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A study on ship's routeing and port zoning audit scheme for eradicating or reducing circumstantial factors of marine casualties and incidents

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A Study on Ship's routeing and Port zoning Audit Scheme for eradicating or reducing circumstantial factors of marine casualties and incidents

By

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature:

Date: 22 October 2012

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ABSTRACT

Title of Dissertation: **A Study on Ship's routeing and Port zoning Audit Scheme for eradicating or reducing circumstantial factors of marine casualties and incidents**

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This dissertation is a study on Ship's routeing and Port zoning Audit Scheme (SPAS) for eradicating or reducing risky circumstantial factors of marine casualties and incidents in coastal waters. It aims to show methods of preventing marine accident from the human element, and to discuss the further development for the maritime safety system of the Republic of Korea as the world's first compulsory scientific audit scheme on ship's routeing and port zoning.

At the outset, this study intended to review the statistics of marine accidents to analyse which causes and places should be focused on to secure maritime safety. It also attempted to analyse serious marine accidents which occurred in ports and approaches. This was to demonstrate which tools were applied successfully to reduce marine accidents caused by the human element. A controversy over a harbour bridge was introduced to prove the importance of objective ship handling simulation.

The STCW, Navigational Aids, the ISM Code and the User-Centred Design were studied as methods of reducing human errors in error enforcing circumstances. To verify that the IMO's safety measures on the human element are corresponding to all categories of human errors, the Marine Casualty Investigation Code of the IMO was referred to. It was found that the IMO could contribute further to preparing any

appropriate measures to deal with the loose interface between liveware and the environment, in other words, navigators and the navigational circumstances. Accordingly, it reviewed the schemes of several maritime States that were relevant to safety of navigation in ports and approaches. As a successful example, the SPAS of the Republic of Korea was analysed. The SPAS is evaluated in Korea as an effective risk finding system in port design and its operation, and a tool for providing the navigators in coastal waters with a better navigational environment. In addition, from the shore-based perspectives, the SPAS has reduced social disputes over maritime safety and accelerated economic construction of infrastructures.

Despite of the successful implementation of the SPAS project, some issues are still open. Chapter 5.5 provides the future direction of the SPAS system as the world's first compulsory scientific audit scheme on ship's routeing and port zoning. Also it contains some recommendations to policy planners for achieving efficient port construction and management taking into account safe navigation. Ultimately, this dissertation aimed to study how human error as a principal causation factor would not turn in marine accidents in heavy traffic zones such as coastal waters.

At the end, it is reiterated that the human element and navigator-friendly circumstances should be considered together in order to reduce marine accidents in coastal waters, to protect the marine environment and to save human lives at sea.

KEY WORDS: Ship's routeing and Port zoning Audit Scheme (SPAS), Marine Casualties and Incidents, Marine Accident Investigation, Statistics of Marine Accidents, Human Element (HE), Human Error, SHEL Model, Liveware, User-Centred Design (UCD)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
CFR	Code of Federal Regulations
CPA	Closest Point of Approach
CPP	Controllable Pitch Propeller
C/O	Chief Officer
ECR	Engine Control Room
EIA	Environmental Impact Assessment
EU	European Union
ETA	Estimated Time of Arrival
EU	European Union
FEW	Finished With Engine
FPP	Fixed Pitch Propeller
GICOMS	General Information Centre on Maritime Safety and Security
IBS	Integrated Bridge System
IMO	International Maritime Organization
INS	Integrated Navigation System
ISC	Integrated Ship Control
ITZ	Inshore Traffic Zone
LEI	Liveware-Environment Interface
LRIT	Long Range Identification and Tracking
MARPOL 73/38	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, as amended
MARPOL PROT 1997	Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, as modified by the Protocol of 1978 relating thereto

MLTM	Ministry of Land, Transport and Maritime Affairs
MOMAF	Ministry of Maritime Affairs and Fisheries
MOCT	Ministry of Construction and Transportation
MSA	Maritime Safety Act of Korea
MSC	Maritime Safety Committee
NAV	Sub-Committee on Safety of Navigation
NUC	Not Under Command
NWPA	Navigable Water Protection Act of Canada
OOW	Officer On Watch
QAS	Quality Assurance System
SBE	Stan-by Engine
SMS	Safety Management System
SOLAS	International Convention for the Safety of Life at Sea
SOLAS 1974	International Convention for the Safety of Life at Sea, 1974, as amended
SOPEP	Shipboard Oil Pollution Emergency Plan
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
TEU	Twenty-foot Equivalent Unit
UK	United Kingdom of Great Britain and Northern Ireland
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
US	United States
USC	United States Code
USCG	United States Coast Guard
UTC	Coordinated Universal Time
VHF	Very High Frequency
VLCC	Very Large Crude oil Carrier
VMS	Vessel Monitoring System
VTS	Vessel Traffic Service

1 INTRODUCTION

1.1 Background

Marine accidents are pieces of evidence that prove failure of maritime safety systems. Therefore, lessons learned from failures could be useful or perfect solutions to reduce the likelihood of such failures recurring in the future.

Although every system, natural or manufactured, is not relieved of failure (Frankel, 1987), the human element is considered to be a major contributor in terms of cause of marine accidents. The proportion of human error causing marine accident varies from 65% to 96% according to scholars worldwide (Kim H.T., 2012). Korean statistics of marine accident agrees that about 80% of accidents are caused by operating errors[1] such as deficiency of sailing readiness, negligence of position fixing, violation of navigation rules and regulations, negligence of watch-keeping, negligence of safety working rules and so on. Furthermore, 97% of collisions, 92% of contacts[2] and 89% of groundings are caused by operating errors[3]. The operating errors could be rewritten as errors conducted by operators. In other words, operating errors would be equal to human errors such as slips, lapses, mistakes or violations according to classification by the International Maritime Organization (IMO, 1997).

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[1] Marine Accident Statistics Book of the Korea Maritime Safety Tribunal (KMST) indicates that 82.9% of the marine accidents in the period of 2006-2011 are caused by the operating errors. Detailed statistics would be mentioned in Chapter 2.

[2] Marine Accident Investigation and Judgement Act (MAIAJ) of Korea distinguishes "Contact" from Collision". Collision is ship-to-ship accident, and Contact is ship-to-unmovable object accidents (MAIAJ Ordinance article 13).

[3] Marine Accident Statistics Book (2006-2011) of the KMST indicates that 96.9 % of collisions, 91.9% of contacts and 88.5% of groundings are caused by operational errors. Detailed statistics would be dealt in Chapter 2.

First of all, human error should be primarily focused on to prevent failure of safety systems because it is a principal causation factor in maritime accidents. Around 70% of marine accidents occurred in territorial waters[4] such as ports, approaching channels and anchorages. It is the coastal waters that should be interesting for safety purposes.

Moreover, modern ships are getting bigger or faster to achieve economy of scale, which exerts baleful influence on the fixed or confined navigable waters. In addition, artificial water facilities including mooring buoys and anchorages beside ship's routes could act as obstacles to safe navigation because they limit navigable waters. These obstacles are generally built in coastal areas, which could be risky factors that are not easily found in the high seas.

Consequently, facilities in coastal waters as hindrance to safe navigation should be scientifically surveyed and analysed to root out or mitigate potential hazards as much as possible before deciding or changing the port design or ship's routeing such as Traffic Separation Scheme (TSS), one-way routes and Inshore Traffic Zone (ITZ). Port zoning is also an important part of port design, which can contribute to minimizing hazards and to promoting safe working. Safe working in the proper order lessens the possibility of accidental spillages and consequent pollution (IAPH, 1991).

Supposing that human errors could not be totally eradicated because seafarers on board might suffer from more fatigue in port and approaches when arriving in, berthing at, working in, and departing from ports (IMO, 1997a)[5]. Further design

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[4] Marine Accident Statistics Book (2007-2011) of the KMST indicated that 70.12% accidents occurred in territorial waters that are not limited to Korean territorial waters.

(unit: %)

Waters \ Year	2007	2008	2009	2010	2011	Average (5 years)
Territorial Waters	75.80	70.21	60.30	68.79	75.48	**70.12**
Others	24.20	29.79	39.70	31.21	24.52	**29.88**

[5] IMO. (1997, November 27). ANNEX: *GUIDEL1NES FOR THE INVESTIGATION OF HUMAN FACTORS IN MARINE CASUALTIES AND INCIDENTS para. 1.2* (Res.A.849(20)). London: Author.

deficiencies and erroneous assumptions can lead to failure of systems by the human element (Frankel, 1987). Safety-friendly navigational circumstances in error enforcing zones that could give more room for absorbing human errors would be one solution to reduce or break down the possibility of marine accidents.

This study intends to depict what the IMO should address further on dealing with human error by using the method of the Casualty Investigation Code[6]. In accordance with the SHEL[7] Model of the Code, the interfaces between Liveware and other factors such as Software, Hardware, Liveware and Environment should be studied to search for the existence of the IMO solutions in the field of the above four interfaces.

In addition, this dissertation will refer to several failures of safety systems such as marine accidents and near misses, and it will mention a controversy over the span of a harbour bridge that ended in blocking the passage of VLCCs in an approaching channel. Most references will be based on marine accident investigation reports of the Republic of Korea and journals. However, when it comes to lessons learned from the above examples, the final report of the investigating authority will be the best but not the last. The actions taken by related authorities to prevent recurrence of similar accidents will be consulted as one of the practical lessons learned.

As practical lessons learned to absorb human errors in dense traffic zone, the Ship's routeing and Port zoning Audit Scheme (SPAS) of Korea will be mainly analysed because it might be c compulsory audit scheme for relieving or preventing human error from evolving into marine accidents in congested areas. Therefore, the related examples of maritime States would be introduced. Effects and results of the Korean

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[6] IMO. (2008, May 16). *ADOPTION OF THE CODE OF THE INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES FOR A SAFETY INVESTIGATION INTO A MARINE CASUALTY OR MARINE INCIDENT* (MSC 84/24/Add.1). London: Author.

[7] SHEL: Software, Hardware, Environment, and Liveware.

compulsory scheme will be also examined so as to suggest improvements in the procedures and framework of the scheme.

Under the above studies, this dissertation deals with a newly developed safety system learned from mishaps in the Republic of Korea. It will provide a model case of how human error could be prevented from developing into marine accidents based on the experience from the SPAS. Furthermore, it is expected that this dissertation will be beneficial to not only Korea but also the coastal States that consider effective enhancing coastal safety with a view to allocating limited administrative efforts.

1.2 Objectives

The objectives of this dissertation are to analyse the importance of the human element on marine accidents by illustrating statistics published by the Korea Maritime Safety Tribunal (KMST). Moreover, as most accidents occur in coastal waters, safety-friendly navigational circumstances could be one of the serviceable solutions to reduce or break down the possibility of accident recurrence in coastal waters. As a way to prevent similar accidents from recurring, the SPAS will be introduced as a method to hinder the evolution of human errors to marine accidents in busy traffic areas.

In order to achieve the objectives, this dissertation will:

- Examine and review the statistics of marine accidents to understand what the main causes of marine accidents are, and where the vulnerable sea areas are;

- Analyse IMO's approaches to the human element under error enforcing conditions;

- Introduce the background events of the mandatory Ship's routeing and Port zoning Audit Scheme of Korea;

- Illustrate the SPAS of Korea with relative examples of other States;
- Review the SPAS taking into account navigator-friendly design; and
- Suggest improving the procedure and framework of the SPAS

1.3 Scope of the Study

This research work consists of 7 chapters. Chapter 1 gives the background, objectives, scope and methodology of the study.

Chapter 2 analyses marine accident statistics to find out which is the most noticeable cause of accidents. It reviews the 5 year statistics of the Republic of Korea together with relevant statistics.

Chapter 3 describes selected approaches of the IMO to the human element. It discusses the tools to deal with the human element on board such as the ISM Code and User-Centred Design. The tools will be compared with the SHEL Model to find out which aspects of the Model should be paid more concern.

Chapter 4 investigates the scheme for user-friendly navigational circumstances that was introduced after serious marine accidents, and debates on design of harbour bridges in the Republic of Korea. It also discusses the background of the new scheme for the social agreement on building marine facilities over navigable waters.

Chapter 5 reviews the instruments of maritime States for ensuring safety at port and approaches. It also describes the differences between the current instruments of maritime States and the SPAS of Korea. The overview, advantages and shortcomings of the SPAS will be scrutinized to show its effectiveness and further improvement.

Chapter 6 summarizes the conclusion with perspectives and utility of the audit scheme as a way to block the holes between the human element and marine accidents.

1.4 Methodology and Sources of Information

This research work was conducted aiming to seek the direction of the safe navigation taking into account navigator-friendly circumstances. To achieve the research objectives, the methodology was mixed with qualitative and quantitative analysis.

The qualitative analysis mainly focused on the review of the SPAS of Korea and relevant examples of maritime States on ship's routeing and port zoning. The collection and review of relevant reports, documents, legislations and journals regarding circumstantial factors of navigation and the legal framework of the SPAS were also undertaken. To investigate the background of the SPAS, investigation reports of marine accidents were reviewed. To add practical issues in this discussion, data collecting from conference proceedings, official meeting reports and public hearings for the last five years were carried out.

On the other hand, the quantitative analysis concentrated on marine accident data to calculate which sector should be interesting for efficient enforcement of administrative power. It needs not only typical data such as the distribution of casualties per accident categories but also detailed statistics which presents causes of accidents. Therefore, the up-to-date statistics of the KMST were analysed because the KMST provides detailed data and on-demand statistics for a relatively long time period. Especially, the statistics of causes and contributing factors regarding accident categories were deeply assayed. Also, relevant cases of other authorities were referred to in order to find out each ratio of factors that contributed to marine accidents.

2 MARINE ACCIDENT STATISTICS

2.1 Introduction

The reason why States investigate a marine accident is to find out the cause of the accident[8]. The Casualty Investigation Code of the IMO also describes that the objective of investigation is to prevent marine casualties and marine incidents in the future. Most member States of the IMO are known to follow the Casualty Investigation Code[9]. As a matter of course, the objective of the KMST, an independent investigation authority of Korea, is also to prevent recurrences of marine accidents[10], although the role of the KMST does not perfectly coincide with the objective of the Casualty Investigation Code[11].

The investigation authorities publish reports on the investigated marine accidents. Generally, the final report contains "Lessons Learned" in the form of safety recommendations. The investigation authorities also publicize the statistics of accidents on a regular basis.

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[8] Federal Bureau of Maritime Casualty Investigation (BSU). *Website of BSU*. Retrieved August 16, 2012 from the World Wide Web: http://www.bsu-bund.de/cln_030/nn_88782/sid_EB5B93E05F8781AA62C43A92DEB8C671/nsc_true/EN/Home/homepage__node.html?__nnn=true

Marine Accident Investigation Branch. *About us: What we do*. Retrieved August 16, 2012 from the World Wide Web: http://www.maib.gov.uk/about_us/index.cfm

[9] The international forum of investigators (MAIIF) pledged to support IMO's role in advancing maritime safety and pollution prevention, and contributed to the development of the Casualty Investigation Code. Retrieved August 16, 2012 from the World Wide Web: http://www.maiif.net

[10] Korean Maritime Safety Tribunal (KMST). Function. Retrieved August 16, 2012 from the World Wide Web: http://www.kmst.go.kr/eng/cms/cms.asp?code=BA

[11] The Code recommends not to apportion blame or determine liability, but the KMST determine liability by request of persons in charge of the accidents. (Source: Maritime Accident Investigation and Judgment Act amended in 1998, article 4.2)

Each individual report could play an important role to enhance maritime safety. For example, M/V *Estonia*[12] capsized in the Baltic Sea on 28 September 1994 because of detachment of the bow door[13]. It is evaluated that the investigation report of the accident contributed to revision of the SOLAS[14] for enhancement of the safety of life at sea as much as the sinking of the passenger ship *Titanic* on 15 April 1012. Actually, there has been no accident caused by detachment of the bow door after the revision of the SOLAS. It implies that the IMO's involvement based on the investigation were successful to avoid recurrence of similar accidents. However, it should be highlighted that the human element was also one of the major contributing factors of the capsizing.

Table 1: Marine Accidents per Ship's Type

Year \ Ship	Passenger ship	Cargo ship	Oil tanker	Tug boat	Others	Fishing boat	Total
2007	13	96	31	55	69	495	759
2008	19	63	25	52	42	435	636
2009	7	83	18	35	47	725	915
2010	18	107	17	46	58	672	775
2011	17	96	37	75	84	888	1,197
Total	74	445	153	282	299	3,215	4,468

(Source: KMST, 2012. p.6)

In addition, the statistics of marine accidents are as much important and useful as individual reports because the statistics can show what the trends of the marine accidents are, and what the common causes of accidents are. Pursuant to the statistics

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[12] Ship's names in this study are italicised just for easy reading.

[13] Joint Accident Investigation Commission was set up on 29 September 1994 among Governments of Estonia, Finland and Sweden, and carried out the investigation (Source: Final report of the accident)

[14] SOLAS: International Convention for the Safety of Life at Sea

made out for a certain period, safety authorities can sort out the main failures of a safety system, and concentrate on complementary measures to cure the system failure.

Table 1 is a typical table of marine accident statistics which sketches exemplarily the distribution of casualties per ship categories for the recent 5 years in Korea. It is evident that fishing vessels are especially responsible for the recorded casualty number. Furthermore, it shows the trends of accidents per multiple vessel types.

