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Comparison Analysis between the IWRAP and the ES Model in Ulsan Waterway

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Abstract : *According to the Marine Traffic Safety Law, revised in 2009, Marine Traffic Safety Audit is introduced to secure the safe navigation, to prevent the marine accident and to maximize the efficiency of the port. In this audit system, marine traffic safety assessment is the most important scheme because the primary purpose of the audit system is to identify potential risk elements affecting safe navigation. Even though the reliability of audit result depends on the selection of assessment models, there are no independent assessment models for Korean coastal waters and most of models used in Korea currently are developed by foreign countries. Therefore, the development of the independent assessment model for Korean coastal water is required. This study, prior to the development of independent assessment model, aims to provide a basic data by comparing two foreign assessment models in Ulsan port area with marine accident statistics data.*

Key words : *Marine traffic safety assessment, IWRAP, ES model, Risk assessment model, Marine accident*

1. Introduction

Coastal waterway has high potential risk of marine accident due to its confined space and heavy traffic. This may lead to severe accident such as collision, grounding, sinking and environmental pollution.

According to the Marine Traffic Safety Law, revised in 2009, Marine Traffic Safety Audit is introduced to secure the safe navigation, to prevent the marine accident and to maximize the efficiency of the port. A maritime safety audit is a formal safety diagnosis examination in the field of existing or future maritime transportation by an independent audit team. It systematically estimates and identifies potential risk elements associated with the development plan and provide an opportunity to improve the traffic safety for development parties.(Cho et al., 2010)

In the process of this audit system, marine traffic safety assessment is the most important part and an evaluation model must be required to implement this assessment.

However, the evaluation models used in Korea are highly limited, and these models are made by foreign countries. There are some problems to apply these models to Korean coastal waters directly, because these models do not contain consciousness of Korean seafarers. Therefore, the development of the proper evaluation model for Korea is required as early as possible.

As a first step of development, this paper implements marine traffic assessment of Ulsan port area by using ES(Environmental Stress) model which is most-used assessment model for marine traffic flow simulation in the audit system and IWRAP(IALA Waterway Risk Assessment Program) which is recommended by IALA and compared between these results and statistic data.

2. Marine Traffic Safety Assessment

2.1 Concept of Marine Traffic Safety Assessment

Marine traffic safety assessment is aimed to understand current traffic flow, to represent and evaluate vessel's actions by statistical or analytical method. Doing marine traffic safety assessment, it is possible to evaluate current status and expected future traffic condition of the target. For example, if some environmental change is given in a port, it would be an alternation of marine traffic flow. Trial and error of port operation policy could be reduced by comparing between current and future condition and analyzing these results. It is highly important in marine traffic studies because it contributes improvement of fairway condition and port facilities by using results of assessment.(Park et al., 2010)

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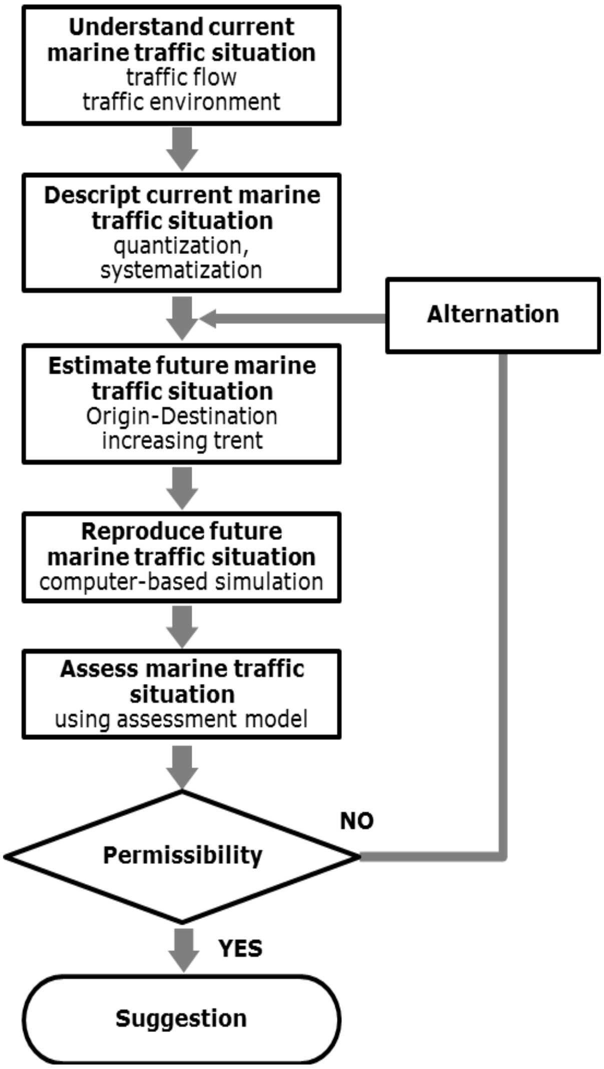

