Determining safety limitations and the frequency of determining vessel location when establishing marine bases on the Vietnam's sea areas

T D Nguyen
Faculty of Navigation, Vietnam Maritime University, Hai Phong, Vietnam
E-mail: nguyenthaiduong@vimaru.edu.vn

Abstract. The article introduces the request of the International Maritime Organization (IMO) for accuracy of vessel position and the maximum interval between two consecutive ship positions. The author focuses on assessing the extent to which IMO's requirements are met when planning a voyage, based on practical experience from himself and a number of other outstanding captains. At the same time, analyse theoretical and practical basis when making decisions about the limited distance to the danger point and the time interval between two determinations of consecutive ship locations to ensure maritime safety. The article builds the process of calculating and manipulating maritime routes to estimate safety through dangerous areas with full theoretical basis and practical seafaring experience.

1. Introduction
The operation of the maritime route is intended to be a basic operation of the marine officer, which is the basis for the captain to plan a safe and economical sea voyage. The theoretical basis and common practice guidelines are documented in the International Maritime Organization (IMO) documents [1], [2] and the company's processes in the International Safety Management System (ISM) [3-5]. However, these are just the most basic and general guidelines, in order to establish a maritime route that envisages quality it requires many specific maritime operations. In this paper, the author specifically discusses two basic issues that need to be calculated when planning a maritime route, piloting it in Vietnam's coastal areas.

The first is the Margin of safety (MOS): when operating a specific route, maritime officers need to determine the safe distance to dangerous areas. However, the theoretical and practical basis for giving the specific value of MOS has not been guided in research papers as well as practical experience.

The second is the frequency of determining the position of the ship (Interval Fixed Positions - IFP): Locating the ship is a necessary and mandatory job for the duty watch officer at sea. The purpose of maintaining the time interval between ship location determinations is to have a basis for adjusting the intended position, leading the ship on the correct course. However, the theoretical and practical basis for the captain to decide the time to locate the ship as well as the full awareness of the duty officer on this issue has not yet had adequate instructions on the ship.

2. Minimum safety distance requirements when operating intended maritime routes
In order to operate the ship route at sea through an area with maritime dangers, it is necessary to determine the distance to that dangerous point in order for the ship to be safe [6-10]. The basis for
determining the safe limit is the accuracy of the ship position determined in that actual condition (figure 1).

Figure 1. Margin of safety (MOS).

Assuming the need to lead a ship from Hai Phong (Hon Dau) to Da Nang (Ly Son), a marine officer should take the following steps:

- Studying documents, maritime safety information, etc. to operate the route from A → B safely and economically,
- The ship route, in addition to the initial element of depth needs to determine a safe distance from maritime hazards. Assuming there is S beach, a safe d_{min} distance is needed, this distance is determined based on the accuracy of the specified position on board.
- Suppose on board a vehicle can determine its position with accuracy judged by a circle centered on F_1, a radius M (95%). To ensure safety, request d_{min}> M. Satisfying this condition, if the AB route is run properly, it will be safe for the ship to pass through Shoal S at the main position F_2.

3. Assess the accuracy of the ship position
As stated above, in order to determine the minimum distance d_{min} to a hazardous area, the accuracy of the location of the vessel on the nearest danger zone must be assessed. Essentially determining the area of probability containing the ship’s position. In theory, the accuracy of a given location can be judged by the area of probability that is a parallelogram, ellipse or error circle. In practice, however it is common practice to use a probability circle with a radius as the average square error of a given position [11].

3.1 The purpose of an assessment of ship position accuracy
Identify the causes of errors: The determination of the causes of errors to take measures to improve the accuracy of the identified location in the process of determining the location of ships. In the process of determining the location of ships, measures to improve the accuracy of the location are shown in practical cases such as: Maritime officers conduct the selection of targets to get the best grip angle θ;
using a long range scale reasonably when measuring distances with radar; choose target closer when measuring azimuth, etc. All these skills are applied based on the analysis of the causes of errors.

Identifying errors and assessing the accuracy of the determined position to guide the ship: The determination of the error and the evaluation of the accuracy of the ship’s position are the basis for the intended maritime declaration operation as well as the determination of the security limit, safety and frequency of ship location.

