Journal of the Korean Society of Marine Environment & Safety
Research Paper
Vol. 21, No. 3, pp. 246-252, June 30, 2015, ISSN 1229-3431(Print) / ISSN 2287-3341(Online) http://dx.doi.org/10.7837/kosomes.2015.21.3.246

A Comparison of ES and PARK Maritime Traffic Risk Assessment Models in a Korean Waterway

Thanh Xuan Nguyen* · Young-Soo Park**† · Matthew Vail Smith*** · Volkan Aydogdu**** · Chang-Hyun Jung*****

* Navigation Faculty, Ho chi Minh City University of Transport, Ho chi Minh, Vietnam
** Division of Maritime Transportation Science, Korea Maritime and Ocean University, Busan 606-791, Korea
*** Korea Maritime and Ocean University, Busan 606-791, Korea
**** Department of Maritime Transportation and Management Engineering, Istanbul Technical University, Istanbul, Turkey
***** Division of Navigation, Mokpo National Maritime University, Mokpo 530-729, Korea

Abstract : *This paper compared the consistency of the Environment Stress(ES) model and the Potential Risk Assessment Model (PARK model, which was developed based on a Korean mariner risk perception) for the Busan adjacent waterway. Evaluation of accuracy and comparison of these two models have been made by Vessel Traffic Service (VTS) officers in the Busan VTS Centre. The assessment results of Busan waterway show that the PARK model is more consistent than the ES model as follows. (1) The difference between assessment results applying ES model and PARK model with risk degree of VTSOs were 34% and 5% respectively in six typical traffic situations. (2) The assessment using PARK model is more suitable and identical with the VTSOs opinion in his or her duty time.*

Key Words : *ES model, PARK model, Assessment, Vessel traffic service officer, Busan adjacent waterway*

1. Introduction

The shipping industries have a great contribution to the Korean economy (approximate amount of contribution is 50 billion dollars per year). Thus, ensuring maritime safety is a very important issue. In order to achieve this goal, Korean Marine Traffic Safety Law was revised in 2009 and the Marine Traffic Safety Audit was introduced to secure safe navigation, prevent marine accidents and maximize the ports' efficiency. In order to achieve these goals, marine traffic safety assessment and finding the best evaluation model has an important and significant effect.

The ES (Environment Stress) model which was developed based on the Japanese navigators (Inoue, 2000) is widely used to evaluate maritime traffic risk throughout the world including Japan, Turkey, Indonesia and Korea (Aydogdu et al., 2012). This model has two inputs: (1) results of a general risk perception survey based on 573 Japanese mariners and (2) medical sensors which were measuring the navigators' heart rate and body temperature for specific simulation scenarios. These two inputs are then combined by a regression equation to calculate environmental factors for a final risk score.

Despite its world-wide attention and use, it is believed that the ES model is specific to Japanese waterways and therefore it might not be appropriate for assessing risk for Korean navigators. Specifically, Son et al.(2009) assessed by comparing analysis the result between ES model and Fuzzy model. And Kim et al. (2011) suggested that neither the survey nor the sensor input of the ES model is suitable for use in Korean waterways. It is fully necessary to develop the suitable risk model for Korean waterways. So, it was developed the potential risk assessment (PARK model) based on a Korean mariner risk perception(Park et al., 2013). PARK model is based on Korean crews' idea and experience. PARK model calculate the risk through internal elements such as characteristics of the vessel (i.e. type, size and tonnage of ships) and external elements such as approaching position of each ship, speed and distance between/among ships.

The purpose of this study is to compare the ES and the PARK models on the Busan adjacent waterway to identify which model provides more accurate risk assessment. Vessel traffic service officer (VTSO) assessment in the Busan VTS centre is utilized to carry out the comparison.

