Comparison of the Frequency of Unsafe Ship-Handling Situations and the Frequency of Marine Accidents at the Kurushima Strait

Masaru YASUDA*, Kinzo INOUE** and Hideo USUI**

*Japan Marine Science Inc.
2-4-6, Irifune Minato, Nagoya, Japan 455-0032
yasuda-jms@proof.ocn.ne.jp

**Kobe University, Faculty of Maritime Sciences
5-1-1, Fukae-Minami, Higashinada, kobe, Japan 658-0022

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ABSTRACT

It is requested to be evaluated whether environmental change in marine traffic passage by maintenance work affect ship handling, safety, when re-design of traffic passage is planned. In the maintenance work, it is also important to evaluate the change of risk and also benefits. However, in a current evaluation index, it is difficult to evaluate the benefit. The recently developed safety index that is led by employing the Unsafe Ship-handling situations model (US-model) is able to estimate risk level of marine accident in a process of a ship handling. We have already reported the relation of the ratio of 10-3 in harbors (Yokohama, Kobe, and Osaka in Japan) [1]. In this study, we acquired the relation of the ratio between the US value and the marine accident at a narrow waterway; Kurushima Strait in Japan, using a ship handling simulator. And we experimented to estimate a marine accident reduction achieved by the maintenance work of the altered shape of passage.

1. Introduction

In Japan composed of small islands, we have depended on sea trade from the old days. So ships' transport is developed, there are grate deal of ships around coastal area. Especially, the SETO inland sea area is overcrowded with big and small, various ships, many marine accidents have occurred. At Kurushima strait in SETO inland sea, it is with not only narrow and curvy shape but also with strong current. Due to this difficulty, this strait is well known as the water area where many marine accidents occurred.

Japanese Government has planed to improve the shape of traffic passage at Kurushima Strait, where many marine accidents has occurred since 1963. But there was no adequate objective index which is enable to evaluate risk reduction achieved by maintenance work. It was called for more objective and more quantitative evaluation method that matched changeful environment.

A benefit of maintenance is estimated by measuring of marine accidents reduction. We developed the Unsafe Ship-handling situations (US) index that is able to estimate a maneuvering safety. And then we obtained an interrelation of a ratio 10-3 between the US value and the marine accident rate(1).

In this study, we focused on the Kurushima strait where is narrow and curved, besides more congested. We came to conclude to obtain not only interrelation between the US and the marine accident but also to estimate the effect of maintenance of the strait

2. Marine Accidents of KURUSHIMA

2.1 Circumstance of Marine Accidents

Table 1 and Fig.1 show the list and the position of the marine accidents occurred in the past around the Kurushima strait. There were 26 marine accidents of 100 tons or more that occurred in the past ten years (1994-2003) around the strait, and in case of 10,000 tons or more, there was no marine accident. In this study, we focused on 20 cases that occurred on the traffic passage.

Table 1 Marine accidents around Kurushima strait (1994 – 2003)

Date					Type	GT	Weather	Wind Dir.	Wind Velo.	Visibility	Route	Dir.	Tide		
Around Uma-Shima and O-Shima															
1995	4	17	15	50	Tanker		fine	ENE	3	4			N	322	3.34
1996	7	12	14	20	Cargo	197	cloud	NE	5	10			N	325	1.95
1998	4	25	2	18	Cargo	199	fog	N	0	0.1	Naka Suido	W	N	324	2.98
1995	4	30	2	2	Cargo	498	fog	calm	0	1	Naka Suido	W	N	312	2.16
1998	4	23	12	40	Cargo	499	fog	SE	3	0.2	Naka Suido	W	N	320	2.49
2003	10	10	22	43	Tanker	297	cloud	calm	2	10			S	166	2.53
1996	5	31	8	5	Cargo	491	fog	ENE	0	0.2	Nishi Suido	W	S	163	2.85
1995	4	30	0	20	Cargo	495	fog	calm	0	1	Naka Suido	E	S	213	1.03
1998	2	5	3	30	Tanker	499	fine	SSW	5	10			S	164	3.56
1995	3	24	18	40	Cargo	554	cloud	NNW	1	2			N	314	1.68
1995	8	29	2	46	Cargo	607	cloud	calm	0	4			N	310	2.45
2002	1	11	1	20	Cargo	1662	fine	WNW	1	10	Naka Suido	W	N	325	2.47
1994	2	9	5	0	Passenger	698	fine	W	19	4			S	186	0.74
2001	8	8	11	54	Cargo	1282	cloud	ENE	2	10	Naka Suido	E	S	164	2.47
1996	7	4	8	8	Tanker	1513	fog	NNE	5	0.1	Nishi Suido	W	S	217	0.15
2001	3	14	0	30	Cargo	2316	fine	SSW	2	10			S	164	3.66
1994	1	11	9	35	Cargo	2829	cloud	calm	1	4	Naka Suido	E	S	161	3.2
2001	10	17	21	10	Cargo	4159	fine	ENE	11	10	Nishi Suido	W	S	166	4.37
1998	4	23	19	27	Cargo	4452	fog	calm	0	0.1	Naka Suido	W	S	158	2.88
2002	4	28	22	40	Cargo	4738	fine	calm	0	10			S	166	4.4

