Journal of the Korean Society of Marine Environment & Safety
Research Paper
Vol. 25, No. 3, pp. 298-305, May 31, 2019, ISSN 1229-3431(Print) / ISSN 2287-3341(Online) https://doi.org/10.7837/kosomes.2019.25.3.298

Consideration of the Possibility of Excursion Ship Passage in Busan North Port using Marine Traffic Assessment Index

Young-Soo Park*† · Myoung-ki Lee** · Jin-kwon Kim*** · Yun-Sok Lee*** · Min-Jeong Park***

*, *** Korea Maritime and Ocean University, Busan 49112, Korea

** Ocean Science and Technology school, Korea Maritime and Ocean University, Busan 49112, Korea

Abstract : *The demand for the revitalization of marine tourism in Busan North Port is increasing due to changes in functions such as an increase in harbor traffic volume and the expansion of marine leisure space in Busan. As a result, Busan City plans to set a phased alleviation target for prohibition of cruise ship operations, and to lift the prohibition of excursion ship operations in North Port following the cancellation of the prohibition of excursion ship operations in South Port in 2017. The purpose of this study is to evaluate the risk of excursion ship operations in Busan North Port by applying the marine traffic assessment index and to examine the possibility of excursion ship operations. For this purpose, port status, marine accidents, and traffic flow of Busan North Port were investigated. In addition, marine traffic assessment indexes, such as traffic congestion, risk based on an ES Model, and IWRAP MkII, a maritime risk assessment tool, were used to assess the risk and possibility of excursion ship operations in Busan North Port. This study can be used as basic data for analyzing the risk factors that may occur when excursion ships are operated in Busan North Port and to define how excursion ships should operate, with related safety measures.*

Key Words : *Busan North Port, Excursion ship operation, Marine traffic congestion, ES model, IWRAP Mk II*

1. Introduction

According to statistics from the Ministry of Culture, Sports and Tourism and the Ministry of Oceans and Fisheries, the proportion of marine tourism as a form of domestic travel is expected to increase from 56 % in 2016 to 60 % in 2020 and to 70 % in 2030. In addition, the United Nations World Tourism Organization (UNWTO) announced that in 2020, six of the 10 major tourism trends will be related to marine tourism, and that marine tourism has a great potential for growth (Busan.com, 2018). Busan is also developing a variety of marine tourism products such as cruise ships in connection with local tourist attractions in the port city of Busan. In recent years, Busan City has promoted the 'Project on the Revision of the Central Laws and Regulations', designed to identify and solve various regulations that hinder regional development. As a result, a phased alleviation target for prohibition of cruise ship operations was defined, and Busan City cancelled the prohibition of excursion ship operations in South Port. The functioning of Busan North Port changed especially due to the movement of port trade and the expansion of marine leisure space because of the development of peripheral ports. As a result, the demand for the revitalization of marine tourism is increasing, and it is expected that the operation of excursion ships in the port will be revitalized. However, large vessels are still utilizing Busan North Port, and there is a risk of vessel traffics.

Until now, it has been hard to find studies identifying risk levels for Busan Port, including Busan North Port, or on the preparation of alternative measures. There is, a study on the improvement of the fairway or strengthening the control of VTS for naval vessels and tugboats (Lee et al., 2007), and a study on the reduction of ship maneuvering difficulties through the introduction of a roundabout separation into the access sea area of Busan Port (Kang et al., 2001), etc. However, there are no studies related to the operation of high speed vessels and excursion ships in Busan Port.

The purpose of this study is to assess the risk and possibility of excursion ship operations in Busan North Port by using the maritime traffic assessment index. For this purpose, port status, marine accidents, and the traffic flow of Busan North Port were investigated. In addition, marine traffic assessment indexes, such as traffic congestion, risk based on an ES Model, and IWRAP MkII, a maritime risk assessment tool, were used to assess the risk and possibility of excursion ship operations in Busan North Port.

