# Database of Navigational Environment Parameters (Water Depth, Sediment Type and Marine Managed Areas) to Support Ships in an Emergency

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**Abstract** : *This study introduces the navigational environment database(DB) compiling water depth, sediment type and marine managed areas (MMAs) in coastal waters of South Korea. The water depth and sediment data were constructed by combining their sparse points of electronic navigation chart and survey data with high spatial resolution using the inverse distance weighting and natural neighbor interpolation method included in ArcGIS. The MMAs were integrated based on all shapefiles provided by several government agencies using ArcGIS because the areas should be used in an emergency case of ship. To test the validity of the constructed DB, we conducted a test application for grounding and anchoring zones using a ship accident case. The result revealed each area of possible grounding candidates and anchorages is calculated and displayed properly, excluding obstacle places.*

**Key words** : *Navigation Environment Parameters, Water Depth, Sediment Type, Marine Managed Areas, Ship Emergency*

## 1. Introduction

In an event of a ship emergency, a rapid decision making by captain is necessary to minimize property damages and casualties. To do this, accurate and objective information such as the ship's condition, surrounding marine environment, expected risks or rescue forces should be provided timely. Recently, a variety of techniques have been developed to produce information to provide a safe navigation place and an escape route to ship and passengers, respectively (Ryu et al., 2017; Hong and Yang, 2017; Park et al., 2018). Among these, a ship's safe zone support module has a function to provide an optimal destination for the prevention of secondary and tertiary damages caused by marine ship accidents. Real-time data service for escape assistance information produced through a escape support module can be used as an useful information to get captain's quick decision-making in an emergency case.

Information that affects the escape of a ship can divide into dynamic information such as wind, ocean currents, etc., and static information such as water depth, artificial structures, etc.(Lee et al., 2012; Lee and Park, 2014; Hong and Yang, 2017; Park et al., 2017; Park et al., 2018). In the case of static information, the collection of information, such as observations and surveys, is carried out by the relevant government agencies, and this data serves as an important environmental factor affecting the navigational safety of the ship. This information is provided through data portals operated by relevant institutions in Korea and is updated periodically or non-periodically.

The Korea Hydrographic and Oceanographic Agency (KHOA) provides information on the water depth, sediment, and fishery through the platform of marine information (www.khoa.go.kr/oceanmap). The Ministry of Land, Infrastructure, and Transport provides GIS data on coastline through the Korea National Spatial Data Infrastructure Portal(http://data.nsdi.go.kr/dataset). The Ministry of Maritime Affairs and Fisheries provides GIS information on unique management and environment preservation waters through the coastal portal (http://coast.mof.go.kr). Also, other relevant institutions provide information on the space required at an emergency of ship, such as the location of safety-related government offices and coastal port locations, through various channels such as official documents and websites. However, this information is provided in a different format and have different settings for spatial resolution and properties. Therefore, data standardization work is necessary for automatic system working, and DB construction required

for efficient management.

In this study, the DB of navigational environment parameters, which is essential to support ships in an emergency, was constructed. Navigational environment information classified as water depth, sediment, and unique waters and special waters were classified again as escape exclusion areas(environmental protection areas, military training areas, etc.), and escape candidate areas(port). ArcGIS program used for spatial interpolation and format change of data. Then, using the built DB, we demonstrated the grounding zone and anchoring zone to support the ship's emergency.

## 2. Navigation environment data

IMO(International Maritime Organization) defines a place of refuge for ships as 'a place for restoring normal condition for ships that needed aid due to the occurrence of marine accidents, reducing the risk of sailing, and protecting people or the environment'(IMO, 2003). Also, several studies suggest emergency anchorages, nearby ports, and intentional grounding zone as ship refuge places(Lee et al., 2012; Lee and Park, 2014; Hong and Yang, 2017; Park et al., 2017; Park et al., 2018). A method was proposed to sum up the assessment of factors such as maritime transport environment, marine environments, and supporting facilities to estimate the candidate area for ship refuge place(Lee et al., 2012; Lee and Park, 2014; Hong and Yang, 2017).