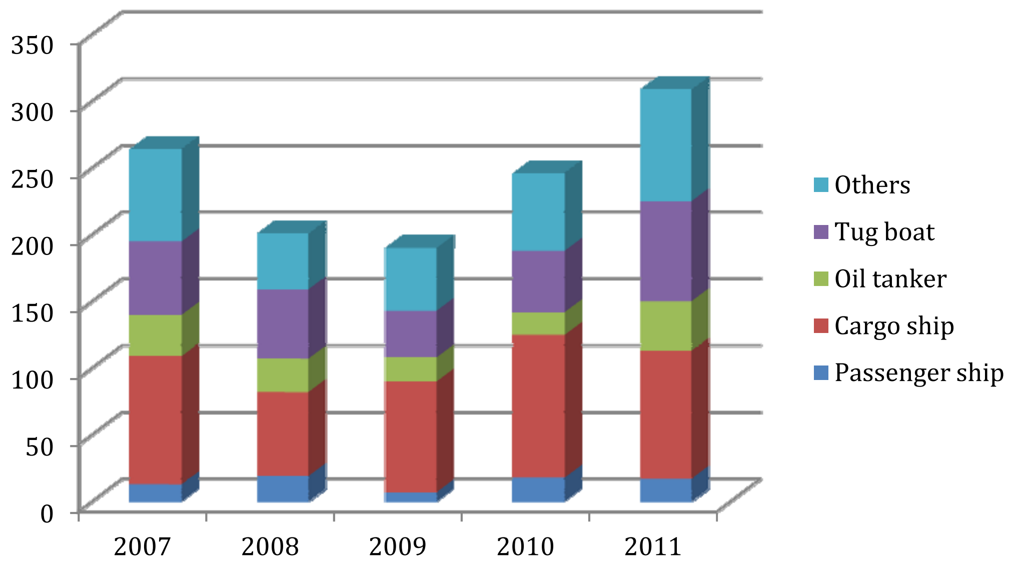

Figure 1: Analysis by Category of Casualty, 2007-2011 (excluding fishing boat)

(Source: Author edited based on Table 1)

Figure 1 is based on Table 1 by the author, which suggests that the accidents were decreasing from 2007 to 2009, and increasing from 2009. Oil tankers and tug boats mainly contributed to the upward move. It could present the need of subdividing the “Others” category because it is also going up. However, Table 1 could be in no position to disclose the actual causes that led to the accidents and to come up with conclusions to set up an affordable safety policy. Thus, other types of statistics are analysed in Chapter 2.2.

Conclusively, if the cause of an individual accident is found through investigation, the treatment can be anticipated to avoid similar accidents and to keep future safety. In addition, when the statistics show the increasing trends of accidents, it is a sign of requiring more attention of the safety authorities concerned.

2.2 Analysis of Marine Accident Statistics

2.2.1 **Error made by Human Element**

Table 2 shows a 5 year term statistics on causes of marine accidents in Korea. Viewed in this light of chapter 2.1, what the statistics indicate should be analysed to find out which causes of accident need more attention.

Table 2 Statistics of Marine Accident Causes (2007-2011)

Cause \ Type of Accdt.		Collision	Contact	Grounding	Fire or Explosion	Sinking	Machinery damage	Distress	Death/ injury	Others	Total	(%)
Operating Error	Inadequate pre-sailing preparation	–	1	–	–	3	–	–	–	4	8	0.5
	Insufficient hydrographic survey	–	4	5	–	–	–	–	–	–	9	0.6
	Straying of designated course	22	1	2	–	1	–	–	–	2	28	1.9
	Negligence of fixing ship's position	3	8	40	–	–	–	–	–	2	53	3.5
	Unsuitable maneuvering	53	14	8	–	7	–	–	1	6	89	5.9
	Negligence of lookout	576	4	5	–	–	–	–	–	–	585	38.8
	Deficiency of preparation for and response of bad weather	10	–	8	1	18	–	2	2	20	61	4
	Inappropriate anchoring and mooring	–	–	1	–	–	–	–	–	1	2	0.1
	Violation of navigation rules	221	1	–	–	–	–	–	–	2	224	14.9

	Negligence of service countrol	–	–	1	–	–	–	–	–	–	1	0.1
	Negligence of watchkeeping	19	2	12	2	–	1	–	–	3	39	2.6
	Others	59	9	9	1	8	–	–	4	5	95	6.3
	Failed to follow safety working rules on board	–	–	1	5	1	–	–	42	6	55	3.6
	Sub Total	963	44	92	9	38	1	2	49	51	1,249	82.9
Percentage (%)		96.9	91.7	88.5	9.5	62.3	1.7	33.3	89.1	60.0	82.9	–
Poor Handing & Defects	Poor handling of machinery, Poor handling of fire	–	–	3	2	5	1	2	–	2	15	1
	Equipment, short circuit	3	–	1	15	2	56	1	–	4	82	5.4
	Defects of hull or machinery	–	–	–	59	1	–	–	–	–	60	4
	Sub Total	3	0	4	76	8	57	3	–	6	157	10.4
Others	Deficiency of passengers embarkation or cargo stowage	–	–	–	1	3	–	–	1	17	22	1.5
	Unfitness of ship operation management	1	–	–	1	6	–	–	–	1	9	0.6
	Unfitness of crew manning	–	–	1	–	–	–	–	–	–	1	0.1
	Unfit navi. aids	–	1	1	–	–	–	–	–	–	2	0.1
	Act of god	5	–	–	–	2	–	–	–	1	8	0.5
	Others	22	3	6	8	4	1	1	5	9	59	3.9
	Sub Total	28	4	8	10	15	1	1	6	28	101	6.7
Total		994	48	104	95	61	59	6	55	85	1,507	100

(Source: KMST, 2012. p.26)

In accordance with Table 2, the highest portion of causes is “Operating Error[15]” such as deficiency of sailing readiness, negligence of position fixing, violation of

[15] The KMST does not define “operating error”. It might be used just for grouping the individual errors made by operators.

navigation rules and regulations and negligence of watch-keeping. The operating error is 82.9%. The "Operating Error" could be expressed as "Error made by Operator". In other words, it is "Error caused by the Human Element (HE)" because seafarers made the operating errors. Conclusively, the operating error could be classified as one of human errors.

Table 3: Analysis of Causes (including HE) for Marine Accidents (1981-1992)

Cause	%	Contributing Cause	%
Outer Conditions	4		
Port/Harbour	2		
Navigational Reasons/Aids	1		
Other (Vessel)	3		
Vessel "Hardware"	16		
Human Element	*74*	Misjudgement (Captain)	11
		Misjudgement (Pilot)	34
		Communication Problems	10
		Misunderstanding	9
		Attention Problems (Pilot & Officers)	23
		Other Human Errors	13

(Source: Oses, 2003)

The percentage of 82.9% is quite the similar number of the preceding study on the human element affecting marine accidents. First, the IMO reported that more than 80% of marine accidents and incidents are owing to human error (Albayrak, 2009). Second, Table 3 shows a percentage of 74%, and relative analyses bring forth percentages from 70% to 95% (with an average value of about 80%) for accidents in the maritime transport chain (Oses, 2003).

In terms of main causes of accidents, the policy planning to reduce marine accidents from recurring in the future should concentrate on human elements. As analysed, it covers the highest percentage of causes of marine accidents.

2.2.2 Areas of Frequent Marine Accidents

Table 4 depicts 29.9% of marine accidents[16] happening in the high seas, for the time period 2007-2011. Over 70% of marine accidents occurred in territorial waters including port and approaches.

Table 4: The Number of Marine Accidents regarding Areas

Area \ Year		2007	2008	2009	2010	2011
Ports & Approaching channels	Incheon	10	13	11	16	25
	Janghang, Kunsan	5	8	2	6	8
	Mokpo	4	2	4	0	3
	Yeosu, Kwangyang	5	6	3	1	4
	Samcheonpo, Tongyoung	2	7	11	1	2
	Masan, Jinhae	2	2	4	3	1
	Busan	13	10	25	21	15
	Okpo, Jangseungpo	3	4	6	0	0
	Ulsan, Pohang	9	4	4	10	4
	Donghae, Samcheok, Sokcho	3	4	6	5	0
	Cheju, Seoguipo	3	2	3	5	2
	Sub Total	59	62	79	68	64
	Percentage (%)	**10.4**	**12.9**	**10.9**	**9.2**	**6.8**
Territorial seas	East sea	42	46	69	56	98
	West sea	158	110	160	155	286
	South sea	158	117	118	192	256
	Japanese waters	12	2	10	36	10
	Sub Total	370	275	357	439	650
	Percentage (%)	**65.4**	**57.3**	**49.4**	**59.6**	**68.7**
High seas	East sea	65	78	136	96	79
	West sea	22	6	26	12	31
	South sea	15	23	68	53	62

[16] The accident data is collected according to the reports from Korean flag vessels and Korean SAR area.

	South East Asian area	24	32	56	38	44
	Others	11	4	1	31	16
	Sub Total	137	143	287	230	232
	Percentage (%)	**24.2**	**29.8**	**39.7**	**31.2**	**24.5**
Total		566	480	723	737	946

(Source: Author added percentage lines to the table of the KMST, 2012. p.3)

In case of collision, Table 5 gives 76.5% as the percentages of collisions in coastal waters. It is evident that the risk of accidents in coastal waters is much higher than that in the high seas.

In terms of places of concern as shown in Table 5, the likelihood of accidents is relatively higher in dense traffic areas, such as ports and approaching channels due to the ratio of traffic volume and confined geographic area. Therefore, geographically the first target of maritime safety should be coastal areas with a view to allocating limited administrative efforts. Therefore, from a managerial perspective, marine traffic management should put most of its emphasis on controlling traffic in the port zone and its approaches to avoid collisions that are the most common accidents when port traffic is dense (Yip, 2006).

Table 5: Collision Sites

Year \ Area	Domestic Ports	Foreign Ports	Territorial seas	High seas	Total
2007	14	0	54	22	90
2008	19	4	43	21	87
2009	24	0	41	22	87
2010	20	0	52	20	92
2011	10	0	58	19	87
Total	87	4	248	104	443
Percentage (%)	**19.6**	**0.9**	**56.0**	**23.5**	**100.0**

(Source: Author added percentage lines to the table of the KMST, 2012. p.35)

2.3 Facts Learned from Statistics

Human errors such as misjudgement and lack of attention are considered to cover about 80% of causes of marine accidents, and over 70 % of mishaps occur in coastal waters.

From the viewpoint of efficient administration, the human element and coastal waters should be considered together since the vast majority of marine accidents occur in coastal waters by human errors. This should be viewed as the first target that needs extreme attention. Detailed designing and obligatory enforcement for maritime safety policy planners to reduce human errors or hinder human errors from evolving into accidents in coastal waters are therefore essential.

The other chapters of this study will be unfolded from the analysed facts of the statistics.

3 SELECTED APPROACHES TO HUMAN ELEMENTS

3.1 General

Most of the significant IMO conventions were originated by serious marine accidents. As shown in Table 6, the SOLAS was established by the sinking of the passenger ship *Titanic*. Human element was also considered internationally due to the grounding and oil spill of the tanker *Torrey Canyon*.

When it comes to the human element, training and education would be the first step. Thereupon, the IMO has developed significant conventions, resolutions and circulars regarding binding human elements with safe navigation. The first development was the STCW[17] for training and education of seafarers on an international level, which was driven by the IMO resolution[18] setting out the vision, principles, and goals for the human element in 1997 (IMO, 1997b).

It contains manning, qualification, and licensing. However, the STCW was not a new scheme because most maritime States already had rules and regulations on training and education of seafarers, and several States regarded it as formalizing a system closely identical to their systems[19].

A highly important resolution on the human element was triggered by the capsizing of passenger ferry the *Herald of Free Enterprise* in 1987. It was the International Safety

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[17] The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978 was adopted in 1978 and entered into force in 1984. Significant amendment was made in 1995.

[18] IMO. (1997, November 27). *HUMAN ELEMENT VISION, PRINCIPLES AND GOALS FOR THE ORGANIZATION* (A.850(20)). London: Author

[19] Consortium of Maritime Trainers of the U.S.. *STCW:Home*. Retrieved 9 September 2012 from the World Wide Web: http://www.stcw.org/big.html

Management (ISM) Code[20] which officially put managerial levels (liveware and software) ashore in the maritime safety system.

Table 6: Major Accidents causing International Instruments

Ship's Name	Year/Place of accident	Abstract	International Instrument
Titanic	1912 North Atlantic	Sinking. Loss of 1,503 lives	SOLAS
Torrey Canyon	1967 UK Dover Strait	Grounding. Oil spill of 119,000 tons	MARPOL STCW
Herald of Free Enterprise	1987 Begium Zeebrugge	Capsizing. Loss of 193 lives	ISM Code
Scandinavian Star	1990 North Sea	Fire. Loss of 158 lives	Accelerating ISM Code

(Source: Author)

The cause of the *Herald of Free Enterprise* was related not to the design of the ship (hardware) but to fatigue of seafarers (liveware). No matter how the IMO has continuously improved ship's hardware, certain marine accidents like the *Herald of Free Enterprise,* the *Scandinavian Star* were not linked to hardware but it was related to mistakes of human elements. In the case of the *Herald of Free Enterprise*, the steps to be taken to avoid a similar capsize in the future were proper procedures (software) for ensuring that the bow and stern doors are closed before proceeding to sea[21].

Accordingly, procedures for preliminary inspections are required to make up for the loopholes of the safety system, For example (Jun, 2004):

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[20] International Safety Management Code was adopted by the IMO through an amendment to the SOLAS Convention, Chapter IX (IMO, 1997) by resolution A.741(18) for the safe operation of ships and for pollution prevention.

[21] MAIB. (1987). *FORMAL INVESTIGATION: MV Herald of Free Enterprise REPORT OF COURT NO. 8074*. London: Author

- Designated seaman should tick off questions on the pre-sailing checklist including bow doors; and

- Designated seaman should check the function of the indicator of bow door whether it is open or shut according to formal procedures.

Within this context, every ship owner should establish a safety policy[22] in the first place, then develop, implement and maintain a safety management system (SMS) for ensuring adequate management, safe operation for ships and environmental protection. Moreover, those systems should be approved by States[23].

It could be evaluated that the IMO developed conspicuous instruments regarding the combination of human elements on board and ashore with safe navigation and management matters.

3.2 User-Centred Design

3.2.1 **Human-Machine Interface**

The Human-Machine Interface (HMI) aims to design an interactive part with efficiency between user and machine (Sanders, 1998). So, the user-friendly interactive part could contribute to reducing mistakes by human elements.

If collision or grounding happened in dense fog by a ship whose radar was off, the officer of watch (OOW) might be blamed, and the cause of the accident could be “operating error” such as “violation of navigation rules and regulations”. The OOW

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[22] Another objective of the ISM Code is for satisfactory protection of marine and coastal environment but excluded in this study in order to focus on safe operation of ships.

[23] In most cases, Recognized Organizations are in charge of approval of the system instead of administrations.

could be blamed twice because of violation of navigation rules and regulations, and non-conformity with the ISM Code. However, it might have another solution except blaming the OOW for avoiding further occurrence of accidents when the radar was switched off by the OOW's mistake.

If the ship is equipped with old-fashioned radars that have several knobs such as dimmer dial, power dial, range dial and sea clutter[24] dial, they are arranged on a panel beside the radar screen and the size and shape of the knobs are nearly the same or similar. When the OOW wants to turn counter-clockwise for more reflection on the radar screen, experienced navigators do not feel any confusion to find the sea clutter dial. If the power dial is just beside the sea clutter dial, any navigators could turn the power dial off instead of turning on the sea clutter dial in error enforcing circumstance. Supposing that the ship was sailing in the busy Malacca Strait just before One Fathom Bank in dense fog, the feasibility of a marine accident will be highly increased because the turned-off radar requires a warming-up period for operation. Actually, the author once turned off the power of the JRC radar by mistake in Dover Strait. Some colleagues had also mentioned the same mistake because the JRC radar was popular at that time.

As a matter of fact, it is not easy to find investigation reports which depict HMI design failure. The above arrangement of dials could be a bad example in terms of the HMI. So, it would be a contributing factor to the accident that was caused by human error.

In conclusion, human error might be a potential contributing factor of hardware. Therefore, the human error might not be a matter of the human itself and maritime training could not be the only answer while planning preventative measures for mistake.

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[24] Wave reflection adjustment

3.2.2 **User-Centred Design**

The way to mitigate the human error explained in Chapter 3.2.1 would not be limited to the STCW or the ISM Code. The HMI between the radar and operator should be more considered. Not a few marine accidents could be evaded by the User-Centred Design (USD) because a poorly designed HMI could be a contributing factor to accidents.

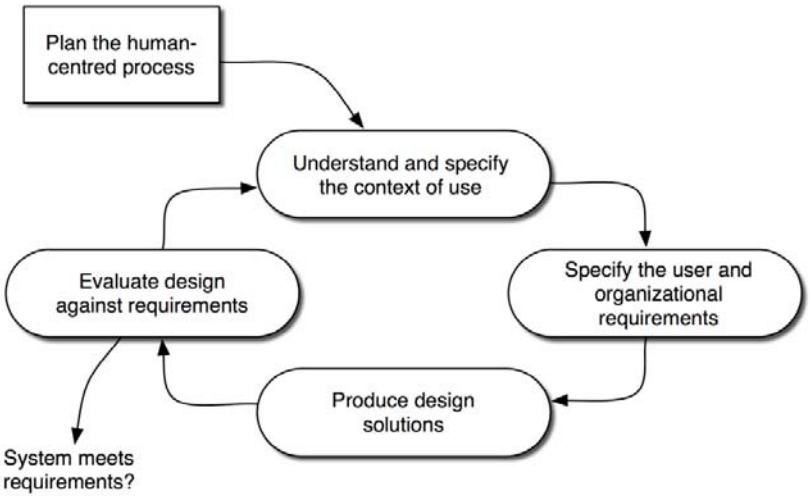

Figure 2: Human Centred Design Process

(Source: Lindström & Malmsten, 2008)

According to the International Standardization Organization (ISO) standard 13407 (Human-centred design process), human-centred activities are included in the general process throughout a development life-cycle. As shown in Figure 2, there are four activities that consist of the main cycle of the UCD[25]:

- First step, specifying the context of use;

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[25] User-entred Design (UCD) is an approach to design that grounds the process in information about the people who will use the product. UCD processes focus on users through the planning, design and development of a product.(Source: UPA)

- Second step, specifying requirements;
- Third step, creating design solutions; and
- Fourth step, evaluating design.

