해양사고 예방을 위한 선진 해사안전체계 연구

(인적과실에 의한 해양사고 저감 기술 조사)

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차례

국외훈련 개요

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훈련기관 개요

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2. 현황

ㅇ UN 산하 국제해사기구(IMO)에서 설립 및 운영 (1983. 7)

* 스웨덴 정부에서 일부 행정 및 재정 지원

ㅇ 개교 후 170여개국 5,000여명의 졸업생 배출(2018 기준)

* 매년 120~140여명 본교입학 (2019년 132명, 한국인 4명)

ㅇ 7개 석사 및 박사 전공과정 운영

* 70여명(29개국)의 교직원 근무, 110여명의 객원교수 등 운영

3. 참고자료

ㅇ WMU Academic Handbook을 통해 교과정 등 상세정보 제공

* https://www.wmu.se/docs/academic-handbook 다운로드 가능

Abstract

Title of Dissertation: **Investigating the use of Technology to reduce maritime accidents caused by human error in the republic of Korea**

Degree: **Master of Science**

After the Titanic accident in 1912, the international community has made continuous efforts to increase the level of safety at sea and to prevent maritime accidents. Due to the development of shipbuilding and safety technology, the hardware safety factor has been continuously improved, but maritime accidents still occur. It is noteworthy that the causes of such maritime accidents are mostly due to human error, which accounts for 90%. With the recent development of advanced technologies such as IT, AI, and sensors, various discussions are underway for the introduction of such technical measures to reduce human errors.

The Republic of Korea is one of the countries with a very high dependence on maritime activities, relying on sea logistics for 99% of the total import and export, and consumes about 78.5 tons of seafood per person. Unfortunately, there are about 2,000 maritime accidents each year, and due to this about 110 people lost their lives. Therefore, reducing maritime accidents caused by humans is an essential task for the sustainable development of the shipping industry and the protection of people's lives.

This dissertation aims to investigate the development and application of technologies for reducing maritime accidents caused by human error, and to suggest which applications to reduce human error are suitable for the coastal area of Korea. To this end, the status of maritime accident statistics, coastal maritime traffic environment, and maritime safety technology was investigated and analysed, and based on these data, the priority of human error reduction technologies applicable to the coast of Korea was derived. In addition, a case study of frequent maritime accidents was conducted to compensate for the lack of data. Finally, based on the data thus derived, five measures are suggested, including the introduction of collision avoidance, the development of a decision support system suitable for small ships such as fishing boats, and the development of software to reduce human error based on maritime safety communication infrastructure.

Even if such human error reduction technology is introduced, it will not be possible to eliminate maritime accidents due to human error. However, reliable technology can help minimize the defect of human error. Human error is caused by the interrelationship of a wide variety of internal and external factors. Therefore, social, geographic, and environmental analysis of the sea area to which human error reduction technology will be applied is an important factor in the development and introduction of related technologies, and more detailed research should be conducted in henceforward.

KEYWORDS: Human error, Safety, Technology, Korea, fishing boat, Maritime accident

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Chapter 1. Introduction

1.1. Background and definition of safety technology

When drivers are in a hurry to drive a car, they sometimes forget to wear a seat belt. If the driver starts the engine without wearing a seat belt, perhaps a loud alarm will continue to sound until the they wear the seatbelt; in some cases, the car may not start. This is one of the technological devices to reduce human error to prevent accidents and to minimize the damage of accidents by informing when drivers forget to wear a seat belt. This technology is very simple but very efficient. Since the introduction of seat belt alarm technology, the wearing rate of seat belts in front seats has increased by 95% and the death rate of traffic accidents has decreased by 45% (Fildes, Fitzharris, Koppel & Vulcan, 2014).

As described above, safety technologies for reducing human errors have already spread to the unrecognized area. This is true not only for the land transportation but also for the maritime and air transportation sectors. Each transportation means is used to transport passengers or cargo, and is operated according to the relationship between each environment according to the characteristics of the transportation means. Since the Industrial Revolution, these transportation methods have been continuously developed, and the technological incompleteness that caused accidents at the beginning of transportation was complemented by the development of related technologies. Paradoxically, even though the hardware defects in transportation have been greatly reduced due to this innovative technological development, accidents continue to occur. It has been recognized that many of these accidents are caused by human error through the analysis of various accidents, and related industries and the international community have continued various efforts to control human factors for accident reduction.

The maritime transport sector has also made continuous efforts to increase the level of safety at sea and reduce maritime accidents. After the Titanic Accident in 1912, the International Maritime Organization (IMO) established the Safety of Life at Sea (SOLAS) Convention to prevent maritime accidents, and 166 countries around the world ratified It (IMO, 2020). The initial SOLAS Convention was aimed at establishing international standards for the structure and safety equipment of ships to prevent major maritime accidents. However, due to technological development and the international community's efforts to reduce maritime accidents, maritime accidents due to structural defects of ships have relatively decreased, but the proportion of accidents due to human errors has continually increased. Crucially, several major maritime accidents[1], such as the Herald of Free Enterprise incident in 1987, once again reminded the seriousness of accidents caused by human error, For these reasons, the International Maritime Organization established the International Safety Management Code (ISM Code). It was implemented worldwide in 1998. The ISM

[1] 1987. 3. Passenger ship Herald of Free Enterprise overturned accident (188 people died): sailed from the port of Belgium without closing the water tight door, 1989. 3. Oil tanker Exxon Valdez stranded accident (45,000 tons of crude oil spilled): Shipped at 140,000 tons of crude oil at Valdez Port, Alaska, USA, 1990. 4. Scandinavian Star fire accident (159 deaths)-Passenger ship sailing the North Sea

Code fulfils its role as a software international regulation to reduce human errors. The ISM Code will be discussed in more detail later.

In this way, the international community's institutional efforts to prevent maritime accidents have continued, along with the development of it. Various safety applications are applied to ships. In broad terms, there will be technologies for human safety, navigational safety, and cargo safety.

Table 1. Ship safety technologies

Categories	Related technology	Etc..
Human safety (Lifesaving and Firefighting)	Marine Evacuation System, Firefighting system, Personal protection equipment	Hull damage monitoring and response technology, Ship engine maintenance and repair monitoring system
Navigational safety	ARPA (Automatic radar plotting aid) Radar, ECDIS (Electronic Chart Display and Information System), GMDSS (Global Maritime Distress and Safety System)	
Cargo safety	Oil spill blocking and response technology, Cargo monitoring system	

The two indicative examples of technology applications used to increase safety at sea are lifesaving and fire extinguishing equipment. Related equipment, such as closed lifeboats and self-expanding lifejackets, has continued to develop technologically to increase the probability of lifesaving. The fire extinguishing technology may be a fixed CO2 fire extinguishing system or a fire detecting system. However, the lifesaving and fire extinguishing safety technologies are not to reduce human errors but a measure to minimize damage in the event of an accident. Perhaps the safety technology for reducing human errors has been applied the most in the navigation safety (Rothblum, 2000).