Lee et al.(2012) considered artificial structures such as the distribution of fishery and navigation buoy, supporting facilities, and expert opinions. Lee and Park(2014) considered the conditions of a location such as water depth, sediment, and environmental protection area, supporting facilities, and maritime transport. In particular, Hong and Yang(2017) proposed a method for calculating dynamic intentional grounding zones that reflect real-time navigational information and oceanic conditions around the accident vessel. Thus, previous studies have suggested a variety of information, including water depth, sediment, and artificial structures as information needed to determine refuge places. Jung et al.(2011) calculated the holding power of the anchor according to the type of sediment. Hong and Yang(2017) proposed an algorithm for calculating grounding zones based on real-time depth. Chae(2011) also suggested the dangers of surrounding offshore structures in the process of drifting ships by seawater flow.

As such, various studies have highlighted the need for navigational environment information in the decision-making processes of ship operators. However, the necessary information for the purpose is collected manually, and there is no database(DB) construction case for automatic system linkage.

## 3. Data and methods

The relevant GIS gathering is essential for establishing navigational environment information DB. Water depth and sediment collected primarily through electronic navigational chart(ENC). However, high-resolution information is essential to creating high-precision candidate groups of ship refuge places in the coastal area where water depth and sediment changes are severe. To complement this, we collected high-resolution water depth and sediment measured by the KHOA. The high-resolution data requires renewal of the security pledge every year, and use and access outside the designated user prohibited under the security regulations. Information about unique waters collected through the information service portal from the relevant agencies.

### 3.1 Water depth and sediment of electronic navigation chart

The ENC manufactured by the standards of the International Hydrographic Organization(IHO, 2000) and includes location information such as water depth, sediment type, buildings, structures, buoys, rivers, and roads. The ENC separates levels according to spatial resolution, and the water depth and sediment type data of level 4, which is the highest resolution(scale 1:30,000-1:90,000), were used in this study. Fig. 1 and 2 show that the entire area of the used ENC includes the Korean Peninsula and annexed the island, ranging from longitude 124°15'36"-132°08'24" E and latitude 32°54'36"-38°50'24" N on coordinate. Fig. 1 shows the merging results of the water depth for the collected ENC. Water depths in some coastal waters exhibit a dense distribution due to merging process of the ENC. Fig. 2 shows the sediment distribution from multiple ENC. It can be seen that the range or density of data is very insufficient compared to the water depth. Especially in the East Sea, data exist only in areas very close to the shoreline. In addition, there is no sediment data in the Mid-Yellow Sea region.
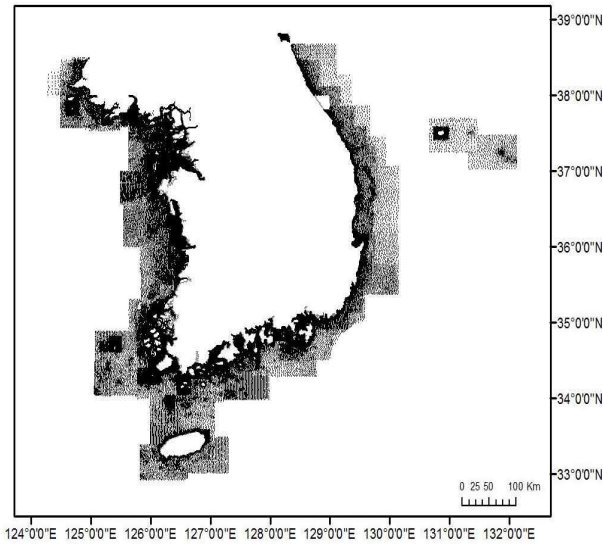
Fig. 1 Distribution map of merged water depth data extracted from the electronic navigational chart(level 4)
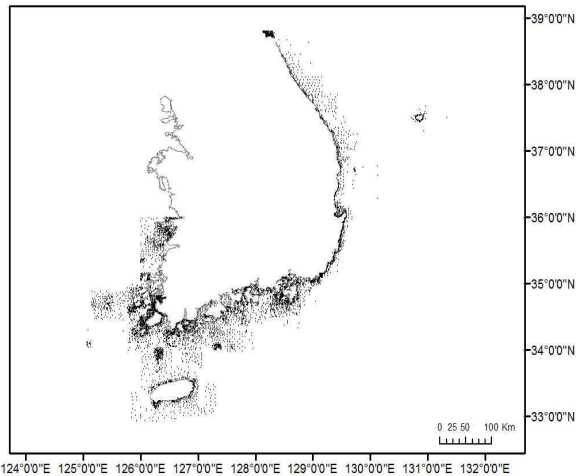


