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Original article

A Study on the Risk Analysis based on the Trajectory of Fishing Vessels in the VTS Area*

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Abstract

According to the statistics of the last five years, fishing vessel accidents accounted for about 80% of collisions of all ships and has led to many casualties. To prevent collision accidents, it is important to assess the collision risk potential related to the sailing characteristics of fishing vessels. The authors represented the traffic patterns of vessels that sail around Wando waters based on Automatic Identification System (AIS) and Radio Detecting and Ranging (RADAR) data. The authors analyzed the statistical near miss data between fishing vessels and non-fishing vessels in the Wando Vessel Traffic Services (VTS) area and assessed the risk of ship collisions. From this research, the authors identified waters with a high risk of ship collisions. The analyzed results can be used as basic data to develop collision prevention strategies which aides the decision making and efficient operation of VTS officers (VTSO).

Keywords: Collision accident, Traffic pattern, Near miss, VTS

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I. Introduction

Registered fishing vessels in South Korea account for about 88% of the registration of all vessels. Our inquiry found the major causes of fishing vessel collision accidents occur because of poor look-out and restricted maneuverability during fishing operations. In addition, fishing vessels of less than 45M, which account for 99% of the registered fishing vessels, are not mandatorily required to participate in VTS. VTS are shore-side systems which range from the provision of simple information messages to ships, such as position of other traffic or meteorological hazard warnings, to extensive management of traffic within a port or waterway.

Previous studies on the marine accidents of fishing vessels, according to Park et al. (2013), undertook questionnaire surveys of seamen on the role of human error in the collision. Lee et al. (2013) considered the basic cause and preventive measures of fishing/non-fishing vessel collision accidents, which were reported by the Korean Maritime Safety Tribunal. Lee and Chang (2005) analyzed the types of errors and casual relationships between human error in human accidents. Kang (2011) studied the casual relationship between fishing vessel accidents and marine meteorological by collision written verdicts. Most studies in the field of collision accidents have only focused on cause analysis by human error. To prevent fishing vessel collisions, it is necessary to understand sailing characteristics such as the trajectory of fishing vessels that are subject to accidents.

According to Heinrich’s Law, near miss situations correspond to the detection of some several thousand hidden unsafe situations behind one obvious case of an accident (Inoue et al., 2007). Many near misses have accumulated to cause the occurrence of one big collision on the sea. The authors analyzed the near miss statistics between fishing vessels and non-fishing vessels to find waters with high risk of collisions. The purpose of this paper is to assess the risk of ship collision by analyzing the maritime traffic patterns based on the trajectory of vessels, which has not been discussed in previous studies, in the Wando VTS area.

This paper is organized as follows: Section 2 is concerned with the maritime traffic environment and statistics on collision accidents in Wando waters. Section 3 analyzes traffic patterns according to the vessel trajectory. Section 4 represents collision risks based on the analyzed near miss between fishing vessels and non-fishing vessels. The conclusion is drawn in Section 5.

II. Current status of the Wando VTS area

2.1. Maritime traffic environment

The Wando VTS area includes a main route connecting the east and west of the southern coast of South Korea and accounts for 70~80% of fish farming. Because these fish farms are located near fairways, they pose a danger to the safety of navigation of vessels. Cross waters pose a risk of collision between crossings from east to west and vertical passenger routes north to south. Furthermore, there is difficulty in the maneuverability of vessels in strong currents and in narrow waters. Table 1 represents the traffic volume in the Wando VTS area. Daily average traffic volumes are 220 vessels in the Wando VTS area; passenger ships accounted for about 48% of traffic.

Table 1: Traffic volume in the Wando VTS area (2013 year)

Division	Volume (The number of ships)	Percentage
Passenger ship	38,579	48%
Merchant ship	8,507	10%
Other ship	33,250	42%
Total	80,336	100%

2.2. Collision accidents in Wando VTS area

Five collision accidents between fishing vessels and non-fishing vessels have occurred in the Wando VTS area during the last 10 years. Fig.1 shows the location of collision accidents that occurred in the Wando VTS area. All accidents occurred in a fairway on passenger ship routes and traffic separation schemes.

Figure 1: Collision accidents in the Wando VTS area

Table 2 shows detailed analysis of collision accidents. According to the official verdict, the cause of all collision accidents was found to be because of poor look-out.