It might not be needed to elaborate on the steps for the maritime community because the ISO already publicized the detailed guidelines on the UCD that is the ISO standard of human-centred design for interactive systems (ISO 9241-210:1010)[26]. Therefore, it would be beneficial to utilize the open standards in the maritime community concerning automation design such as integrated bridge system (IBS), Integrated Navigation System (INS) or e-Navigation.

3.2.3 **Application of the User-Centred Design**

There are several leading studies on the application of the UCD in the maritime community. Typical development has been performed by the ATOMOS[27] project since 1992, which was driven by the EU for Integrated Ship Control (ISC). Ten organizations including European institutes, ship classification societies and universities joined and introduced the concept of the UCD for advancement of navigational safety (Kim H.T., 2012).

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[26] ISO 9241-210:2010 provides requirements and recommendations for human-centred design principles and activities throughout the life cycle of computer-based interactive systems. It is intended to be used by those managing design processes, and is concerned with ways in which both hardware and software components of interactive systems can enhance human–system interaction. (Source: ISO. Retrieved August 20, 2012 from the World Wide Web: http://www.iso.org/iso/catalogue_detail.htm?csnumber=52075)

[27] ATOMOS (Advanced Technology to Optimize Manpower Onboard Ships, 1992~1994), ATOMOS II (Advanced Technology to Optimize Maritime Operational Safety, Integration, and Interface, 1996~1998), ATOMOS IV(Advanced Technology to Optimize Manpower Onboard Ships, ~2005)

Major maritime States keep studying the HMI as a part of the UCD for navigational safety. For instance, Chalmers University of Technology in Sweden participated in the NACOS Platinum Project that was for developing the IBS on basis of the UCD, and human factors in the engine department have been analysed for enhancement in the design of the engine control room. The HORIZON[28] project was for examining the fatigue of watch officers (Lützhöft, 2012). THALASSES [29] was a framework programme of the EU for adopting human element for evaluating the socio-economic impact of new technology in the maritime transportation system.

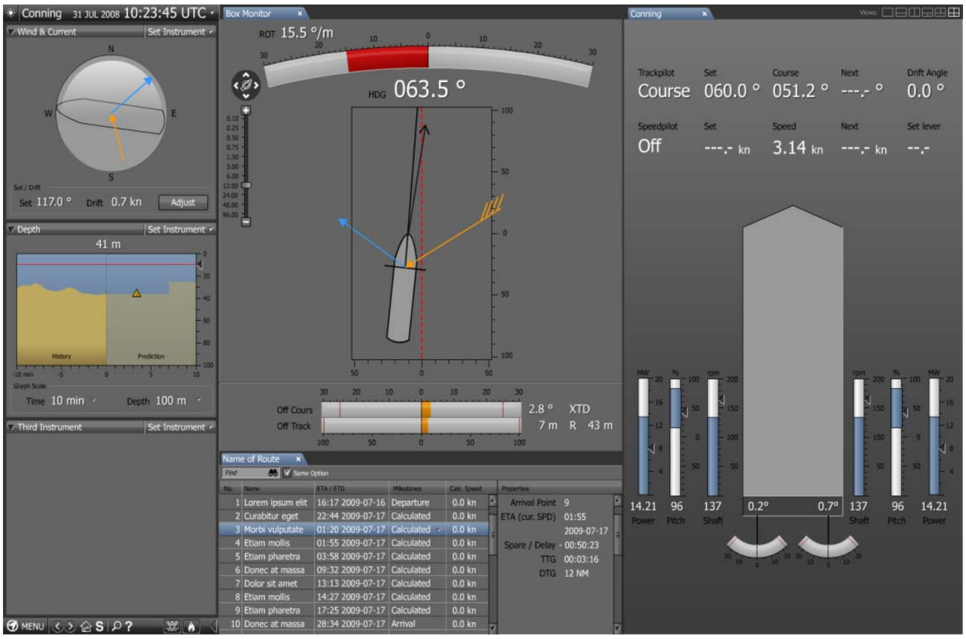

Figure 3: Layout of the enhanced Conning Display of the NACOS Platinum INS

(Source: Lützhöft, 2012)

Figure 3 is a recent example of the UCD embodied equipment that was devised by an expert group including mariners and engineers by taking into account the end-user, humans on board, through exchanging expertise and experience (see Figure 4).

[28] 8 institutions participated in the HORIZON project that was supported by the EU. 3.78milion Euro invested for 2009-2011.

[29] New Technology in Maritime Transport Interacting with the Human Element : Assessment of Impacts

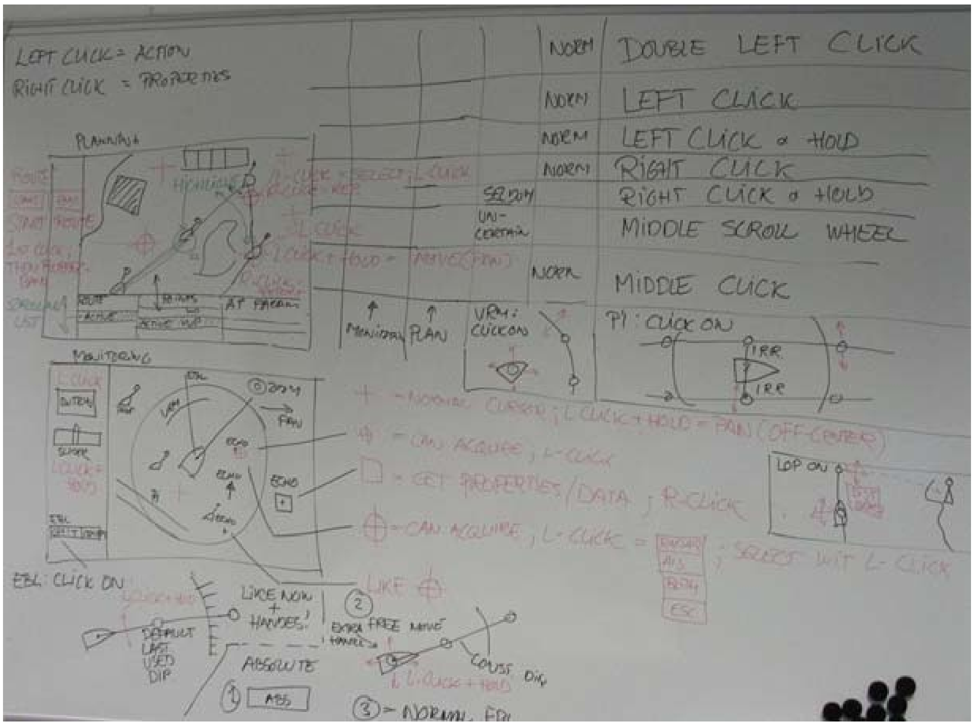

Figure 4: Brainstorming Board to devise INS screen

(Source: Lützhöft, 2012)

3.2.4 **Quality Assurance System**

If the IMO or individual States decided to introduce the UCD for the navigational equipment, the Quality Assurance System (QAS) should be considered to check compliance of the UCD. When it comes to the QAS to check the adaptation of the ISO standards concerned, there are already many known tools even in the maritime community. For instance, the ISM Code is a type of QAS tools. The ISM auditor could check the document in compliance with the ISO standards for the target equipment or factories.

As a matter of fact, the e-Navigation system or the Integrated Bridge System (INS) could be one of the targets of the UCD and the QAS. Then new navigational equipment to be replaced could be followed.

3.3 Investigation Tools for Marine Accidents caused by Human Element

3.3.1 SHEL and Hybrid Models

The human elements dealt with in the IMO are complex and multi-dimensional matters related to every factor which affects human-system interface including social, legal, human ability, cultural and health and design factors (Kim H.T., 2012). The left Figure 5 is the original diagram of the IMO Casualty Investigation Code, and right diagram is an analysis of the IMO's work on the human element in maritime safety, which shows a simplified explanation that presents a number of factors that have a direct or indirect impact on human conduct and the potential to carry out tasks.

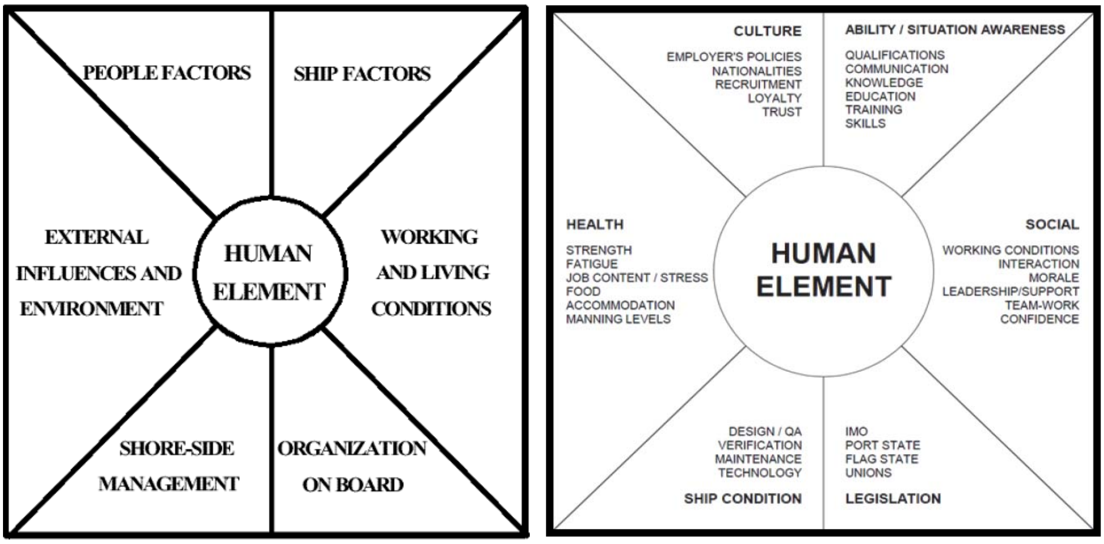

Figure 5: Topics to be covered by Investigation

(Source: IMO, 1999) (Eriksson, 2003)

Therefore, the IMO set up guidelines for providing practical support of the systematic investigation into human elements in marine accidents and to let the development of effective analysis and preventive action be achieved (IMO, 1999, 2007). The SHEL Model was introduced to get assistance in analysing the contribution of human elements to errors. The author edited Figure 6 by summarizing Appendix 2 of Casualty

Investigation Code, and added sub-titles in the boxes so as to present the scope of the SHEL Model for reviewing at a glance.

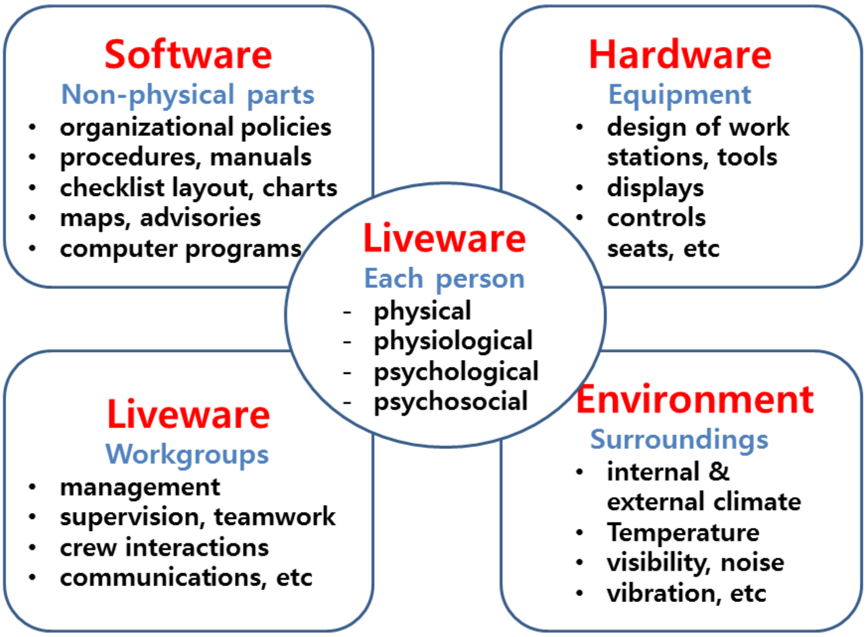

Figure 6: SHEL Model

(Source: Author)

As shown in Figure 6, the SHEL Model places the target person or end user at the centre of the figure because the target person is a central component and interacts with software, hardware, the environment and other persons who are peripheral components.

The occurrence sequence of accident is illustrated in the Hybrid Model[30] of Figure 7. The aligned cheese holes of each defence wall become the passage of accident occurrence. So, even a little change of the walls could defend the accident albeit in the

[30] The data collected during an investigation can be organized, using multiple components of the modified SHEL model, into a framework surrounding an occurrence template, based upon the Reason model. Causal factors, i.e. the unsafe acts/decisions and conditions, are thereby identified. (Source: IMO A.884(21) Appendix 1)

wrong place at the wrong time. Therefore, the system failure occurs though a series of aligned loopholes of each step. It would be natural that preventative measures be ready to block the holes as a result of human element investigation.

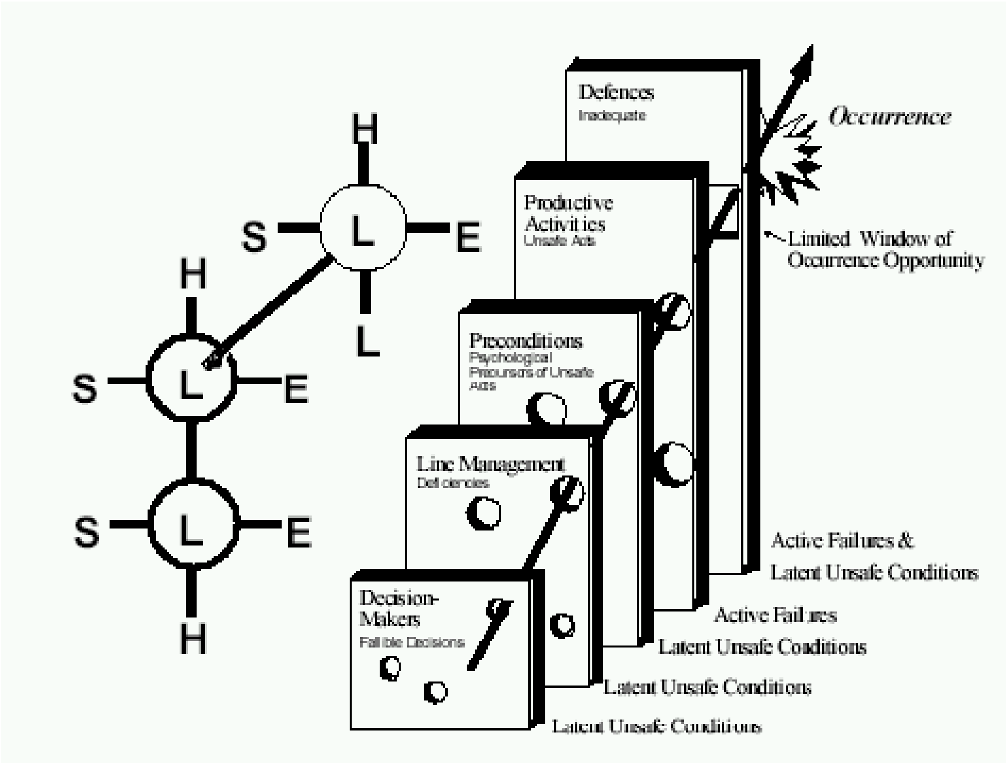

Figure 7: SHEL and Reason Hybrid Model

(Source: IMO A.884(21) Appendix 1)

3.3.2 Measures devised to deal with Human Element

The maritime community has generally focused on training of seafarers, ship design and equipment requirements in compliance with the safety standards set in international regulations. Therefore, remarkable developments in the field of hardware, software, liveware and its relationships were achieved as shown in Figure 8 albeit insufficient tools for the UCD.

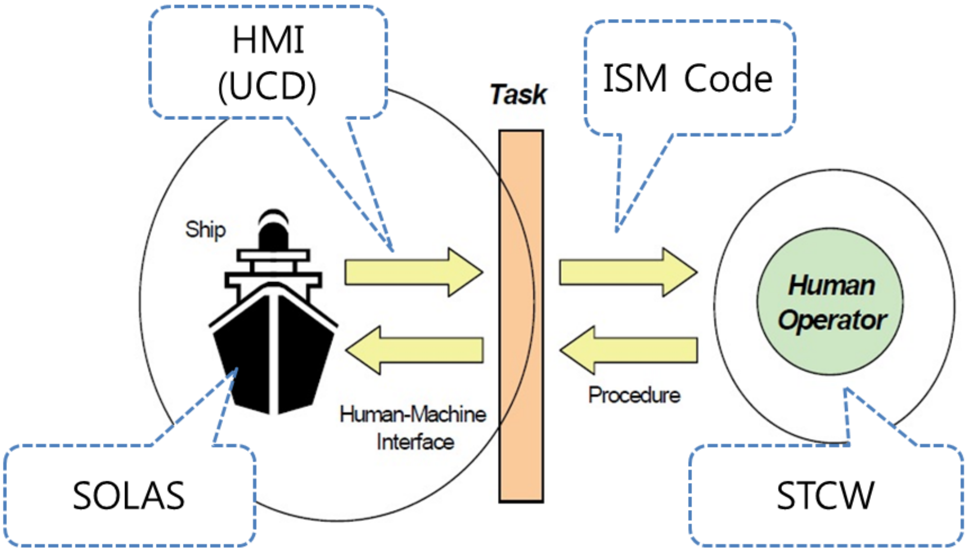

Figure 8: IMO instruments in Ship System and Human Operator

(Source: Author added blue dotted boxes on Kim H.T., 2012. p.55)

Figure 8 might present IMO's typical point of view. However, it would not be enough from the viewpoint of marine accident investigators who keep the Investigation Code of the IMO. The Code requires that the role of human elements be analysed and suggests recommendations concerning human-oriented relationships for depicting the broken or loose interface according to the elements of the SHEL Model. The investigators should address preventive measures to fill in the found loopholes or to recover the damaged interface.