The primary goal of vessel traffic services (VTS) centre is to

* First Author : nxt912@gmail.com, +84-90-959-2001
† Corresponding Author : youngsoo@kmou.ac.kr, 051-410-5085

※ This paper is a revised version of presentation at 2013 Asia Navigation Conference in Busan, Korea.

provide support for safe navigation. To reach this goal, VTSOs are rigorously trained to monitor and evaluate navigational safety in order to prevent any potential accidents. Thus, VTSOs are considered experts on assessing maritime traffic risk levels accurately. In this study, we consider the risk assessments of VTSOs, so-called "ground truth", as a reference point for assessing accuracy and characteristics of the ES and PARK models.

The comparison is carried out in two different perspectives:

(1) Comparison on traffic risk assessment of vessels in some typical traffic situations

(2) Comparison on areas where VTSOs should focus on duty time

This paper uses the AIS data in the Busan adjacent waterway which were collected for 7 days from 13 to 19 December 2012, to do traffic survey and evaluate marine traffic risk by using the ES Model and the PARK model. The assessments of VTSOs who are working in the Busan VTS centre, were collected through a questionnaire survey in September 2013.

2. The Busan Waterway and Models Introduction

2.1 The Busan Waterway and Busan VTS

The Busan adjacent waterway (BAW) which is mentioned in this paper is the waterway in the control of the Busan VTS centre, the Busan VTS area, as shown in the figure 1.

Fig. 1. Busan VTS area.

The waterway is about 8 nautical miles around the Busan VTS centre. Inside this waterway, there are three harbours: Northern, Gamcheon and Dadaepo and five anchorages from N-1 to N-5. Figure 2 shows traffic density and main traffic routes in BAW.

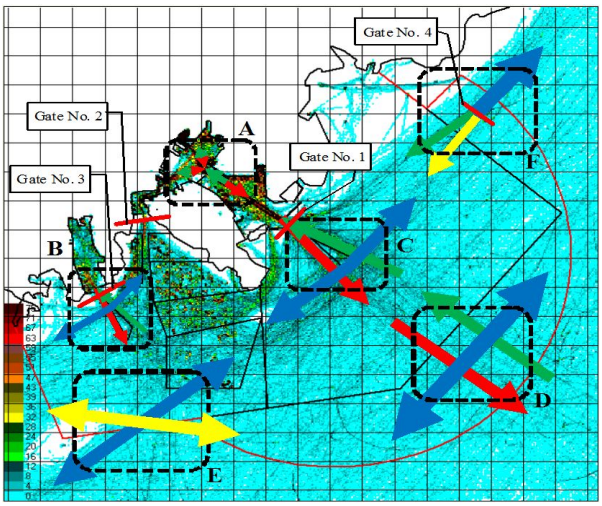


Fig. 2. Traffic density and main routes in BAW.

Figure 3 shows the overall distribution of ship length and ship types in BAW.

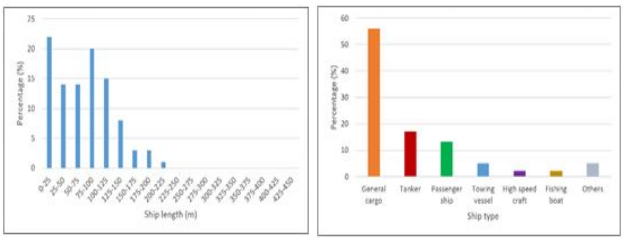


Fig. 3. Distribution of ship length and types in BAW.

The Busan VTS centre is located in main entrance of the Northern Harbour, about the centre of the Busan VTS area. The VTS area is divided into 2 sectors: No.1 and No.2. The sector No.1 covers the Northern Harbour waterway and the adjacent waterway in the east of the VTS centre. While the sector No.2 covers western waterway which consists the Gamcheon, Dadaepo harbours and "N" anchorages (from N-1 to N-5).

There are about 20 VTSOs working in this VTS centre. Their average experience at sea is 4 years and 6 years at VTS centre.