Fig. 1 Safety assessment process

Fig. 1 shows a typical process of marine traffic safety assessment. Marine traffic assessment is made up five steps, understanding, description, estimation, reproduction and assessment. Suggestion is given by identifying permissibility of a current status assessment or comparing with future status assessment.

Assessment result would be changed by selection of assessment model, so it is important to select proper assessment model.

2.2 Marine Traffic Safety Assessment Models

Table 1 shows several kinds of marine traffic safety assessment models and their features.(Kim, 2011)

This research used two assessment models, ES model and IWRAP to evaluate Ulsan port area which is one of the busiest port in Korea and having regular vessel traffic.

Table 1 List of marine traffic safety assessment models

Assessment Model	Features
IWRAP	- Recommended by IALA(Quantitative model) - Calculating collision and grounding probabilities - Theoretical explanation for calculation is limited
ES Model	- The most-used model in MSA - Calculating maneuvering difficulties by surrounding environments - Awareness of Korean mariners is not reflected
PAWSA	- Recommended by IALA(Qualitative model) - Assessment by expert group - Highly depended on the consist of group members
FSA	- Evaluating the costs and benefits of solutions - Various application models(MARA, PMSC, etc.) - Could be influenced by assessor's opinion
US Model	- Assessment by stopping distance - Ship handling simulation is the precondition - Could not apply in complex traffic condition
Others	- Assessment by vessel encountering frequencies - Assessment by give-way action frequencies - Assessment by complexity of traffic routes - SJ Model(Mariners' subjective awareness) - BC Model(Collision awareness with other vessels) - Assessment models used in road traffic engineering

3. Assessment Methods of IWRAP and ES Model

3.1 IWRAP

IWRAP is designed to provide a quantified risk assessment results involved with vessel traffic in specific geographical areas.(Peter Friis-Hansen, 2008) This model provides annual collision and grounding probabilities by inputting traffic condition such as vessel traffic volume and waterway traffic distribution, etc. and waterway condition such as depth, width, current, other meterological conditions. Fig. 2 shows the calculation items of IWRAP.

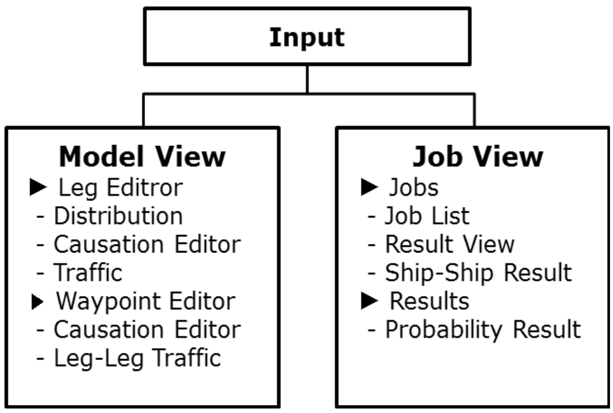

Fig. 2 Modules of IWRAP input

(1) Model View

Basic data for calculation such as leg information and traffic information is input in Model View.

Fig. 3 shows leg and depth setting for assessment. Leg is the principal and necessary element for the safety assessment in IWRAP. Depth is used for the grounding calculation.

Fig. 3 Set leg and depth in IWRAP

Fig. 4 shows traffic data to be input in IWRAP. Annual traffic volume per ship's length level, traffic lane distribution and weight of each accident case are input in this scheme.