Table 2. Traditional technology for Navigation Safety

Technology	Functions
Radar (S-Band, X-Band)	Detection, Information
ARPA (Automatic radar plotting aid)	Information, Warning
ECDIS (Electronic Chart Display and Information System)	Decision supporting
AIS (Automatic identification system)	Information
GPS (Global Positioning System)	Information
Echosounder	Information, Warning
GMDSS (Global Maritime Distress and Safety System)	Communication
Gyrocompass	Information
Auto Pilot	Support

The human error reduction safety technology discussed in this dissertation is intended to be defined as it applied to ships and land to support decision-making by operators to prevent accidents of ships and prevent judgment errors in advance. In addition, this dissertation intends to limit the scope of human error reduction technology to the field of navigational safety in ships and land support facilities. Also, it is intended to include non-human navigation assistance applications, such as artificial intelligence (AI) or algorithms for predicting risk. Human error is caused by complex interrelationships of very various factors, so it is very diversely defined according to the field and situation (Er, 2005). However, in this dissertation, human error is defined as a mistake in the decision-making process related to the operation of a ship or as a mistake due to external and internal influences.

1.2. Aim and objectives

Despite the development of maritime safety technology, maritime accidents continue to occur. According to Allianz Insurance statistics (see Figue.5), about 75% of maritime accidents are caused by human error. Such accidents caused by human error have caused many lives and property loss in the world. In addition, for the sustainable development of shipping, which accounts for more than 90% of global logistics, the reduction of maritime accidents due to human error is an essential task.

Until now, the international community counting on IMO has continued institutional efforts to reduce human error through the SOLAS Convention and STCW (Standards of Training, Certification and Watchkeeping for seafarers 1978), Convention. However, human error is not caused by human nature but is caused by complex causes by various external and internal factors, so there is a limit to reducing it only by institutional efforts. Innovative developments in recent Information technology (IT) and sensor technologies have enabled support to effectively reduce human error in the transportation sector. In the field of land and air transport, human error reduction technology is already applied.

The coast of the Republic of Korea is a sea area where many ports are located, various types of ships are operating, and many fishing activities are carried out. In particular, according to statistics from the Korean Maritime Safety Tribunal, about 90% of maritime accidents are caused by human error, so reducing accidents due to human error is a very urgent task in the Republic of Korea. Therefore, this dissertation aims to investigate which human-error reduction technology is suitable for the coast of the Republic of Korea to effectively reduce accidents caused by human error.

For this purpose, this dissertation is to review the current status of related technologies for the reduction of accidents caused by human errors, which account for the highest proportion of maritime accidents, and to analyse the environment related to maritime traffic and human factors. To this end, this dissertation first attempts to analyse the current state of maritime accidents caused by human errors and to find out the current status of relevant international regulations. Secondly, the current status of safety technologies for reducing human errors that have been developed and applied will be examined, and thirdly, the maritime traffic environment and human factors in the Republic of Korea will be analysed. Lastly, based on the above survey, it is intended to derive what kind of human error reduction technology is suitable for the coastal environment in the Republic of Korea and propose a development plan.

1.3. Scope & limitations

The scope of this dissertation covers navigational safety-related technologies for cargo ships, passenger ships, fishing boats, and leisure vessels operating off the coast of Korea (including the Exclusive Economic Zone). Military vessels and coastguard vessels not intended for commercial purposes are excluded. Among the various safety applications applied to ships, it is limited to the navigators. It also includes ships, as well as related technologies, applied on-land facilities.

1.4. Research Methodology

This dissertation will be carried out in five steps using a combination of qualitative and quantitative techniques. This dissertation is divided into 7 chapters. The first chapter is an introduction, describing the reasons for selecting the subject of this dissertation, the definition of key keywords, and the purpose of the dissertation. The second chapter presents related theories to help understand human error, which is the most important topic of this dissertation. In this chapter, literature surveys were mainly used. The third chapter analyses statistics on maritime accidents caused by human error. In this chapter, qualitative research skills related to statistical analysis were applied. The fourth chapter analyses the maritime traffic environment on the coast of the Republic of Korea to which human error reduction technology will be applied. This chapter investigates and analyses the general overview of Korea's maritime traffic safety policy, as well as statistics on registered ships, port layout, topographic characteristics, and seafarer related phenomena. This chapter applied qualitative research skills and literature review. The fifth chapter investigates the current status of maritime safety technology. This chapter investigates and analyses the international community's discussion trends on major safety technologies related to human error reduction technologies, the development status of these in the field of land and air transport, and the current status in the Republic of Korea. This chapter mainly use a literature review. The sixth chapter derives the priorities of human error reduction technologies required in the coast of Korea, based on the overview of human error (chapter.2), maritime accident statistics (chapter.3), maritime traffic environment (chapter.4), and maritime safety technology status (chapter.5) data surveyed and analysed in the previous chapter. In order to derive the priorities of such technology development, items with a high risk of accidents were selected for each data, and risk assessment skills were used to analyze the linkage of these items. In addition, based on the priorities of the development of human error reduction technology derived as described above, the measures of human error reduction technology applicable in the Korean coast was suggested.