† Corresponding Author : youngsoo@kmou.ac.kr, 051-410-5085

2. Analysis of the status of Busan North Port

2.1 Investigation of port status of Busan port

Busan Port is the first port in Korea that opened in 1876. It is the world's second largest transshipment port and the sixth largest container port in the world. It is composed of North Port, New Port, Gamcheon Port, and Dadaepo Port. As of 2017, North Port has 5 container terminals, 1 TOC terminal, and 12 general cargo terminals, with 6 anchorages (BPA, 2017a). With the opening of the Busan New Port, it is necessary to move and rearrange the conventional and container harbor traffic volume (North Port → New Port) and to re-adjust the North Port functioning. Currently, the Busan North Port redevelopment project is being promoted to strengthen social functions such as the expansion of the new concept marine leisure space centered on Busan North Port. Fig. 1 represents the pier and berth arrangement of the Busan North Port (BPA, 2017b).

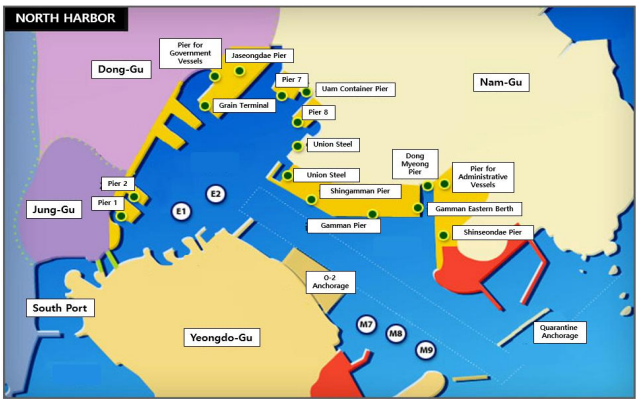

Fig. 1. Position of Busan North Port's piers and anchorages.

There is a speed limit of 10 knots in fairways over 18m in depth in Busan North Port's inner and outer port, and 5 knots in shallow water fairways. Also, when navigating from the outer port to the inner port, the height of Busan Port Bridge and the opening time of the bridge should be considered. In addition, it is necessary to follow the Traffic Separation Scheme near Busan Port and especially, it is necessary to pay attention to the fishing net of the port when navigating at night (National Geospatial Intelligence agency, 2014).

2.2 Investigation of marine accidents status in the vicinity of Busan Port

A total of 267 offshore accidents occurred in the vicinity of Busan Port in the last 5 years, showing a steady increase from 2014 to 2016, and a slight decrease from 2017 onwards. In the number of marine accidents by type of accidents, the number of engine and steering gear failures was the highest at 67, collision and contact at 56, and marine pollution at 42. In the number of marine accidents by ship type, the number of merchant vessels was the highest at 129, fishing boats at 92, and yachts and boats at 34 (KMST, 2018). Fig. 2 shows the marine accidents in the vicinity of Busan Port in the recent 5 years.

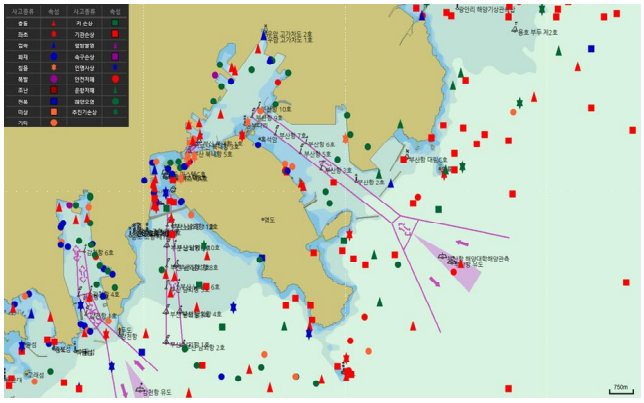

Fig. 2. Location map of marine accidents in the sea near the Busan Port.

The locations of traffic accidents which are collision, stranding, and contact accidents are related to the purpose of this study are as follows. Accidents occurred a lot at the south outer port fairway and anchorage, the area of sea near Saengdo, Busan bridge and anchorages in Busan North Port, etc. Especially in the North Port, accidents occurred more frequently in places where the traffic flow outside the fairway was not constant, than on the inside.

2.3 Traffic survey and traffic flow analysis

In order to devise the navigation method for excursion ships when introducing them in Busan North Port, the characteristics of the traffic flow at the No. 1 fairway are analyzed. As a result, the flow can be divided into three types – the ship navigating along the No.1 fairway, the ship departing or joining the fairway for berthing to Shinseondae pier or the Gamman pier, and the ship leaving the fairway in the direction of the anchorage or joining the fairway from the direction of the anchorage. Fig. 3 shows the traffic flow in the No.1 fairway.