Fig. 2 Distribution map of sediment data extracted from the electronic navigational chart(level 4)

## 3.2 High resolution water depth and sediment

For the complex Korean coastal waters, the understanding of high-precision maritime environmental information is an essential element for generating optimal ship escape support information. Currently, available ENC provides information with excellent accuracy, but more high-resolution DB is needed to build to provide optimal escape support information in coastal waters. The KHOA regularly conducts high-precision measurement projects on selected areas and limitedly provides high-resolution water depth and sediment measurement data.

The KHOA is acquiring high-resolution water depth data by using a multi-beam echo sounder loaded on survey ships for coastal waters. Due to the limited access like security, the coordinates, and the water depth at the location provided after conducting a security examination on Mokpo, Jeju, Goheung, Wando, Geomundo, and some areas in the West Sea where many passenger ships operated. All the collected coordinates and water depth information was converted to a point-format shapefile using the ArcGIS program. Fig. 3 shows the high-resolution depth data collected by the KHOA observations. Compared to Fig. 1, it can be seen that the water depths of the South Sea area and north of Jeju Island densely distributed.
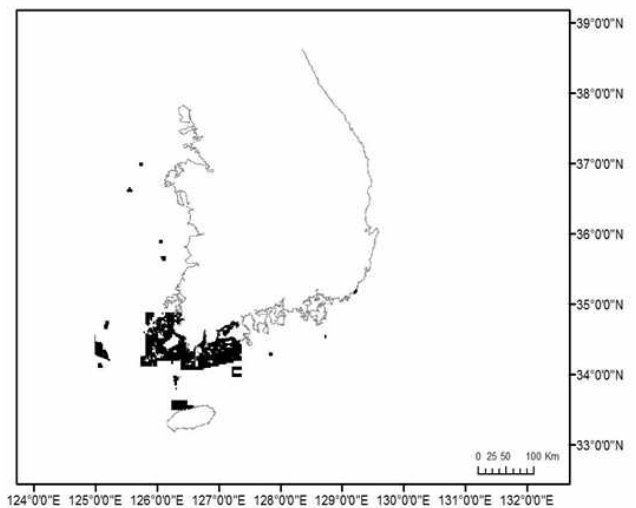


Fig. 3 Distribution map of the high resolution water depth(Mokpo, Jeju, Goheung, Wando, Geomundo, and some areas of the West Sea)