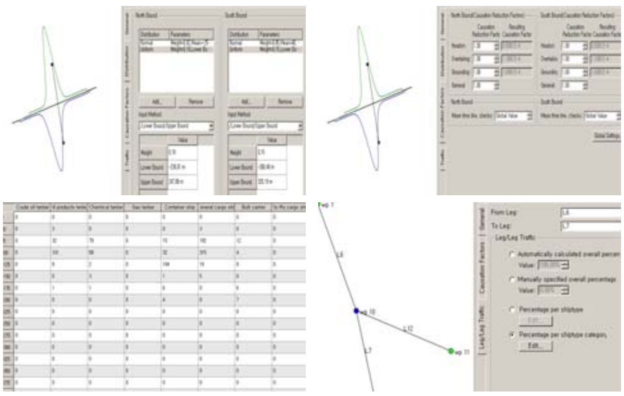

Fig. 4 Traffic data to be input in IWRAP

(2) Job View

In Job View, calculated probability results can be seen by table and visualized chart data.

Fig. 5 shows result view of IWRAP assessment. Annual collision and grounding probabilities are shown in the table and risk degree is marked by different colors in the chart.

Grounding results are divided by vessel's status, powered and drifting. Collision results are divided by each accidents.

		Unit
Powered Grounding	1.53535	Incidents/Year
Drifting Grounding	0.131029	Incidents/Year
Total Groundings	1.66638	Incidents/Year
Overtaking	0.000369556	Incidents/Year
HeadOn	0.00168456	Incidents/Year
Crossing	5.5415e-05	Incidents/Year
Merging	1.05215e-05	Incidents/Year
Bend	0.000369947	Incidents/Year
Area	1.8446e-08	Incidents/Year
Total Collisions	0.00249002	Incidents/Year

Fig. 5 Result data in IWRAP

3.2 ES model

ES model expresses in quantitative terms the degree of stress imposed by topographical and traffic environments on a mariner.(Inoue, 2000) This model is most-used in marine traffic assessment of Maritime Safety Audit in Korea.

Calculation of stress value in ES model is composed of the following three parts.(Park et al., 2002)

(1) Evaluation of ship handling difficulty arising from restrictions on the water area available for maneuvering. A quantitative index expressing the degree of stress forced on the mariner by topographical restrictions(ES_L value, ES value for Land) is calculated on the basis of the TTC(Time to Collision) with any obstacles.

(2) Evaluation of ship handling difficulty arising from restrictions on the freedom to make collision-avoidance manoeuvres. A quantitative index expressing the degree of stress forced on the mariner by traffic congestion(ES_S value, ES value for Ship) is calculated on the basis of the TTC with ships.

(3) Aggregate evluation of ship handling difficulty forced by both topographical and traffic environments, in which the stress value(ES_A value, ES value for Aggregation) is derived by superimposing the value ES_L and the value ES_S in the course.

The rank of stress can be classified according to the extent to which a dangerous situation causes a particular SJ(Subjective Judgement) value in the range of ±90° around the present ships course. Table 2 shows the stress ranking in ES model which is set up by classifying the range of stress as 0 to 1000.

Table 2 Stress ranking and acceptance criteria

SJ : Mariner's Judgement		Evaluate $\Sigma[SJ]_i$	Stress Ranking	Acceptance Criteria
0	Extremely safe	0	Negligible	Acceptable
1	Fairly safe			
2	Somewhat safe			
3	Neither safe of dangerous	500	Marginal	
4	Somewhat dangerous	750	Critical	Unacceptable
5	Fairly dangerous	900	Catastrophic	
6	Extremely dangerous	1000		

4. Marine traffic safety assessment by using IWRAP and ES model in Ulsna port area

4.1 General information

Fig. 6 shows a fairway layout of Ulsan port. Ulsan port is composed of three fairways: Fairway no.1 is the route for entering Ulsan main port and mainly used by car carrier and tanker ships. Fairway no.2 is for entering Jansaengpo and mainly used by small vessels and fishing boats. Fairway no.3 is for Onsan and mainly used by tanker ships.

