International Journal of Navigation and Port Research
Vol.29, No.2 pp. 159~164, 2005 (ISSN-1598-7701)

A Study on the Correlation between Maritime Safety and Safety Factors

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Abstract : *Maritime safety is influenced by several factors, for example, technical factors, human factors and operational factors. To improve maritime safety, each country should identify which factors will bring about a marine accident. This case study approached statistical method to find out correlations between marine accidents and safety records in Korean merchant fleet. There were no statistical significance between marine accident rate and PSC detention rate and human factor rate. But there was statistically significant relationship between marine accident rate and PSC inspection rate. It is possible to presume that in the developing country the stronger the government shows its will, the less such accidents occur.*

Key words : *Maritime Safety, Marine Accident, PSC, Safety Factor, Correlation*

1. Introduction

Since the earliest times, the sea has always been synonymous with insecurity for those who venture on going there. The history of navigation since ancient times shows the needs of safety. According to Lloyd's List during 1770~1775, for example, total loss of 112, slightly more than one in ten of total marine casualties, occurred in the open sea, 63 of these being described as foundered or lost at sea (Earle, 1998). The introduction of the ISM code, ISPS code and other recent amendments to SOLAS and STCW are all recent efforts to improve safety in the shipping industry. In statistical terms, there has been a significant improvement in the number of ships and lives lost. The sea has become a safer place, although this statement must be proved by observing that crews are now smaller and more passengers travel by air, thereby has reduced the risk of marine accidents.

The Korean government inaugurated the Ministry of Maritime Affairs and Fisheries (MOMAF) in 1996. From that time, the policy, implementation and investigation of maritime safety are controlled under one minister. The result of an effort to reduce maritime casualties shows that the safety of the Korean merchant fleet has dramatically improved. Nevertheless, many problems need to be resolved in order to improve the maritime safety in Korea yet further. The activities for maritime safety in each country are different due to their historic maritime backgrounds and safety culture. The Korean government, like almost all developing countries, has benchmarked the maritime safety systems of the traditional maritime countries and adopted and applied good ones to their systems. Some systems have been successfully launched in Korea but others have proved difficult because of budget shortages, lack of understanding, rejection by vested interest groups, or difference in culture, etc.

This study, therefore, aims to investigate statistical correlation between marine accident rate and safety records and suggest practical factors to improve maritime safety in Korea.

2. The method and limitation of the study

As a methodology for this study, a literature survey was carried out to define maritime safety and safety factors. An empirical study was then carried out to identify the relationship between marine accidents and these safety factors by using a statistical package (SPSS).

This study of maritime safety is limited essentially to merchant vessels. The reason is that the historical data was not sufficient to conduct research on the fishing and recreational sailing sectors. The safety records used in this study are from the recent 10 years of maritime casualty records.

3. Definition of maritime safety and maritime safety factor

To prevent accidents effectively and to increase efficiency, it is very important to define the concept of safety and its main factors.

Safety is a word which everybody understands but which

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is difficult to define because we use 'safety' in broad terms across a wide range of areas. In dictionary terms, 'safety' means the condition of being safe; freedom from danger or risks (Oxford Dictionary, 1997), but recently freedom from 'injury' has been added (Yahoo dictionary, 2004).

Maritime safety is a form of transport safety at sea. The general object of transport safety is to protect human life, bodies and property from traffic invasions. Thus the term of 'safety' in 'maritime safety' or 'safety at sea' means both the material state resulting from the absence of exposure to danger, and the organization of factors intended to create or perpetuate such a situation. Furthermore, at the present time, maritime safety is regarded as one of the essential reasons for policing the marine environment, and as a justification for any major departures from the principle of the freedom of the seas.

Generally speaking, maritime safety is often construed as being about the safety of navigation. But recently, the problems of piracy, terrorism and other violent acts at sea have been raised widely. Thus, this study will define 'maritime safety' as a broad concept such that it may be defined as 'the condition of being safe: freedom from danger, risk, injury or unlawful acts at sea.' (Boisson, 1999)

A marine transportation system comprises three interacting components: (1) the ship and her equipment (hardware), (2) the rules and regulations, codes of practice, operating procedures and casualty records and statistics (software), (3) the personnel involved, both afloat and ashore (humanware) (Allievi, 1991). Accordingly, maritime safety factors should be divided into technical factors (the hull and all machinery, equipment, instrumentation, etc.), human factors (the professional requirements, individual characteristics, aptitude, mental attitudes and education and training etc.) and operational factors (rules and regulations, codes of practice, navigation system, port operations, pilotage, cargo handling, passenger safety, etc.).