2.2 Introduction of ES Model and PARK Model

1) Introduction of ES Model

The ES model was developed by Japanese professors for risk assessment in waterways. It expresses the degree of stress

imposed on a mariner by topography and traffic environments in quantitative terms(Inoue, 2000). This model is used in marine traffic assessment of Maritime Safety Audit in Korea.

2) Introduction of PARK Model

In order to develop a marine traffic safety assessment model in accordance with the characteristics of Korean coastal areas as well as seafarers, the Korean research team studied the elements related to marine traffic safety of a ship. Korean crews' idea and experience were collected and analysed for the development of the model(Park et al., 2013). Figure 4 shows stress ranking in the ES model and the PARK model.

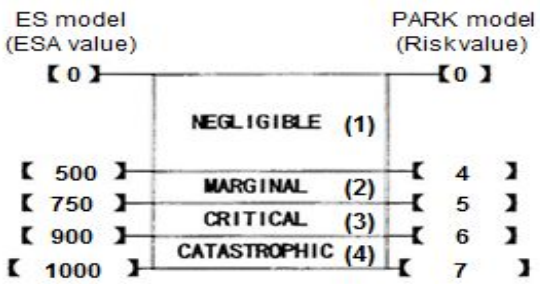


Fig. 4. Stress ranking in the ES model and the PARK model.

3. Results of Comparisons

In this section, the comparison results between the ES model and the PARK model based on opinion of VTSOs' will be presented. In order to be able to obtain results of the ES model and the PARK model, a computer program that AIS data run on it is used. Afterwards, evaluation study on VTSOs is carried out by a questionnaire survey that conducted on 17 VTSOs in the Busan VTS centre. In order to collect impartial evaluation of VTSOs, some specific traffic situations are determined and asked in the questionnaire survey form.

3.1 Developing in the Busan adjacent waterway

In this stage the typical traffic situations are determined through three steps as followed:

(1) Step 1: conducting traffic survey in the entire waterway to determine traffic density and traffic routes. Then, identifying the areas which have heavy traffic and/or frequent routes intersecting. After carrying out this step, 6 typical traffic areas in the Busan waterway are identified which were numbered from A to F as shown in figure 2.

(2) Step 2: the traffic density in each area is monitored to find out peak hours of the traffic. An example is shown in figure 5.

(3) Step 3: typical traffic situations based on real traffic in each area during peak hours that have the most congested traffic are selected.

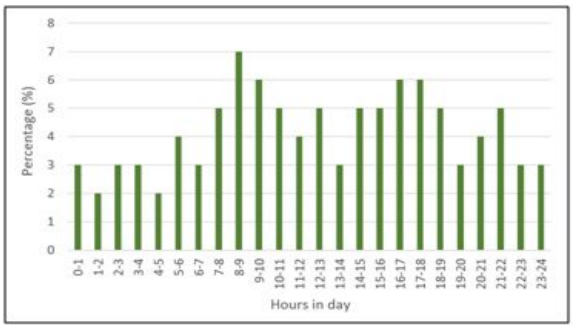
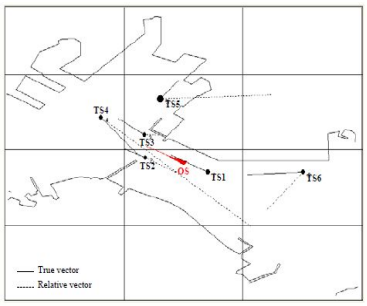


Fig. 5. Traffic density for each hour of the day at gate No.1 in area A.

The figure 6 shows a sample typical traffic situation(traffic situation 1) in the area A(indicated in figure 2) of the Busan adjacent waterway. Information of target ships(TS), own ship (OS), type of ship, ship dimension(Length overall-LOA and Breadth-B), ship heading-course, speed, closest point of approach (CPA) and time to closest point of approach(TCPA) are also given in figure 6.