Hence, Figure 9 based on SHEL Model discloses loose interface between a navigator as central component and navigational circumstances as environment. The difference between Figure 9 and Figure 10 is the consideration of circumstantial factors called "Environment".

To summarize four interfaces related to the centred human:

- First, Liveware-Liveware Interface could be controlled by the STCW.

- Second, Liveware-Software Interface could be adjusted by the implementation of the ISM Code of the SOLAS.

- Third, Liveware-Hardware Interface could be addressed by the UCD. This sector needs further discussion for QAS by the IMO approval.

- Last but not least, example instruments of Liveware-Environment Interface (LEI) are not found in the IMO level.

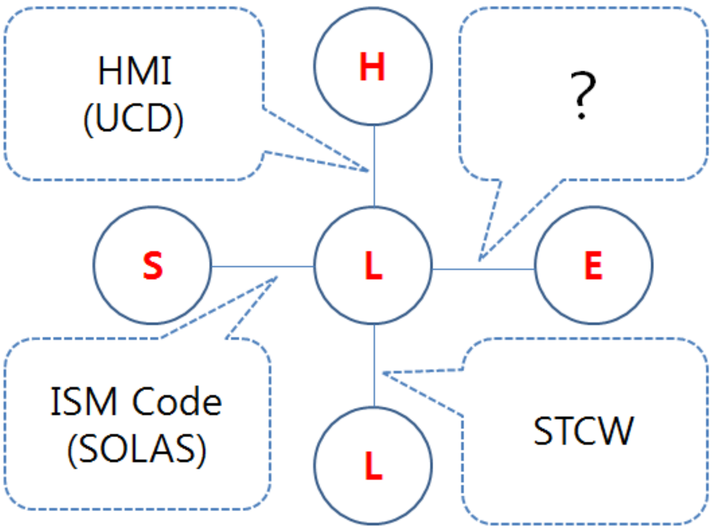

Figure 9: International Measures in relation to the centred Liveware

(Source: Author)

As it has been strongly insisted on to sketch an instance of LEI measures from the IMO instruments, the Traffic Separation Scheme (TSS) could be an example of the LEI. The TSS plays a role in reducing risky conditions between a navigator (Liveware) and navigational circumstances (Environment) considering the TSS separates head-on situations of ships in narrow channels or dense traffic routes. However, the drawing of TSS depends totally on individual States. The IMO has not given any instructions or guidelines yet for how to draw the TSS, how to audit it or how to maintain it.

Conclusively, the LEI would be a new agenda of the IMO and the maritime community.

3.4 Summary on the Selected Approaches to Human Elements

The IMO has endeavoured to enhance ship's design, equipment and stability. Often as one measure among others, adequate training and certification of seafarers have also been emphasized to address the contribution of the human elements to marine accidents.

Supplementary systems on shore that give warning to navigators prior to encountering risk at sea would be complementary treatment considering that human errors are not totally eradicated by training and certification. The system would be Vessel Traffic Service (VTS), Vessel Monitoring System (VMS)[31], and e-Navigation system. Furthermore, objectives to the amelioration of human interference would be automation design such as Integrated Bridge System (IBS), Integrated Navigation System (INS) or e-Navigation through well-designed HMI. The UCD would be one more solution to suppress marine accidents caused by mistake while operating shipboard equipment because the UCD is a consideration of end-user friendly design from the beginning of a system product. In other words, the design should be performed to reduce human errors by accumulating information about end-users and reflecting characteristics of end-users (UPA, 2012). Thus, the contemporary maritime industry could get benefits from the more sophisticated design taking into account the UCD.

[31] Recently, the term of VMS is defined by IMO in "Performance standards and functional requirements for the long-range identification and tracking (LRIT) of ships" by Resolution MSC.263(84) adopted on 16 May 2008 as "a system established by a Contracting Government or a group of Contracting Governments to monitor the movements of the ships entitled to fly its or their flag. A Vessel Monitoring System may also collect from the ships information specified by the Contracting Government(s) which has established it."

Marine accidents can be reduced by one of the aforementioned approaches that might be the seafarer himself or interface between seafarer and ship, seafarer and management level. The tools were generally originated from the STCW, the ISM Code or the HMI studies.

However, this study found that it needs to assay to portray a number of human aspects in marine accidents, relatively to navigational environment. Therefore, the IMO could stretch more effort to address any appropriate solutions to deal with the LEI, interface between operators or end-users (Liveware) and operating circumstances (Environment). The LEI needs to be analysed further, so that it might be recommended as a new work reference of the IMO and the international shipping community.

4 USER-FRIENDLY NAVIGATIONAL CIRCUMSTANCES

4.1 Introduction

This chapter discusses several marine accidents, and debates on the width of main pillars of harbour bridges for safe passage of ships in the Republic of Korea. The above cases became the background of the new scheme for navigator-friendly design of ship's routeing and port zoning for safe navigation, which could be an example measure of dealing with LEI.

Firstly, the collision between a crane barge *Samsung No.1* with a motor tanker *Hebei Spirit* was recorded as the most serious oil pollution in Korea, which could have been prevented if there were safe anchorages within harbour limits. It became a direct motive to introduce the SPAS.

Secondly, the allision between the LPG tanker *New Wave II* with the pier was a near-miss in terms of huge gas explosion. In addition, the collision between chemical tankers *Seunghae* and *Jeongyang* will be mentioned. The two accidents were caused by poor communication among navigators in a narrow channel. These accidents also demonstrated the importance of the LEI matter.

Lastly, it will mention a controversy between the land road party and the sea road party over the span of Incheon Grand Bridge that ended in blocking the passage of VLCCs in an approaching channel to the port of Incheon. It also became a case of the necessity of scientific and systematic study on ship's route.

Analyses of marine accidents are based mainly on final reports of marine accident investigations of the KMST. The aforementioned controversy on the harbour bridge refers to technical journals and interviews with officials in charge.

4.2 Marine Accident

4.2.1 **Collision between a Crane Barge with a VLCC**

Synopsis

At 07:06 (LT)[32] on 7 December 2007, a crane barge *Samsung No.1* being towed by two tug boats collided with the anchored tanker *Hebei Spirit*, carrying 260,000 tonnes (290,000 short tons) of crude oil at the position of N36° 52′16″, E126° 03′02″. The barge was floating free after the cable linking it to the tug snapped short in the heavy weather. The collision occurred near the port of Daesan on the West Sea coast of Taean[33]. It was 252° (T)[34], 5.1 miles off from the nearest the lighthouse.

The drifting barge *Samsung No.1* hit the motor tanker (M/T) *Hebei Spirit* nine times at the port side of the single hull tanker. Three of the five portside tanks aboard the *Hebei Spirit* were punctured, and 10,900 tonnes (12,547 kℓ) of crude oil leaked into the sea (Supreme Court of Korea, 2011).

Course of the Accident

On 6 December 2006, M/T *HEBEI SPRIT* arrived in the vicinity of discharging port. The VTS centre informed the VLCC to anchor beyond harbour limits. The VLCC anchored at the position of N36° 52′29″, E126° 03′14.5″ with 9 shackles on deck, 8 shackles in water. It was 4.8 miles off, 255° from the nearest light house and 7 miles off from northeast of the TSS. The captain finished with engine (F.W.E) and changed navigation watch to anchor watch.

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[32] Local Time = UTC + 9 hrs. If not otherwise stated all times in the chapter 5 are given in Local time.

[33] Vicinity of Taean is known as one of the most beautiful and popular beaches of Korea, where includes a national maritime park, many cultivating farms and one of the largest wetland areas of Asia

[34] True Course

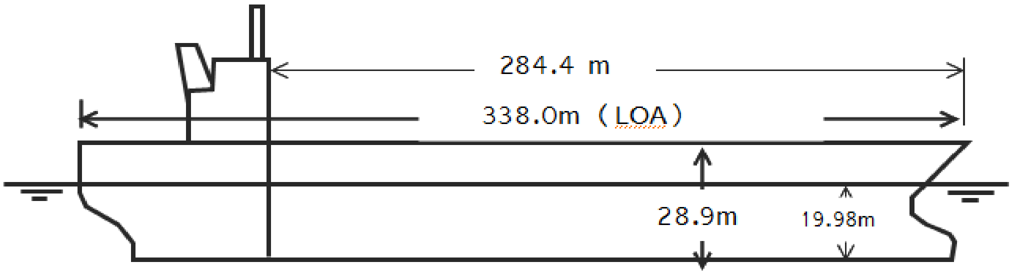

Figure 10: Ship's Particulars concerning Collision

(Source: Final Report of the KMST)

The anchor position was beside main routes to three major ports. The blue lines in Figure 11 show the main routes to the ports of Daesan, Pyeongtaek and Incheon.

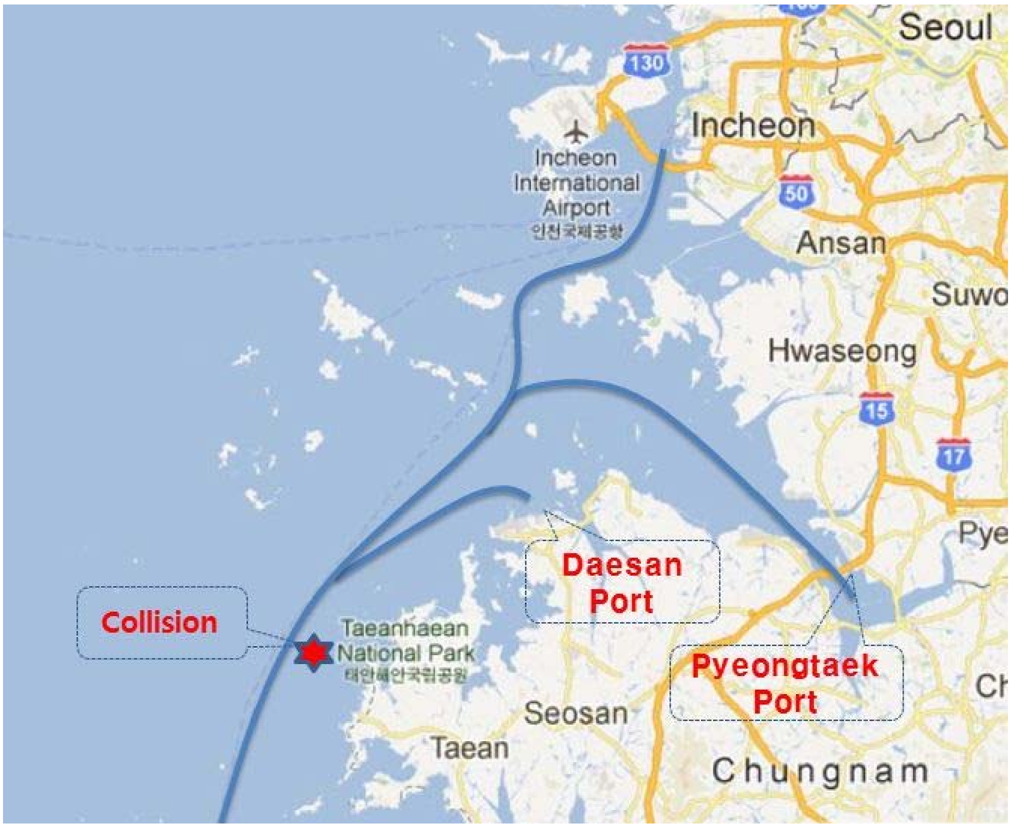

Figure 11: Ships' Main Routes and Collision Site

(Source: Author)

The VLCC was scheduled to get a pilot on board at 14:00 the next day in order to moor to a Single Buoy Mooring (SBM), 20 miles off from the anchored site.

At about 14:50 on 6 December 2007, a lead towing vessel *Samsung T-5* and a subsidiary towing vessel *Samho T-3* commenced towing a crane barge *Samsung No.1* and an anchor boat *Samsung A-1*, bound for Samsung Heavy Industry in Geoje Island from the construction site of the Incheon Grand Bridge.

Figure 12: Towing Fleet

(Source: White Book of M/T Hebei Spirit Oil Spill, 2011)

At 22:40, a wind wave advisory warning was issued by the Meteorological Administration. However, the towing fleet did not notice the weather report.

At 23:30, the true course over ground of the towing fleet deviated from 206° to 186° because of westerly winds and waves, but the captain did not notice it and handed over the watch to the C/O. The speed was 3.5knots.

At 23:55, the chief engineer of the VLCC completed replacement of a discharging valve of number 3 cylinder of the main engine but did not open the cooling water valve of number 3 cylinder.

At 00:30 on the day of accident, the OOW did not know the deviation of true course, and changed helm to autopilot. The towing vessel suffered heavy yawing. The speed dropped to about 2 knots. The crane barge *Samsung No.1* was drifted to port side due to strong winds and waves from starboard side. The true course of the fleet was about 210° while sailing in zigzag.

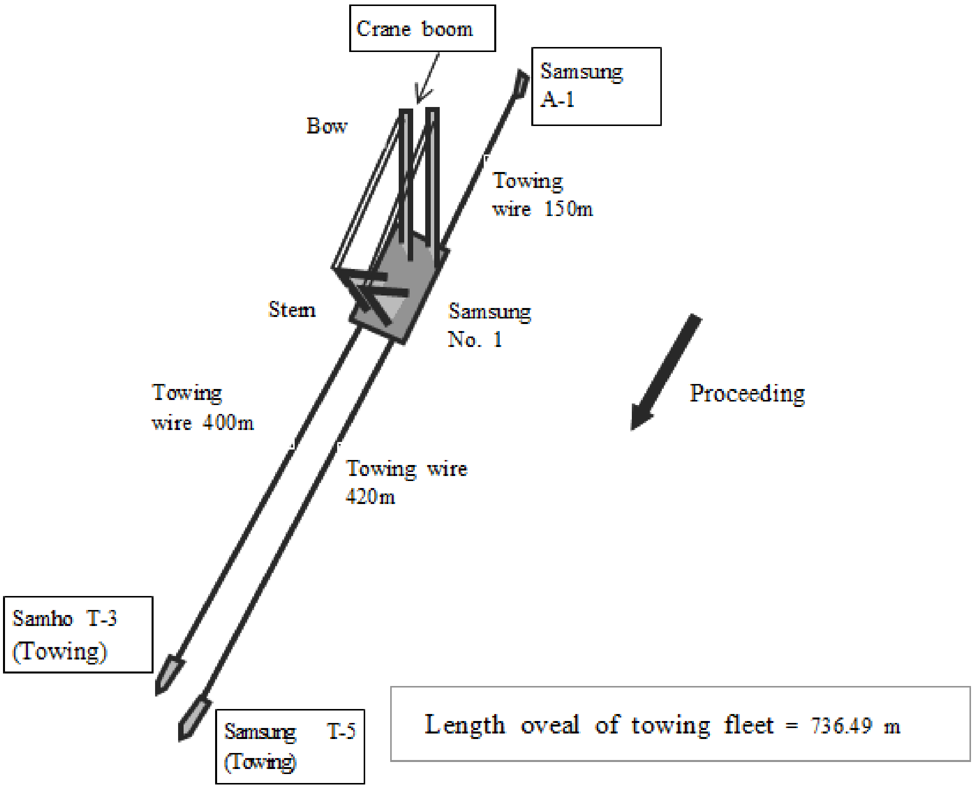

Figure 13: Line-up of Towing Fleet

(Source: White Book of M/T Hebei Spirit Oil Spill. 2011)

At 04:00, the OOW reported the heavy weather to the captain. The captain came on bridge and found that the speed was 1.7 knots, and the fleet almost lost the course keeping ability. The captain decided to return to the port of Incheon. The fleet drifted 1 mile to the east while the captain slowed down the speed so as to return to Incheon.

At 04:44, when the towing vessel turned to starboard, the fleet was pushed to the east.

At 05:17, the heading was north but the fleet drifted to the east. So, the captain gave up returning to Incheon, and changed the course to the west so as to pull the barge.

At about 06:00, the OOW of the VLCC noticed that the towing fleet approached 1 mile off with the speed of 1 knot. The heading of the VLCC was northward.

At 06:05, the towing fleet drew near 0.7 mile off, and the heading of the fleet was westward but drifted towards the south where the VLCC anchored. The fleet was approaching slowly to port bow of the VLCC by heavy weather. The captain of the tanker anticipated that the fleet might pass abeam portside with CPA 0.3 mile.

At 06:10, the captain of the VLCC ordered stand-by engine (S.B.E.) and forecastle station. At 06:14, while the towing fleet drifted to the south and approached anchored *Hebei Spirit*, the distance became 0.5 mile.

At 06:17, main engine was ready to use. The captain used the engine several times with dead slow astern and stop so as to slack anchor chains for giving more room ahead.

At 06:27, when the anchor chain of the VLCC was slacked 4 shackles more, the captain was informed from the VTS centre that the towing fleet had been drifting due to restriction in ability to manoeuvre by heavy weather.

At 06:32, the towed crane barge *Samsung No.1* crossed the bow of the VLCC. At 06:40, the crane barge passed with the CPA of 0.3 miles off, bearing 340°(T). It was abeam of portside of the VLCC.