The KHOA collected sediment information in coastal waters through the air hyperspectral sensor(CASI-1500), diving, sample investigation, and ground-spectrum methods. In this study, based on 2018, Jumunjin-Imwon port(128°49′48″-129°22′12″ E, 37°12′00″-37°54′36″ N), Uljin(129°20′24″-129°30′36″ E, 36°39′00″-37°12′00″ N), Donghaesi-Busan port(129°20′24″-129°35′24″ E, 35°24′00″-36°39′00″ N), Busan (129°06′00″-129°10′48″ E, 35°04′48″-35°09′36″ N), Taean (126°15′36″-126°22′12″ E, 36°22′48″-36°40′12″ N), Goheung (127°06′00″-127°33′00″ E, 34°24′00″-34°43′48″ N), the sediment type of these six areas was collected. The sediment type classified into six categories, including pearl, pearl and sand mix, sand, gravel, rock, and submerged dike. Then we provided a shapefile of polygon properties. Also, in order to make areas distinction easier, we sorted layers and assigned colors differently by sediment. Fig. 4 shows the sediment type for six regions collected through observations. In particular, the sediment in Taean area was not included in ENC.
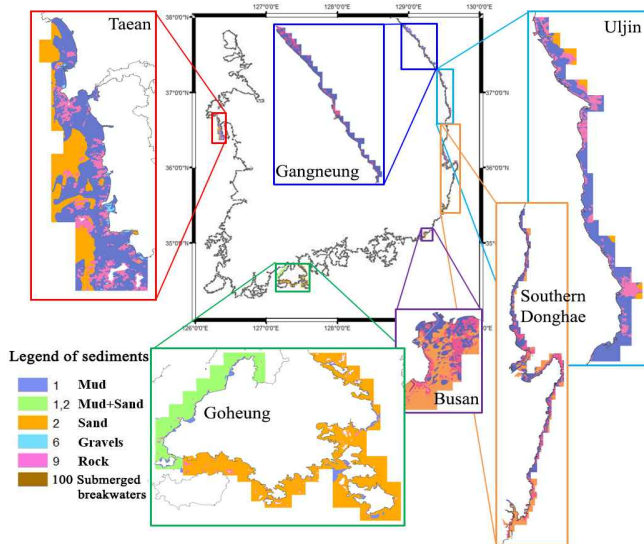
Fig. 4 Distribution map of sediment survey data in coastal
waters(Taean, Goheung, Busan, Gangneung, Uljin
and southern Donghae)

## 3.3 Spatial data of marine managed areas

The Marine Managed Areas(MMAs) means a specific
zone designated or controlled by the government for
pollution, risk management, conservation of resources
(Orbach and Karrer, 2010). The MMAs classified into
particular management areas for marine pollution, marine
training areas for marine risk, environment preservation
area for resource, and farm preservation according to the
purpose. Table 1 shows that the marine information
platform of KHOA(www.khoa.go.kr/oceanmap), the Korea
National Spatial Data Infrastructure Portal of the Ministry of
Land, Infrastructure, and Transport(http://data.nsdi.go.kr/dataset),
and the coastal portals of the Ministry of Maritime Affairs
and Fisheries(http://coast.mof.go.kr) used for collecting
spatial information of MMAs.

## 4. Results of database construction

In this study, the DB of water depth, sediment, and
MMAs spatial information, which is the considerations in
the calculation of candidate groups for ship escape in
coastal waters, was constructed. The scope of the water
depth DB construction is to set up the seas with water
depth more than 0m and less than 30m, using the ENC and
high-resolution measurement information and make a grid
to a resolution of 50m. To construct the sediment DB, we
used a water depth DB construction grid with a 50m

resolution. The sediment of each grid was the input of the
nearest information from the ENC and measured sediment
information. Then, if there is no sediment information
within 1 km of the grid center, it is set to blank. The
MMAs spatial information was converted to the format of
shapefile using ArcGIS.

## 4.1 Database of high resolution water depth using electronic navigational chart and measurement data

The ENC water depth has a low resolution but covers a
large area. On the other hand, surveyed depths have very
high resolution, but only in some areas. Besides, both data
indicate the depth of the nonuniform grid. The purpose of
this study is to construct a DB used to select a place of
refuge for ships, and a grid of high-resolution data is
efficient for operation and management. Also, the suitability
of data capacity must be considered since it involves the
purpose of providing real-time information.

In this study, in order to improve the accuracy of the
designation of the ship refuge place, we separately
constructed a DB of high-resolution depth for the coastal
area where ship accidents occur frequently. The coastal
waters are assumed to be 0-30m depths around the Korean
peninsula. The spatial resolution of the depth of the coastal
waters DB set at 50m, and the ENC and the KHOA data
used. In the region where the two data overlap, data
processing is performed to remove the ENC data. The data
of the adjacent location in the surveyed water depth
classified into the same object and the polygon generated,
and the electronic chart water depth data included in the
polygon removed. Fig. 5 shows that the remaining depths
after the removal of the ENC and the surveyed depths were
merged to create high-resolution depth DB. Compared with
Fig. 1, it can be seen that the depth data of the south-west
sea and the north sea of Jeju have changed.