ID	Type	LOA (m)	B (m)	Course	Speed (knot)	CPA (nm)	TCPA (min)
OS	Tanker	107	17	305	5.9		
TS1	Tanker	70	10	306	5.8	0.2	-72.7
TS2	Tug	21	5	303	3.3	0.1	6.9
TS3	Tug	22	6	314	4.8	0.4	14.9
TS4	Tanker	70	10	161	9.1	0.1	3.7
TS5	Container	93	16	32	4.5	0.9	1.2
TS6	Tanker	70	10	266	7.2	0.9	5.4

Fig. 6. A sample of typical situation(traffic situation 1).

3.2 A Comparison based on traffic risk assessment of a vessel in certain situations

This section will present a comparison on assessment index of the traffic risk of a vessel between the ES model, the PARK model and VTSOs in six typical traffic situations in the Busan adjacent waterway.

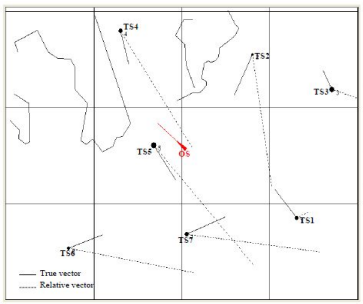
1) Traffic situation 1

As shown in figure 6, the traffic situation 1 is in the area A inside the Busan port waterway. OS is a tanker, LOA=107 meters (m), beam=17 m and approaching to berth, in the direction 305 degrees with speed 5.9 knots. There are some tug boats, tankers and container ships sailing ahead in the same directions to the OS. Information of target ships and OS are also given in figure 6.

In this situation, the risk index of the OS by using the ES model and the PARK model are 552 and 4.72 respectively. After converting these values to stress rank as shown in figure 4, they are 1.2 and 1.7. According to VTSOs, in this situation the stress rank of the OS vessel is 1.4 (with standard deviation 0.5).

2) Traffic situation 2

As in situation 1, the situation 2 is based on the approaching route of the Gamcheon port in the Busan adjacent waterway. This area also has two main routes: route for ships arrive/depart the Gamcheon port and the northeast-southwest route. In this situation, as shown in figure 7, the OS(container vessel, LOA=115 m, B=16 m) is approaching the Gamcheon port with a speed of 7.5 knots with direction 310 degree. There are six target ships around the OS(LOA from 34 m to 180 m) which are navigating in the same way ahead and crossing directions. Stress rank values of the OS according to the ES model, the PARK model and VTSOs are 1.4, 1.9 and 2.1 respectively.

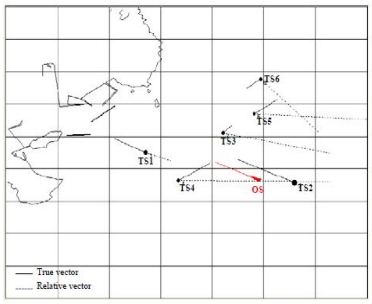


ID	Type	LOA (m)	B (m)	Course	Speed (knot)	CPA (nm)	TCPA (min)
OS	Container	115	16	310	7.5		
TS1	Container	149	22	320	7	1.1	-38.1
TS2	Tanker	34	7	206	8.6	0.9	4
TS3	Container	150	20	333	4	1.1	-20
TS4	Container	153	22	165	6.5	0.1	6.4
TS5	Tanker	180	32	145	8	0.2	1.1
TS6	Tanker	61	12	70	7.5	1.2	5.2
TS7	Container	103	17	68	8.5	0.9	-0.5

Fig. 7. Traffic situation 2.

3) Traffic situation 3

The situation 3 is based on traffic in the area C as shown in figure 2, about three nautical miles(nm) outside the break water. Traffic in this area has two main routes: (1) route of ships arrive and depart the Busan port; (2) route of ships sail from northeast to southwest and vice versa along the coastal. The OS is a container ship, 113 m in long, 18m in beam and on the way to the Busan port at 15.5 knots, bearing 303 degrees. There are six target ships which are sailing in the same way ahead and crossing directions. The details of OS and target ships are shown in figure 8. Stress rank values of the OS according to the ES model, the PARK model and VTSOs are 0.2, 1.8 and 2.6 respectively.