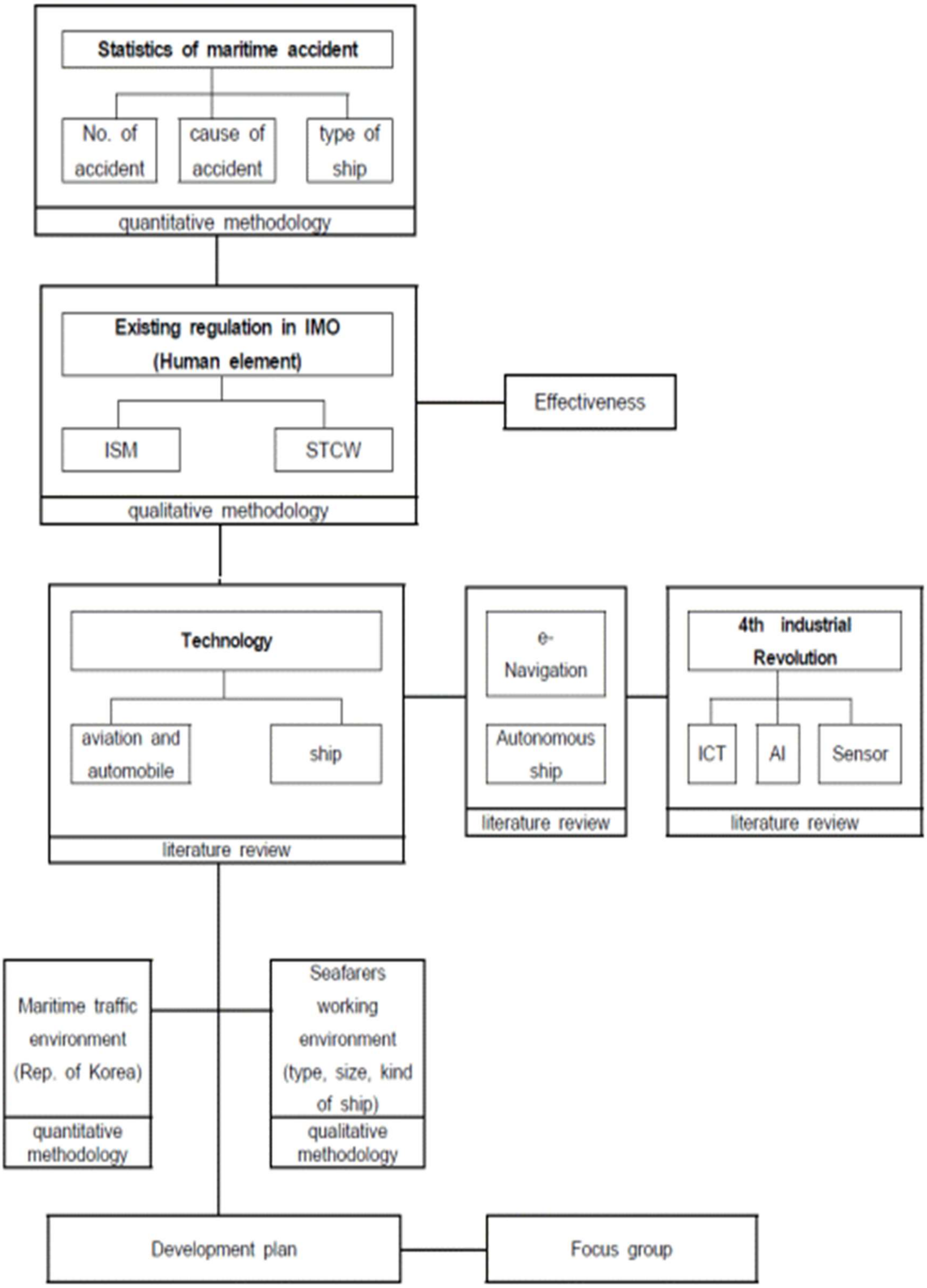


Figure 1. Research Methodology

Chapter 2. Overview of the human error in the Maritime sector

In this chapter, to understand human error, which accounts for the highest proportion of maritime accidents, various theories related to human error are reviewed and the institutional efforts of the international community to reduce them.

2.1. Overview of human error

According to the Formal Safety Assessment (FSA) guidelines of IMO, human error on a ship is necessary for the seafarers' ability to complete the job.

It is considered to occur when the level falls below the level, and it is defined that this is not because of the lack of competence of the job performer, but rather because the competence of the job performer is hindered by adverse circumstances (IMO, 2007). Examples of theories that support this opinion include the Shell model, the Domino theory, and the Swiss cheese theory.

The SHELL model was developed by American aeronautical psychologist Edward and later improved by Frank Hawkins by adding a relationship with another worker (L). The relationship between the human operator (L) and the hardware (H) such as machinery and equipment, the relationship with the software (S) representing operational regulations and procedures, the relationship with the environment (E), and another worker, the human (L) The interrelationships are illustrated schematically.

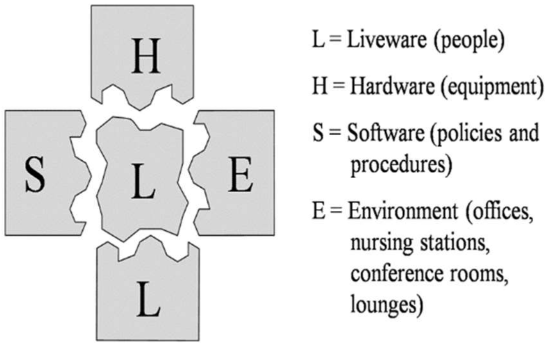


Figure 2. The SHELL model

The Domino theory was proposed by H.W. Heinrih, and it was considered that the process of occurrence of a disaster occurs similarly to the process of serial collapse of dominoes. A disaster is manifested by a series of events in a series of times. Among these continuous actions, defects in the home environment and social environment are the first causes of accidents. These causes are linked to personal defects, and accidents occur when unsafe human behaviour or unsafe conditions appear, and these accidents can then lead to disasters.

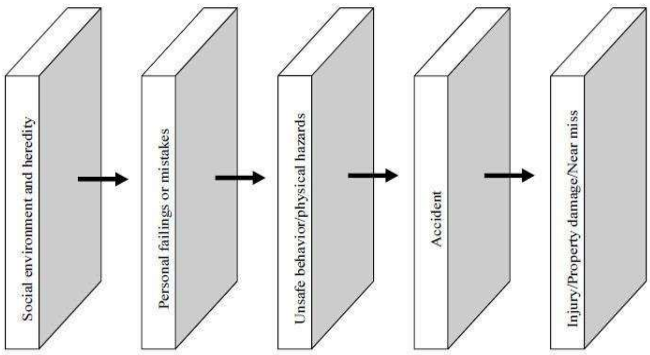


Figure 3. Domino Theory

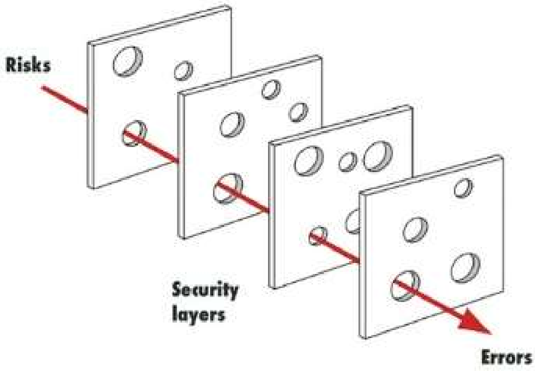


Figure 4. Swiss cheese theory

The Swiss cheese theory was proposed by James Reason, an authority on human error research. This theory explained the accident process with Swiss cheeses with small holes in the middle. It is mentioned that accidents are generally caused by a series of human errors and that there are signs related to the occurrence of accidents long before the accident. In this model, the prevention of human error is the priority to prevent accidents. To prevent human error, the defects of safety devices and error neglect systems must be minimized.

The human factor was defined as a complex multi-dimensional issue that affects maritime safety and marine environmental protection. It involves the entire spectrum of human activities performed by seafarers, shore-based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties, all of whom need to cooperate to address human element issues effectively (IMO A 20/Res.850).

The human factor in the shipping sector can be largely divided into organizational and personal factors. Personal factors include stress, health and living condition, shift work, decision making, situation awareness, communication, and fatigue. In addition, organizational factors include safety culture, safety education, and safety climate. These individual factors are influenced by various environments and situations (Chauvin, et al 2013).

Human Factors are influenced by

• The individual (experience/fitness)

• Type of work (dynamics / complexity / ergonomics)

• The environments (internal/external)

• The work organization (processes/relationships)

These human factors are influenced not only by the characteristics of the individual but also by the organizational characteristics of the human factors. In particular, since the basic hardware and software safety system is built in modern times, accidents caused by human error are more affected by organizational systems than by individual characteristics. As such, human factors are affected by a wide variety of environmental factors. Moreover, these environmental factors are different depending on the situation, so it is difficult to simply define them.

2.2. Regulatory approach toward human factor

Among the various risks covered in the international conventions related to human error, hardware elements such as structures for the safety of ships and preventing fire and, life-saving equipment are managed through certificates and maintained through periodic inspections. (Berg, 2013) Relatively clear criteria are applied to these hardware elements. On the other hand, elements of human factors are relatively difficult to confirm compared to hardware facts or visible standards, and it is relatively difficult to check whether the standards are maintained continuously due to various situations. For the systematic operation of ship safety management, IMO introduced the International Safety Management Code (ISM).