4. Ship casualty statistics and safety records

Many studies published up to date relating to maritime safety look only at limited records, for example, the total loss of vessels and deaths of seafarers. This is, in many ways, understandable. Whilst Flag States may be unable or unwilling to provide details of all vessel casualties, the loss of a vessel is much more likely to come to the attention of the maritime community. However, accident and incident data can be obtained from more reliable and comprehensive sources on the safety of vessels such as variable organizations. This study has utilized data from the Lloyd's casualty database, government official records of maritime accidents and Port State Control inspection records.

4.1 Total loss record

Lloyd's Register of Shipping casualty review publishes losses of all ships of more than 100 gross tonnes. Figures in Table 1 show the total number of vessels and total losses of Korea, classified by flag. Comparing merely the number of total losses is less meaningful because the total fleet are different in each country. Hence this study uses the total loss rate of register based fleet, ie the ratio of losses to the number of vessels at risk.

Table 1 Total loss rate

Year		'93	'94	'95	'96	'97	'98	'99	'00	'01	'02
World Total (Cargo vessel)		0.36	0.35	0.35	0.36	0.34	0.38	0.33	0.32	0.28	0.20
Korea	Total Ship No.	2,085	2,121	2,246	2,327	2,441	2,381	2,417	2,502	2,426	2,532
	No. of Total loss	13	11	7	1	4	5	3	4	5	8
	Total loss rate	0.62	0.52	0.31	0.04	0.16	0.21	0.12	0.16	0.21	0.32

Source : World Casualty Statistics, Lloyd's Register of Shipping, 2004 and 2004 Statistical Year Book of MOMAF.

4.2 Marine accident record

The total loss rate is not sufficient to compare itself with the maritime safety activity because the number of total losses compared to their total fleet size is too small to judge the effectiveness of their respective maritime safety activity. Therefore, the total marine accident rate in Table 2 will give a more accurate picture than the total loss rate alone.

The Korea Maritime Safety Tribunal (KMST) issues periodical reports on Korean vessels involved in accidents. The accident rate for Korea was calculated by using the numbers of accidents recorded in the annual reports of the KMST and also the registered fleet numbers from Lloyd's Register of Shipping data.

Table 2 Marine accident rate of Korea (by over 100gt)

Year	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02
No. of Reg	2,085	2,121	2,246	2,327	2,441	2,381	2,417	2,502	2,426	2,532
No. of Accid	234	288	333	307	268	236	260	194	242	284
Rate (%)	11.22	13.58	14.83	13.19	10.98	9.91	10.76	7.75	9.98	11.22

Source : Lloyd Statistics, 2004 and the KMST Annual Report

4.3 PSC inspection record

Port State Control (PSC) is a key element in the effective policing and enforcement of international standards. Table 3 shows the PSC inspection rates for Korea. The PSC inspection ratio is calculated by the number of inspections by Port State Control Officers (PSCO) compared to the number of vessel calls in the Korean ports. PSC inspection data were collected from the Paris Memorandum of Understanding (Paris MOU) and the Tokyo Memorandum of Understanding (Tokyo MOU). The PSC inspection of the Pacific area has been conducted from 1994. Hence Korea has inspected foreign vessels from 1995 although there were very small inspection numbers at the start.

Table 3 PSC inspection rate of Korea

Year	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02
No. of Ship call	*	*	7,423	7,683	8,027	8,088	8,088	8,400	9,380	9,480
No. of Inspection	*	*	247	749	1,096	1,286	1,846	2,200	2,348	3,354
Inspection Rate(%)	*	*	3.3	9.8	13.7	16.1	23.1	26.2	25.0	35.4

* Data not available

Source: Paris MOU and Tokyo MOU Annual Report

4.4 PSC detention record

Vessels are detained when the condition of themselves and their crew does not correspond substantially with the applicable Conventions. Such detentions ensure that the vessel cannot sail until she can proceed to sea without presenting danger to the vessel or persons onboard.

The detention records in Table 4 used in this study have been collected from the Paris MOU, the Tokyo MOU and USCG annual reports. As the Tokyo MOU started in 1994, this study used the PSC detention records from 1995.

Table 4 PSC detention rate of Korea

Year		'95	'96	'97	'98	'99	'00	'01	'02
Paris MOU	Inspection	43	35	65	54	36	28	31	33
	Detention	3	2	3	2	0	1	3	0
USCG	Inspection	*	*	*	103	85	79	88	92
	Detention	*	*	*	1	2	0	4	1
Tokyo MOU	Inspection	263	406	441	401	418	584	658	736
	Detention	13	27	17	40	38	52	41	17
Total	Inspection	306	441	506	558	539	691	777	861
	Detention	16	29	20	43	40	53	48	18
	Rate(%)	5.23	6.58	3.95	7.71	7.42	7.67	6.18	2.09

Source : Paris MOU, Tokyo MOU and USCG Annual Report

4.5 Human error record

Humans can make a mistake anytime and anywhere. By identifying human errors it can be anticipated what might cause an accident, and be ensured that risks can be avoided before they become critical. Although the importance of human error is often emphasized, there are surprisingly little useful data for Korea.