Table 2 : Collision accidents analysis in the Wando VTS area

Year	Kind of Vessel	Gross tonnage (ton)	Cause	Weather
2007	Fishing vessel / Cargo vessel	69 / 1,482	Poor look-out	Fine
2008	Fishing vessel / Cargo vessel	15 / 2,064	Poor look-out	Fine
2009	Fishing vessel / Cargo vessel	5 / 1,249	Poor look-out	Fine
2010	Fishing vessel / Cargo vessel	180 / 2,821	Poor look-out	Restricted visibility
2011	Fishing vessel / Tug boat	79 / 324	Poor look-out	Bad weather

III. Sailing characteristic in the Wando VTS area

3.1. Trajectory of fishing vessels and non-fishing vessels

To extract the trajectory of vessels, the authors collected the AIS data and RADAR data of vessels sailing around the Wando VTS area for 3 days (72 hours). Then, the trajectory of fishing vessels and non-fishing vessels was represented using the MATLAB program.

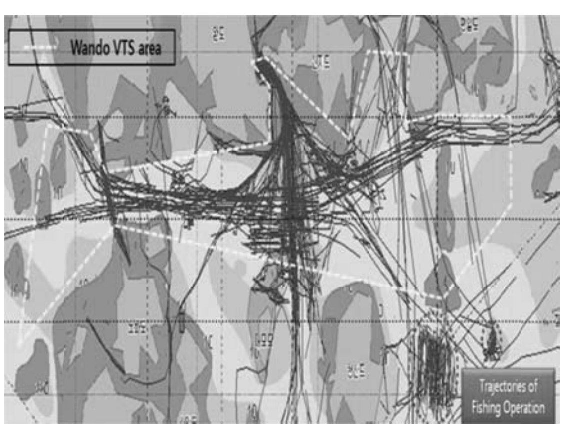

Figure 2(a): Trajectory of fishing vessels

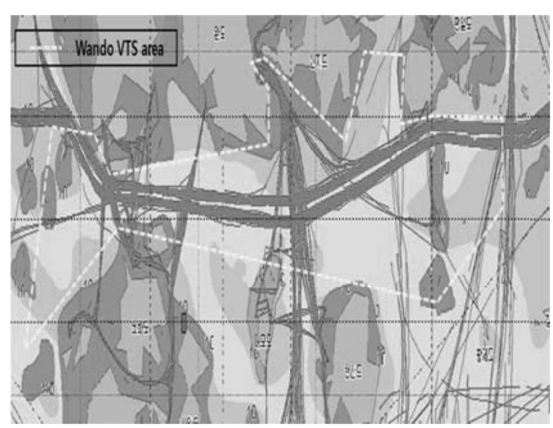

Figure 2(b): Trajectory of non-fishing vessels

Fig.2 (a) shows the trajectory of fishing vessels for 3 days. Fishing vessels sail in a disorderly manner and do not keep to the fairway. The range of the crossing intersection is widened for the fishing vessel and non-fishing vessel because the fishing vessel crosses obliquely, not on a right angle crossing, to sail the shortest distance to the destination. Fig.2 (b) shows the trajectory of non-fishing vessels for 3 days. In contrast to fishing vessels, the non-fishing vessels have the characteristics of sailing along the recommendation route. The North-south passage and east-west passage are distinctly distinguished. It is also easy to clearly find the passage and port of call.

3.2. Mean speed of fishing vessels and non-fishing vessels

Fig.3 represents the speed distribution of fishing vessels and non-fishing vessels sailing in Wando waters. Fig.3(a) shows that the mean speed in fishing vessels is 9.5 knots. For non-fishing vessels, the mean speed is 10.1 knots. In the case of fishing vessels, speeds of less than 5 knots were relatively much more common compared with non-fishing vessels.