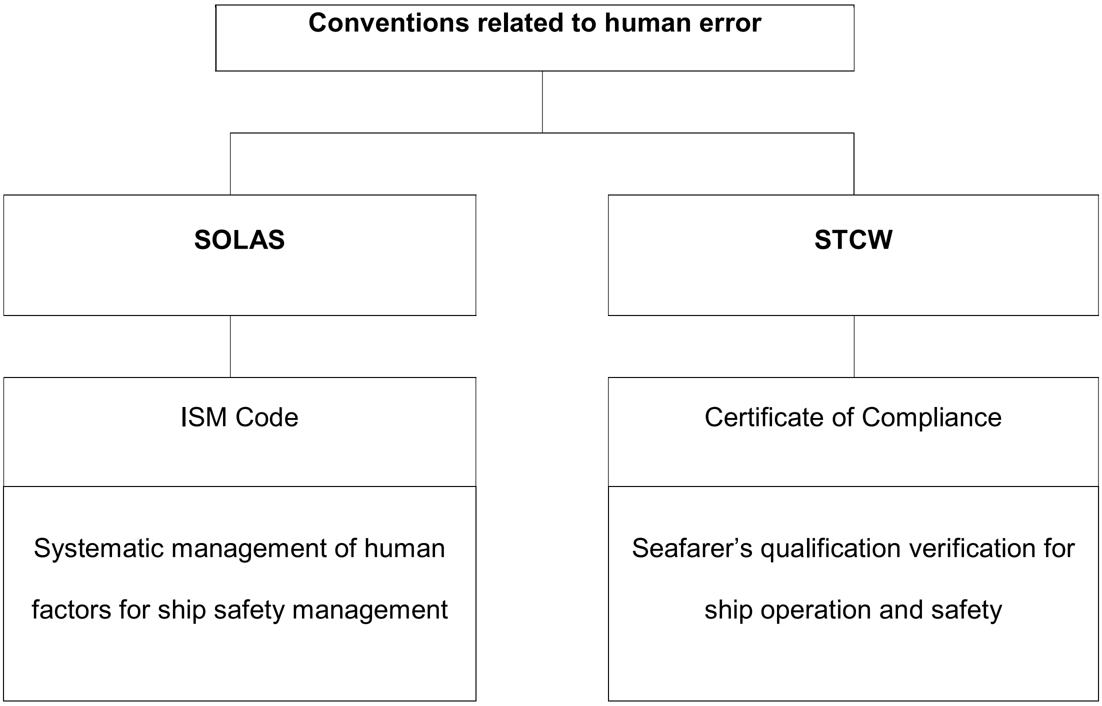
The International Maritime Organization(IMO) recognized that the increasing number of maritime accidents caused by human errors has established relevant regulations to prevent maritime accidents caused by human errors. The most notable system for reducing human errors is the International Safety Management Code (ISM Code). Due to the growing awareness of the need for internationally systematic ship safety management, the IMO adopted it in October 1993 to implement the ISM Code. It was amended in Chapter 9 of the SOLAS Convention. Also, from 1 July 1998, the amended Convention was to be applied step by step. One of the most important elements of the ISM Code is that ships operate under a safety management system and the Code defines the ship owner's responsibility and authority to ensure that the ship's safety management system operates efficiently. In addition, a systematic procedure was established to systematically control the activities of the seafarers involved in the operation of the ship.

The ISM Code aims to establish a safety management system for shipping companies and ships. Before the introduction of the ISM Code, the ship's safety management depended on the shipping companies' capabilities and the ability of the seafarers; however, after the introduction of the ISM Code, the shipping company and the ship were institutionalized to have a documented safety system and continuously manage it. The introduction of the ISM Code has become a new turning point in IMO's maritime safety-related policies, which were mainly promoting ship accident prevention policies by strengthening ship structures and equipment (Hanchrow, 2017).

It is true that in the early stages of the introduction of the ISM Code, the importance of document work for systematic management of ship safety management was higher than necessary (Størkersen, 2018). Seafarers and shipping companies were burdened with documentation of safety management records rather than the original purpose of the ISM Code for the systematic management of ship safety. However, since then, the international community's concerns and efforts for efficient implementation and application of the ISM Code continued, and now it is developing as an effective safety management tool counting centred on the management of human factors (Berg, 2013).

Another important Convention for control of the human factor is the International Convention on Standards of Training, Certification, and Watch-keeping for Seafarers (STCW). In March 1967, following the accident of a large tanker, the Torry Canyon, near the coast of France, the recognition that international unification standards for seafarers' qualifications were needed, the International Maritime Organization (IMO) established the STCW Convention. The Convention establishes the criteria for human factors for securing ship safety by proposing minimum qualification for seafarers and by establishing relevant training standards according to the characteristics of ships and cargoes.

Table 3. The normal flow of regulations of human error in the maritime sector



By establishing the above two regulations, it is firstly possible to secure basic human factors through standardized seafarers qualification standard, and secondly, to manage the human factor related to shipping operations.

As explained above, the international community's efforts to reduce human error are focused on systematically reducing the errors of human nature itself. However, in addition to such institutional efforts, efforts to reduce human error continue through technical support according to the development of related technologies, and in recent years, with the rapid development of automated ships and IT technologies, discussions on this are rapidly progressing.

Chapter 3. Statistics and status of maritime accidents and human error

This chapter attempts to identify the status and causes of human error accidents through statistical analysis of maritime accidents. To this end, the trend was analysed using various maritime accident statistics such as the total number of maritime accidents and the ship type and tonnage of the ship. Further, statistics and causes of maritime accidents due to human error were analysed, and such statistical analysis data were used as basic data for deriving the priorities of human error reduction technologies in Chapter 6.

3.1. Statistics of maritime accident-related human error

According to insurance company statistics on maritime accidents, about 76% of accidents worldwide are caused by human errors (Russ, 2017). These statistical data are derived based on the number of claims for insurance claims applied to the Convention.