The human error rate for Korea is calculated using the KMST annual accident reports. These annual reports do not use the term 'human error', so this study has re-classified 'Carelessness in Navigation', 'Mishandling of Machinery' and 'Improper Stowage of Cargo' as 'Human Error'.

Table 5 Human error rate of Korea

Year		'93	'94	'95	'96	'97	'98	'99	'00	'01	'02
Human error	Carelessness in Navigation	77	97	107	148	96	98	86	80	88	91
	Mishandling of Machinery	9	7	10	12	11	9	6	9	6	13
	Improper Stowage etc	1	6	3	2	2	7	7	7	4	2
	Sub total	87	110	120	162	109	114	99	96	98	106
Non-human deficiency		23	14	15	16	8	25	7	10	14	10
Grand total		110	124	135	178	117	139	106	106	112	116
Human error rate (%)		79.1	88.7	88.9	91.0	93.2	82.0	93.4	90.6	87.5	91.4

Source : Author reorginized by the Marine Casualty Statistics of the KMST

Table 5 shows that the human error rates for Korea have been steadily maintained during the last 10 years with the highest percentage averaging 88.6% .

5. Research modeling

5.1 Theoretical considerations

Basically, the theoretical basis for this model is that maritime safety factors will influence the operation of vessel through a safety management system. If the safety management system of a vessel is working correctly, the vessel will be operated safely. Otherwise, an accident will have occurred and consequently have caused pollution to the marine environment, loss or damage to the vessel, or death and injury to the seafarers.

For this study, maritime safety is considered to comprise four classes of factor; technical factors, human factors, operational factors (which are relevant to the safety of navigation) and security factors (which are relevant to the safety of trade). These factors will impact on the safety management system of the vessel individually or will cause complex interaction on another. At present, there are no useful data to measure 'safety of trade'(such as maritime

security), so this study is limited to demonstrating any relationship between maritime safety and 'safety of navigation'.

Fig. 1 shows a simple model illustrating the maritime safety factors involved in vessel operation.

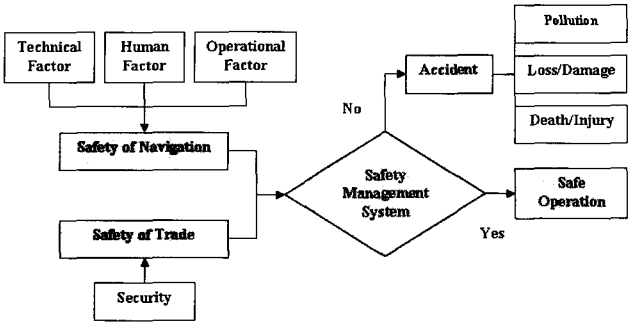

Fig. 1 A model of the marine safety factors involved in vessel operation

5.2 Formal hypotheses

To explore the influence of marine safety factors in the operation of Korean vessels, the following formal statement of the hypotheses is provided:

1) Statistically significant links between selected safety factors and maritime accident data will exist. This hypothesis explores the influence of safety factors on the causes of observed maritime accidents.
2) Certain factors will have more potential influence to reduce marine accidents than others. If these significant factors were defined, governments can concentrate their policy on them in order to improve maritime safety.

These questions can be explored with the use of several safety records that are acting as a proxy for maritime safety.

Correlations can be a very useful research tool but they tell us nothing about the predictive power of variables. If regression analysis is used, one or more independent variables (IVs, predictors) can predict values of the dependent variable (DV, the outcome).

The model may be formally expressed as:

Maritime safety = f (Technique, Human, Operation)

In this study, marine accident rates are used as a representative variable of maritime safety (dependent variable) because marine accidents can be regarded as an outcome of maritime safety activities. It is considered for the purposes of this study that the number or rate of total losses of ships in a fleet is the most suitable indicator for assessing the degree of safety of that fleet. It is thought that the lower number of ships incurring accidental total loss per 1,000 would not be as appropriate as a safety indicator.

As to the independent variables, this study has adopted three representative variables:

1) the PSC detention rate as an indicator for technical factors;
2) the human error rate as an indicator of human factors; and
3) the PSC inspection rate as an indicator of operational factors.

The use of the PSC inspection rate as an indicator for operational factors requires further explanation. Operational factors include all the tasks which the ship has to perform, and therefore, it is the combined responsibility of shore and ship management to ensure that all operational procedures are implemented. Port State Control is a method of checking on the success of Flag State enforcement, and therefore the PSC inspection rate may be regarded as an outcome of the operational system of the Flag State, in other words, the government's will. Of course, there are considerable differences between Port State Control and Flag State Control mechanisms, so caution is required in construing their effects on safety.

The model was estimated using SPSS *win*.