Resolution A.529(13) [4] of the International Maritime Organization (IMO), adopted on November 17, 1983, provides for the accuracy standard of the position of ships of less than 30 nautical miles hours / hours specified (table 1).

| Phase of voyage          | Oder of accuracy                                      |
|-------------------------|-------------------------------------------------------|
| Harbour entrances, etc. | Depend on local circumstances                         |
| Other waters            | 4% of distance from danger with a maximum of 4         |
|                         | nautical miles                                        |

Thus, in case of maritime in limited waters, the port area does not have specific standards for accuracy of ship position. However, when navigating a ship in this area, there is always a high demand for accuracy of the ship’s position and other requirements need to be prioritized such as: time to locate the ship, continuity or ability. Safe ship position control. The remaining maritime area has specific standards for position accuracy. Especially when coastal shipping, the accuracy requirements of the ship position determined by any positioning methods and systems need to be accurately calculated [4], [5]. There are many methods of locating a ship but these days it is mainly applied to locate the radar board and the GPS receiver.

3.2 The purpose of an assessment of ship position accuracy
The ship runs in the direction of 1150 passing through the wreck of S. The maritime area has many favourable geographic targets for determining the location of the ship by radar. Radar position has high accuracy and reliability. To determine the minimum safe distance to S beach, it is necessary to determine the position error of the ship. Figure 2 illustrates the case of determining the location of F1 ship by two simultaneous radar distances to two targets A and B. The error of F1 positioning is calculated as follows [6]:

\[
M_1 = \pm \frac{1}{\sin \theta} \sqrt{\Delta n_1^2 + \Delta n_2^2} = \pm \frac{\sqrt{2} \varepsilon_D}{\sin \theta}
\]

with:
- \(M_1\) – the average square error of the specified position,
- \(\theta\) – the angle between two position lines,
- \(\Delta n_1, \Delta n_2\) – the average square displacement of the position line,
- \(\varepsilon_D\) – the average square error of the radar distance.

Figure 2 illustrates the case of determining the position of the ship by two simultaneous radar distances to two targets A and B. The corresponding distances are two and two, DA and DB, from the estimated position of the clamping angle to two, the objective is the angle between the two distance position lines simultaneously [7]. Average square error of distance measurement by radar can be obtained in two ways: Marine officers determine by themselves the method of average square error on board or refer to the actual survey data available, example using nautical errors [8]. The average square error radius of the position determined by two simultaneous distances F1 is:
\[ M_1 = \pm \frac{0.51\sqrt{2}}{\sin 66^\circ} = 0.08 \text{NM} \]

Probability of containing vessel position of center circle F1, radius M1 is 65%, in maritime use 95% probability, equivalent \( M_2 = 2M_1 = 0.016 \text{ NM} \). Improving safety, using radius \( M_3 = 3M_1 = 0.24 \text{ NM} \), the probability of containing ship position is 99.7%. Thus, where it is possible to determine the position of the ship by two radar distances simultaneously to two targets before crossing the area of dangerous shoals S, the minimum distance is determined as: \( d_{\text{min}} > M_3 \). Then, if leading the ship along the designated AB route, at position (F2) main horizontal closest to Shoal S, the ship's position within the probability area is a circle (F2, M), ensuring safety.

![Figure 2. Safety limit when a position is identified by radar.](image)

3.3 Safety limit when boat position is determined by GPS receiver

In maritime practice, the position of the ship is determined to be the most probable position and will be the center of the circle of probability area containing the ship's position (figure 3). However, there is no basis to confirm that the determined position is the most probable position. On the other hand, the probability circle containing the ship position is scalar. Assuming there is a case where the ship position is within the boundary of the probability circle, this results in an area of probability that contains the ship's position very different from the conventional definition. The location distribution determined by the GPS system is diverse, the area of probability is difficult to determine.