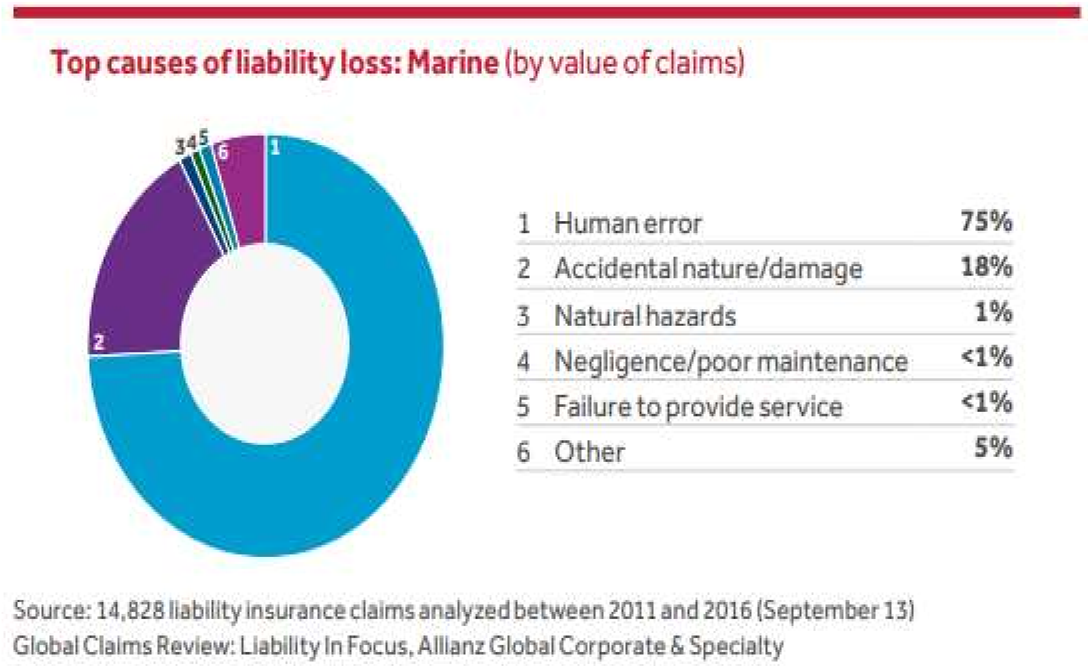


Figure 5. Statistics of causes of the maritime accident

3.2. Overview of the maritime accident in the Republic of Korea

According to data from the Ministry of Oceans and Fisheries a total of 2,971 maritime accidents occurred in 2019, and 102 people died or went missing on the coast of the Republic of Korea (The Korean Maritime Safety Tribunal, 2017). The above maritime accident statistics simply show the most recent maritime accidents in the Republic of Korea. However, to derive the direction of the development of human error reduction technology, which is the purpose of this dissertation, statistical data over a longer period are required. To this end, in this dissertation, unfortunately, it is not the most recent statistical data, but it is intended to be based on the statistical data for 5 years from 2012 to 2016. Nevertheless, fortunately, when comparing these five years of maritime accident statistics with the recent statistics of maritime accidents, there is a small gap of around 5%, which will be a reliable basis for the past five years.

As a result of the analysis of the causes of maritime accidents, 8,404 cases of maritime accidents occurred in the Republic of the Korean flagged vessels and the coast of the Republic of Korea from 2012 to 2016.

Table 4. Overview of maritime accident for the Republic of Korea

Categories		2012	2013	2014	2015	2016	Total
Number of registered ship (A)		84,466	80,647	77,730	76,500	76,408	-
	Vessel[2](b)	9,435	9,360	9,313	9,274	9,182	-
	Fishing boat(c)	75,031	71,287	68,417	67,226	67,226	-
Percentage of fishing boat(c/A)		88.8%	88.4%	88.0%	87.9%	87.9%	-
Number of accident		1,573	1,093	1,330	2,101	2,307	8,404
Number of ship		1,854	1,306	1,565	2,362	2,549	9,636
Number of ship (Vessel)		539	467	536	741	755	3,038
Number of ship (Fishing boat)		1,315	839	1,029	1,621	1,794	6,598

[2] The rest of the ship, except for fishing boats

It is noteworthy that 68.5% (6,598) of fishing boats accounted for a high proportion of all maritime accidents (9,636). In the coastal waters of the Republic of Korea, intensive fishing activities are carried out. As of 2016, the number of fishing boats registered in the Republic of Korea is approximately 76,408, which is 8.3 times that of other ships. The fishing boat will be examined in more detail later when analysing the maritime traffic environment on the coast of the Republic of Korea.

Among the vessel, the proportion of other ships (1,502) such as barges, and dredgers is the highest, and cargo ships (558), tugboats (455), tankers (280), and passenger ships (243) maritime accidents occurred in order.

As a result of the analysis of the proportion of accidents by tonnage of ships, 81.3% of maritime accidents are caused by small-sized vessels less than 100 tons. This is presumed to be due to the high number of accidents on fishing boats, and may also be due to the increasing number of accidents on small leisure boats.

Table 5. Statistics of marine accidents by vessel tonnage

Categories	2012	2013	2014	2015	2016	Total
5 ton	652	342	437	891	994	3,316
5 ton - 20 ton	422	318	377	596	631	2,344
20 ton - 100 ton	422	339	382	499	536	2,178
100 ton -500 ton	139	108	139	148	156	690

500 ton – 1,000 ton	33	24	36	34	48	175
1,000 ton – 5,000 ton	86	94	95	97	98	470
5,000 ton – 10,000 ton	22	27	27	31	17	124
10,000 ton – 50,000 ton	36	34	35	30	26	161
Over 50,000 ton	20	9	15	14	23	81
Unknown	22	11	22	22	20	97
Total	1,854	1,306	1,565	2,362	2,549	9,636
Percentage of Less than 100 tons	81%	76%	76%	84%	85%	81%

A total of 908 deaths and missing occurred over the five years because of these maritime accidents, resulting in an average of 182 deaths per year. The loss of human life continued to decline, but it increased significantly due to the '14 Sewol accident (including 304 people). It is noteworthy that 61.3%[3] of human accidents have occurred on fishing boats in the last five years.

[3] In the case of the death or disappearance of the Sewol accident, the rate of human accidents on fishing boats is 71.7%.

Table 6. Maritime Accident Life Loss Statistics

Categories	2012		2013		2014		2015		2016		Total
	Fishing boat	Vessel	Fishing boat	Vessel	Fishing boat	Vessel	Fishing boat	Vessel	Fishing boat	Vessel	
Death	72		62		404		76		73		687
	50	22	35	27	89	315	62	14	60	13	
Missing	50		39		63		24		45		221
	45	5	34	5	44	19	19	5	43	2	
Sub-Total (Death+ Missing)	122		101		467		100		118		908
	95	27	69	32	133	334	81	19	103	15	
injury	163		206		243		295		293		1,200
	108	55	121	85	176	67	186	109	221	72	
Total (Death+ Missing+ injury)	285		307		710		395		411		2,108
	203	82	190	117	309	401	267	128	324	87	

According to the results of statistical data analysis for each type of maritime accident, the collision accidents accounted for the highest proportion of 661 (31.4%).

These statistics showed that it is important to focus on the implementation of safety policies to prevent collisions between ships.

Table 7. Statistics on types of the maritime accident

Categories	2012	2013	2014	2015	2016	Total
Collision	66	156	155	133	151	661
Human casualties	60	52	117	154	139	522
Rollover	24	10	318	31	15	398
Etc.	76	42	30	56	71	275
Fire/Explosion	45	44	32	12	24	157
Sinking	14	3	58	9	11	95
Total	285	307	710	395	411	2,108

As a result of analysing the overall maritime accident statistics for 5 years, the total number of registered ships and the number of accidents in the Republic of Korea has not changed significantly. However, it is noteworthy that small vessels such as fishing boats have a very high proportion of maritime accidents. However, the rate of occurrence of maritime accidents is mostly fishing boats, but the ratio of accidents to registered vessels is 9.8% for fishing boats and 33.1% for merchant vessels, which is 3.4 times higher[4]. In addition, the number of registered leisure vessels is steadily increasing, and the number of accidents is increasing accordingly. Cargo ships, fishing boats, and leisure boats are subject to different safety regulations and standards according to the characteristics of each ship. However, the maritime traffic environment is not formed by only one type of ship. Each ship has different characteristics, but through interaction, it affects the entire maritime traffic environment, so overall unification of safety management is essential.