At 06:54, tug boat *Samsung T-5* moved forward much faster than before because the towing line was broken. After a while, the tug boat *Samsung T-5* moved back to the barge *Samsung No.1*. The captain of the VLCC noticed it, but did not recognize that the towing line was broken at that time.

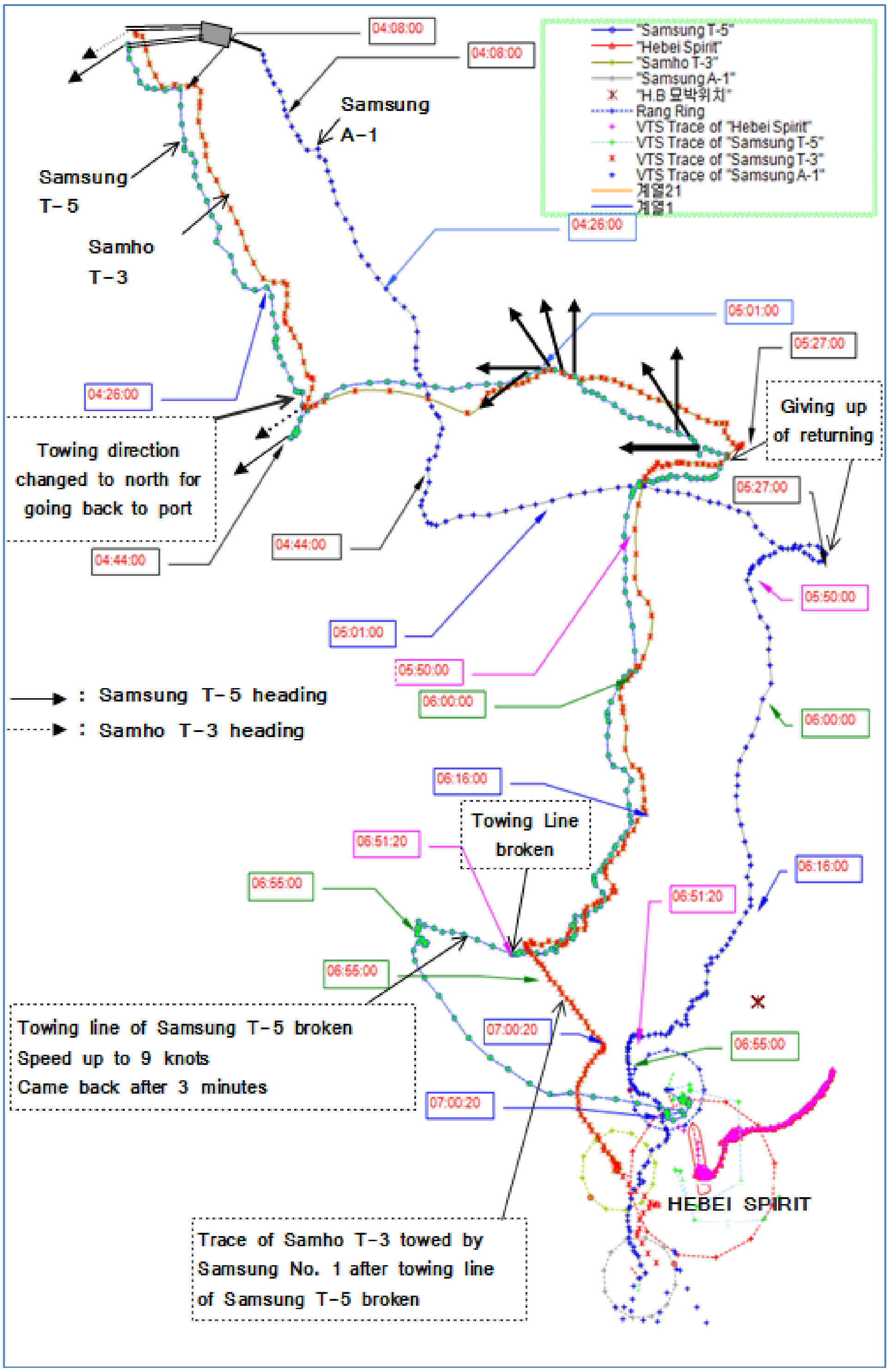

Figure 14: Sketch of the Course based on VTS data

(Source: Author modified track data of the KMST)

At 06:58, the VLCC used slow astern and half astern engine. After a while, the cooling water high temperature alarm of No.3 cylinder of main engine sounded[35], and the R.P.M of the main engine slowed down automatically. So, the VLCC became Not Under Command (NUC) condition.

At 07:04, the main engine recovered. The captain used the main engine with dead slow astern, slow astern, dead slow astern and half astern.

At 07:06, the VLCC was struck by floating free barge *Samsung No.1*.

At about 07:28, the captain was reported oil pollution from crews and found crude oil leakage from No. 1, 3, 5 cargo tanks.

Figure 15: Punctures of M/T Hebei Spirit

(Source: White Book of M/T Hebei Spirit Oil Pollution, 2011)

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[35] M/Eng. #3 Cyl. C.F.W. Outlet. High Temperature Alarm

Figure 16: Polluted Beach in Taean

(Source: Korea Coast Guard, 2007)

Lessons Learned

The KMST made 11 recommendations to seafarers, ship owners, insurers and safety authorities. Most recommendations were about conformity to existing rules and regulations on safe navigation and emergency response such as SOPEP[36]. Recommendations about human elements were two items;

- To designate cargo handling officer to alleviate fatigue of navigation watch officers,
- To apply the ISM Code to towing fleets even engaged in domestic navigation.

[36] Shipboard Oil Pollution Emergency Plan, 73/78 MARPOL Annex 1 Chapter 5 rule 37

The MLTM submitted revision of the Maritime Safety Act (MSA) to adapt the ISM Code to towing the fleet when it sails between domestic ports. However, the fatigue reduction action has not been taken yet.

4.2.2 **Analysis**

The KMST publicized the cause and contributing factors of the accident as follows;

> This collision was made by a towing fleet that was composed of towing vessels *Samsung T-5, Samho T-3*, an anchor boat *Samsung A-1* and a crane barge *Samsung No.1*. The towing fleet failed to cope early with heavy weather, and suffered near loss of maneuverability at sea. However, the towing fleet did not warn nearby vessels of the drifting condition, and no safety action like anchoring was taken in emergency. The towing wire of *Samsung T-5* was broken by wind and wave when the towing fleet drifted and got close to anchored tanker *Hebei Spirit*. So the floating free barge *Samsung No.1* drifted and collided with the anchored tanker *HEBEI SPRIT*. Main cause of the accident was supplied by the towing fleet.
>
> In addition, negligence of watchkeeping beside the heavy traffic route, indolent response of *Hebei Spirit* led late action for collision avoidance. Furthermore, main engine was not ready to be started in urgent situation, which is contributing factor of the accident (KMST, 2008).

Accordingly, human errors intervened in the accident. The captain of the towing vessel did not pay proper attention to the weather, and the OOW of the tanker neglected watchkeeping. So, the two parties in charge were late in evaluating the approaching danger. If the persons in charge performed good seamanship, the accident would not have occurred. In that case, preventive measures should focus on how to drive the seafarers to perform good seamanship. Therefore, the KMST suggested the application of the ISM Code which is a well known preventive measure to human error by systematic check.

However, the focus of the MLTM was more comprehensive and different from the view of the KMST in counter measures for preventing further accidents. The MLTM as an authority for safety of maritime traffic, first of all, designated a waiting area far beyond the fragile area between main routes and harbour limits because vessels navigating through the main routes could drift to the site of the accident again.

The port of Daesan was constructed beside the main route to the ports of Inchoen and Pyeongtaek. Before the inauguration of the port of Daesan in 2007, most cargoes of Daesan petro-chemical complex and nearby industrial complex were transferred to the port of Incheon or Pyeongtaek for sea transportation (KMOA, 2007). In this context, it is regrettable that the port designer did not consider the risk of drifting. If the designer viewed the whole traffic system of the region, the port zoning including inner harbour anchorage might be differently designed. Therefore, the revision of the MSA included a compulsory audit scheme for analysing navigational conditions around ship's routes and port zones (Kim, 2011).

Nevertheless, the oil pollution of M/T *Hebei Spirit* was a catalytic initiator rather than an original creator of the audit scheme.

4.2.3 **Summary of Marine Accidents**

As determined by the final report of the KMST, even a little drifting could be devastating in the wrong place at the wrong time. It was proven in chapter 2.2.2 that the denser the traffic is, the higher the danger of accident is. So, port zones and confined channels are prone to accidents. The worst oil pollution incident in Korea also occurred in one of the busiest zones and main routes to three major ports.

The MLTM turned attention from seafarers in charge to the accident site considering that human errors could not be totally eradicated. Therefore, it would be the case that had the tanker not dropped anchor at the position, the collision could have been avoided. As a matter of fact, the fully loaded *Hebei Spirit* could not anchor in the inner harbour of Daesan because there were not enough anchorages for receiving VLCCs. Thus the tanker dropped anchor outside of the harbour.

It showed that design deficiencies led to the failure of systems. So, well designed ports, including port zoning, can reduce the human element contribution to the failure of the system.

4.3 Near Miss

4.3.1 **Allision between a LPG Carrier with a Chemical Pier**

At 03:21 on 25 April 2003, the LPG carrier *New Wave II* (3,244 G/T) struck the LG-Caltex pier in the port of Kwangyang[37]. It could have led to a very serious explosion because the pier was surrounded by explosive chemical piping, tanks and industry complex. It could be classified into a near miss in terms of explosion.

There were 4 two-way routes within the harbour limits and one special traffic area[38] at the mouth of the port. As shown in Figure 17, the dotted circle was the most risky area in the route No.2, and the width of the two-way route was about 200-250 metres without centre separation buoys (KMST, 2004).

Course of the Allision

The *New Wave II* sailed through route No.2 from route No.1 with the full speed of 11 knots. The visibility was 200-300 metres in rainy weather. The ship was approaching the narrow channel of the route No.2 with the course of 270°. The pilot received detailed traffic information of the route No.2 from the VTS centre.

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[37] The port of Kwangyang was one of the fastest developing ports in Korea because it was surrounded by world-class chemical industry complex.

[38] Deep draft vessels and dangerous goods carriers have priority for course keeping in the Special Traffic Area. (Source: MSA article 10)

At 03:18, the pilot changed course to 265° and found the LPG carrier *Dukyang No.3* that was 0.3 miles off on the port bow side. In addition, the red light of *Daemok No.1* was first sighted 0.75 miles off on 10° from the starboard bow.

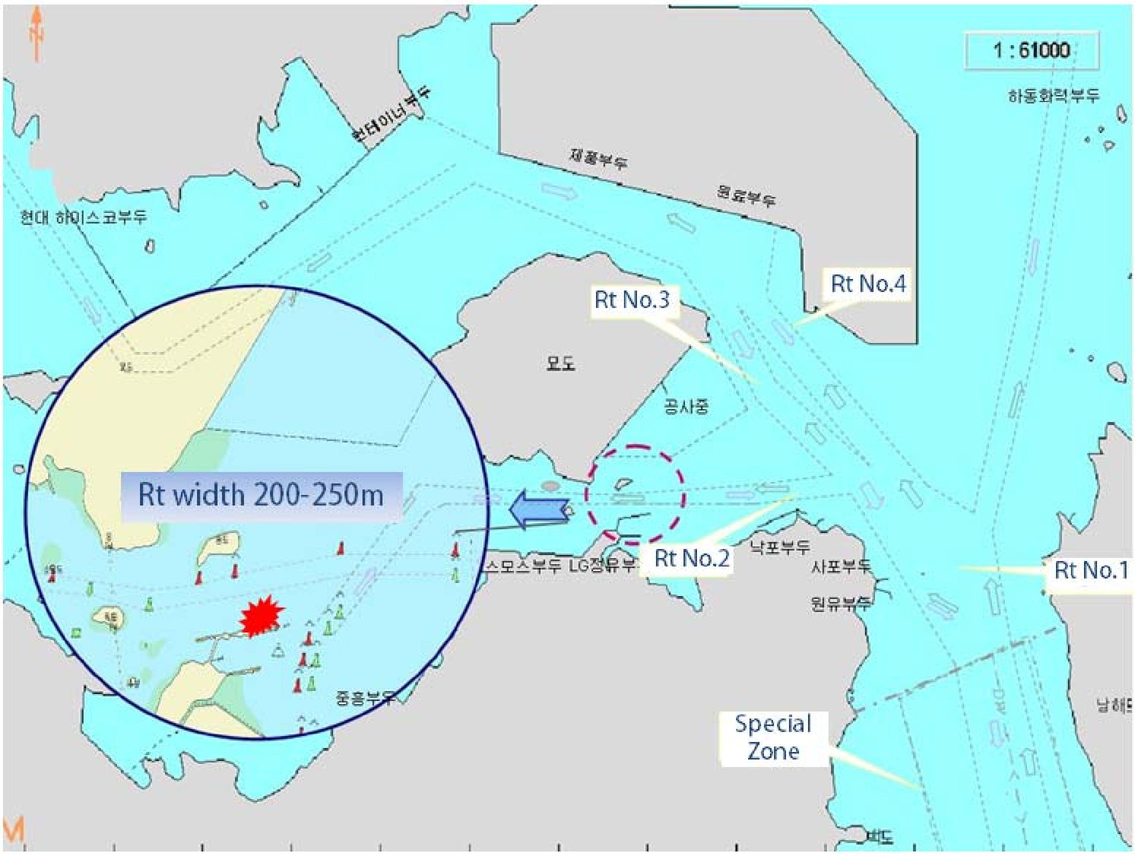

Figure 17: Risky Area of the Port of Kwangyang (Route No. 2)

(Source: Author)

At 03:20, the approaching *Daemok No.1* was about 150 metres apart. The pilot of *New Wave II* thought that *Daemok No.1* might pass by port side (port to port), and asked the captain of *New Wave II* to inform the *Daemok No.1*. of the pilot's intention. The pilot believed that promise was made for port to port passing. However, the navigation lights of the opposite vessel *Daemok No.1* was changed from red light to both lights, then green light. So, the pilot of *New Wave II* ordered immediately to steer to hard port. The collision was evaded. However, the *New Wave II* approached the LG-Caltex pier that was 150 metres apart. The pilot ordered hard starboard rudder, full astern engine and dropped a starboard anchor.

At 03:21, the bow of the *New Wave II* rotated to port side due to the CPP[39] and hit the pier with the speed of 5 knots by forward inertia.

Fortunately, the allision damaged only to the shell plate of the *New Wave II* and fenders of the pier. However, if the outbound vessel *Dukyang No.3* had left the pier a little late, the *New Wave II* would have collided with the loaded LPG carrier *Dukyang No.3*. The explosion of the two LPG carriers might have induced more serious explosion of the LPG piping and the nearby chemical complex.

Lessons Learned

Miscommunication between ships led to misjudgement. Misjudgement in narrow channels has led to marine accidents. So, unclear communications between ships were pointed out as a contributing factor by the KMST, and the VTS centre was advised to perform positive intervention to avoid head-on situations in the narrow channel of the route No.2 (Mokpo, 2003).

4.3.2 **Accident caused by Miscommunication**

There was another accident between oil tankers at the same route No.2 on 23 December 2004. The inbound tanker *Seunghae* suggested that the outbound tanker *Jungyang* should pass the narrow channel first, but the outbound tanker asked the inbound ship to enter the channel without hesitation. So the inbound tanker believed that the outbound tanker would give way, and the collision occurred in the channel.

[39] Most merchant ships are equipped with the Fixed Pitch Propeller (FPP). The bow of the ship rotates to starboard side when it uses astern engine. However, the New Wave II was equipped with the Controllable Pitch Propeller (CPP). So it moves port side while using stern engine.

The accident caused 623 kl of oil leakage into the sea, but early response by the oil pollution prevention team stopped the spread of the leakage.

The regional Maritime Safety Tribunal[40] advised that the VTS centre should carry out positive intervention in ample time to avoid danger including head-on situations in the narrow channel of the route No.2. The seafarers in charge were blamed for human errors.

Finally, the port authority prohibited the two-way passing at the narrow channel[41] to avoid head-on situations, and the VTS centre commenced designating the order of passing the channel. No more accidents have been reported yet after the treatment measures.

4.3.3 **Analysis**

The direct cause of the two accidents was miscommunication which is a kind of human errors. However, the successfully applied preventative measure was changing the two-way route to a one-way route. It could be interpreted that the possibility of human error was cured by changing navigational circumstances. Therefore, it would not be wise to stick only to training of seafarers or the VTS system to reduce human errors.

4.3.4 **Summary on Near Miss**

Similar marine accidents were repeated although the KMST recommended active intervention of the VTS. However, the accidents did not happened any more by designating the two-way routes as one-way route.

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[40] The KMST has four regional branches.

[41] Notification No. 2004-10 of Yeosu Regional Maritime Affairs and Fisheries Office on 5 March 2004. Vessels longer than 35 metres (including towing fleet) are not allowed to pass by in the narrow channel of route No.2 day and night without permission of the VTS centre.

The treatment measure should be focused on because of the possibility of reducing human error due to adjusting navigation environment. In this context, the favourable environment that blocks development of human error to marine accident could be defined as navigator-friendly circumstances.

4.4 CONTROVERSY OVER THE SPAN OF HARBOUR BRIDGES

4.4.1 Introduction

The day before the oil pollution of the *Hebei Spirit*, the collided barge *Samsung No.1* was engaged in lifting the longest deck of a harbour bridge between the main pillars of the Incheon Grand Bridge. The lifting work was televised nationwide, but the same barge was shown again on TV news next day because it struck the VLCC.