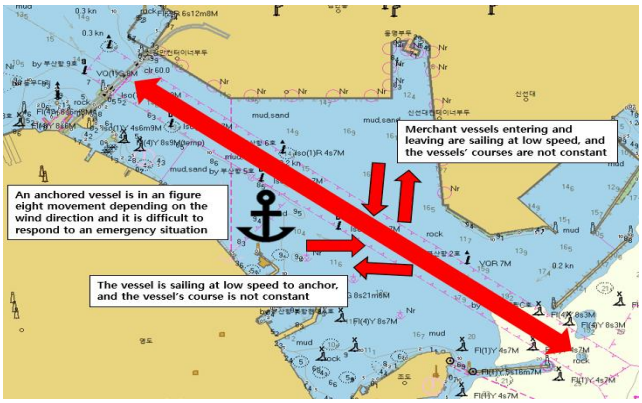

Fig. 3. Traffic flow in the No.1 traffic route.

The vessel following the No.1 fairway shall navigate at a speed of less than 8 knots in accordance with the Regulations on Busan Port Navigation, etc. However, in case of the vessel which is berthing at Shinseondae pier or Gamman pier, it must-mostly navigate at low speed and with inconsistent course. In addition, vessels that are anchored in the O-2, M-7 ~ 9 anchorages are not only to be navigated with low speed and with inconsistent course but also with 8-form movements according to the wind direction, and it is difficult to respond to emergencies (Lee and Kim, 2019).

3. Assessment of marine traffic according to excursion ship operation in Busan North Port

3.1 Marine traffic assessment based on the marine traffic congestion

(1) Outline of marine traffic congestion

Marine traffic congestion is a measure of the actual marine traffic volume as a percentage of the maritime traffic volume capacity for a certain fairway. If the marine traffic capacity is equal to the actual marine traffic volume, the marine traffic congestion value of the fairway becomes 100 %, which is considered to have reached the theoretical limit allowable for traffic capacity. It is often used as a simple indicator that represents the relative marine traffic capacity of the fairway and the congestion situation of the fairway on an average. The equation for calculating the marine traffic congestion is as follows (Park et al., 2013).

$$Q = \frac{1}{\gamma s} WV \quad (1)$$

$$Q_P = Q \times 0.25 \quad (2)$$

$$T_C = \frac{Q_T}{Q_P} \quad (3)$$

Here,

- Q : Basic traffic volume of fairway (vessels/h)
- γ : Occupied area's longest diameter (Km)
- s : Occupied area's shortest diameter (Km)
- W : Width of fairway (Km)
- V : ship speed (Km/h)
- T_C : Traffic Congestion
- Q_T : L2 converted Traffic volume per hour
- Q_P : Practical Traffic Volume

(2) Assessment of Busan North Port' s marine traffic congestion

The data of Busan Port traffic surveyed from April 28 to April 30, 2015, was used for the traffic congestion analysis in Busan Port No. 1, and the gate line was set to the lower part of Busan Port Bridge. The width of the Busan Port No.1 fairway is about 340m, and an average of about 196 vessels are in and out of the port per day, with an average of 8.2 vessels per hour. Especially, 08:00 to 09:00 can be regarded as the peak time with the largest number of 48 vessels passing through for 3 days. In this study, considering the narrow channel in the port, the congestion value was assessed by using the occupied area $(6.0L \times 1.6L)$ in the narrow channel and port. Also, the standard ship was defined as a ship with a total gross tonnage (G/T) of 1,000 tons and LOA of 70 m, which is close to the average coastal vessel of Korea. Table 1 shows the representative ship length and the L^2 conversion factor by tonnage.

Table 1. Ship length and L^2 conversion factor by tonnage

	LBP (m)	Representative ship length (m)	L conversion factor	L^2 conversion factor
Less than 100	7 ~ 26	20	0.29	0.08
100 ~ 500	26 ~ 50	40	0.57	0.32
500 ~ 3K	50 ~ 90	70	1.00	1.00
3K ~ 5K	90 ~ 110	100	1.43	2.04
5K ~ 7K	110 ~ 120	115	1.64	2.69
7K ~ 10K	120 ~ 140	130	1.86	3.46
10K ~ 20K	140 ~ 180	150	2.14	4.58
20K ~ 50K	180 ~ 220	200	2.86	8.18
50K ~ 100K	220 ~ 340	280	4.00	16.00
100K or more	300 ~	330	4.70	22.20

Table 2 shows the practical traffic volume calculated using this conversion factor.