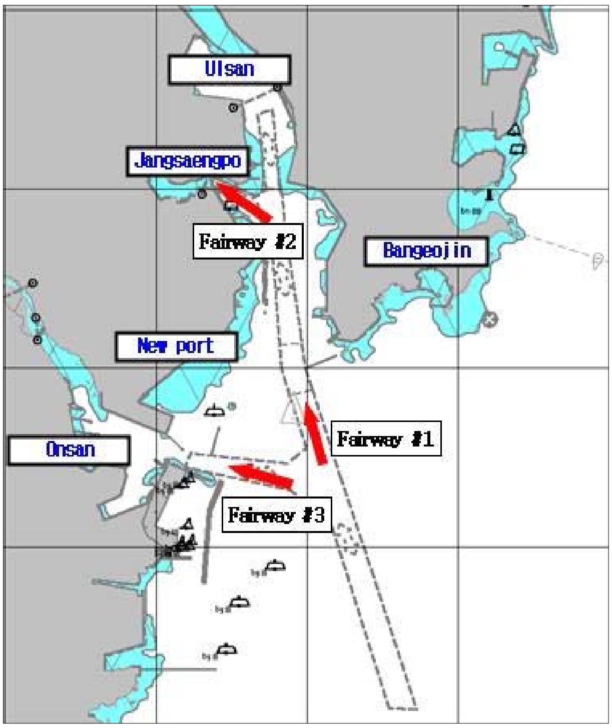

Fig. 6 Fairway layout of Ulsan

4.2 Assessment result by IWRAP

(1) Traffic leg and volume

Fig. 7 shows a layout of target legs. Each legs are assigned according to fairway layout, mentioned in Fig. 6, and traffic route between Onsan and East Sea is added.

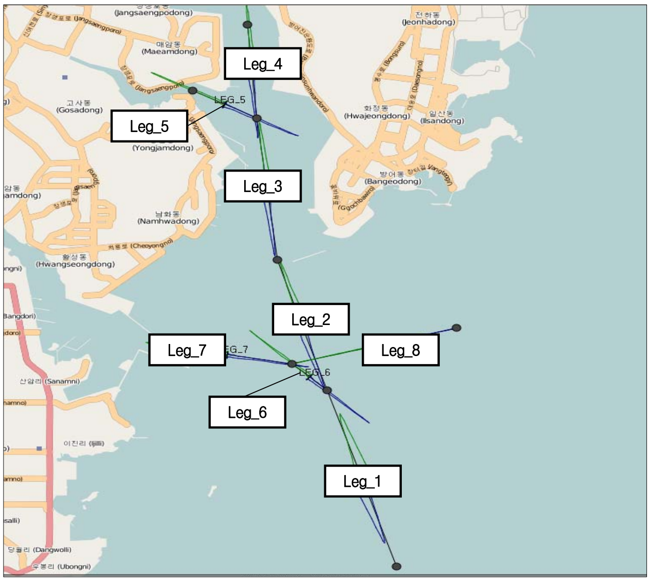

Fig. 7 Setting traffic legs in Ulsan waterways for calculating IWRAP

Entering and departure data in PORT-MIS based on 2008 is used for this assessment. Because these data are sorted by tonnes and types of vessels, converted to each length of vessels according to "Criteria of design for port facilities and fishery ports" to input traffic volume in IWRAP.(MLTM, 2008)

Table 3 is an example of traffic volume data by each leg to be input IWRAP.