Figure 18: The Incheon Grand Bridge crossing the entrance of the port of Incheon

(Source: Author added the width of the bridge on Incheon Bridge, 2009)

The Incheon Grand Bridge was designed to connect the Incheon International Airport in Youngjong Island with the Incheon superhighway linked to the capital city, Seoul. It shortened the transit time up to one hour from Seoul to the Incheon International

Airport. So, it rendered great services to the cost-down of land logistics. It cost a total of 1,084 million USD (Incheon Bridge, 2009).

The total length of the bridge is 21.38Km including 12.34km of a two-way 6-lane expressway on the sea. The longest span between the bridge pillars is 800 metres. It has a vertical clearance of 74 metres. The bridge can stand ship's collision of 100,000 DWT with 10 knots (KMU, 2007).

4.4.2 **Debates between Land Road Party and Sea Road Party**

Construction work was performed from June 2005 to October 2009, although the construction contract was signed on September 1999. Two years was consumed for deciding the span of the main pillars before finalizing the blue print. The Ministry of Construction and Transport (MOCT)[42] was interested in fast construction with an economic budget. However, the Ministry of Maritime Affairs and Fisheries (MOMAF) did not agree on the span of the bridge because it could be an obstacle to safe navigation (Kim, 2009).

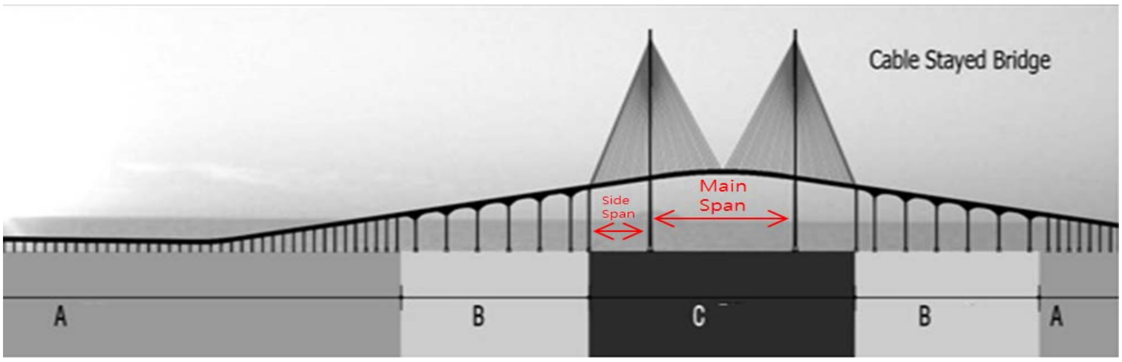

Figure 19: Outline of the Incheon Grand Bridge

(Source: Author added the red arrows and remarks on Incheon Bridge, 2009)

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[42] According to the reform of the governmental organization of the Republic of Korea, former the Ministry of Maritime Affairs and Fisheries (MOMAF) and the Ministry of Construction and Transport (MOCT) have unified into the Ministry of Land, Transport and Maritime Affairs (MLTM) in 2008. (Source: Author)

Generally, the construction parties including land traffic authorities and private companies tend to have an economic view point. They focus more on the commercial requirements rather than maritime safety, which cause not only risk of maritime traffic, but also some severe conflicts between the parties concerned (Lee, 2009).

The part C of Figure 19 was a matter of argument. The MOCT asked the opinion of the MOMAF on two options of the 550 metres and 450 metres' spans between the pillars. However, the MOMAF requested that the span between the main pillars should be 700-1000 metres, and the side span should be over 250 metres. The MOCT modified the suggestion to 675 metres after ship handling simulations that were carried out by the Korea Ocean Institution (KOI)[43]. Then, the MOMAF demanded two main spans of 550 metres. The demand was based on the ship handling simulations performed by the maritime universities[44] that had been arguing against the study result of the KOI because their points of view to safe navigation were basically different from that of KOI. Also, the MOMAF did not give any reliability to the simulation result of the KOI (Kim, 2009).

Once, the construction company proposed an alternative plan based on other simulations. The span of the main pillars was 675 metres and the side span beside the main pillars was 280 metres. However, the MOMAF did not agree on the alternative plan. Under the intervention of Vice Prime Minister, it was agreed between the two ministries after several times of ministerial meetings that the span of the main pillars in the design stage were supposed to be 700 metres taking into account the urgent road traffic need, and that a reliable third party institution would perform the ship handling simulations to search for risk assessment and safety enhancement (Kim, 2009).

[43] The institution produced and operated full mission ship handling simulators. (Source: Author)

[44] The university is equipped with Kongsberg full mission ship handling simulators. (Source: Author)

So, a well-known Japanese institution carried out the bridge passing simulation more than 20 times, and handed in three options with conditions about the span of the main pillars. Finally, the cable stayed bridge had five span lengths of 80 metres, 260 metres, 800 metres, 260 metres and 80 metres (Incheon Bridge, 2009).

4.4.3 **Different Results from Different Conditions**

More than three well-known institutions home and abroad were involved in the ship handling simulations but the results were different from one another.

Regardless of the function of simulators, one of the reasons why the institutions turned in different results of the studies could be the consideration of different inputs of the weather conditions into the simulators. If wind speeds were strong, the ship would be more pushed to the leeward side. When current directions were abeam to the ship's side, the ship would easily deviate from the planned course. Considering that simulators are a kind of calculator which renders output answers based on input data, the standard input data is as much important as the simulator itself.

Therefore, every input factor of simulation needs scientific verification for the accuracy and social agreement for the model ship. If that was the case that the standard of input data should be fixed, the government or any other organization of authority should present guidelines for data input in order to confirm reliability of the simulations. Moreover, there should be scientific tools to evaluate the safety margin for simulation of ship or any other official standards for ship's routeing (Cho, 2010).

4.4.4 **Side Effect of the Harbour Bridge**

Incheon is the second largest port city in Korea, and most industries in Incheon are linked to the port management. The local government of Incheon supported and relied on the MOMAF because fluent sea traffic was more important for the further development of Incheon.

On 19 October 2009, the Incheon Grand Bridge opened to traffic and became the landmark of the city of Incheon with the record of the 5th longest bridge among cable stayed bridge in the world.

As studied, the span of the bridge was decided by agreement between the MOCT and the MOMAF. The clearance of the bridge did not get any concern. When the bridges over the approaching channels were completed, it was found that the empty or fully loaded VLCC could not sail in or out from the inner harbour of Incheon[45] because the model ships chosen for the simulations were 100,000 dead weight tonnage of bulk carriers (KMU, 2007). The VLCCs have more air draft than that of model bulk carrier and more impulse to the bridge pillars. Moreover, there was one more harbour bridge over the northern approaches as shown in Figure 20.

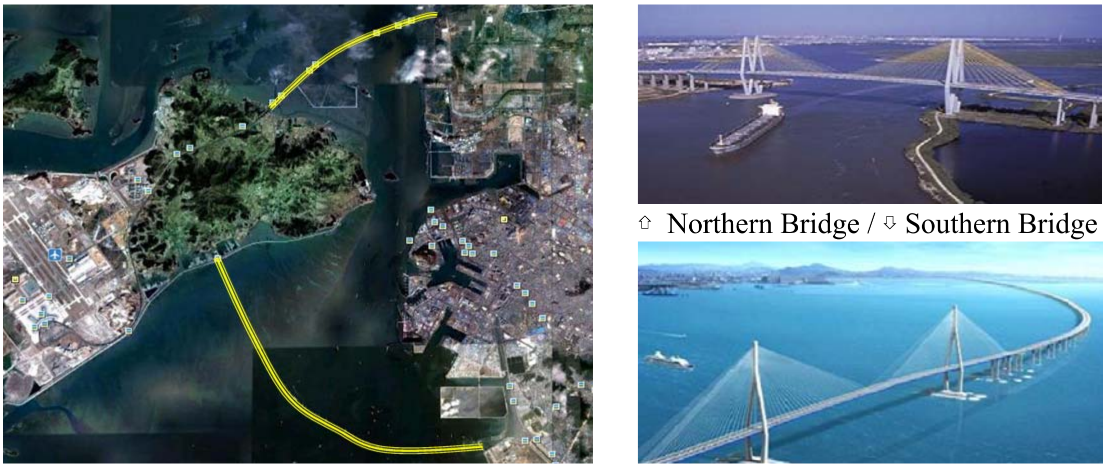

Figure 20: Two bridges surrounding the port of Incheon

(Source: Author)

According to the interview with the official in charge of port management, an oil refinery company, SK Energy, tried to hire VLCCs for transporting crude oil to the

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[45] Author interviewed the official in charge of the port management in 2011.

port of Incheon in 2010. However, the port authority could not accept the proposal because of vertical clearance of the Incheon Grand Bridge and the strength of protective pillars of the bridge that was designed to stand ship's collision of 100,000 DWT with 10 knots. The oil refinery company amended its proposal from full loaded VLCC to half loaded VLCC in 2001. However, no agreement has been made yet.

It might be safe to predict that the inner harbour of Incheon could not be used by big ships like VLCCs. In addition, recently designed huge ships like 15,000 TEU container carriers could not enter the inner port of Incheon, which means the development of the city would be limited forever in case that the bridges exist.

4.4.5 **Summary on Controversy over the Span of Harbour Bridges**

The Incheon Grand Bridge was built under the negotiation of two ministries which were in charge of land transportation and sea transportation. It took two years to reach mutual agreement based on scientific studies, such as ship handling simulations. However, the results of scientific studies were different from one another, and they were favourable to clients.

In this regards, the so-called scientific simulations could be fabricated by manipulating input data. In case of malice, the anticipated results could be created by editing input data. Even in good faith, the categories of input data should be fixed by scientific research and social agreement because the two ministries failed to enter the perspective of the port development. So, the bridge blocked the passage of VLCCS in view of the results so far achieved.

It could be concluded that the simulation conditions are more crucial points to acquire scientific and accurate results than mutual agreement. Moreover, the categories of input data are also crucial points for comprehensive and reliable simulation.

Two lessons were learned from the debates over the span of the bridge and port entry of VLCCs:

- To standardize the condition of ship handling simulation,

- To classify subjects for consideration in accordance with category of business.

4.5 Summary on User-Friendly Navigational Circumstances

Repeated marine accidents could be, sometimes, irresistible consequences when the design of ship's route and port zoning was carried out without scientific consideration to safe navigation.

If rooms for absorbing human errors are given, not a few marine accidents could be evaded. In the case of the *Hebei Spirit*, even a little drifting made devastating result in port areas and approaches. In other words, the collision could have been avoided unless the VLCC had dropped anchor at the busy water zone. It proved that design deficiencies led to the failure of systems considering the *Hebei Spirit* was not allocated to safe anchorage. It would be worth noticing the allision of LPG carrier *New Wave II*. Though the captain was blamed because of human error, the successful preventative measure came from modifying navigational circumstance.

This study demonstratively found that human error as the main cause of marine accident might not be eradicated by warning liveware or enhancing software alone. The navigational environment could play more practical roles in the matter of human error.

The span between the main pillars of the Incheon Grand Bridge was calculated on the basis of scientific simulations. Ship handling simulations had been generally applied to analyse the risk factors of navigational circumstance. However, the ministries concerned did not agree on the first draft span because the results of simulations were not independent from clients.

The span of 800 metres between the main pillars of the cable-stayed bridge was finally agreed between the two ministries after more than 20 simulations by an independent third party. No matter how agreed and simulated, the bridge became an obstacle in the near future because VLCCs could not enter the inner port through the bridge. The size of the model ship was reflective of current biggest vessels. The future ship considering port receptability was not reflected at the table of mutual agreement.

Especially, taking into account that the same size of ship's route would be regarded as shrinking when the traffic volume increased, vessels became bigger or faster. What is known as human error might be, sometimes, evidence not to blame seafarers but to urge safety administrations to scrutinize the navigational environment.

In conclusion, carefully designed or modified ship's routes and water zones can reduce human element contributions to the failure of safety systems. For this reason, the design of ship's routeing and port zoning require scientific research for maritime safety. Moreover, the research should be protected and guaranteed by independent standards.

5 SHIP'S ROUTEING AND PORT ZONING AUDIT SCHEME

5.1 Introduction

Navigational risk has been increasing significantly in recent years owing to the growing traffic volume and increasing size of ships. In addition, a variety of marine facilities such as harbour bridges, SBMs or jetties could be obstacles to safe navigation. Those installation and busy traffic could symbolize the economic development. However, the development running ahead of safety could result in accidents. As it was studied in Chapter 4, one of the best ways to avoid marine accidents caused by human elements is relieving or eliminating, if possible, the navigational circumstances that are sensitive to human errors.

Not a few marine investigation reports of the KMST depicted that risky circumstances had continuously contributed to near misses or marine accidents. However, the port design and water zoning were dealt with by the land-based concept for pursuing fast development. Even though maritime safety parties had tried to tackle the construction of obstacles in navigable waters case by case retroactively, the deciding power was on the land-based parties (Cho, 2010).

Meanwhile, the oil pollution of M/T *Hebei Spirit* cast deep impact on the Republic of Korea. So the maritime safety parties could stand firm for the needs of reforming retroactive procedures. The maritime safety bureau of the MLTM suggested that the Marine Safety Act (MSA) be amended to include new maritime safety policies that were admitted at the Presidential Meeting[46].

The SPAS was the most outstanding scheme of the amendment. The SPAS was to evaluate the maritime traffic safety on port zoning, ship's routeing and marine facility

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[46] On February 2008, the Presidential meeting admitted the draft of new safety policy on maritime traffic that included the SPAS, prohibition of port entry of single hull tankers etc. (Kim, 2011).

construction. The ship handling simulation became a compulsory step and detailed guidelines for the condition of simulation were enacted by the law in order to put the former controversies on liability to disappear. The amended act[47] entered into force on 28 November 2009 (MLTM, 2009).

This chapter aims to introduce the examples of safety measures in port zones and approaches, comparing the SPAS with existing schemes of major maritime States. The concept and procedure of the SPAS will be described to research advantages and shortcomings of the SPAS.

5.2 Examples of Safety Measures in Coastal Waters

The IMO is recognized as the international body responsible for establishing and recommending measures concerning ships' routeing in international waters (USCG-NC. 2005). On the other hand, the coastal waters are under the control of coastal States (UNCLOS article 2).

The IMO carries out approval of the Traffic Separation Scheme (TSS) in international waters, although there are no any international schemes or guidelines for checking the suitability of ships' routeing. Some coastal States adapted safety audit systems for the safety of coastal navigation. There will be briefly explained to compare with the SPAS of Korea.

[47] Korean law is divided into three levels (Act -> Enforcement Decree -> Enforcement Rule). The lower level laws should have any foundation in the upper level law to be written.

1. Acts should be passed the review under the National Assembly.
2. Enforcement Decree should be reviewed by the President.
3. Enforcement Rule should be screened by the Prime Minister.
4. Ordinance of Minister can be issued by the Ministers under the mandate of the law. (There are several forms of Ordinances, i.e. Notification for people, Directive for government officers, Guidelines or Instructions for all.

5.2.1 **The United Kingdom and Hong Kong**

The UK enforced the Port Marine Safety Code of 2009 that applied to all harbour authorities. Basically it uses the Formal Risk Assessment techniques to identify risks in harbours and approaches. It aims at maintaining the marine safety management system being in place to ensure that all risks are controlled - the more severe ones must either be eliminated or kept as low as reasonably practicable (UKD, 2009). The Code is generally interested in plans and an assessment of harbour authorities' performance in meeting their obligations at least once every three years.

Hong Kong kept a similar policy to that of the UK. Hong Kong publicized the risk of maritime traffic in its sea area after performing a wide range of strategic research that was to survey maritime traffic on the basis of risk evaluation. The standard for risk management was ruled by the Hong Kong government (MMU, 2007).

There is a harbour board for taking responsibility of safety audit. The role of the harbour board in the UK and Hong Kong is as important as the audit institutions in Korea. However, the Code did not supply any specific technical guidelines for auditing the safety system of the target waters or approaches.

Owing to the maritime traffic system in Hong Kong, there has been no human loss casualty in Hong Kong, one of the busiest ports in the world, since 1971 until the crash between a ferry and an excursion boat happened on 1 October 2012. Thirty-eight passengers died and six crew members were detained. Some maritime experts of Hong Kong criticized that increased traffic volume and continued proclamation work along the piers changed the navigational circumstances, which requires the review of the UK style maritime traffic system (Hwang, 2012). Therefore, new approaches to the safety audit system of Hong Kong are expected.

5.2.2 **The United States of America**

The United States Coast Guard (USCG)[48] holds the authority for ship routeing measures such as designation of fairways and fairways anchorages in U.S. waters. The USCG operates the Port and Waterways Safety Assessments (PAWSA) under authorities of 33 USC.[49] 1221 - Port and Waterways Safety Act of 1972, as amended by the Port and Tanker Safety Act of 1978. The PAWSA aims at providing specific results and measures for optimal routeing of ships to, in and from major ports in conjunction with all other marine activities occurring in that area. For instance, it is to confirm that every fairway and anchorage in fairways might be designated or established to provide unobstructed approaches for ship (USCG, 2012).