Table 2. Practical traffic volume of Busan North Port

Width of fairway (m)	Average Speed (knot)	Longest Diameter	Shortest Diameter	Basic traffic volume (vessels/h)	Practical traffic volume (vessels/h)
340.0	10.50	6L	1.6L	140.55	35.14

The basic traffic capacity of Busan North Port is 140.55 vessels per hour and practical traffic capacity is 35.14 vessels per hour. Also, to investigate the change in congestion due to excursion ship operations, the congestion by time of one and three excursion ships operation per hour was analyzed. Since the size of the ship to be operated at Busan North Port is not fixed at this time, it is assumed that it is a small ship with a length of 50 m according to the berth capacity (500 DWT) of the excursion ship berth. Fig. 4 ~ 6 are graphs showing the congestion by time on each day.

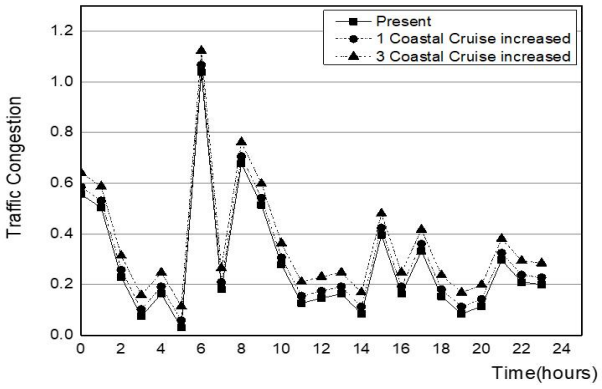

Fig. 4. Comparison of traffic congestion on Day 1.

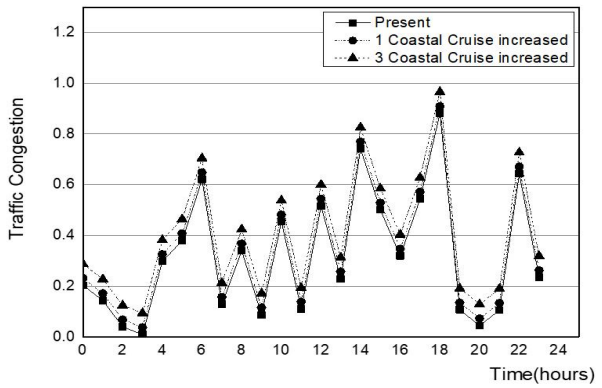

Fig. 5. Comparison of traffic congestion on Day 2.

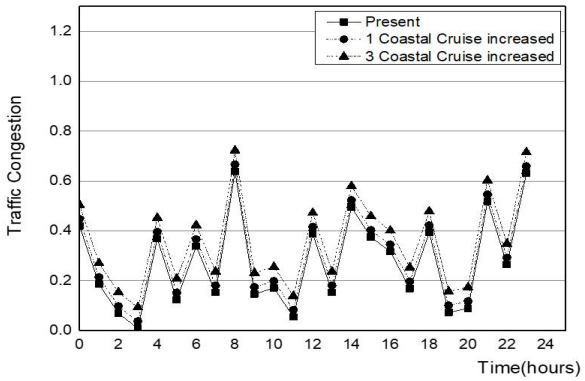

Fig. 6. Comparison of traffic congestion on Day 3.

Table 3 shows the traffic congestion at peak time (08:00 to 09:00), 3-day averages, 10:00 to 16:00 and the congestion calculation results for one and three excursion ships operation per hour at that time.