![Figure 3. Ship position distribution in probability area.](image)
3.4. Calculate the area of probability containing ship locations

The ship's position is determined by a GPS receiver operating on the chart, the average square error of the ship's position can be determined experimentally as follows:

At a fixed position, locate the ship "n" repeatedly with a GPS receiver. The center of probability area is "O" with the following coordinates:

Latitude: \( \varphi_o = \frac{1}{n} \sum_{i=1}^{n} \varphi_i \) \( ( \varphi_i \) is the latitude position received for the “i”)

(1)

Longitude: \( \lambda_o = \frac{1}{n} \sum_{i=1}^{n} \lambda_i \) \( ( \lambda_i \) is the longitude the position has received for the "i")

(2)

Applying the method of average square error. Latitude for latitude and longitude for a given position are calculated as follows:

\[ \Delta\varphi_i = \sqrt{\frac{1}{n-1} \left( \sum_{i=1}^{n} \Delta\varphi_i \right)} \]
\[ \Delta\lambda_i = \sqrt{\frac{1}{n-1} \left( \sum_{i=1}^{n} \Delta\lambda_i \right)} \]

(3)

(4)

The error of distance (probability area radius) of ship position is calculated by the following formula:

\[ M = \sqrt{(\Delta\lambda)^2 + (k\Delta\varphi)^2} \]

(5)

with \( k = \frac{D}{\varphi} \) is the increase in the proportion of chains along the meridians and parallels.

Latitude forward:

\[ D = 7929,915 \cdot \log_{10} \left( \tan \left( \frac{\pi}{4} + \frac{\varphi}{2} \right) \times \left( \frac{1-e \sin\varphi}{1+e \sin\varphi} \right)^{\frac{3}{2}} \right) \]

(6)

Equatorial region or latitude limited from 30°N ÷ 30°S, the chain rate increase is not large, the radius of a circle of probability area containing the ship's position determined by a GPS receiver can be approximated according to the formula:

\[ M = \sqrt{(\Delta\varphi)^2 + (\Delta\lambda)^2} \]

(7)

The radius M calculated for one time the average square error according to formula (5) has a probability of containing the ship position of 65%. In shipping often the area of probability M (95%) or M (99.97%) should be calculated for three times the average square error of 3M.

Therefore, when traveling in the area of reliability of GPS locations is poor, maritime officers need to determine the area of probability containing the ship's position. The average square error radius M3 of the probability circle containing the vessel position 99.7% that the basis for determining a safe distance: \( d_{\text{min}} > M_3 \).

4. Assess the accuracy of the ship position

Section 3 shows how to determine the safe limit (the minimum distance to the nearest danger point \( d_{\text{min}} \)). Figure 2 illustrates the case of a ship safely sailing through the nearest hazardous area shallow beach S if the correct maritime route A → B is followed and the conditions are met \( d_{\text{min}} > M(99.7\%) \) (with \( M(99.7\%) \) is the radius area of probability containing the ship's position 99.7%).

Leading ships on the right routes must determine the position of ships by various methods to adjust the estimated positions. The necessity of determining the frequency of locating reasonable ships is illustrated in figure 4.
Supposing that the location of the vessel (F₁) is equal to two radar distances simultaneously to two targets A and B at 08:00. The distance to the nearest maritime danger point is \( d_{\text{min}} = 10\text{NM} \), the accuracy of the position determines \( M(95\%) = 0.3\text{NM} \). Refer to table 2 to calculate the time interval between two consecutive ship locations:

With \( d_{\text{min}} = 10\text{NM} \), the required accuracy is 1.2 NM, a definite position on board in this case satisfies the condition: \( M(95\%) = 0.3\text{NM} < 1.2\text{NM} \).

To ensure safety, the time interval between two consecutive locations to determine the actual ship location must be smaller than the time calculated in table 2. With \( d_{\text{min}} = 10\text{NM}, M(95\%) = 0.3\text{NM} \), refer to table 2, the maximum ship location time is 45 minutes. On the ship there are usually times of determination: continuous, 15 minutes, 30 minutes and 01 hour. Therefore, the minimum time interval between two consecutive ship location determinations for this case is 30 minutes.

**Table 2. Accuracy standards.**

| Minimum distances from danger (n.m.) | Accuracy required (n.m.) | Accuracy of position – fixing system (n.m.) |
|-------------------------------------|--------------------------|---------------------------------------------|
|                                     |                          | 0.0  | 0.1  | 0.25 | 0.5  | 1.0  | 2.0  |
| 10                                  | 0.4                      | 12   | 12   | 9    | —    | —    | —    |
| 20                                  | 0.8                      | 28   | 28   | 27   | 22   | —    | —    |
| 30                                  | 1.2                      | 48   | 48   | 47   | 44   | 27   | —    |
| 40                                  | 1.6                      | 72   | 72   | 71   | 68   | 56   | —    |
| 50                                  | 2.0                      | 100  | 100  | 99   | 97   | 87   | —    |
| 60                                  | 2.4                      | 132  | 132  | 131  | 129  | 120  | 73   |
| 70                                  | 2.8                      | 168  | 168  | 167  | 165  | 157  | 118  |
| 80                                  | 3.2                      | 208  | 208  | 207  | 206  | 198  | 162  |
| 90                                  | 3.6                      | 252  | 252  | 251  | 250  | 242  | 210  |
| 100                                 | 4.0                      | 300  | 300  | 300  | 298  | 291  | 260  |