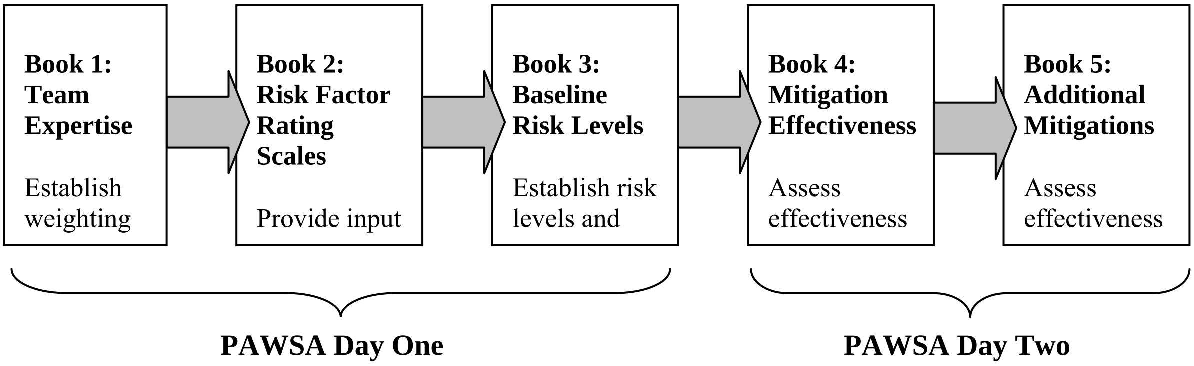

Figure 21: Simplified Overview of the PAWSA Process

(Source: USCG-NC, 2005)

[48] The United States Code (USC) title 14 and title 33 contain the responsibility of the USCG and management of the navigation and navigable waters. The first chapter of 33 Code of Federal Regulations (CFR), Navigation and Navigable Waters, entitles the USCG to manage maritime safety.

[49] The USC enacted by Congress enables the CFR. Regulations of the CFR spell out in further detail how the executive branch will interpret the law. (Source: University of Minnesota. FAQ. Retrieved 9 September 2012 from the World Wide Web:

As shown in Figure 21, the PAWSA process is a two-day workshop whose members are composed of waterway users, stakeholders, and the agencies/entities responsible for implementing selected risk mitigation measures because it is to survey major waterway safety hazards, estimate the level of risk related to fairways, evaluate potential mitigation measures, and set the stage for enforcement of selected preventative measures to decrease risk (USCG, 2012).

To sum up, the PAWSA could be classified into the expanded harbour board of the UK. Although the PAWSA results are collected by a quantitative method using spreadsheets for the data collected from each book, the convened group members use a qualitative method to fill in the books because they depend on their expertise and experience. Computer simulations are not involved in the process.

5.2.3 **Canada**

Canada enforced the Navigable Water Protection Act (NWPA) in 1985. It was lastly amended on 12 March 2009. It is composed of 5 parts[50] and has 5 subsidiary regulations[51] for safe navigation.

The NWPA has something in common with the SPAS in various ways. First of all, the law only aims at navigational safety at navigable waters. Second, the target of the law includes most work including construction[52] at sea. Third, the minister in charge of maritime safety holds the power of approval in every case of work at sea.

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[50] Part 1: Approval of Works, Part 2: Obstacles and Obstructions, Part 3: Ferry Cables and Swing or Draw Bridges, Part 4: Administration & Enforcement, Part 5: Review

[51] 1) Ferry Cable Regulations, 2) Navigable Waters Bridges Regulation, 3) Navigable Waters Works Regulation, 4) Proclamation Exemption the Waters of Sandy Pond from the Operation of Section 22 of the Navigable Waters Protection Act, 5) Proclamation Exemption Tom MacKay Lake from the Operation of Section 22 of the Act

[52] “Navigable water” includes a canal and any other body of water created or altered as a result of the construction of any work (NWPA article 2)

Table 7: Comparison between MSA (SPAS) and NWRA

Categories	SPAS of Korea	NWRA of Canada
Title of Act	Maritime Safety Act Enforcement Decree Enforcement Rule Ordinance of Minister[53]	Navigable Water Protection Act Five sub-regulations
Enactment	2009	1985
Purpose	Professionally to inspect, measure, evaluate any risk factors of the navigation safety which may affect to maritime traffic safety and be happened by the designated marine businesses[54] (MSA article 2.16)	No work shall be built or placed in, on, over, under, through or across any navigable water without the Minister's prior approval of the work, its site and the plans for it (NWPA 5. (1)).
Character	Specific target business, fixed audit items and evaluation method	Comprehensive target work, unspecified audit process
	Weighing on independent and impartial audit reports on the business according to specific guidelines	Weighing on navigational safety during and after the business instead of the business itself
	No works can be begun without the Minister's approval	Minister's decision for work is imperative
	Informing related authorities and business owners of the audit result	Publicizing the approved business to local newspapers

(Source: Author)

[53] Ordinance of Minister can be issued by the Ministers under the mandate of the law. (There are several forms of Ordinances, i.e. Notification for people, Directive for government officers, Guidelines or Instructions for all. (Source: Author)

[54] 1) Establishment and change of water area; 2) Construction / attachment or repair of structures such as bridge / tunnel / cable, etc. installed in the water area; 3) Development / redevelopment of harbor or wharf; and 4) Other business to affect conspicuously to maritime traffic safety as prescribed by Ordinance of the Ministry of Land, Transport, and Maritime Affairs.

The Canadian system is much similar to Korean system. Table 7 shows the similarities and differences. However, the NWPA of Canada has many common clauses with the SPAS of the MSA, there are no specific guidelines on the audit process and technical parts such as simulation standards which Korea and Japan have.

5.2.4 **Japan**

Japan also has a method to evaluate the risk of maritime traffic in harbour areas.

Table 8: Comparison between Korean and Japanese Audit Systems

Categories	**KOREA**	**JAPAN**
Regulation	Ordinance of the MLTM (Compulsory)	Guidelines of the Marine Casualty Prevention Association (Recommendation)
Aim	To secure navigational safety by removing risky factors caused by business in navigable waters	To secure navigational safety by quantitative analysis of effects caused by business on vessel traffic
Target business	Port construction, water zoning. Traffic Separation Scheme, etc.	Port management plan, Facility construction, Maritime traffic system, etc.
Evaluation Target	Business outline, Environmental elements, Navigational circumstances, Traffic survey, Diagnosis of traffic characteristics, Users' opinion	Environmental elements, Navigational circumstances, Existing facilities, Navigational aids, Model vessel
Evaluation Method	Simulations of Ship handling, Berthing/unberthing, Traffic congestion	Simulations of Ship handling, Traffic congestion
Assessment	Assessment Committee	Consultative Committee

(Source: Author)

According to the Port Act article 27, all construction and development work in port and approaches should be authorised by port authorities. In addition, though it is not a compulsory step, the port authorities ask the opinion of the Japanese Coast Guard.

Then the Japanese Coast Guard summons the Marine Accident Prevention Committee whose members are experts of the maritime community in Japan (KMU, 2007).

The auditing process and simulation guidelines are much similar to the Korean system as shown in Table 8, but the Japanese guidelines are on a voluntary basis.

5.3 Summary of Examples of Safety Measures in Coastal Waters

In cases of the UK, Hong Kong and the USA, the safety schemes rely on the expertise and experience of the participants of safety audits, whatever their titles are. In addition, the stakeholders are invited to the audit meetings so that the impartiality of the audit result could be controversial because the audit result depends generally on the participants and they could try to negotiate for mutual agreement. Then, the final safety measures might be minimized more than expected by navigators. On the other hand, once the agreement is made, it would be easy to enforce the new safety schemes according to the result of audit because all parties concerned participated in the audit.

Though the stakeholders participate in the course of audit in Korea and Japan, their roles are confined to certain steps of the audit process. The stakeholders' contention could be checked by computer simulations. Especially, as the simulation standards are already fixed for how to identify risk factors, estimate, evaluate and finalize for recommendations. So, scientific research could be used to persuade the stakeholders who do not agree on certain matters. Moreover, the final decision is made without stakeholders. So, it would better to induce stronger measures for maritime safety.

Every State must have chosen its best policy for navigational safety in coastal waters according to their historical background. In terms of independency of auditing, the Korean system might be one of the most scientific and objective systems because auditing procedures are already fixed and collected data are processed by quantitative tools like computer simulations.

5.4 Overview of the SPAS

5.4.1 **Background**

Even though the legalization of the SPAS was expedited by the tragedy of M/T *Hebei Spirit*, the scheme had already been studied before the tragedy.

On October 2007, the Mokpo National Maritime University (MMU) completed the study for a draft framework of safety impact assessment in maritime traffic. The study was initiated by the maritime safety bureau of the MOMAF because retroactive steps for ensuring navigational safety in coastal waters were not enough to prevent human error evolving into accidents in heavy traffic zones. In addition, on December 2007, the Korea Maritime University (KMU) carried out the study on the draft guidelines for the bridge construction crossing harbours or harbour entrances. The study was financially supported by the Port Logistics Bureau of the MOMAF because the bureau also had been anticipating standard steps against several bridge construction plans made by local governments and even the construction bureau of the MOMAF.

These two studies aimed at ensuring safe navigation in busy maritime zones from the view point of navigational safety and port efficiency. The SPAS was reported to the Presidential meeting of Korea as one of the safety policies following the oil spill of M/T *Hebei Spirit*.

5.4.2 **Concept of the SPAS**

The SPAS is a compulsory formal safety assessment scheme for maritime traffic safety[55]. The scheme is a systematic process for estimating and identifying potential risks associated with marine development, and for providing opportunities to improve

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[55] The purpose of the SPAS is to prevent marine accident and to promote efficient traffic (MSA article 1, 2).

traffic safety. Therefore, the task of SPAS is practically to identify potential hazards from the early stage of design which might affect safe navigation, and to suggest all possible measures to eliminate or mitigate those risks (Cho, 2009).

The definition of the audit scheme is in the 2nd article of the MSA. It states that the audit is a professional survey, measurement and evaluation of the hazards that may occur at sea by the following type of work:

- Setting up or modification of water zone;
- Construction or maintenance of bridges, tunnels or cables in water;
- Development and redevelopment of harbours and ports; and
- Any projects designated and announced by the Minister of the MLTM as remarkably sensitive to maritime traffic.

Conclusively, the audit scheme should be applied to almost all the marine type of work except special cases like emergency restoration service at sea[56].

5.4.3 **Auditing Institutions**

For the purpose of reliable and independent auditing, there are four official auditing institutions that are equipped with two facilities of a three dimensional full mission ship handling simulator, and a minimum of eight qualified auditors[57]. The registered institutions are, at present, the Mokpo National Maritime University[58], the Maritime & Ocean Engineering Research Institute[59], the Korea Maritime University[60], and the

[56] MSA article 16
[57] MSA article 19, Enforcement Rule of the MSA article 15
[58] Refer to the World Wide Web: http://www.mmu.ac.kr/
[59] Refer to the World Wide Web: http://www.kordi.re.kr/
[60] Refet to the World Wide Web: http://www.hhu.ac.kr/

Institute of Maritime and Fisheries Technology[61]. The four institutions are independent of design or construction companies.

5.4.4 **Overall Process**

The SPAS is required to commence when a project owner plans to build marine facilities like bridges over sea routes, or to designate navigable waters as navigation prohibited zone like anchorage or marine protected area.

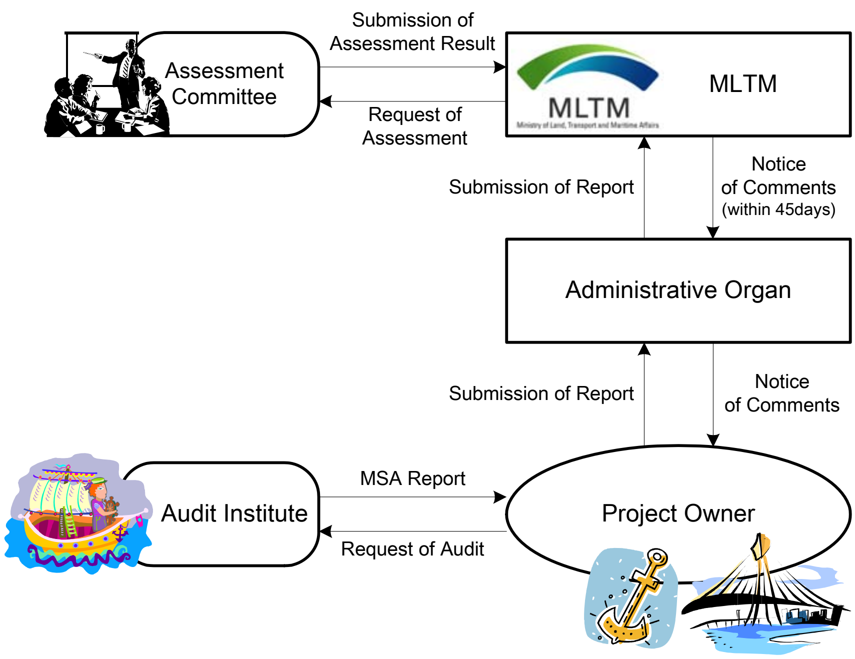

Figure 20: Administrative Procedure of the SPAS

(Source: SPAS Guidelines of the MLTM, 2010)

As shown in Figure 20, project owners ought to ask registered audit institutions to make the audit report on their draft drawings. Then, the audit institution performs auditing according to guidelines of the MLTM. The audit report should be passed the Assessment Committee of the MLTM.

[61] Refet to the World Wide Web: http://www.seaman.or.kr/

It is completely self-governing market system because the auditing institutions compete with each other to contract with project owners who consider the balance between quality of the audit result and budget to be invested. Although projects owners are interested in minimum cost for maximum profit, the quality of audit report is not negligible because the project cannot be approved by the Minister of the MLTM when the audit result is decided as "poor" by the Assessment Committee (Cho, 2010).

5.4.5 **Auditing Process**

When the auditing institutions set to work, they keep track of designated four steps as illustrated in figure 21.

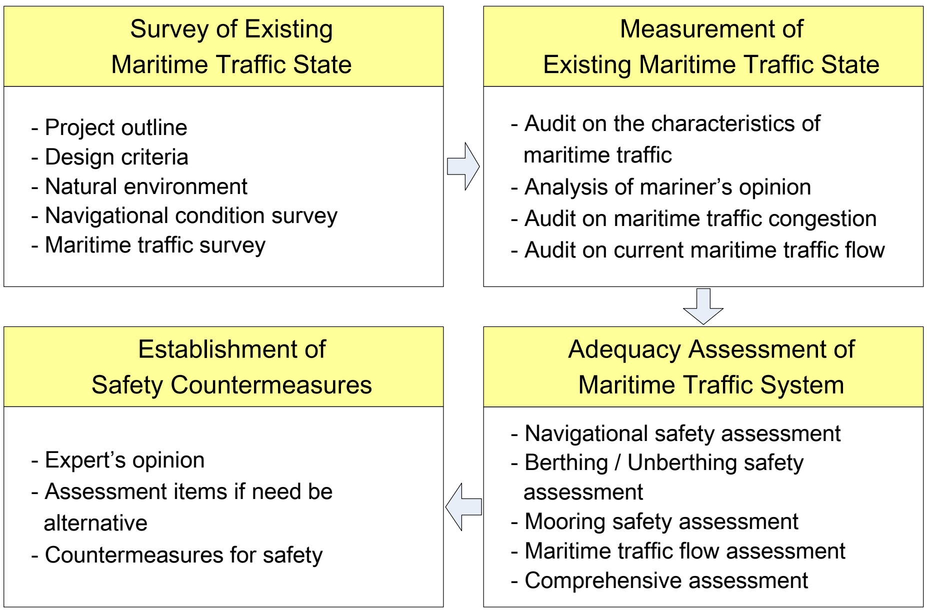

Figure 21: Auditing Process

(Source: SPAS Guidelines of the MLTM, 2010)

First of all, the audit institution surveys existing maritime traffic in the region of construction site but not limited to the site. The auditors utilises integrated data of various systems such as VTS, AIS, VMS, LRIT and the data exchange system of GICOMS[62], but they have to visit and check the target region actually by radars or any other traffic gauging equipment according to the guidelines on the SPAS of the MLTM.

The auditors analyse the traffic patterns and receive opinion of seafarers who have sailed in the region. Then, auditors assess the risks using full mission ship handling simulators with the help of active captains and pilots. The conditions of ship handling simulation are already standardized by the Guidelines of the SPAS. For example, the input wind speed should be prevailing wind direction and speed which should be maximum instantaneous wind, maximum wind, and average wind[63].

The audit institution holds minimum 3 meetings to ask the opinions of experts and stakeholders. The auditor records, classifies and evaluates all the opinions taking into account navigational safety and the additional burden of development expenditure. In this course, the SPAS showed an unexpected advantage in harmonizing the opinions of the stakeholders. For instance, when the new port project is under consideration, pilots, port managers and construction companies might have different opinions. The project owner generally might be interested in saving budget. The pilots might want wider routes, and the port management authority might require wide berths. It took several years to reach mutual agreement before the SPAS, which led to the squandering of the social resources. However, it was not easy for the stakeholders including project owners to argue against the result of independent and scientific

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[62] General Information Centre on Maritime Safety and Security (GICOMS) is to provides a general picture for all Korean ships regardless of their location in the world and for all ships in Korean waters on the basis of Geographic Information System (GIS). Moreover, the GICOMS is to share information between related governmental agencies. (Ankwang, 2011)

[63] Guidelines on the SPAS article 14.1

simulations. The total period of the project was short, which decreased the loss of opportunity cost.

Finally, the audit institution reports the validity of the draft drawing to the project owner. If needed, the two parties consult with each other to edit original drawings to reduce risks at sea under minimum additional expenditure.

The final report of audit is supposed to be laid before the MLTM for approval.

5.4.6 **Approval of the Audit Report**

The Assessment Committee are convened by the Minister of MLTM so as to evaluate the quality of the submitted audit report[64]. The Committee is composed of over 20 experts such as delegates from the Marine Officers' Association, the Pilots' Association, the Shipowners' Association and the Ship Classification Societies[65], professors who teach nautical science or port management, government officials in charge of maritime traffic or port operations, marine accident investigators. Stakeholders are not permitted to join the Committee, although several participants come from stakeholders' organizations, and they are from the safety division of the organizations.

The evaluation results made by the Committee should be notified to the project owner with a review opinion. When the assessment result is decided as a poor audit, the audit institution should replenish the final report of audit to supplement deficiencies with safety measures for eradicating circumstantial factors of potential maritime accidents[66].