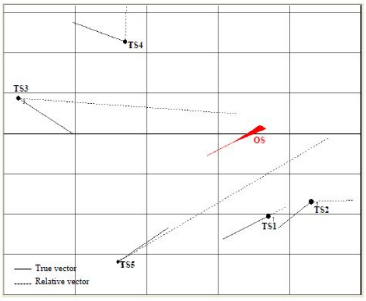
ID	Type	LOA (m)	B (m)	Course	Speed (knot)	CPA (nm)	TCPA (min)
OS	Container	113	18	303	15.5		
TS1	Other	100	16	305	11.3	0.3	33
TS2	Passenger	160	25	303	20.1	0.3	8
TS3	Tug	21	6	37	4.6	1.2	4
TS4	Container	96	11	49	12.5	0	4.2
TS5	Tanker	34	9	46	9.9	2	0.5
TS6	Tug	25	8	224	6	1.8	9.8

Fig. 8. Traffic situation 3.

4) Traffic situation 4

The situation 4 is based on traffic in area D, about 7 nautical miles outside the break water. Traffic routes in this area are same as in area C. In this case, the OS is sailing from northeast to southwest and there are 5 target ships sailing around in the same way ahead and crossing directions as shown in figure 9.

The OS is a mother container ship(LOA=300 m, beam=40 m) which is keeping avoidance with a crossing ship on her starboard side(TS3, CPA=0.3 nm, TCPA=12.2 min) and an ahead ship(TS5, CPA=0.8 nm, TCPA=9.6 min). Stress rank values of the OS according to the ES model, the PARK model and VTSOs are 0.0, 1.7 and 2.0 respectively.



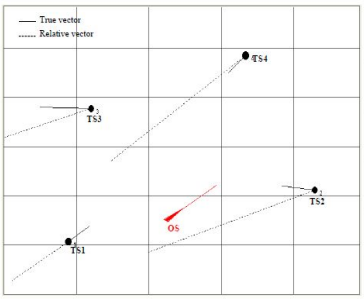
ID	Type	LOA (m)	B (m)	Course	Speed (knot)	CPA (nm)	TCPA (min)
OS	Container	300	40	228	11.3		
TS1	Container	114	17	228	9.4	1.7	43.5
TS2	Container	133	19	215	9	1.8	-10.9
TS3	Tanker	123	15	139	12.8	0.3	12.2
TS4	Container	79	14	303	9.7	1.9	-9.7
TS5	Other	68	8	40	12.2	0.8	9.6

Fig. 9. Traffic situation 4.

5) Traffic situation 5

The situation 5 is based on traffic in area E, about 4 nautical miles far from the nearest coastline. There are two traffic routes in this area: east-west route and northeast-southwest route. In this situation, as shown in figure 10, the OS is sailing from southwest to northeast. Two target ships, TS1 and TS4, are

sailing on the same route in same and ahead directions. The two other target ships, TS2 and TS3, are sailing in crossing direction from east to west. Same as situation 4, the OS has to avoid collision with the TS2(CPA=0.4 nm and TCPA=6.2 min). In this case the length overall of both two ships is about 100 meters but the TCPA is only about 6 minutes so the OOW on board the OS has to take prompt action for avoiding collision with the TS. Stress rank values of the OS according to the ES model, the PARK model and VTSOs are 0.0, 1.4 and 1.6 respectively.

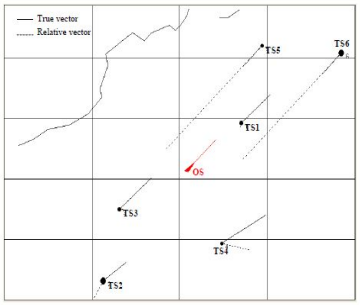


ID	Type	LOA (m)	B (m)	Course	Speed (knot)	CPA (nm)	TCPA (min)
OS	Tanker	115	18	44	15.1		
TS1	Container	100	16	43	6.6	0.6	-8.8
TS2	Tanker	84	13	280	7.1	0.4	6.2
TS3	Container	85	14	272	10.8	2.5	0.2
TS4	Other	120	17	214	6.7	1.4	8.9

Fig. 10. Traffic situation 5.