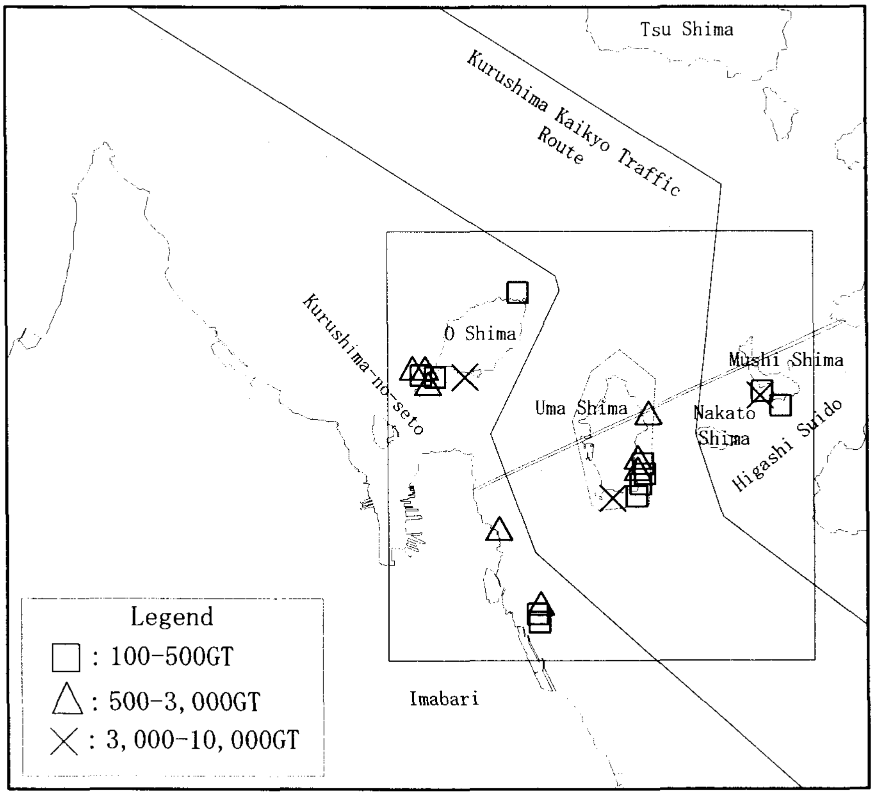

Fig.1 Position of marine accidents (1994-2003)

2.2 Estimation of the Ratio of the Marine Accidents

We classified the marine accidents into 4 sizes (100-500GT, 500-3,000GT, 3,000-10,000GT, 10,000GT-). Numbers of the ship in each size were referred to a traffic investigation that was executed in the past.

Table 2 shows the estimation of the ratio of marine accidents.

Table 2 Ratio of marine accidents (1994～2003)

	Actual number of ships (2days)	Estimation number of ships (10years)	Number of Marine Accident	Ratio of Marine accident
100-500GT	496	905,200	9	9.94E-06
500-3,000GT	350	638,750	8	1.25E-05
3000-10,000GT	87	158,775	3	1.89E-05
10,000GT-	29	52,925	0	
Total	962	1,755,650	20	1.14E-05

3. Judgment of Unsafe Ship-handling Situation

When we calculate the prediction wake, we used a concept of the Potential Area of Water[2][3]. Prediction wake is calculated at each second under the hypothesis that the rudder and engine motion are fixed.

The time span of prediction wake to be calculated is corresponds to the SST (Short Stopping Time) of the ship, and when the prediction wake collide against other ship or obstacle, inside the time span of TTC (Time To Collision), such situation is judged to be an Unsafe ship-handling situation.

4. Correspondence between the US and Marine Accidents

4.1 Experiment of Ship-handling Simulator

1) Model Ship

Table 3 shows the model ships of the simulator experiment.