Table 3. Comparison of traffic congestion

Time		Peak time	Daily mean congestion	10:00 ~ 16:00
Day 1		0.6770	0.2800	0.1994
Day 2		0.3396	0.3197	0.4250
Day 3		0.6382	0.2729	0.2729
Mean congestion		0.5516	0.2909	0.2991
Maximum congestion		0.6670	0.3197	0.4250
If 1 excursion ship is sailing per hour	Mean	0.5797	0.3190	0.3273
	Max	0.7051	0.3478	0.4532
If 3 excursion ships are sailing per hour	Mean	0.6360	0.3531	0.3835
	Max	0.7614	0.4041	0.5094

The maximum congestion at peak time of Busan North Port was 67.70 %, and when 1 excursion ship is operated, the maximum congestion value increased by 2.81 % to 70.51 %. When 3 excursion ships are operated, the average congestion value increased by 8.44 % to 76.14 %. Also, the maximum congestion at peak time is 89.86 % when 8kts, the reference speed of Busan Port, is applied. There is a 3.74 % increase in the case of 1 excursion ship operation and 11.21 % increase in the case of 3 excursion ships operation, respectively. Therefore, although the congestion result increases somewhat depending on the number of excursion ships per hour, the analysis shows that it does not have a significant effect when one excursion ship is operated per hour.

3.2 Assessment of marine traffic based on ES (Environment Stress) Model

(1) Outline of ES Model

The ES model is a risk model that expresses the degrees of the operator's stress of ship maneuvering as a qualitative value and as an index of environmental stress value (ES value). The environmental stress value can be expressed from 0 to 1000, and it is classified into the Ship of ES value (ESS) determined by the risk of collision with other ships and Land of ES value (ESL) determined by the maneuvering environment such as obstacles and terrain. ES value is expressed as the sum of Subjective Judgment (SJ) for ship maneuvering and traffic. In this study, Busan North Port was assessed with ESS. The equation for calculating the environmental stress is shown in Equation (4) (Inoue et al., 1998).

$$\begin{aligned} SJS &= f(R / V) \\ &= \alpha \times (R / V \cdot V / Lm) + \beta \\ &= \alpha \times (R / Lm) + \beta \\ &= \alpha \times (R') + \beta \end{aligned} \quad (4)$$

Here,

SJS : Subjective stress on relative distance to other ships in collision relationship

R : Relative distance V : Relative speed

Lm : Average length of own ship and the other ship

R' : Relative distance with the other ship standardized from Lm

α,β : Factors determined by the encountering condition between own ship and the other ship

(2) Assessment of ESS at Busan North Port

Fig. 7 ~ Fig. 9 shows the ESS of vessels that passed through Busan North Port from 09:00 on April 9, 2019, to 09:00 on April 12, 2019, and plotted by color according to the degree of stress.

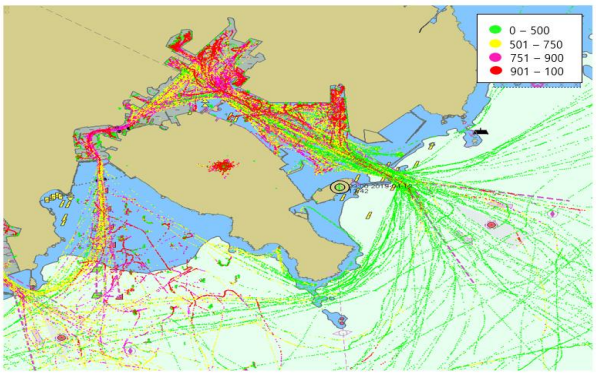

Fig. 7. Distribution of ESS Value on Day 1.

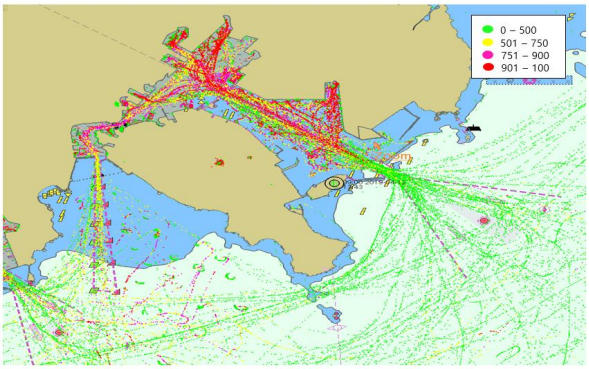

Fig. 8. Distribution of ESS Value on Day 2.