ArcGIS Inverse Distance Weighted(IDW) Toolbox was used
to generate 50m grid information. The IDW based on the
assumption that the relevance and similarity between the values of
a particular position and a surrounding position are inversely
proportional to distance(Setianto and Triandini, 2013). In order to
input the IDW, the depth data converted into the UTM coordinate
system, and the number of neighborhoods included in the
influence range for a selected point set to 15. Fig. 6 shows that
the raster file produced using IDW was separated using a polygon
file of a 0-30m depth area. The separated raster file was saved
as the shapefile of the point attribute and entered into the DB.

Table 1 Classification of spatial information of special waters and offering portal information

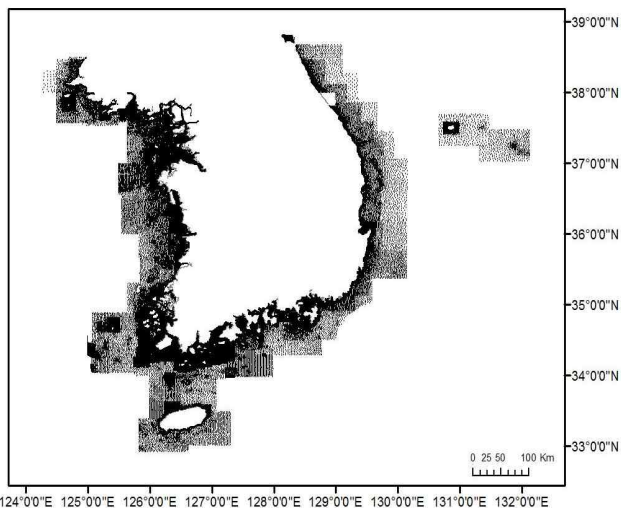| Large classification | Medium classification | Small classification | Offering portal |
|---|---|---|---|
| | Fishery information | Fishery information | – The marine information platform of KHOA (개방해) |
| | Industrial waste disposal area | Industrial waste disposal area | |
| | Traffic safety specific waters | Traffic safety specific waters | |
| | Special management waters | Special management waters | |
| | Environmental preservation waters | Environmental preservation waters | |
| Escape exclusion areas | Ecological landscape conservation area | Ecological landscape conservation area | |
| | Wetland protection area | Wetland protection area | – The Korea National Spatial Data Infrastructure Portal of the Ministry of Land, Infrastructure, and Transport |
| | Marine training and shooting area | Air force training site | |
| | | Army training site | |
| | | Naval training site | |
| | | Agency for Defense Development training site | – The coastal portals of the Ministry of Maritime Affairs and Fisheries |
| | | Korea Coast Guard training site | |
| Escape candidate areas | Costal port | Costal port | |
| | Trade port | National administration, local administration | |
| | National fishery | National fishery | |

Fig. 5 Merging map of ENC water depth and measured
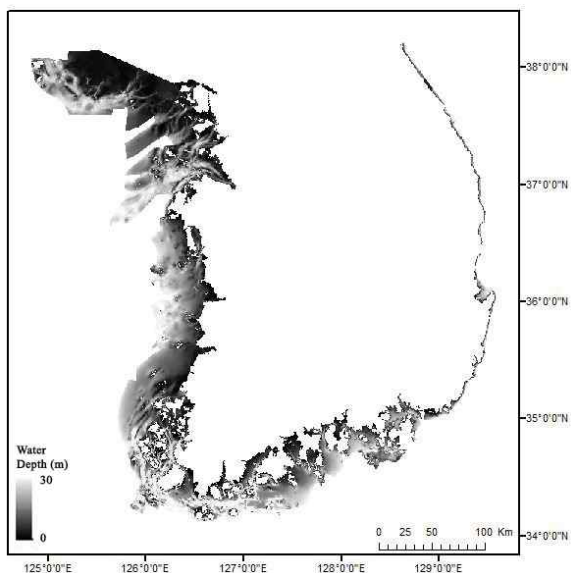water depth by KHOA