The decision of the ship size of the simulator was based on the ship size of the marine accidents. And the ship type was unified to the cargo vessel from a result of 80% of the marine accidents was cargo.

Table 3 Model ship of simulator experiment

Model Ship	Loa(m)	Lpp(m)	B(m)	Draft(m)
499GT	64.55	60.00	10.00	4.23
3,000GT	105.29	97.60	15.20	6.49
10,000GT	130.00	123.00	21.80	7.50

2) Conditions of Environment

i) Wind Condition

The velocity of the wind was assumed to be the average value (3.5m/sec) when the marine accidents occurred. The wind direction was assumed to be the most wind direction (ENE) at the IMABARI observatory.

ii) Current Condition

Table 4 shows the frequency of current velocity and direction when the marine accidents occurred.

Because the average current velocity was around 2.3kt - 2.6kt and there was not specific difference, this average velocity (2.5kt) was assumed to be the current velocity of the base point (34-06-12N, 133-00-00E). And the current situation of the whole area was estimated by the current simulation.

Table 4 Frequency of current (when the marine accidents occurred)

Ship	Current Dir.	Current Velocity
100-500GT	N	2.58
	S	2.49
	both	2.54
500-3,000GT	N	2.20
	S	2.04
	both	2.10
3,000-10,000GT	N	−
	S	3.88
	both	2.54
All Ship	N	2.44
	S	2.65
	both	2.57

Current Class	Frequency	
1	2	10%
1.5	1	5%
2	2	10%
2.5	5	25%
3	4	20%
3.5	2	10%
4	2	10%
4.5	2	10%
5	0	0%
Total	20	

3) Experiment case and subject

Table 5 shows the number of marine accidents generation by the ship size and the traffic passage and the direction. According to this table, there is no marine accident when the ships sail bound for east, when the ship sail bound for west at NAKA and NISHI traffic passage.

In the simulator experiments, 7 patterns were set based on the actualities of such accidents.

Table 6 shows the cases of the simulator experiment. We asked 8 captains to maneuver; therefore experiment was executed 56 cases in total.

Table 5 Frequency of marine accidents (1994-2003)

Route	Naka Suido		Nishi Suido	
Course	E	W	E	W
100-500GT	1	3		1
500-3,000GT	2	1		1
3,000-10,000GT		1		1
Total	3	5	0	3

Table 6 Pattern of simulator experiment

Pattern	Ship	Course	Suido	Dir.	Current	Wind Dir.	Wind Velocity
1	499GT	W	Naka	N	5 - 6knot	ENE	3.3m/sec
2			Nishi	S			
3	3,000GT	W	Naka	N			
4			Nishi	S			
5		E	Naka	S			
6	10,000GT	W	Naka	N			
7			Nishi	S			

4.2 Interrelation between the US and the Marine Accidents

Table 7 and Fig.2 show the ratio of the frequency of the marine accidents and the values of the US when the ship sailed at Kurushima strait with the ship-handling simulator.

The time in the Table 7 means the navigation time within the calculation area that was shown in Fig.1. Consequently, the US value increases depending on the sailing speed, even if the value of the US is the same.

In Fig.2, the US value show the tendency to increase when ship size becomes large, and the relation between US and marine accident is corresponding in the ratio of 10-4.

In this way, it is suggested to presume the risk of the marine accident by estimating the magnitude of the US value in the maneuvering process. It becomes possible to estimate the benefit from an environmental change by a developing and maintenance work.

Table 7 Relation between ratio of US and ratio of marine accidents

Ship	Frequency of US	Time	Ratio of US	Ratio of Marine Accident	Ratio between US and Marine Accident
500GT	1,170	15,993	7.32E-02	9.94E-06	1.36E-04
3,000GT	8,923	21,074	4.23E-01	1.25E-05	0.30E-04
10,000GT	8,500	18,806	4.52E-01	1.89E-05	0.42E-04