6) Traffic situation 6

The situation 6 is based on the actual traffic in coastal waterway area F as shown in figure 2. Traffic in this area is mainly in the northeast – southwest direction. Ships arrive or depart the Busan port often sail closer to the coast(blue arrow) than others just passing through this area(yellow arrow). The situation in figure 11 shows the OS(tanker, LOA=100 m, beam=16 m) is sailing along the coast on direction 333 degrees with speed of 12.4 knots. Six target ships(LOA from 27 to 120 m) are sailing in the same and ahead direction around the own ship. Stress rank values of the OS according to the ES model, the PARK model and VTSOs are 0.3, 1.5 and 1.5 respectively.



ID	Type	LOA (m)	B (m)	Course	Speed (knot)	CPA (nm)	TCPA (min)
OS	Tanker	100	16	33	12.4		
TS1	Tanker	60	12	35	11.5	0.5	52.9
TS2	Other	100	16	40	8.1	0.3	-27
TS3	Tanker	81	12	35	12.7	0.6	86.1
TS4	Other	55	8	47	13.6	1	-13.6
TS5	Tug	27	7	212	8	0.4	6.4
TS6	Container	120	17	212	8.3	0.4	7.4

Fig. 11. Traffic situation 6.

The table 1 below shows aggregate comparison between traffic risk assessment results of the OS of the ES model, the PARK model and VTSOs on the six traffic situations as presented above. Table 1 shows that the average difference of stress rank values which are given by the ES model and VTSOs is 1.35(34 %) and is 0.20(5 %) between the PARK model and VTSOs. It means in these typical traffic situations, the assessment of the PARK model is closer with the assessment of VTSOs than the ES model.

Table 1. Summary of assessment results of ES model, the PARK model and VTSOs

situations No.	Average assessment results of VTSO	Standard deviation	Assessment results of the ES model	Assessment results of the PARK model	Difference between		Remark
					ES model-VTOs	PARK model-VTSOs	
1	1.4	0.5	1.2	1.7	0.2	0.3	Inside harbour
2	2.1	0.4	1.4	1.9	0.7	0.2	
3	2.6	0.5	0.2	1.8	2.4	0.8	Outside harbour
4	2.0	0.4	0.0	1.7	2.0	0.3	
5	1.6	0.5	0.0	1.4	1.6	0.2	
6	1.5	0.5	0.3	1.5	1.2	0.0	
Average					1.35	0.20	
Standard deviation					0.65	0.23	

3.3 Comparison on areas of VTSOs' duty time

While a VTSO is on duty, he or she has to monitor all traffic inside the VTS area. However, the marine traffic risks are different in each area. Therefore, he or she often focuses on the areas which vessels' movements become difficult. In other word, VTSOs often focus to areas where stress ranking of passing vessels normally is in "MARGINAL" rank (ESA value is higher than 500 and/or Risk value is higher than 4.0). The diagram which is called hazard map, shows areas that have stress rank level in "MARGINAL" condition or higher.

Based on this idea, this comparison will compare the hazard maps which are created based on the ES model and the PARK model with hazard map which is created based on VTSOs' experience. Each VTSOs are asked to mark on a map the areas which they often focus during their duty time. Then, these maps are aggregated to form a hazard map as shown in figure 12.