Fig. 6 Raster file of interpolated water depth in
0-30m range

## 4.2 Database of sediment data in coastal waters

This section described the process of integrating the sediment of ENC and measured data. First of all, because the notation of the ENC and the measured data are different, we made it uniform using the notation name and number of the electronic chart, as shown in Table 2. In the electronic chart, because there is no number assigned, 'Submerged breakwater' is numbered as 100 in the DB. In generally, submerged breakwaters are not included in the sediment classification, but included because they affect the safety of ship navigation. In order to increase

Table 2 The name of sediment data in coastal waters

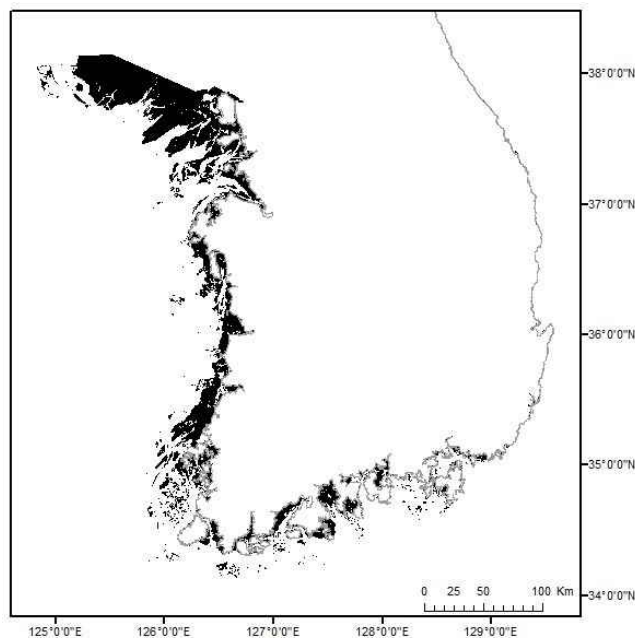| Sediment name | Sediment number |
|---|---|
| Mud | 1 |
| Sand/Mud | 12 |
| Sand | 2 |
| Gravels | 6 |
| Rock | 9 |
| Submerged breakwater | 100 |



Fig. 7 Raster file of re-sampled sediment data in coastal
water

the calculation efficiency when calculating the ship support information, the grid of the integrated sediment and the depth information is set to be the same. The merged sediment information was generated by inputting in the same grid with the ENC and the measured location information. Furthermore, the sediment information at the 'NaN' grid generated by the spatial interpolation method with the 'Nearest' option. Fig. 7 shows the re-sampled sediment data in coastal water.

## 4.3 Database of special data of marine managed areas

In order to select a refuge place of ship, it is necessary to set the area where escape is impossible to prevent secondary damage. On the other hand, information about the surrounding ports is needed to restore the vessel's and
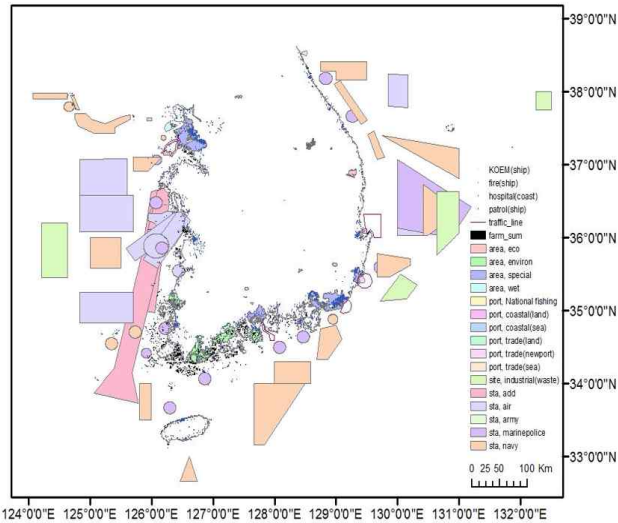
Fig. 8 Classification result considering with the
characteristics of MMAs

reduce the risk of navigation, and it may be considered a refuge place. Therefore, in this study, it was classified into a non-escape and escape candidate area considering the characteristics of MMAs, as shown in Table 1. The non-escape areas include fishing zones, environmental protection waters, military training waters, etc., and the escape candidate areas include port information. The spatial information classified into layers according to the classification criteria and the shapefile of the polygon attributes generated by using ArcGIS. Fig. 8 shows the classification result considering the characteristics of MMAs.