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[64] Guidelines of the SPAS article 28.

[65] There are two classification societies in Korea. Korean Register of Shipping (KR) and Korea Ship Safety Technology Authority (KST).

[66] Guidelines of the SPAS articles 23-24.

Also, the target business like bridge construction cannot be launched until the final report passes the Committee[67].

Table 9 shows assessment items that have to be performed in detail by auditors. It means that the Assessment Committee would check whether the audit institution carried out the assessment items regarding business types in the vertical axis of Table 9. The upright axis presents the target business of audit, and the horizontal axis lists the scope of the audit. The mark "●" in the table should be performed for each target business.

Table 9: Assessment Items regarding Business Types

Audit item / Target business		Survey of traffic state	Measurement of traffic state	Ship handling simulation				Safety measures
				Navigational Safety	Berth/ Unberth	Mooring	Traffic Flow	
Water zone	Designation	●	●	●	△	–	△	●
	Change	●	●	●	△	–	–	●
Facility in water zone	Construction	●	●	●	△	△	●	●
	Repair	●	●	●	–	–	–	●
Harbor /Port	Development	●	●	●	●	●	△	●
	Redevelop-ment	●	●	●	●	●	–	●
Other business appointed by the MLTM		●	●	●	△	△	△	●

● : Mandatory, △ : Recommendable on occasion

(Source: Guidelines of the SPAS)

[67] MSA article 18.

When it comes to technical details, the chief of the Maritime Safety Institution of the Ship Safety Technology Authority becomes the Secretary of the Assessment Committee.

The Secretary checks the technical parts of the audit report. For example, the minimum width of the traffic lane should conform to "Guidelines on Port Design of Korea". If needed, the Rules of PIANC[68] and USACE[69] are referred to. Furthermore, the validity of the lane width should be verified by ship handling simulations. So, the Secretary ascertains what kinds of input data are used in simulations. In case of wind, it should be prevailing wind direction and speed which are maximum instantaneous wind, maximum wind, and average wind[70]. The Secretary reports the survey results to the Assessment Committee to help decision of Committee members.

5.5 Analysis of the SPAS

5.5.1 Advantages of the SPAS

The SPAS might be a turning point in dealing with human elements in heavy traffic zones because it is a practice of mental switchover to the human element, which declares that human error could not be evolved to marine accidents by the enhancement of circumstantial factors.

At the first stage of formulating the scheme, the SPAS was regarded as one more red tape by the business owners who were afraid of an increase in total budget and business duration. However, several deadlocked businesses could be commenced by the audit scheme which induced mutual agreement among stakeholders by scientific

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[68] Permanent International Association of Navigation Congresses

[69] United States Army Corps of Engineers

[70] Guidelines on the SPAS article 14.1

and objective auditing. Currently, the construction and development parties welcome the scheme because it heightened the probability of estimation. So, the new scheme is evaluated as reasonable procedure in the project of marine development of Korea. Furthermore, it is expected that the new scheme contributes not only to maritime safety but also to efficient port management and economic port construction, which may bring great benefits to the whole maritime industry.

Conclusively, it is expected that well designed sea routes, where the emergent cases are anticipated, could diminish potential risks, and would result in enhancement of maritime safety. The advantages and potential benefits obtained by the implementation of the SPAS are as follows.

- Ship's passage becomes safer, and the efficiency of port management could be maximized by reducing or eliminating risky factors.

- The overall risks that the safety authority should confront could be decreased. It would induce savings of administrative burden such as accident-related efforts and expenditure.

- Port designers will pay active attention to the safety of navigation, and the design technology considering maritime safety could be improved in self-governing market.

- Project owners would not hesitate to accept the new audit system because the whole duration of business could be pre-estimated and audit institutions would make alternative proposals to shorten the business duration and change design with minimum additional expenditure.

5.5.2 **Shortcomings of the SPAS**

The SPAS entered into force on 28 November 2009 and it is one of the most scientific and objective measures. Even though the SPAS was inaugurated successfully in Korea, the system is not fully verified yet due to lack of experience through trials and errors. With a view to the technological advances in ship handling simulation as a crucial process of the SPAS, it shows that the audit system requires constant research to develop audit application for devising and verifying technical standards at this initial phase, so that more objective and scientific improvements can be achieved. To realize and achieve the ultimate goal of the SPAS, all possible knowledge and techniques related to auditing should be examined in such audit system.

However, several shortcomings could be analysed in comparison with audit schemes of other industries.

The first compulsory assessment scheme of Korea was the Environmental Impact Assessment (EIA) by the Environment Protection Act of 1977. The instrument became one of the most important measures to maintain sustainable development. However, it has been criticized that most EIA reports were not easy to understand for stakeholders and they were perfunctory and written in the same way, which could not prove their effectiveness because of feeble post-management (National Assembly, 2012). The Ministry of Environment prepared for amendments of the related law in order to introduce a port-management scheme and examination of an auditor's qualifications (Hwan-Kyung Ilbo, 2012).

Post-Construction Audit

In accordance with the Traffic Safety Act of Korea, there are three types of audits. Normal audits are basically performed in the design phase, and inauguration and operation phases as well. Furthermore, the special audits could be performed when traffic accidents frequently occurred[71] at the audited area.

The SPAS recognizes a preliminary audit. It does not have the concept of post-construction audit. The result of the preliminary audit depends generally on simulations, but the simulations do not perfectly reflect real sites from time to time. Therefore, it would be helpful to introduce the post-construction audit to verify the similarities and differences between the simulated virtual environment and constructed real site, which might enhance the simulation conditions in the long run. In the process of the post-audit, the navigators' opinion who participated in the preliminary audit should be gathered and reflected regularly. The feedback would be helpful for the enhancement of the SPAS.

In terms of audit expenses, the project owners are in charge of the preliminary auditing expenses because they need auditing. When it comes to special audits after installation of facilities, the project owners already completed the projects, so they would not intend to bear additional burden. It is suggested that the effort to establish new funds might be desirable in cooperation between the government and the audit institutions, because audit institutions may bear the results of preliminary audits and primary beneficiaries in the enforcement of the audit scheme, and the government might hold ultimate responsibility for safety and another beneficiary of reduced marine accidents.

Starting Point of Audit

The sooner the audit is carried out, the safer the results are taken, and the less it costs (U.S. Department of Transportation, 2006). Specific outset timing for audits has not been stated in the MSA[72]. Therefore, it is not certain when the audit should begin.

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[71] Traffic Safety Act article 36

[72] MSA article 15 (Maritime Traffic Safety Diagnosis) (1) Any person who intends to perform a diagnosis required business (hereinafter referred to as the "Businessman") shall execute a maritime

It could cost beyond the allotted budget for change of blue print just before the construction phase. That is, it would be more beneficial to edit blue the print through a feasibility study in the pre-design or design stage. Also, it would be more recommendable to edit the blue print through a feasibility study in the pre-design stage, and the audit contract between audit institution and project owner should be divided into two parts. The first part will be a feasibility study for auditing at the pre-design stage. The second part will be the remaining formal risk assessment at the design stage.

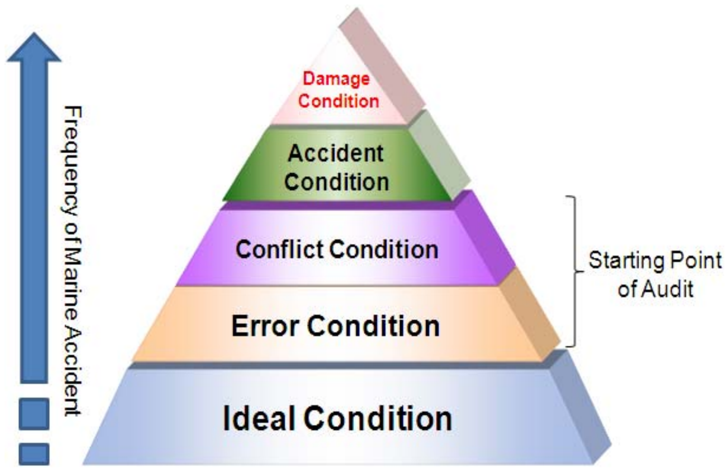

Figure 22: Phase Model

(Source: Cho summarized Durth & Bald, 1987)

In particular, as shown in Figure 22, the ideal condition does not need a safety audit. The second phase of error condition would become a starting point of a safety audit. If the phase lasts, it would be expected that the frequency of marine incidents would rise (Cho, 2011).

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traffic safety diagnosis in accordance with the diagnosis criteria as prescribed by Ordinance of the Ministry of Land, Transport, and Maritime Affairs.

It should be the principle to perform an audit before detailed design. This is because the earlier the audit is carried out, the more efficient and economic it can be in terms of safety and cost.

Expansion of audit institutions

There are four registered audit institutions in Korea. They do not keep the balance with the number of target businesses because more than 50 bridges connecting main land and island, or island and island are scheduled to be launched in the near future according to the official in charge of national road management division of the MLTM. Furthermore, marine parks, piers for international passenger ships, and port renewal projects along the coast line are under consideration by local governments. Furthermore, when a big marine project is announced, bids are invited for the design and construction. Many companies or consortiums may require the help of audit institutions. Therefore, the number of audit institutions should be equivalent to project number.

In detail, the auditing institutions should be equipped with two mock-up bridge systems for the three dimensional full mission ship handling simulators[73] and eight qualified experts. Most marine institutions and training centres of shipping companies have qualified simulators. So the equipment requirements do not matter for registration. However, expert qualification requires quite high standards. There are three classes of auditors. To be a first class auditor, 4 year audit experience is required as a holder of 2nd class deck officer certificate or doctor’s degree related to maritime safety. There are less than 20 first class auditors in Korea. Therefore, the examination for auditor's qualification should be considered to cultivate experts in relatively short time.

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[73] The institution should have traffic flow gauging and analysis equipment (Enforcement Rule of the MSA article 15)

International Cooperation

Even though the simulation method is a scientific tool, many other skills can be utilized for identifying risk factors in coastal waters. Japan is a State that uses simulation skills in the course of port design. First of all, a bilateral meeting between two neighbouring States would be beneficial to improve auditing skills. In addition, the ship handling or port design societies of the world could be invited to share their knowledge and techniques.

Finally, keeping in mind that the international routeing has been dealt with by the Sub-Committee on Safety of Navigation (NAV), the Committee might require the audit result of the proposed routeing for approval. In this case, the technical guidelines of the SPAS would contribute to devising the IMO guidelines for auditing of ships' route.

5.6 Summary of the SPAS

Coastal States maintain legal instruments for safe navigation in ports and coastal waters. Some States operate experts groups to identify risk factors and evaluate potential mitigation measures, which are managed by the government. Other States cultivate private audit institutions to be utilized by the business market.

In 2009, the Korean Government enforced an audit scheme for ship's routeing and port zoning. The character of the audit scheme compared to the other states' measures lies in the fact that it is a mandatory set of rules and regulations according to the Maritime Safety Act. Furthermore, it presents specific guidelines for audit procedure, data collecting and data input of ship handling simulators. The stakeholders participate in the course of audit, but their opinions might be checked by scientific analyses using simulations. Therefore, the deviation of audit reports might be slight, so the final report would be objective and reliable.

The final audit report should pass through a quality check by the Assessment Committee that is managed by the government. Therefore, the SPAS has a double check system. It implies that more objective and stronger safety measures can be adopted. Conclusively, the characteristics of the SPAS can be summarised as a scientific and objective audit scheme working in a self-governing market to deal with human error in heavy traffic zones.

6 CONCLUSIONS

Modern vessels have become significantly bigger or faster to achieve economies of scale, which have been burdens on fairways that had been used for traditional vessels. Moreover, the feasibility of marine accidents became higher in coastal waters as the increasing installation of marine structures and continuing port development. Navigators should pay more attention to the route which held heavy traffic. However, from the view point of accident prevention, blaming navigators to be the cause of marine accidents could be inadequate because a navigator-friendly environment might fill in the risky holes of a safety system.

In this context, the author examined the statistics of marine accidents because statistics on causes of marine accidents are a key to preventative measures. Also, without the positions of accidents, it would not be possible to conduct effective enforcement of limited administrative power. It was confirmed that the human element had played a significant role in provoking marine accidents. About 80% of the causes of marine accidents were human errors such as slips, lapses, mistakes and violations. In addition, over 70 % of mishaps occurred in coastal waters like port zones and approaches. To sum up, the vast majority of marine accidents occurred in coastal waters by human errors. The result implied that maritime safety policy for reducing human error or changing the route from human error to marine accident in coastal waters should be the main concerns of safety management parties.

The IMO has approached the issue of maritime safety from a predominantly technical point of view. The conventional solutions have been to apply engineering and technological answers to promote safety and to minimize the consequences of marine accidents. Accordingly, safety standards have primarily addressed ship's strength, stability and equipment requirements. Despite these technical innovations, very serious marine accidents have continued to occur. Hence, the IMO has shown interest in adequate training and certification of seafarers in order to address the contribution of the human element to marine accident. Considering that human-oriented accidents are not totally eradicated by training and certifications, a supplementary system on shore such as VTS and VMS that give warning to navigators prior to encountering risk became a complementary treatment.

In addition, the ISM Code of the IMO became a conspicuous instrument regarding the combination of human element with safe navigation and management matters because it required systematic approaches on risky working conditions. Furthermore, the UCD could be one more solution to suppress marine accidents caused by operators' mistake because the UCD is a consideration of an end-user friendly design from the beginning of the system product. The UCD should be applied in the integrated bridge project of the IMO and future navigational equipment.

To verify that the aforementioned safety measures are corresponding to all categories of human errors, the Marine Casualty Investigation Code was referred to because it was developed to identify the categories of human errors. It was found that the IMO could contribute further to preparing any appropriate measures to deal with the loose interface between liveware and the environment, in other words, navigators and navigational circumstances.

In detail, several marine accidents caused by human errors were examined to look into the relationship between operator and operating environment. It was analysed that recurrence of marine accidents could be irresistible consequences when artificial circumstances of navigation such as ship's routeing and port zoning were designated without scientific consideration to safe navigation.

In case of the *Hebei Spirit*, even a little drifting made a devastating result under a low tolerance environment to human error. In the case of the LPG carrier *New Wave II,* the successful preventative measure came from modifying the navigational circumstances such as changing the two-way route to the one-way route. Conclusively, the navigational environment could play a more practical role in the matters of human error in terms of preventative measures.

As a scientific tool of navigational risk detection, ship handling simulation was utilized in Korea. However, the case of the Incheon Grand Bridge showed that the input data was imperatively important for reliable results. In addition, taking into account that the same size of ship's route would be regarded as shrinking when the traffic volume increased, as vessels became bigger or faster, the future circumstances should be anticipated in choosing standards of a model ship and data input.

Additionally, the legal framework of several maritime States on coastal navigation management was analysed. In cases of the UK, Hong Kong and the USA, the safety schemes relied on the expert group including stakeholders. Japan maintained computer simulation methods for risk assessment in addition to the expert group meeting. Canada is equipped with a powerful law which endowed the minister in charge of maritime safety with authorities for approval of marine work including constructions at sea.

The Korean Government has actively introduced various safety measures to enhance navigational safety in coastal zones since the biggest oil pollution in 2007. As one of the new measures, the audit scheme on ship's routeing and port zoning was activated in 2009 to provide a better environment for navigators in coastal zones. The SPAS could be a mixture of merits from audit schemes of major maritime States. The foundation act is as powerful as that of Canada. The audit results are produced through an independent scientific process like Japanese system. The experts concerned are invited to the audit meetings like the UK and US cases.

The characteristics of the SPAS lies in the fact that it is a mandatory set of rules and regulations including specific guidelines for audit procedure, simulation process and technical details, which enable the system to work independently in a self-governing market. Hence, the deviation of audit reports might be minimised, and the final report would be objective and reliable. Additionally, the SPAS was proven that it was not one more red tape, as it has shorten the time for mutual agreement among stakeholders because the system worked on the basis of its independency and objectivity in a self-governing market.

For the enhancement of the mandatory audit scheme of Korea, and attempting to introduce the SPAS to the international maritime community, the author is of the opinion that the following issues should be considered.

Firstly, the post-construction audit should be considered with a view to the frequency of the audit. As reviewed in Chapter 5.5, when traffic accidents frequently occurred, the additional special audit should be performed. The comparison and survey between the simulated virtual environment and constructed real site would contribute to the improvement of the SPAS.

Secondly, the specific outset timing for audit should be designated. It would be more beneficial to edit the blue print in the pre-design stage, and the audit contract between audit institutions and project owners should be divided into two parts. The first part will be a feasibility study for auditing at the pre-design stage. The second part will be the remaining formal risk assessment at the design stage.

Thirdly, the examination for an auditor's qualification should be considered to cultivate experts in relatively short time. At present, the number of audit institutions does not keep the balance with the quantity of the target business. The qualification of experts became an admission barrier because it requires quite long experience with related certificates and academic degrees. Therefore, qualifying examination is recommendable for securing auditors.

Lastly, international cooperation would accelerate the improvement of the audit skills including simulation techniques. It is recommendable to start from bilateral meetings between States that possess similar schemes, and to proceed to multilateral meetings, and then to reach the IMO level. The NAV of the IMO might deal with the technical guidelines of the SPAS for applying the skills to approving international routeing of ships.

In conclusion, the SPAS might be a turning point in dealing with the human element in marine accidents because it does not focus on the ability of seafarers who are not free from human error, but aims at enhancing safety margins between navigators and the navigational environment. In addition, the SPAS system should be evaluated and upgraded continuously in line with the progress of the development of scientific tools and navigators' needs. All requirements for auditing adopted by maritime States should be scrutinized for enhancement and application to the SPAS system to cut links between human error and marine accidents, or make it flexible enough to compensate human error in error enforcing zones.

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