For creating a hazard map based on the ES model, a program is used to calculate ESA values of all vessels passing the waterway during 7 days. Then, the number of vessels which has ESA value over 500 in each area is counted. The area has highest value is considered as an area which has density equal

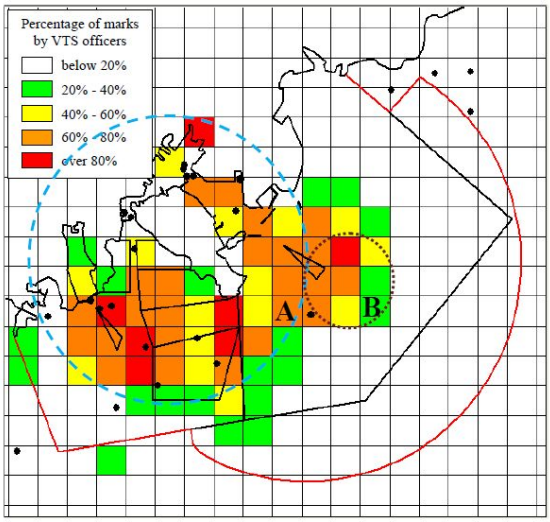


Fig. 12. A hazard map based on VTSOs' experience.

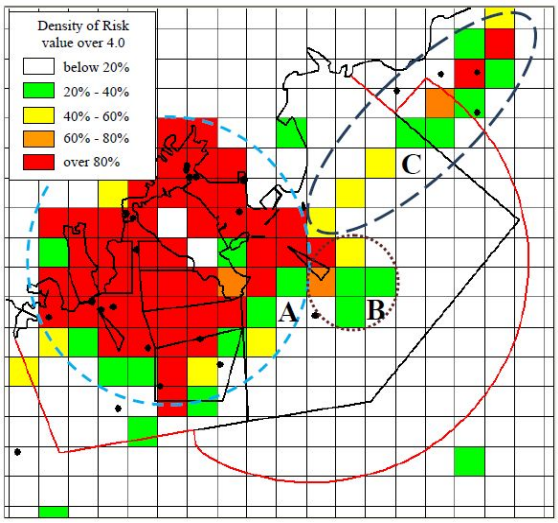


Fig. 14. A hazard map based on the PARK model.

to 100. Density of other areas will be calculated by comparing with this area. By this way, a hazard map based on the ES model is created as shown in figure 13. In the same way, the number of vessels which has Risk value over 4.0 in each area is counted to create the hazard map based on the PARK model as shown in figure 14.

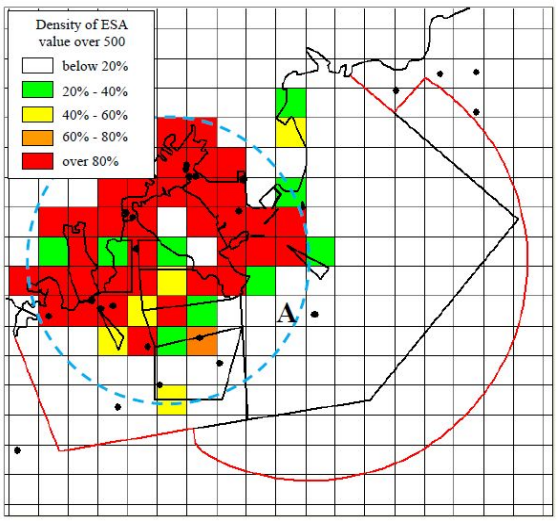


Fig. 13. A hazard map based on the ES model.

The black dots inside the figure 12, 13 and 14 are position of collision accidents which happened in years from 2008 to 2012. By comparing figure 13 and 14 with figure 12 qualitatively, it could recognize that:

- Area A in three figures is identical.
- Also, area B in the hazard map based on the PARK model (figure 14) and the hazard map based on the VTSOs' experience (figure 12) is identical.
- Area C is the specific difference area between the hazard map based on the PARK model (figure 14) and the two others (figure 12 and 13). This discrepancy can be explained as follows:

(1) Vessels which sail in the area C are mainly tug boats and small tankers moving between ports in Korea. About 70 % of vessels are less than 50 m in length. Because of this reason, VTSOs are likely to focus on these vessels less than bigger ones in area A. Therefore, the area C does not exist in the hazard map which is created based on VTSOs experience (figure 12).