Table 3 IWRAP - Traffic volum in Ulsan

	Type(ea) / Length(m)	Crude Oil	Oil Product	Chemical	Gas	Container	General Cargo	Bulk Carrier	Ro-Ro	Passenger	Fast Ferry	Support	Fishing	Pleasure	Others	Total
LEG 1	0-25	11	230	127	27	46	71	60	18	1	0	0	0	0	149	740
	25-50	70	1,550	834	176	298	481	394	122	2	0	0	1	0	1,008	4,936
	50-75	99	2,182	1,195	248	431	670	559	168	3	0	0	1	0	1,413	6,969
	75-100	97	2,150	1,155	244	411	667	546	170	3	0	0	1	0	1,399	6,843
	100-125	38	828	453	94	163	254	213	64	1	0	0	1	0	537	2,646
	125-150	14	283	165	32	62	84	75	20	1	0	0	0	0	182	918
	150-175	13	257	168	30	67	70	72	14	0	0	0	0	0	159	850
	175-200	26	518	327	59	127	146	142	30	1	0	0	0	0	323	1,699
	200-225	9	188	112	22	43	55	50	13	0	0	0	0	0	119	611
	225-250	9	202	101	23	35	66	50	18	1	0	0	0	0	135	640
	250-275	7	138	66	16	22	46	33	13	0	0	0	0	0	92	433
	275-300	1	15	7	2	2	5	4	2	0	0	0	0	0	10	48
	300-325	0	6	4	1	1	2	1	1	0	0	0	0	0	4	20
	325-350	4	78	47	9	18	23	22	5	0	0	0	0	0	49	255
LEG 2 & 3	0-25	8	179	82	21	26	61	43	18	1	0	0	0	0	121	560
	25-50	52	1,256	573	142	183	423	298	122	2	0	0	1	0	847	3,899
	50-75	71	1,721	786	195	250	579	409	168	3	0	0	1	0	1,161	5,344
	75-100	72	1,748	798	198	254	588	415	170	3	0	0	1	0	1,179	5,426
	100-125	27	655	299	74	95	220	156	64	1	0	0	1	0	442	2,034
	125-150	9	202	93	23	30	68	48	20	1	0	0	0	0	137	631
	150-175	6	140	64	16	21	47	34	14	0	0	0	0	0	95	437
	175-200	13	310	142	35	45	105	74	30	1	0	0	0	0	209	964
	200-225	5	127	58	15	19	43	30	13	0	0	0	0	0	86	396
	225-250	8	183	84	21	27	62	44	18	1	0	0	0	0	124	572
	250-275	6	131	60	15	19	44	31	13	0	0	0	0	0	88	407
	275-300	1	15	7	2	2	5	4	2	0	0	0	0	0	10	48
	300-325	0	5	3	1	1	2	1	1	0	0	0	0	0	4	18
	325-350	2	52	24	6	8	18	13	5	0	0	0	0	0	35	163

(2) Traffic distribution

Distributions of each leg are set up normal distribution according to the previous study on the Japanese inland sea. In accordance with this study, center of distribution is fixed a tenth of fairway width from the right side of the center of fairway. Standard deviation is calculated as follows:(Park et al., 2001)

$$\sigma = -9.49 + 0.106\omega + 3.33Q \quad \text{Eq.} \qquad (1)$$

where,

σ : Standard deviation (m)

ω : Width of fariway(m)

Q : Traffic volume (vessel/hour)

Table 4 shows input data of each leg. Values for distance from center of each leg are input one-ten of given fairway width. Values for annual traffic of each leg are calculated by PORT-MIS data with entering and departure port record.

Table 4 IWRAP - Distribution in Ulsan

	Width (m)	Distance from center (m)	Annual traffic (vessels)	Traffic volume (vsl/hour)	Standard deviation (m)
Leg 1	550	55	27,608	3.15	59
Leg 2	330	33	20,899	2.39	33
Leg 3	300	30	20,899	2.39	30
Leg 4	250	25	13,380	1.53	22
Leg 5	185	19	7,519	0.86	13
Leg 6	185	19	6,262	0.71	12
Leg 7	185	19	6,709	0.77	13
Leg 8	10	1	447	0.05	1

(3) Assessment result

Table 5 shows a result of marine traffic safety assessment of Ulsan port area by IWRAP. Result value is consisted of two types of grounding, powered and drifting grounding, and six types of collision, overtaking, head on, crossing, merging, bending and regional collision. In this

Table 5 Assessment result applying IWRAP in Ulsan waterways

Case	Result	Unit
Powered Grounding	1.37536	Incidents / Year
Drifting Grounding	0.839026	Incidents / Year
Total Groundings	2.21438	Incidents / Year
Overtaking	0.198466	Incidents / Year
Head On	0.263021	Incidents / Year
Crossing	0.0440573	Incidents / Year
Merging	0.0287787	Incidents / Year
Bend	0.147784	Incidents / Year
Area	2.70438*e-07	Incidents / Year
Total Collisions	0.682107	Incidents / Year

assessment, 2.21 grounding accidents and 0.68 collision accidents per year are calculated by IWRAP. Fig. 8 shows that fairway no.1 has relatively high risk than other fairways.