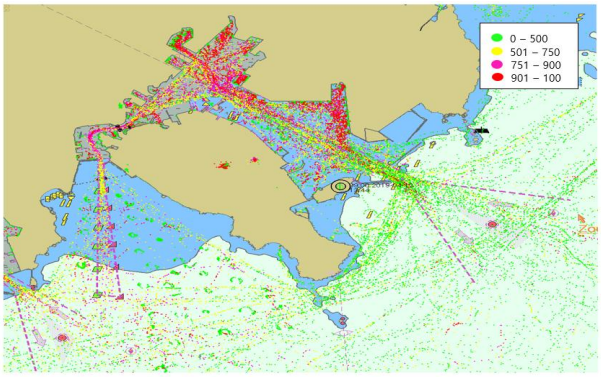

Fig. 9. Distribution of ESS Value on Day 3.

Utilizing the ES model – based ESS for Busan North Port, the No.1 fairway of Busan Port, it is evaluated that the vessel berthing at Shinseondae and Gamman pier, inside the Busan North Port and in the vicinity of the breakwater outside of port will be dangerous.

(3) Inference of ship maneuvering difficulties in Busan North Port

To make an inference of the ship maneuvering difficulties when excursion ships are operated in the Busan North Port, it was found out how much the ship maneuvering difficulties on the sea increased due to the increase in the number of vessels. A study on the degrees of ship maneuvering difficulties changed due to the increase in the number of existing vessels was referred to for this. The size of the excursion ship was assumed to be a small vessel of 50 m as mentioned earlier.

Fig. 10 is a graph showing the change in ship maneuvering difficulties due to an increase in the number of passing vessels per hour, divided into small, medium, and large sized vessels from 400 m to 1 mile of width of the fairway (Inoue and Park, 2000).

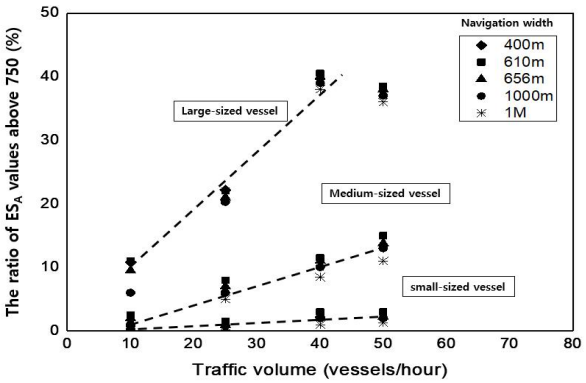

Fig. 10. The relationship between ship size and ship maneuvering difficulties.

When the traffic volume of the small vessels changed by 10 vessels, the ratio of ship maneuvering difficulties changed by 0.5 %. Therefore, the difficulty is 0.05 % for 1 excursion ship to be operated in Busan Port in the future, 0.25 % for 5 cruises and 0.5 % for 10 cruises. In other words, the ship maneuvering difficulties will increase slightly, but the rate of increase will not be too large.

3.3 Collision probability assessment based on IWRAP MkII

(1) Concept of IWRAP Mk II

IWRAP MkⅡ is the modeling tool used for maritime risk assessment. It is used to estimate the frequency of collisions and groundings in a given waterway based on information about traffic volume/composition and route geometry. Fig. 11 shows the concept of the IWRAP MkⅡ model calculation.

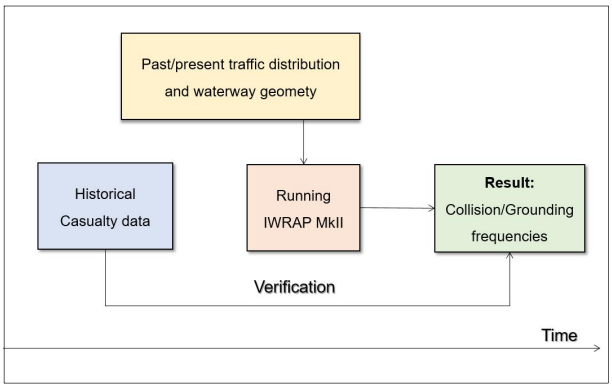

Fig. 11. Conception of IWRAP MkⅡ Model calculation.