### 4.4 Utilization of database

The built database can be used to extract a suitable place for the ship to stay in an emergency situation. We collected the AIS information of the collision accident between the Oriental Pearl II and the PILION ship at 06:28 on 05 January 2011 and defined it as an incident corresponding to escape level 1 by 'crash' regarding the contents of the written judgment. The navigation environment parameters included in a regular radius around the location of the target vessel was extracted and is used to calculate the candidate of grounding zone, contingency anchorage and exclusion area, respectively.

Fig. 9 is the output screen of the results of the calculation of the grounding zone, contingency anchorage, and the candidate exclusion area. The green and yellow circles indicate the possible location of the grounding zone and contingency anchorage, respectively. The blue polygon indicates the escape exclusion zone. If a candidate area for

the grounding zone or contingency anchorage included in the escape exclusion zone, it will be changed to red and be output to the candidate exclusion areas. When the ship's location is changed, the information contained in the radius is automatically changed and updated. Then, the extracted navigation environment parameters used as input data to the escape route selection algorithm proposed in Park et al.(2018). This algorithm estimates the most suitable evacuation site considering the ship's condition and surrounding environmental factors. In the situation in Fig. 9, the grounding zone was guided to the excellent contingency place(red line), and the surrounding coast guard ship guided to the second contingency(yellow line).
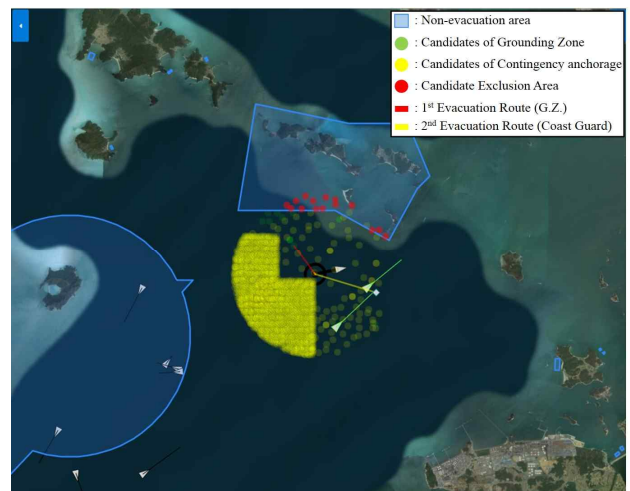


Fig. 9 Results screen of estimated grounding zones,
contingency anchorages and evacuation routes

## 5. Conclusion

In this study, the navigational environment parameters for coastal waters were constructed using the ENC, measurement data, and geographic information. Then, it was used as the supplementary data to find contingency places in an emergency ship. For the water depth and sediment data, the ENC and high-resolution data provided by the KHOA used. In the case of ENC, its data exists in most areas of the Korea Peninsular, but is less accurate due to low resolution. To compensate for this, we collected high-resolution data, although data exists only in some areas.

The geographic information on ports, fish farms, and unique waters in the coastal waters of the Korean Peninsula established into DB in the form of a polygon-type shapefile. The data obtained from the

KHOA′s portal '개방海', the coastal portal of the Ministry of Maritime Affairs and Fisheries and Korea National Spatial Data Portal of the Ministry of Land, Infrastructure, and Transport. All data were converted into shapefiles using the ArcGIS program or organized by sorting out the layers. Using the navigation environment database, we applied it to an algorithm that automatically extracts the intentional grounding zone and contingency anchorages in the ship emergency.

For high-resolution water depths and sediments, data collection was performed only for those areas that surveyed and available for the release of information. In the case of MMAs, only the data registered in the information portal used. In particular, it estimated that there are many unregistered artificial structures, such as fisheries and buoys. If these structures are detected by remote sensing technology in the future, more accurate marine obstacles can be added. Although data collection limits exist, it expected that the established DB through this research would be usefully utilized for extracting the contingency place of the ship in an emergency.

## Acknowledgements

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