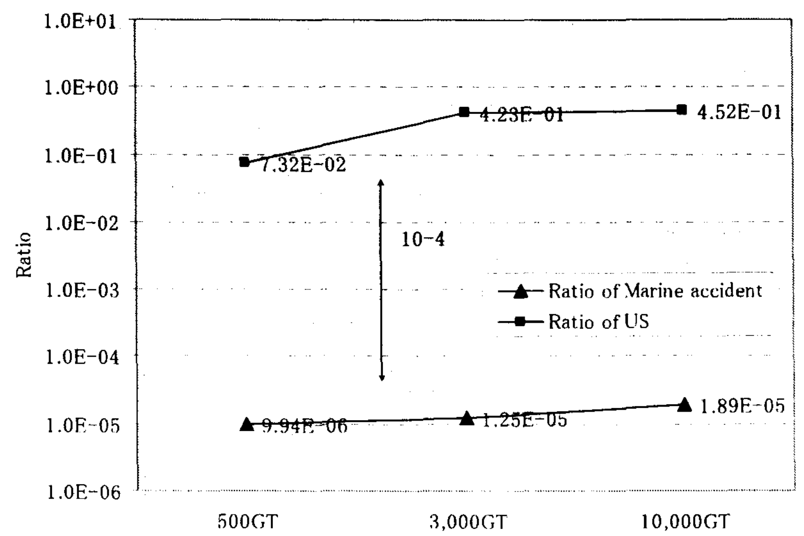

Fig.2 Relation between US and marine accident

5. Effect of a Marine Accident Decrease of Passage Maintenance

When the government plans to maintain traffic passages, it is requested to estimate the benefit and the cost achieved by the maintenance work, and it is important to consider the relevancy of the maintenance work.

Although it was difficult to evaluate such a benefit from risk reduction of the marine accident, it is possible to estimate the benefit by clarify the relation between the US and the marine accident.

Here, using the ship-handling simulator, the Kurushima strait was taken up as a model case, the marine accident rate before and after the maintenance was estimated, and the presumption of the marine accident reduction rate achieved by maintenance work was calculated provisionally.

5.1 Assumption of the traffic passage shape

The maintenance plan was assumed that the winding corner was eased as shown in the Fig.3, and the width was expanded.

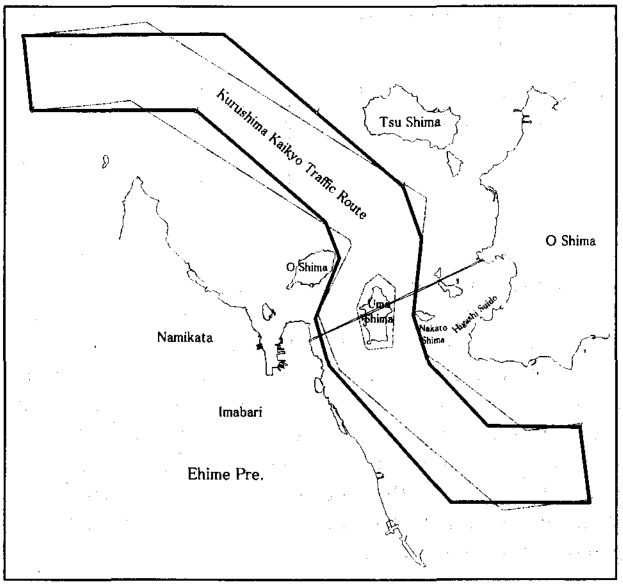

Fig.3 Route shape after a maintenance

5.2 Assumption of the Model Ship and Conditions

The model ship was assumed the 280,000DWT VLCC and the 40,000DWT container vessel from the reason that larger sized vessel becomes to be able to navigate by the maintenance work as shown in Table 8.

The current condition was assumed the most frequency value (about 6kt in the narrowness part) when the marine accident occurred. And the wind condition was assumed calm.

However, in case of the experiment of the VLCC, less than 3 knots of the current velocity at the narrowest part was set, because it is not realistic that sailing in such a strong current as over 3 knots.

Table 8 Model ship of simulator experiment

Model Ship	Loa(m)	Lpp(m)	B(m)	Draft(m)
Container	247.9	230	32.2	11.5
VLCC	322	310	56	20

5.3 Simulator Experiment Cases

Table 9 shows the simulator experiment cases.

Table 9 Simulator experiment cases

Case	Model Ship	Course	Suido	Current Dir.	Current Velocity	Wind
1	3500TEU Container	E	Naka	S	6kt	Calm
2		W	Nishi			
3		E	Nishi	N		
4		W	Naka			
5	VLCC (280,000DWT)	E	Naka	S	3kt	
6		W	Nishi			
7		E	Naka	N		
8		W	Nishi			

5.4 The Marine Accident Reduction Rate by the Maintenance

Table 10 shows the frequency of the US values before and after the maintenance work.

And here estimated rate of marine accident led from the relationship of the ratio between the US frequency and the marine accident frequency are shown .