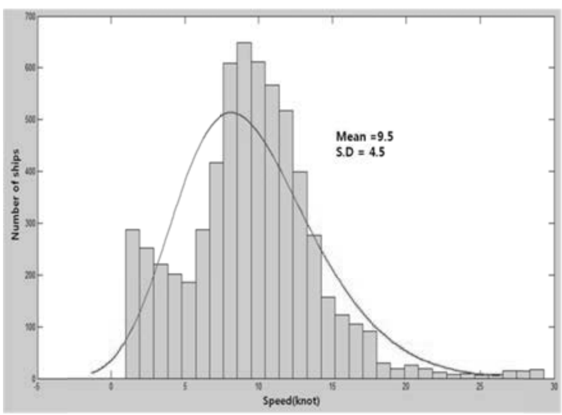

Figure 3(a): Speed and S.D of fishing vessels

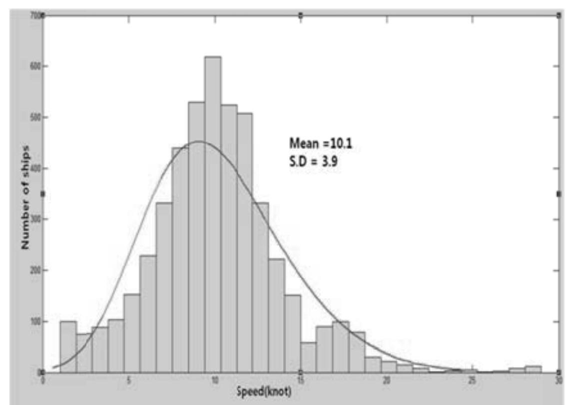

Figure 3(b): Speed and S.D of non-fishing vessels

IV. Near miss in the VTS area

4.1. Application of Near miss

A theory applicable to ship collisions is known as Heinrich's Law, in a workplace, for every accident that causes a major injury, there are 29 accidents that cause minor injuries and 300 accidents that cause no injuries (Heinrich, 1980) as shown in Fig.4. This theory can be applied to marine accidents. Repeated incidents that come close to collisions will lead to big accidents. According to Heinrich's Law, to prevent big accidents, it is necessary to reduce the minor incidents.

Figure 4: Heinrich's Law

Near miss can be defined as a situation in which two ships come close to collision although a collision accident does not occur. While the collision accident is an important part of the risk assessment, this section focuses on the situation of coming close to a collision. The authors fixed no more than 0.3NM of DCPA (Distance to Closest Point of Approach) and no more than 5min of TCPA (Time to Closest Point of Approach) as near miss in light of the maritime traffic environment of the Wando waters. These values were obtained by "bumper area," defined as the area a vessel actually occupies the waterway and includes a zone around the vessel in which other vessels' bumper areas should not overlap (Frandsen et al., 1991). But these values are not always applicable in all situations: they can change according to traffic volume, weather or other factors.

4.2. Near miss results

The authors analyzed near collisions in light of DCPA and TCPA between fishing and non-fishing vessels in the Wando VTS area. From the results of the analysis, the authors can find the high risk waters for collisions between fishing vessels and non-fishing vessels. The analysis criterion of near miss is shown in Table 3.

Table 3 : Criterion of Near Miss

Encounter Type	Difference in heading between two vessels	Application Criteria	Period
Overtaking	000°~020°	· DCPA : 0.3NM · TCPA : 5min	Jan 4, 2013~ Jan 6, 2013 (3days)
Head-on	160°~180°		
Crossing	020°~160°		

Fig. 5 shows the occurrence point of near miss in the VTS area. As shown in Fig.5 (d), waters of high risk of collision are intensively distributed passenger ship routes, traffic separation schemes and the entrance of Wando harbor.

