, overtaking and head-on situation. We implemented the analysis of variance and multiple comparisons on survey results to identify the difference of factors. Using the regression analysis, we created a model.

![Figure 1 – An excerpt from the questionnaire on operator’s perception of risk](https://edocs.imo.org/Processing/English/NCSR 2-INF.10.docx)
4 In order to validate the model derived from the survey, we used a simulated ship steering device and performed experiments on 35 different cases. We were able to confirm the validity of the model's factors and came up with an equation as follows:

\[
\text{Risk value} = 5.081905 + T_p + T_f + L_f + W_f + C_f + L_f + P_f + 0.002517L + C_s + S_{hi/o} + S_p - 0.004930 \\
\times S_{sd} - 0.430710 \times D
\]

\[T_p = \text{Type factor} \]
\[T_f = \text{Ton factor (Ton)} \]
\[W_f = \text{width factor (m)} \]
\[C_f = \text{career factor} \]
\[L_f = \text{license factor} \]
\[P_f = \text{position factor} \]
\[L = \text{LOA (m)} \]
\[C_s = \text{crossing factor} \]
\[S_{hi/o} = \text{in/out harbor factor} \]
\[S_p = \text{speed factor (kt)} \]
\[S_{sd} = \text{speed difference (kt)} \]
\[D = \text{distance (NM)} \]

5 In the equation stated above, the degree of danger is expressed through a value ranging from one to seven. The range between one and three is recognized as a safe situation, between three and five unsafe, and that above five is dangerous.

**Risk of collision evaluation system**

6 A program was developed to verify the appropriateness of the model for use as a technological factor of e-navigation. The program utilizes AIS information of ships and evaluates the risk of collision between the own ship and other ship as well as that between other ship and other ship. The results of the evaluation, which is information on the degree of collision risk, is categorized by ship and waters. The flow chart of the program is described in figure 2.
7 The composition of the system is seen in figure 3. The AIS Pilot plug is used to receive AIS information of other ships, which is passed on to the program using a Wi-Fi transmitter. In an environment where Wi-Fi is available, the ship operator will be able to easily use the program in a remote setting.

Figure 3 – Composition of system

8 The display system of the program is shown in figure 4. The basic display system is similar to the RADAR and it can verify the degree of danger by vessels and waters through a colour code.

Figure 4 – Display of the program
<table>
<thead>
<tr>
<th></th>
<th>Function details</th>
</tr>
</thead>
<tbody>
<tr>
<td>①</td>
<td>Own ship is always displayed at the centre</td>
</tr>
<tr>
<td>②</td>
<td>Information of other ships is displayed using the AIS information</td>
</tr>
<tr>
<td>③</td>
<td>Information of own ship including GPS position, HDG, COG, SOG is displayed</td>
</tr>
<tr>
<td>④</td>
<td>Information of the other ship including name, GPS position, relative HDG/DISTANCE, COG, SOG, CPA, TCPA, BCR, BCT is displayed</td>
</tr>
<tr>
<td>⑤</td>
<td>The degree of risk of collision is displayed by the Model.</td>
</tr>
<tr>
<td>⑥</td>
<td>Degree of risk around own ship is displayed through colour code (1 ~ 4: green, 4 ~ 5: yellow, 5 ~ 7: red)</td>
</tr>
<tr>
<td>⑦</td>
<td>Displays relative HDG/ distance of the other ship from the mouse cursor’s position and own ship</td>
</tr>
<tr>
<td>⑧</td>
<td>Scale of monitor, direction of stem, rearrangement of other ship’s information</td>
</tr>
</tbody>
</table>

9 The program displays ships with a collision risk of 5.0 and above, which indicates a dangerous situation, with a red line for clear identification. It also calculates the degree of risk of collision with every other vessels 360 degrees around the own ship. For the lowest level of collision risk for every one degree is displayed on the screen with its corresponding colour code to indicate the level of risk by waters.

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ANNEX 2

Examples of test and result

1. We conducted a test in the coastal area in order to validate the level of risk calculated by the model. To this end, the degree of danger subjectively felt by the ship operator and that indicated by the model were compared.

2. The test took place in the Korea Maritime and Ocean University (KMOU) during a coastal voyage on April 15, 2014 in Namhae. The ship faced two near-collision situations during the test, even though the weather and visibility was very good.

**Encounter with the M/V Eastern Express**

3. On April 15, 2014 15:50LT (+9), the M/V Eastern Express and the test vessel (T/S HANBADA) came into a head-on encounter situation. Figure 5 shows the situation of the ship two miles before collision.

![Figure 5 – Display of encounter with the M/V Eastern Express](image)

4. The graph in figure 6 shows the average degree of danger felt by ship operators and that indicated by the model in the case of encounter between M/V Eastern Express and the test vessel (T/S HANBADA). The ship operator recognized the situation as being dangerous when the distance with the other ship was 3 NM. When the distance narrowed to 1 NM, the OOW altered the course of the ship to avoid a collision. Despite the slight gap in human perception and the result of the model, the result shows that the tendency is similar.
Encounter with the M/V Saenuri

On April 15, 2014 18:10LT (+9), M/V Saenuri and the test vessel (T/S HANBADA) came into a crossing encounter situation. Figure 7 shows the situation 1.7 NM before encounter.
The graph in figure 8 shows the average degree of danger felt by ship operators and that indicated by the model in the case of encounter between the M/V Saenuri and the test vessel (T/S HANBADA). It can be seen on the graph that the ship operator judged the situation to be dangerous when the distance with the other ship was 3 NM. When the distance was shortened to 0.2 NM, the OOW changed the course to prevent a collision. There is a slight difference between the ship operator’s perception and model result, but the result shows that the tendency is similar.

Test in Busan port

The test was implemented to confirm and verify the ability of the program to identify multiple risk factors. It took place in Busan port, one of the most complex ports in the Republic of Korea. We installed the program on the training ship of the Korea Maritime and Ocean University (KMOU), T/S HANBADA that was moored on KMOU's wharf, from which we received AIS information. The narrow entrance of Busan port gave rise to various situations, from which figure 9 was derived.

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**Figure 8 – Risk graph (Saenuri)**

**Figure 9 – Display of congested waterway**
8 With the program, we could observe multiple encounter situations, check the degree of danger from the perspective of the own ship and provide a less dangerous course from the ship's position. Furthermore, it displayed in red dangerous situations from which the course shall be altered immediately (degree of danger of 5.0 and above).

![Figure 10 – Risk of every ship on screen](image)

9 Figure 10 indicates the risk value of every vessel, the number of which in the case was ten, related to the own ship. Vessel B and Vessel E show the largest degree of danger. Vessel B is the overtaken vessel and Vessel E was in a head-on situation with the own ship. The ship operator is able to refer to red-coloured information in a congested area to figure out other ships that require immediate response. Moreover, the program allows users to confirm the degree of danger for each waters and when to change the course.