4.3 Assessment result by ES model

Fig. 9 shows the replay scene of marine traffic flow simulation in the same condition with IWRAP. Fig. 10 shows the risk assessment result by following the traffic flow simulation. In this result, risk of fariway no.1 and no.3 is ranked high within target area.

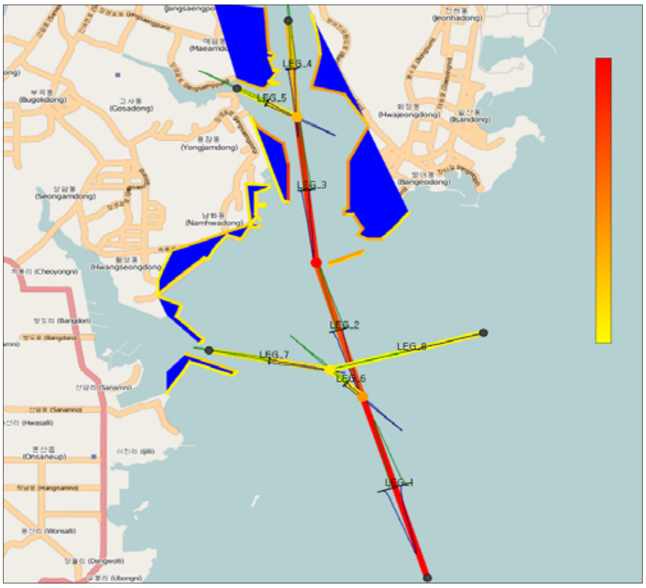

Fig. 8 Assessment result applying IWRAP in Ulsan waterways

Fig. 9 Replay scene of marine raffic flow simulation in Ulsan waterways

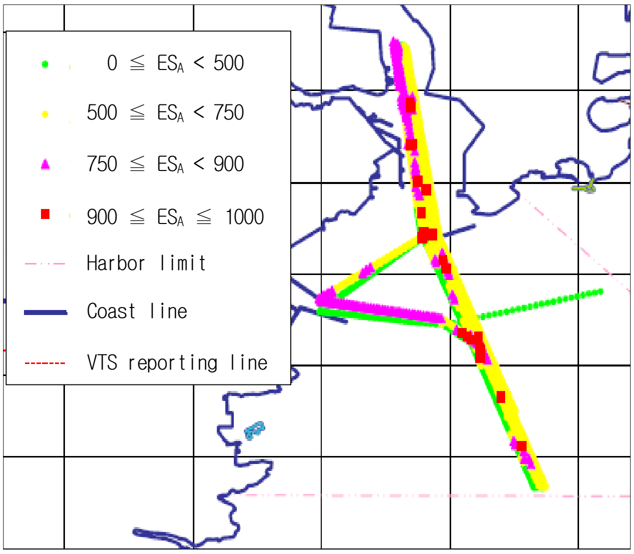

Fig. 10 Assessment result applying ES model in Ulsan waterways

Table 6 shows the result value in each stress ranking. The proportion of unacceptable value($750 \leq ES_A \leq 1000$) is 8.27%

Table 6 Result value of ES model assessment

Stress	Value	Proportion(%)
$900 \leq ES_A \leq 1000$	74	2.13
$750 \leq ES_A \leq 900$	213	6.14
$500 \leq ES_A \leq 750$	1707	49.19
$0 \leq ES_A \leq 500$	1476	42.54
Sum	3470	100.00

UK Health and Safety Executive publication studied the results of three accident ration studies acquired from various industrial activities by Heinrich in 1950, Bird in 1969 and Tye-Pearson in 1974. Although the ratios themselves were different, the trend was very similar. Fig. 11 shows the results of a typical set of data in the form of an accident ratio pyramid.(Chengi Kuo, 2007)

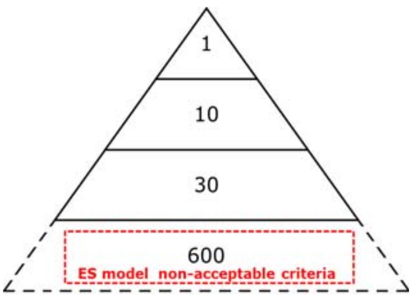

Fig. 11 Position of ES_A value in Heinrich's law

In this paper, ES model assessment simulates non-avoidance ship handling and it figures out the potential risk. Therefore, the unacceptable value in ES model is relevant the bottom of the accident ration pyramid as Fig. 11. According to this accident ratio, each accident is connected with 600 potential hazards which is classified as the unacceptable value of ES model assessment.