3.3. Statics of maritime accidents caused by human error in the Republic of Korea

According to the Korean Maritime Safety Tribunal, 10.9% (920 cases) of accidents were investigated from 2012 to 2016, of which 91.4% (841 cases) of maritime accidents were caused by human error. (Korean Maritime Safety Tribunal, 2017) The statistical data used in this chapter were targeted at 920 cases of accidents in which detailed investigations of maritime accidents were conducted.

Table 8. Statistics on the causes of maritime accidents

Categories	Number of Accidents	Cargo vessel	Fishing boat
Total	920	439	481

[4] Fishing boat accidents (67,226 registered ships, 6,598 accidents), empty ship accidents (9,182 registered ships, 3,038 accidents)

Human error	Sub-total	841	402	439
	Improper look-out	379	161	218
	Improper watch	15	9	6
	Improper collision avoidance	26	9	17
	Inadequate anchorage and mooring	0	0	0
	Neglected service director	8	1	7
	Non-compliance with ship safety regulations	100	41	59
	The error of the ship's position	31	11	20
	Inadequate waterway survey	0	0	0
	Improper ship operating	47	35	12
	Poor preparation for departure	6	5	1
	Poor route maintenance	4	4	0
	Violation of navigation regulations	4	1	3
	Prepare and poor response for bad weather	19	9	10
	Poor handling of machinery	97	60	37
	Hull, engine facility design defect	56	25	31
	Poor loading of passengers and cargo	17	14	3
	etc.	32	17	15
Machinery defects	Poor fire handling, wire aging, short circuit, etc.	12	3	9
etc.	irresistible force such as natural	13	7	6

	disaster			
	Inadequate navigation aid facilities	4	4	0
	Inappropriate ship operation management	31	16	15
	Improper seafarers placement	0	0	0
	etc.	19	7	12

When analysing the causes of marine accidents caused by human errors in more detail, 379 cases (41.2%) of an improper lookout and 100 cases (10.9%) of non-compliance with ship safety work were taken. As such, improper lookout is seen as the most representative cause of human error. These results are expected to have various reasons, such as fatigue of seafarers and lack of expertise of watch officers.

Table 9. Statistics by cause of maritime accident and type of accident

Cause of accident	collision	Contact accident	Grounding	Rollover	Fire Explosion	Sinking	Machinery Failure	Human casualties	Etc.	Total
Improper look-out	345	16	8	2	0	3	0	3	2	379
Non-compliance with ship safety regulations	0	0	0	2	3	1	0	84	10	100
Poor handling of machinery	2	5	0	2	22	0	44	1	21	97

Poor handling of machinery	0	1	0	5	34	3	1	1	11	56
Improper ship operating	15	13	5	5	0	4	0	3	2	47
Error of ship's position	0	1	28	0	0	2	0	0	0	31
Improper ship operating	4	4	0	4	8	5	1	2	4	32
Improper collision avoidance	26	0	0	0	0	0	0	0	0	26
Prepare and poor response for bad weather	2	2	2	5	0	7	0	1	0	19
Improper watch	3	1	7	0	1	0	0	0	3	15
Poor loading of passengers and cargo	0	0	0	5	5	1	0	0	6	17
Error of director	0	0	0	0	1	0	0	7	0	8
Poor preparation for departure	1	1	3	0	0	1	0	0	0	6

Poor route maintenance	3	0	1	0	0	0	0	0	0	4
Violation of navigation regulations	4	0	0	0	0	0	0	0	0	4
Inadequate anchorage and mooring	0	0	0	0	0	0	0	0	0	0
Inadequate waterway survey	0	0	0	0	0	0	0	0	0	0
Total	405	44	54	30	74	27	46	102	59	841

The statistics by human error show the direct cause of the accident according to the result of the accident investigation. However, as mentioned above, human error occurs for a variety of reasons, so it is necessary to comprehensively analyze the seafarer, the maritime traffic environment, and the situation of the shipping industry to understand the cause of the human error. The next chapter will review the comprehensive maritime traffic environment in the Republic of Korea.

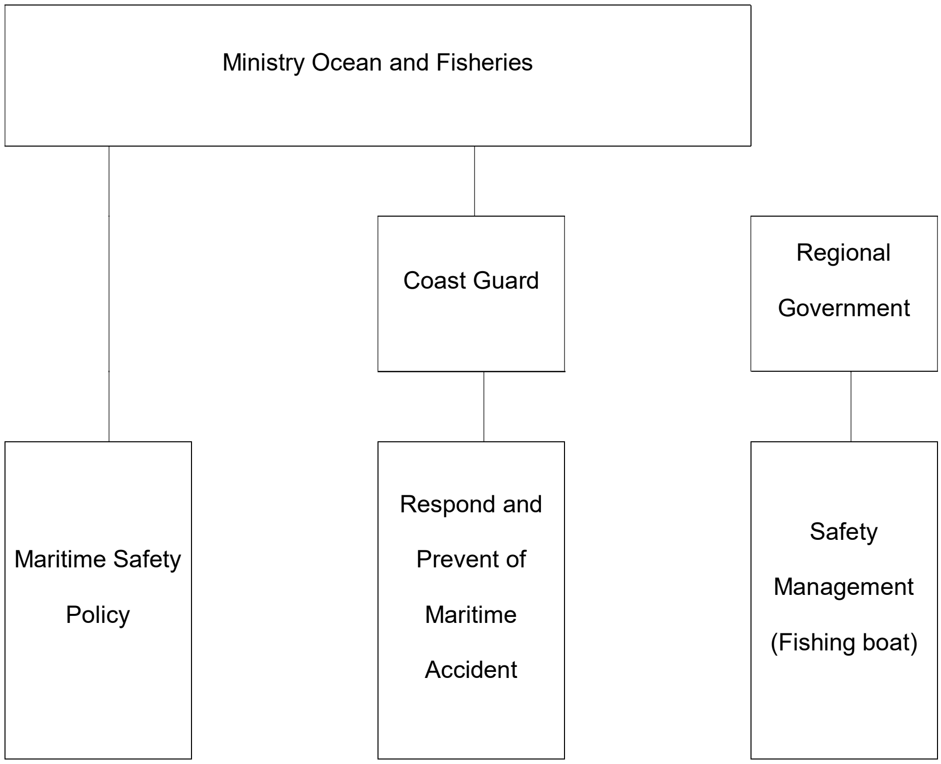
Chapter 4. Analysis characteristic of Maritime safety in the Republic of Korea

This chapter will analyse the maritime traffic environment on the coast of the Republic of Korea to which human error reduction technology will be applied. The institutional environment of the Korean maritime safety policy and the geographical and economic environment such as the distribution of ports and the volume of sea traffic was examined. In addition, it attempted to analyse the overall maritime traffic environment along the coast of the Republic of Korea by analysing the characteristics of fishing boats, which are the main components of the traffic environment along the coast of Korea, and the current status of seafarers who are the subject of human error.