This study has tried to calculate the collision probability, and the basic risk equation of IWRAP MkII that calculates the collision probability and it follows Equation (5) (IALA, 2010).

$$R = P \times C \quad (5)$$

Here,

R : Risk

P : Probability that undesired incident occurs

C : Consequences of undesired incident

(2) Assessment of the probability of collision in Busan North Port

The collision probability assessment of Busan North Port was based on the 7 days' traffic survey data from February 26 to March 4, 2019. Fig. 12 shows the traffic density by plotting the passing vessels in Busan North Port for 7 days.

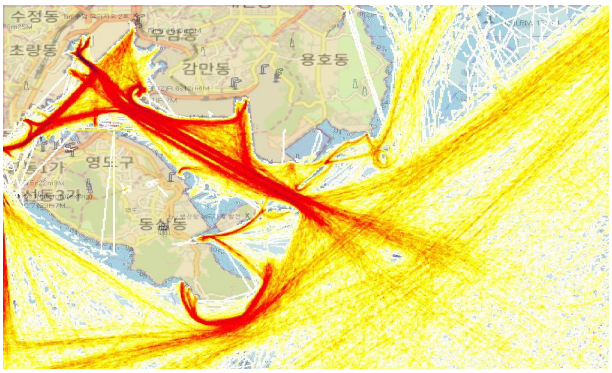

Fig. 12. Density plot of Busan North Port.

As a result of the distribution of density, the traffic density was high in both the No.1 fairway, which is inside the breakwater, and in the vicinity of each pier. The collision probability model was derived based on the traffic, and only the sea areas where excursion ships are likely to operate are considered at this time. As a result, the collision probability of the target area was analyzed to be 1.096 incident per year. Fig. 13 shows the collision probability of each leg by color.

Fig. 13. Collision probability evaluation result.

The results of the collision probability analysis showed that the collision probability was the highest in the vicinity of the No. 5 pier lighters wharf, where small vessels berthed mostly, and most in the No.1 fairway. Also, it is analyzed that the probability of collision with vessels going in and out of the container terminal was high.

The derived collision probability calculation model is applied to investigate the collision probability variation according to the excursion ship operations. The size of the excursion ship is assumed to be a small ship of 50 m as mentioned above, and the collision probability when 1 excursion ship and 3 ships per hour goes through is analyzed. Also, it is assumed that the excursion ship departs from the coastal passenger pier and moves through the breakwater in the direction of Oryukdo. Table 4 compares the present, and the cases of 1 and 3 excursion ships operations per hour.

Table 4. Comparison of collision probability

(Unit : Incidents/Year)

	present	1 excursion ship increased	3 excursion ships increased
Overtaking	0.111	0.111	0.157
Head-On	0.205	0.205	0.268
Crossing	0.632	0.631	0.834
Merging	0.058	0.058	0.058
Bend	0.091	0.091	0.091
Area	-	-	-
Total Collisions	1.096	1.097	1.408

It is analyzed that 1.096 incidents are likely to occur in the waters where the current excursion ship operation is expected. If 1 excursion ship is operated per hour, it will be 1.097 incidents per year, and if it is operated 3 times, it will be 1.408 incidents per hour. That is, there is no significant effect when 1 excursion ship is operated.

3.4 Semi-conclusion

To investigate the effect of excursion ship operations on the traffic flow of Busan North Port, the sea traffic congestion, ESS, and collision probability are calculated and compared with the existing operations and the assumption that excursion ships are going to be operated soon. As a result, the sea traffic congestion value increased by 2.81 % to 70.51 % when the excursion ship was operated one time per hour, and the maximum congestion value rose by 8.44 % when 3 excursion ships were operated per hour. The ESS was estimated to increase by 0.05 % with 1 excursion ship entering per hour, 0.25 % for 5 excursion ships entering per hour, and 0.5 % for 10 ships entering per hour.

In addition, the probability of collision analyzed through the IWRAP MkII was calculated at an increase of 0.001 incidents per year in the case of 1 excursion ship operation, resulting in 1.097 incidents per year. Also, 0.312 incidents per year increase was projected for the case of 3 excursion ships operation, resulting in 1.408 incidents per year. Therefore, if only one excursion ship is operated per hour, it will not affect the current traffic flow.