It shows that the rate of the marine accident decreases to 1*10-5 when comparing with before the implementation of maintenance work.

If the number of VLCC passed Kurushima Strait in past ten years is assumed to be 37,940 from the actual data in 2004, it is predicted that the reduction of marine accident in ten year is 0.4 (37,940*10-5).

Fig.4 shows the US values as compared with before and after the maintenance work. Although as the result of maintenance work, great number of reduction of marine accident was not seen, the reduction of the US values were large especially in VLCC. It means that the maintenance work is able to be expected more effectiveness for a vessel such as VLCC that maneuverability is poor.

Table 10 Estimation of rate of Marine acciden

Ship	Course	Suido	Current		Actual Route			After Maintenance		
					Time	Freq. US	US	Time	Freq.US	US
Container	E	Naka	S	6	708	292	0. 41	816	353	0. 43
		Nishi	N	6	1276	367	0. 29	1000	530	0. 53
	W	Nishi	S	6	1107	381	0. 34	1157	148	0. 13
		Naka	N	6	702	293	0. 42	673	322	0. 48
VLCC	E	Naka	S	3	946	603	0. 64	1009	338	0. 33
		Nishi	N	3	1261	360	0. 29	1554	220	0. 14
	W	Nishi	S	3	1135	425	0. 37	1224	231	0. 19
		Naka	N	3	906	469	0. 52	965	402	0. 42
Total					8041	3190	0. 40	8398	2544	0. 30
					Estimate Rate of Marine Accident		4.0E-05	Estimate Rate of Marine Accident		3.0E-05

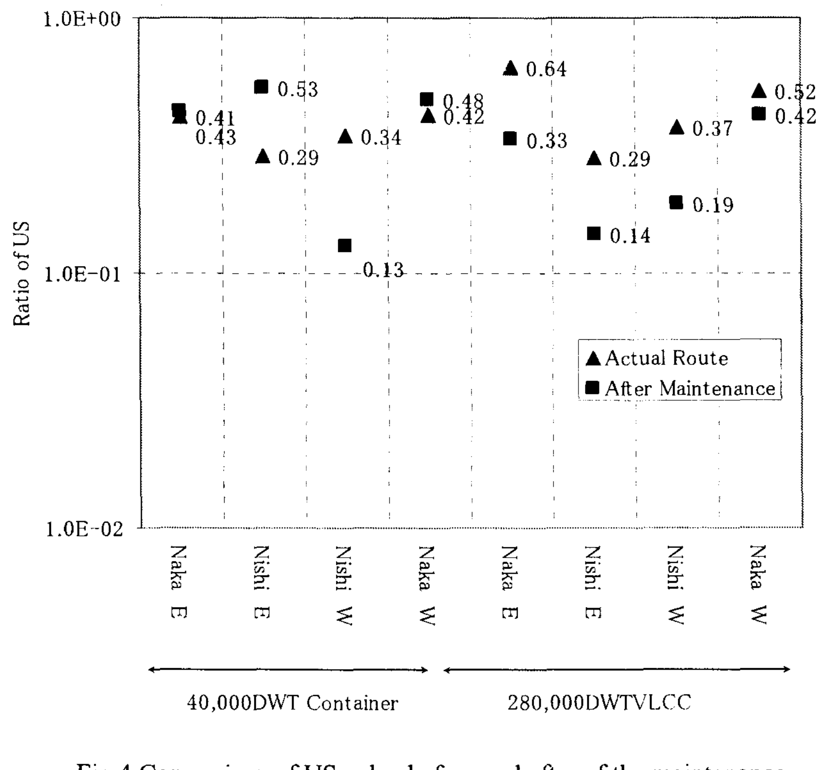

Fig.4 Comparison of US value before and after of the maintenance

6. Conclusion

The change of maneuvering safety is requested to be evaluated objectively and quantitatively when the passages are re-designed.

In addition to it, it is important to evaluate the cost and benefit achieved by the implementation of the maintenance work, and examine the validity.

However, we haven't suitable index to do so until now.

US-model introduced here is a powerful tool to evaluate the change of risk of accident, which shows accident occurrence rate in probabilistic figure.

It has already reported that there is the relationship of ratio of 10-3 between the US value and the marine accident inside traffic congested harbors[1]. In the present paper, through ship handling simulator experiments, the US values show the tendency to increase when ship size becomes large, and the relation between US and marine accident is corresponding in the ratio of 10-4. And estimation of the marine accident reduction achieved by the maintenance work of the narrow water passage was demonstrated.

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