6. Model results

6.1 Correlation

SPSS output provides a matrix of the correlation coefficients for the three variables of Korea. The PSC detention rate and the PSC inspection rate are negatively related, and the human error rate is positively related, to the accident rate. PSC inspections have moderately influenced marine accidents in the Korean fleet relative to other factors. Similarly, human error has had little influence on the marine accident rate.

Table 6 Matrix of the correlation

	Accident rate	PSC detention rate	Human error rate	PSC inspection Rate
Pearson correlation	1	- 0.340	0.067	- 0.672
Significance level		0.410	0.853	0.068
N	10	8	10	8

The significance value of the PSC inspection rate is 0.068 which is close to 0.05. Even though the significance value of PSC inspection is close to 0.05, the influence of PSC inspection to the maritime accident should be interpreted

with caution. There are no statistical relationships between marine accidents and these safety factors in Korea.
Although the relationship between the human error rate and the marine accident rate is very low, human error is actually a major influential factor in Korean fleet with ranges of 79.1%~93.4% (See Table 5).

6.2 Regression

The SPSS output provides the following linear equation for Korean maritime safety.

Korean maritime safety = 14.187 - 0.533 PSC detention + 0.035 Human error - 0.166 PSC inspection

The R square value is 0.708, which means that the factors of PSC detention rate, human error rate and PSC inspection rate can explain upto 71% of the accident rate. The association between the maritime accident rate and PSC detention, human error and PSC inspection rates is strong.

Table 7 Summary of Regression analysis

Model	R	R square	Adjusted R square	St. error of the estimate	
	0.842	0.708	0.490	1.53480	
Model	Sum	DF	Mean square	F	Probability value
Regression Residual Sum	22.892 9.422 32.314	3 4 7	7.631 2.356	3.2391	0.143
Model	Unstandardized coeff.		t	Probability value	
	B	Standard Error			
(Constant)	14.187	15.906	0.8902	0.423	
PSC detention rate	-0.533	0.318	-1.677	0.169	
Human error rate	0.035	0.169	0.209	0.845	
PSC inspection rate	-0.166	0.058	-2.852	0.046	

The Probability value (P=0.143) which assumes that the null hypothesis is true, is only 14 in 100 and the regression equation is therefore statistically insignificant.

The regression coefficients B of the PSC detention rate and the PSC inspection rate are negatively related to the marine accident rate, but the human error rate is positively related. The regression coefficient B for the PSC detention ratio was 0.533; human error ratio 0.035, and the PSC inspection ratio was 0.166.

The smaller the value of significance (and the larger the value of t), the greater the contribution of that predictor. For this model, the PSC inspection ratio is (t = 2.852, p = 0.046) and is a significant predictor of the maritime accident rate than either the PSC detention ratio (t = 1.677, p = 0.169) and the human error ratio (t = 0.209, p = 0.845). This interpretation is true only if the effects of the PSC detention rate and the human error rate are held constant.

In summary, the regression analysis suggests the following predictions:

1) The model for predicting marine accidents in Korea is not sufficient by only using the data of PSC detention rate, human error rate and PSC inspection rate.
2) The PSC detention rate was found to be negatively related to the marine accident rate.
3) There is a significant link between the PSC inspection rate and the marine accident rate in that the more the PSC inspection rate increases, the less marine accidents occur.

7. Conclusion

There is no specific recipe for safety. This is because numerous factors are involved in each situation and different cultures will have their own distinctive affects on maritime safety. For this reason, the maritime safety system of a developed country could not be applied directly to the developing country.

This study presented the econometric results obtained from a correlation and regression model of the marine accident rates of Korea, which has tried to establish the statistical significance of a number of characteristics that might influence the shape of the marine accident pattern in Korea.

Reviewing the statistical results for the regression analysis of Korea, it can be seen that:

1) The data reveals that there is apparently no clear cut pattern in terms of casualty rate and type of safety factor in Korea.
2) The prediction model for marine accidents in Korea is not sufficient by only using the data of PSC detention rate, human error rate and PSC inspection rate.
3) There is no statistical significance between the marine accident rate and the PSC detention rate, human error rate, and PSC inspection rate.

However, there was a statistically significant negative correlation between the marine accident rate and the PSC inspection rate. Any increase in the PSC inspection rate should result in a decline in the accident rate. It follows therefore that, subject to the government's will, improvement might be made, for example, by establishing an organization to employ more PSC inspectors and provide sufficient funds for operation. It is also possible to presume that the more the government's will is exercised, the less

accidents will occur in the developing countries.

It is often repeated that more than 80 per cent of all marine accidents are caused by human error, and the human error rate of Korea has been steadily maintained at high levels during the last 10 years. It might therefore be concluded that measures taken by the maritime community to prevent accidents should target this factor.

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Received 14 March 2005
Accepted 29 March 2005