4. Conclusion

In this study, the port status, marine accidents, and traffic flow of Busan North Port are analyzed and, based on these, the marine traffic congestion and risk based on the ES model and maritime risk assessment tool (IWRAP MkⅡ) were used to assess marine traffic to evaluate the potential for excursion ship operations in Busan North Port. The results are as follows.

(1) As a result of analyzing the current state of marine accidents and traffic flow in the vicinity of Busan North Port, it was found out that many accidents occurred outside of the fairway, where the traffic flow is not constant. This is because of ships departing or joining the fairway for berthing, and the ships leaving the fairway in the direction of the anchorage, or joining the fairway from the direction of the anchorage.

(2) As a result of analysis of marine traffic congestion, it was seen that the maximum congestion value in peak time increased by 2.81 % when 1 excursion ship was operated, and by 8.44 % when the 3 excursion ships were operated per hour. In addition, the ESS analysis showed an increase of 0.05 % when 1 excursion ship was shown as entering per hour, and a 0.25 % increase when 5 shipws were entering per hour. The collision probability calculation by IWRAP MkII showed that the probability of collision increased by 0.001 incident per year when 1 excursion ship was operated and 0.312 incidents per year increased when 3 excursion ships were operated per hour. Therefore, as a result of the analysis of the marine traffic congestion, collision probability of IWRAP MkII, and the risk shown through the ES model, when 1 excursion ship operates per hour, it does not affect the current traffic flow or risk.

However, in the case of actual excursion ship operations, it is necessary to further identify the risk factors that may arise using this study as basic data, and to more carefully define the safety measures and excursion ship operation methods.

References

[1] Busan Port Authority(2017a), BPA Port Brochure, pp. 2-7.

[2] Busan Port Authority(2017b), Web site for Port Operation / Construction, http://www.busanpa.com (Accessed: May 2019).

[3] Busan.com(2018), Web site for Busan Sightseeing Blue Ocean is marine - Trapped in departments of Busan city 'Marine tourism of Busan', http://www.busan.com/view/busan (Accessed: May 2019).

[4] IALA(2010), IALA Waterway Risk Assessment Programme (IWRAP) Theory, Web site for Predicting Collision Frequencies, https://www.iala-aism.org/wiki/iwrap/index.php/Predicting_Collision_Frequencies (Accessed: May 2019).

[5] Inoue, K., M. Kubono, M. Miyasaka and D. Hara(1998), Modeling of Mariners' Perception of Safety when Being Faced with Imminent Danger (In Japanese), Journal of Japan Institute of Navigation, Vol. 98, pp. 235-245.

[6] Inoue, K. and Y. S. Park(2000), A Study on Basic Analysis for Marine Traffic Management-1: Effect of Total Amount Traffic Control in Narrow Waterway, The Journal of Japan Institute of Navigation, Vol. 103, pp. 69-76.

[7] Kang, Y. S., J. Y. Jong, Y. S. Park, H. K. Lee, B. S. Moon and J. S. Park(2001), A Study on the Assessment of the Marine Traffic Safety at the Pusan Approaching Waters, Journal of the Korean Institute of Navigation, Vol. 25, No. 3, pp. 257-268.

[8] Korea Maritime Safety Tribunal(2018), Web site for Annual report of Marine Accident, http://www.kmst.go.kr (Accessed: May 2019).

[9] Lee, C. H. and J. K. Kim(2019), A Study on the Revision of the Rules for the Busan Port Navigation Act for coastal cruise tourism revitalization in Busan North Port, Journal of the Korea Society for Fisheries and Marine Sciences Education, Vol. 31, No. 1, pp. 264-274.

[10] Lee, Y. S., M. Jung, C. U. Song, J. S. Park, Y. S. Park and I. S. Cho(2007), A Study on the Traffic Improvement at an Approach Area of Busan Harbor, Journal of Korean Navigation and Port Research, Vol. 31, No. 5, pp. 345-351.

[11] National Geospatial Intelligence agency(2014), Sailing Direction (enroute) - coasts of korea and china, National Geospatial Intellience agency by USA, Vol. 17, pp. 34-41.

[12] Park, J. S., Y. S. Park and S. J. Na(2013), Marine Traffic Engineering and Policy - Dongwonmunhwasa, pp. 187-191.

Received : 2019. 05. 10.
Revised : 2019. 05. 27.
Accepted : 2019. 05. 28.