(2) The lateral distribution of traffic at gate No.4 (as indicated in the figure 2) shows that vessels sail in the area C have high possibility of head-on and crossing direction so that the traffic risk in this area will become high. This is noticeable that there were 4 collision accidents in the area C during the period from 2008 to 2012.

The above analysis shows that the area C in the hazard map based on the PARK model is entirely consistent with actual traffic in the area.

4. Conclusion

Waterways of each country have their own characteristics like topography, oceanography, shipping/fishing activities and personal characteristics of seafarers. Therefore, to assess the marine traffic safety accurately each country should select the most suitable assessment model for their own waterways.

VTSOs are persons who have very good ability and knowledge for assessing the navigation risk of vessels. Therefore, this paper uses the assessment results of VTSOs of the Busan VTS centre as the basis to compare assessment results of the ES model (a Japanese model which is now widely use in Korea) and the PARK model (a Korean model which has been developed since 2012) to find out the best and compatible models with Busan adjacent waterway. The comparison is done in two contents with the results as follows:

(1) Comparison on traffic risk assessment of a vessel in six typical traffic situations: difference between assessment results using the ES model and the PARK model with assessment results of VTSOs are 34 % and 5 % respectively.

(2) Comparison on areas where VTSOs should focus on duty time: a qualitatively assessment shows that the areas which are indicated by the PARK model are more identical with the opinion of VTSOs and more suitable with the actual traffic in the waterway than the ES model.

Both comparisons above show that the PARK model is more consistent with the Busan adjacent waterway than the ES model. Busan port is one of the major ports of the Korea, the total amount of containers passing through the port in 2012 was the fifth in the world (World Shipping, 2013). In addition, the Busan adjacent waterway has the full features of Korean waterway such as many small islands around, winding coastline and congested traffic with mostly Korean-flagged vessels. Therefore, it can be said broadly that the PARK model is more consistent with the Korean waterway than the ES model. However during the comparison process, the PARK model shows that there are some limitations that should be improved in future researches:

- Considering the influence of weather elements in safe navigation such as day/night and especially fog because it usually occurs in Busan waterway.
- In the PARK model, risk of an own ship is determined by the maximum value of Risk values of the own ship in correlation with each target ships around. In fact, the risk of marine traffic safety generally increases while the number of target ships increase.

References

[1] Aydogdu, Y. V., C. Yurtoren, J. S. Park and Y. S. Park (2012), A Study on Local Traffic Management to Improve Marine Traffic Safety in the Istanbul Strait, The Journal of Navigation-The Royal Institute of Navigation, Vol. 65, No. 1, pp. 99-112.

[2] Inoue, K.(2000), Evaluation Method of Ship handling Difficulty for Navigation in Restricted and Congested Waterways, Journal of Navigation-The Royal Institute of Navigation, Vol. 53, No. 1, pp. 167-180.

[3] Kim, D. W., J. S. Park and Y. S. Park(2011), Comparison Analysis between the IWRAP and the ES Model in Ulsan Waterway, International Journal of Navigation and Port Research, Vol. 35, No. 4, pp. 281-287.

[4] Park, Y. S., J. S. Kim and Y. V. Aydogdu(2013), A Study on the Development the Maritime Safety Assessment Model in Korea Waterway, Journal of Korea Navigation and Port Research, Vol. 37, No. 6, pp. 567-574.

[5] Son, N. S, S. Y. Kim and I. Y. Gong(2009), Study on the Estimation of Collision Risk of Ship in Ship Handling Simulator using Fuzzy Algorithm and Environmental Stress Model, Journal of Korea Navigation and Port Research, Vol. 33, No. 1, pp. 43-50.

Received : 2015. 05. 12.
Revised : 2015. 06. 13.
Accepted : 2015. 06. 26.