4.1. Overview of the policy of maritime safety in the Republic of Korea

Korea's maritime safety management system can be divided into two major areas. The Ministry of Maritime Affairs and Fisheries is in charge of establishing policies to prevent maritime accidents, and the Coast Guard is in charge of responding to maritime accidents.

Table 10. Organization of maritime safety in the Republic of Korea



The policy to prevent maritime accidents includes registration of ships, management of safety standards, and periodic inspections, and response to maritime accidents includes on-site activities such as search and rescue. In addition, the subject of safety management is divided by ship type. In the case of general merchant ships and passenger ships, they are directly managed by the Ministry of Oceans and Fisheries, and in the case of fishing boats, the regional government and Coast guard are in charge of the safety management. However, despite the differences in management according to the types of ships, the Ministry of Oceans and Fisheries is in charge of establishing a comprehensive policy for maritime safety and accident prevention.

4.2. Maritime traffic environment of the Republic of Korea

The Republic of Korea has 31 trade ports, 29 coastal ports, and 109 national fishing ports, and infrastructure for shipping and fishing boats is established nationwide (Ministry of Oceans and Fisheries of Republic of Korea, 2017). The daily ship traffic on the coast of the Republic of Korea reaches an average of 16,600 ships (2017), and fishing boats account for about 67% of the total operating vessels, and the proportion of ocean-going vessels sailing the coast of Korea is about 14.7%. In addition, the total number of registered vessels in Korea is 91,580, of which 73.4% of fishing boats, 10.1% of cargo ships, and 16.5% of leisure vessels (2015). In other words, the coastal area of the Republic of Korea possesses a complex and diverse maritime traffic environments such as high fishing strength, active maritime trade, various marine facilities and ports, passenger transport, and marine leisure.

For this reason, fishing accidents on the coast of the Republic of Korea, that is, maritime accidents of non-conventional vessels, are very high. In addition, the seafarers of fishing boats are very old and are exposed to a high-intensity working environment, causing many maritime accidents due to human error. Therefore, in the Republic of Korea, the introduction of human error reduction technology for ships covered by the Convention is important, but the introduction of human error reduction technology for ships is not covered by the international Convention such as fishing boats, which is also very important.

The number of ships entering and departing from Korea's ports was with an average of 400,000 ships in the last five years, but the cargo volume continued to increase (1.2 billion tons per year). As a result, these statistics show that the size of ships is increasing.

Table 11. Port entry and departure trends in the Republic of Korea

Categories	Total		Entering		departing	
	Number of vessels	Ton	Number of vessels	Ton	Number of vessels	Ton
2011	401,009	3,332,703	200,378	1,654,601	200,631	1,678,102
2012	395,035	3,473,468	197,354	1,726,678	197,681	1,746,790
2013	390,245	3,595,360	195,009	1,792,619	195,236	1,802,741
2014	385,941	3,667,786	192,912	1,829,485	193,029	1,838,301
2015	400,746	3,943,939	200,226	1,966,688	200,520	1,977,251

As the economic level of the Republic of Korea increases, the marine leisure population is also increasing. In 2015, the number of leisure vessels registered in sea and inland waters was 15,172, and the number of passengers was 2.7 million annually[5], which is expected to increase continuously in the future. In terms of safety

[5] * ('11) 2,924,000 people → ('12) 2,978,000 people → ('13) 2,862,000 people → ('14) 2,149,000 people

management, it means that new safety management targets that are different from the previous safety management policies will be changed.

4.3. Analysis of vessel operation characteristics related to fishing boats

As mentioned above, fishing boats are one of the most important factors that characterize the maritime transportation environment along the coast of Korea. As of 2016, the number of fishing boats registered in the Republic of Korea was 67,226, accounting for 73.4% of all registered vessels.

Table 12. Current Status of Registered Ships in Korea (Ministry Ocean and Fisheries, 2016)

	Total	Vessel						Fishing Boat	Leisure Boat
		Ferry Boat	Cargo Ship	Tanker	Tug	Towing Vessel	Etc.		
No. (%)	91,580 (100%)	299 (0.33%)	716 (0.78%)	757 (0.82%)	1,265 (1.38%)	1,954 (2.13%)	4,191 (4.58%)	67,226 (73.4%)	15,172 (16.5%)

Since most of these fishing boats operate within 30 miles of the coast, they have a direct impact on the traffic environment. In addition, since ships engaged in fishing have the characteristics of limited maneuverability, it can be said that the influence of fishing ships on the maritime traffic environment is even greater. Also noteworthy is that about 40% of all registered fishing boats are concentrated in the West Sea and 21% in the South Sea. The west and south seas of Korea are topographically composed of the Rias coast, and as a sea area where most of the ports are concentrated, so the maritime traffic density is higher due to fishing boats.

Another notable fact is those small fishing boats with less than 10 tons' account for 94.8% (63,714), leading the complex maritime transportation environment across the coast of the Republic of Korea. It is also noteworthy that most of these ships are non-powered ships.

Table 13. Status of Small fishing boat

Categories	Total		Powered(engine) ship		Non-powered(non-engine) ship	
	Number	Ton	Number	Ton	Number	Ton
Fishing boat	67,226	544,626	66,234	543,721	992	905

4.4. The environment of the seafarers according to the characteristics of the ship

The Republic of Korea has a specialized seafarers supply system for each ship type. In the case of general cargo ships and passenger ships, most of the demand is being supplied through two maritime universities, which are educational institutions for training specialists. These seafarers work as officers or engineers on ships and provide relatively high-quality services because they have completed specialized training.

According to statistics from the Ministry of Oceans and Fisheries of the Republic of Korea, as of 2015, there were a total of 37,000 seafarers of Korean nationality, including fishing boat seafarers. However, the wage gap between seafarers and land workers is narrowing as Korea's growth of the national economy increases and living standards improve, and accordingly, the number of seafarers is decreasing. In particular, this phenomenon is more prominent among young people with higher education levels.

Table 14. Seafarers statistics

Categories			2011	2012	2013	2014	2015
Total			38,998	38,906	38,783	37,125	36,976
Korea Flag	Sub. Total		35,421	35,355	35,381	34,016	33,975
	Vessel	Sub. Total	17,635	17,577	9,544	17,228	17,155
		International Voyage	9,371	9,308	8,207	9,378	9,308
		Domestic Voyage	8,264	8,269	17,577	7,850	7,847
	Fishing Boat	Sub. Total	17,786	17,778	17,630	16,788	16,820
Foreign	Sub. Total		3,577	3,551	3,402	3,109	3,001

Flag	Vessel	3,280	3,232	3,068	2,758	2,670
	Fishing Boat	297	319	361	351	331

Most notably, this phenomenon is accelerating the aging of Korean seafarers. Among seafarers with Korean nationality, 59.5% of them are over 50 years old. In particular, in the case of domestic ships with lower wages and inferior working conditions, the ratio of seafarers 50 years or older is 77.7%.