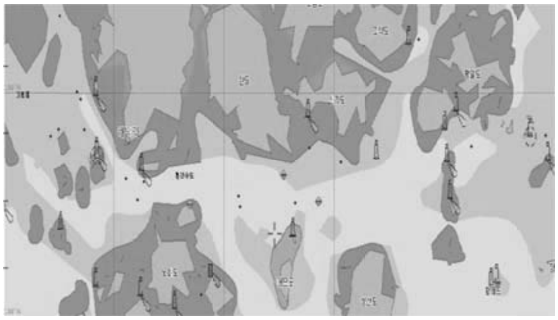

Figure 5(a): Overtaking Near misses

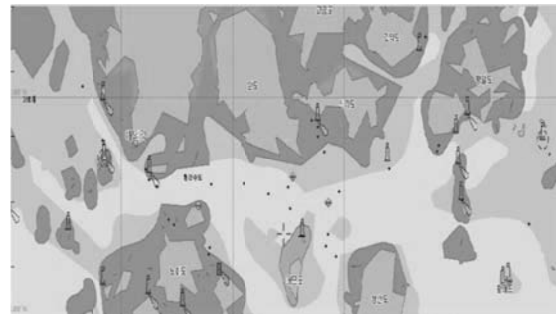

Figure 5(b): Head-on Near misses

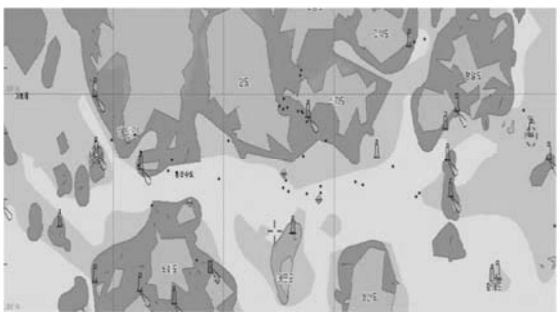

Figure 5(c): Crossing Near misses

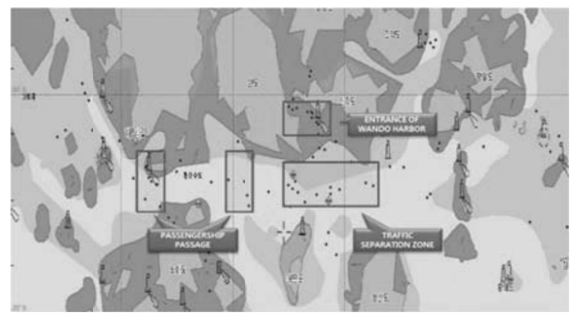

Figure 5(d): All Near misses

Encounter situations can be classified into three types: overtaking, head-on, crossing. As shown in Fig. 6, a total of 83 incidents were identified in the period under analysis. According to the encounter type, crossing in 45% of cases posed the highest risk of collision, and the next frequent cases were head-on (34%), and overtaking (21%)

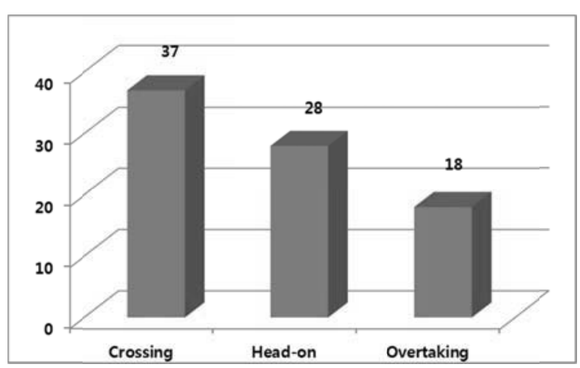

Figure 6: Frequency by encounter type

Based on the above results, the authors calculated the occurrence probability of a near miss for passenger ship routes, traffic separation schemes and the entrance of Wando harbor for high risk in the VTS area. The occurrence probability of near miss, P_r , is given by:

$$P_r = \frac{N_c}{N_t} , \tag{1}$$

Where P_r= the occurrence probability of near miss; N_c = the number of near miss; and N_t = traffic volume in the designated area. According to the above formula, the authors calculate the occurrence probability as shown in table 4.

Table 4: Occurrence probability of near miss classified in 3 zones

Zone	The number of Near miss	Traffic volume (The number of ships)	Occurrence probability of near miss
Passenger ship passage	11	110	0.10
Separate traffic scheme	12	90	0.13
Entrance of Wando harbor	10	85	0.12

Table 4 shows that occurrence probability of near miss in separate traffic scheme zone was 0.13 with the highest probability, and the next highest probability was the entrance of Wando harbor (0.12), followed by passenger ship passage (0.10).

Compared to other waters in the Wando VTS area, the above three traffic waters show relatively higher occurrence probability of a near miss between fishing vessels and non-fishing vessels. Accordingly, it is considered that VTSO should focus more on sailing vessels in those areas for the purpose of preventing collisions.

V. Conclusion

To prevent collision accidents of vessels, cause analysis of previous studies is important, but it is also important to understand the sailing characteristics of vessels. The objective of this paper was to analyze the traffic patterns based on the trajectory sailing around the Wando VTS area and assess the collision risk between fishing vessels and non-fishing vessels according to near miss analysis. While non-fishing vessels keep to the fairway, fishing vessels represent a risk of collision with non-fishing vessels caused by irregular sailing patterns. Waters of high risk collision between fishing vessels and non-fishing vessels are concentrically distributed passenger ship routes, traffic separation schemes, and the entrance of Wando harbor.

For results of encounter type between two vessels, crossing at 45% was the highest risk of collision. The occurrence probability of near miss shown was between 0.10 and 0.13 on average in the above-mentioned waters. Based on these results, Wando VTSO needs to provide safety information such as risk of collision to sailing vessels in the Wando VTS area.

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