At the specified position (F₁), the probability circle contains the ship's position is (F₁,M), suppose the ship's actual position in this case is (F₁₁), lies on the boundary of probability area.

**Figure 4.** Frequency of locating the ship.
At 08h30m, the ship is determined by two radar distances simultaneously to two targets A and B are located (F2). The duty officer is aware of the drift of the ship, adjusting the direction to return to the AB route. Therefore, the ship passed the shallow beach (S) safe in the most dangerous position (F3).

In case the frequency of locating reasonable ships is not determined, the regular ship identification interval is 01h. Assuming the ship's actual location at 08:30 am (F21), lie on the boundary of the probability circle (F2,M). By the time it was time to locate the next ship at 09:00, the ship was exhausted at the location (F3). This example demonstrates the need to calculate the frequency of determining a reasonable ship position to ensure safety when navigating near maritime hazards (figure 4).

The above example shows that it is necessary to calculate the frequency of determining a reasonable ship position to ensure safety when sailing near maritime hazards. In summary, in order to operate the proposed maritime route and lead the ship through the danger area the following steps must be carried out:

B1: Determine the distance to a maritime danger point.
B2: Selecting the method of determining the location of the ship to apply in the danger area.
B3: Calculate the error of the determined position according to the selection method.
B4: Decide on safety limits, ensure distance to the nearest danger point $d_{\text{min}}$ must be greater than the radius of the circle of absolute probability of containing the ship's position: $d_{\text{min}} > M(99.7\%)$.
B5: From the parameters $d_{\text{min}}, M (99.7\%)$, Calculated according to table 2 to apply the frequency of locating reasonable ships.

5. Conclusion
Operating the proposed maritime route is the most important basis for safe and economic trip planning. Stemming from the practical problem when constructing an expected maritime route from the port of departure to the port of destination, the maritime officers always have problems in determining the theoretical and practical basis when performing specific operations. be. The article has addressed the goal given in the problem statement, specifically as follows:

Safety limit is considered to be a safe distance from a maritime danger point. This value should be greater than the radius of the circle, the absolute probability of the location being determined in the hazardous area ($d_{\text{min}} > M(99.7\%)$).

The time interval between two consecutive ship locations (frequency of ship location). This value is calculated according to the provisions of resolution A.529 (13) of International Maritime Organization with the reference parameters are: the accuracy of the position determined M (99.7%) and the distance to the point nearest maritime danger ($d_{\text{min}}$). The calculated time period is combined with the actual applicable time period for making appropriate recommendations.

Finally, the newspaper provides basic steps to manipulate safe maritime routes through hazardous areas. The implementation process has a sufficient theoretical basis and practical evidence through cases applied in coastal areas of Vietnam.

References
[1] IMO 2006 Passage planning principles
[2] IMO 2006 Passage planning practice
[3] IMO 2018 International Safety Management Code
[4] IMO 1983 Resolution 529(13) Accuracy Standards for navigation
[5] IMO 1995 Resolution 813(19) General requirements for electromagnetic compatibility (EMC) for all electrical and electronic ship’s equipment
[6] Pham K Q, Nguyen T D and Nguyen P H 2012 Terrestrial navigation 2 textbook. Science and Technology Publisher
[7] Januszewski J 2014 The International journal on marine navigation and safety of sea transportation 8
[8] Simon C J, Dupuy D E and Mayo-Smith W W 2005 RadioGraphics 25 69–83
[9] Brace C L 2009 *Current Problems in Diagnostic Radiology* 38(3) 135–43
[10] Chang Y, Che W, Yang L, Yang L and Chen G 2008 *Proceedings of the International Conference on Microwave and Millimeter Wave Technology (ICMMT 08)* 4 1703–6
[11] Nathaniel B 1995 *The American Practical Navigator* (National Imagery and Mapping Agency, Bethesda, Maryland)