Using this method, annual collision probability value in ES model is same with follows:

$$27608 \times 0.0827 \div 600 \div 2 = 1.95 \text{ (incidents/year)} \quad \text{Eq. (2)}$$

4.4 Comparison with statistical data

Accident data from 2001 to 2008, based on the judgement by Korea Maritime Safety Tribunal, is shown in Tables 7~8 and Fig. 12. Collision accidents mainly occurred on the junction between fairway no.1 and no.2, the junction between fairway no.1 and no.3 and near the southern entrance of fairway no.1.

Table 7 Annual accident record in target area

Year	Collision	Grounding	Fire	Death	Sum
2001	1	0	1	0	2
2002	2	1	0	1	4
2003	1	3	0	1	5
2004	2	0	0	0	2
2005	3	0	0	0	3
2006	1	0	0	0	1
2007	3	0	0	0	3
2008	1	1	1	0	3
Sum	14	5	2	2	23

Table 8 Accident record in target area sorted by type

	Collision	Grounding	Fire	Death	Sum
Cargo ship	3	0	1	0	4
Fishing boat	10	2	0	0	12
Tanker	7	2	1	1	12
Tug	5	1	0	1	7
Container	1	0	0	0	1
Others	2	0	0	0	2
Sum	28	5	2	2	37

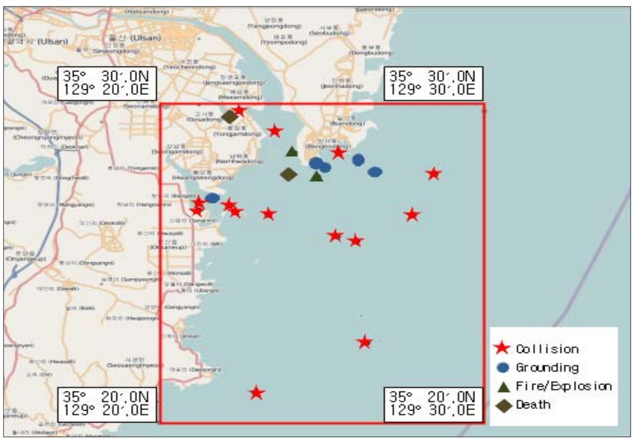

Fig. 12 Marine traffic accident data in Ulsan waterways

Table 9 classifies collision accident data by related vessel in collision. Accident data between fishing boat is excluded because the PORT-MIS data does not contain a fishing boat. As a result, collision accidents excluding between fishing boat are 12 cases and 1.5 accidents per year. It is an intermediate value between IWRAP and ES Model assessment result.

Table 9 Collision accident classified by related vessel

Collision accident	Number	Proportion(%)
between non-fishing boat	6	42.9
between fishing boat and non-fishing boat	6	42.9
between fishing boat	2	14.2
Sum	14	100.0

5. Conclusion

Marine traffic in Korean coastal water is affected by nature environment and others. For this reason, in Marine Traffic Safety Law, Maritime Safety Audit is introduced to secure the safe navigation, prevent the marine accident and to maximize the efficiency of the port. The most important part in the audit system is the marine traffic safety assessment model.

There is no independent assessment model for Korean coastal waters, so the ES model which is developed in Japan is mostly used in the audit system. However, ES model is not completely suitable in Korean waters because it doesn't reflect the risk consciousness for Korean mariners.

In this study, risk assessment of Korean coastal water, especially in Ulsan port area, is taken by foreign risk assessment models, IWRAP and ES model. And statistical data is used for comparison with assessment result.

It is shown that actual position of marine accidents were intermediate position between IWRAP and ES model. It means that ES model reflects more comprehensive mariners' risk consciousness than IWRAP.

For the furure studies, it is essential that using various kind of foreign assessment models to establish a reliable basic data for the development of independent assessment model for Korean waters.

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