Table 15. Current status of the age distribution of seafarers in The Republic of Korea (2015)

Categories		Under 30 year old	Under 40 year old	Under 50 year old	Under 60 year old	Over 60 year old	Total
Officer	Navigator	1,782	1,256	1,872	3,540	3,540	11,580
	Engineer	1,826	147	1,168	3,104	3,104	10,351
	Radio Officer	0	0	36	0	93	197
	Sub. Total	3,608	1,403	3,076	6,644	6,737	22,128
Crews		522	1,720	3,826	5,515	3,265	14,848

Total	4,130	3,123	6,902	12,159	10,002	36,976
(%)	11.2%	8.5%	18.7%	32.9%	28.7%	100.0%

Due to the aging of seafarers, the proportion of foreign seafarers is increasing, accounting for 39.9% of all seafarers. Of the 61,600 seafarers engaged in Korean flagships, 36,976 are Koreans and 24,624 foreigners (12,809 non-fishing boats, 11,815 fishing boats). By nationality, the proportion of Chinese seafarers was the highest in 2007. However, due to the increase in wages of Chinese seafarers, seafarers from Vietnam, Myanmar, and the Philippines have recently increased.

Even though the Republic of Korea has a specialized seafarer training system through maritime universities, it is expected that the seafarer' shortage will continue to intensify due to the situation in the whole society. In particular, the employment of foreign seafarers is increasing rapidly due to the aging of seafarers of Korean nationality.

Chapter 5. Status of safety technology of reducing human error

In this chapter, in order to analyse the linkage and utility of human error reduction technology and existing maritime safety technology, it will give an overview of safety technology reduction technology and the development and application status of human error reduction technology in similar transportation means such as land and air transportation. In addition, the current state of discussion on technology to reduce human error in the international community was examined. Finally, the development and application status of technologies related to human error reduction, such as the maritime safety IT system in the Republic of Korea, were investigated.

5.1. Overview of safety technology to reduce human error

In the process of the ship's operation, seafarers sense and perceive a variety of information, use their knowledge to judge the situation, make decisions, and take action. If a problem occurs in any part of this process, the seafarer makes a mistake, and sometimes this mistake leads to an accident.

Table 16. Process of decision making

sense and perceive a variety of information	⇨	Judge the situation	⇨	Make decisions	⇨	Take action

Human errors cannot be eliminated but can be reduced with effort. One of these efforts is the application of human error reduction technologies such as human-centered design of ship, a decision support system, collision prevention system, and alarm/monitoring device.

Efforts in terms of technology to prevent accidents caused by human error have not been made in recent years. In the past, attempts have been made to design equipment to reduce human error and mechanical devices to prevent human error, and this has been effectively utilized as a means to prevent human error. For example, the dual operation of the button of an important device on the ship, and the form of operation only when remote control of valves and local operation are coincident were used. However, these technologies were used as a means to reduce the final error in the decision stage rather than to reduce the judgment error of human decision-making. Most of the human error reduction technologies in the past have not exceeded these technological limits.

However, with the development of advanced technologies such as communications, sensors, and artificial intelligence (AI) along with the 4th industrial revolution, the development and application of human error reduction technologies have entered a new stage. In particular, the introduction of automatic navigation/operation and autonomous technology in the transportation field is drawing attention in terms of reducing accidents caused by human error, in addition to the economic effect of labor cost reduction and transportation efficiency.

5.2. Development status of safety technology in the Land and Aviation transportation sector

In the automotive industry, research and application of human error reduction technologies are most active. Human error in road accidents is estimated at 94 percent. (Tierney, 2019). The automobile industry has made great efforts to reduce such a high proportion of human error accidents. Recent developments in related technologies, such as sensors and data management, are rapidly innovated. The most notable area of interest is autonomous vehicle technology. Many advanced technologies are applied to autonomous vehicles, but the most important is sensor technology. This sensor technology is also used to check human error such as drowsiness while driving.

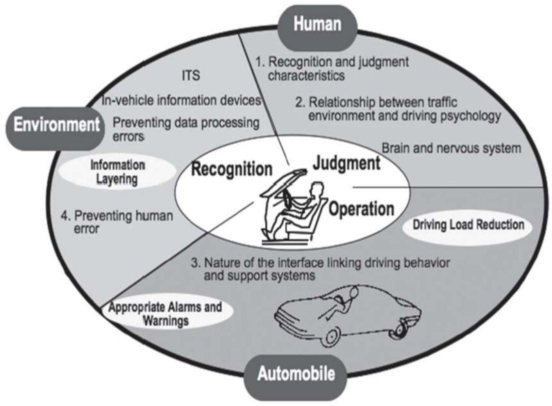


Figure 6. Strategic domain for driving support system technology (source: IATSS RESEARCH Vol.30, 2006)

Two technologies are applied to detect driver drowsiness. The first detection technology is to monitor the driver's face through a camera and to check the speed of the eyelid winding to determine whether the driver is drowsy. The second detection method is based on vehicle performance data. If the driver falls asleep while driving, the vehicle has difficult in maintaining lanes keeping, steering wheel movement, and lateral acceleration. The sensor of the vehicle collects and analyzes these signs, and if it matches the driver's drowsiness signal, the drowsiness prevention system alerts the driver and finally intervenes in the operation of the vehicle's brakes and steering wheel to prevent accidents (Grace et al, 2002).

In addition, another human error prevention technology is collision avoidance systems. The system consists of a front, rear, and side system, and the sensor detects obstacles and other vehicles by distance. Afterward, when the distance is close, an alarm is sounded to alert the driver, and when the distance is closer than a certain value, additional measures such as brake operations are taken (Harper et al, 2016).

To review the collision avoidance system in more detail, there is Forward Collision-Avoidance Assist (FCA). FCA is a device that recognizes the vehicle in front through a detection sensor and warns the driver when a collision is expected, and automatically activates the brake in an emergency to avoid a collision or minimize damage (Autonomous Emergency Brake, AEB). In recent years, it is developing into a system that detects not only vehicles in front, but also pedestrians. This FCA is evaluated as the most effective technology for minimizing the damage caused by traffic accidents as 94% of automobile accidents are caused by the driver's careless actions. It is emerging as a prerequisite for automobile safety technology. A device similar to FCA is Forward Collision Warning (FCW). This system has the same principle as the FCA, but the difference is that it only warns, not automatically brakes like FCA. To briefly understand the operating principle of FCA and FCW, this system is a radar sensor and a camera, a controller, a brake pedal position sensor, and an EBCM (brake control module) that controls the brake system.

In addition, when linked with a more advanced intelligent driving management system, it is additionally connected to automatic transmission control module (TCM), accelerator pedal sensor, body control module (BCM), and engine control module (ECM). The principle of operation is that the front camera recognizes the vehicle ahead in front of the vehicle, and the radar checks the distance between vehicles. In general, the radar sensor can measure the distance of the vehicle ahead within about 60m. Based on these data, the relative speed and distance between vehicles as well as the time are calculated until the collision. In addition, it warns the driver of a collision risk based on the predicted collision time, vehicle distance, speed, and safety distance programmed in advance, or automatically intervenes in operation such as brake operation. (“immediately effective in”, 2017)

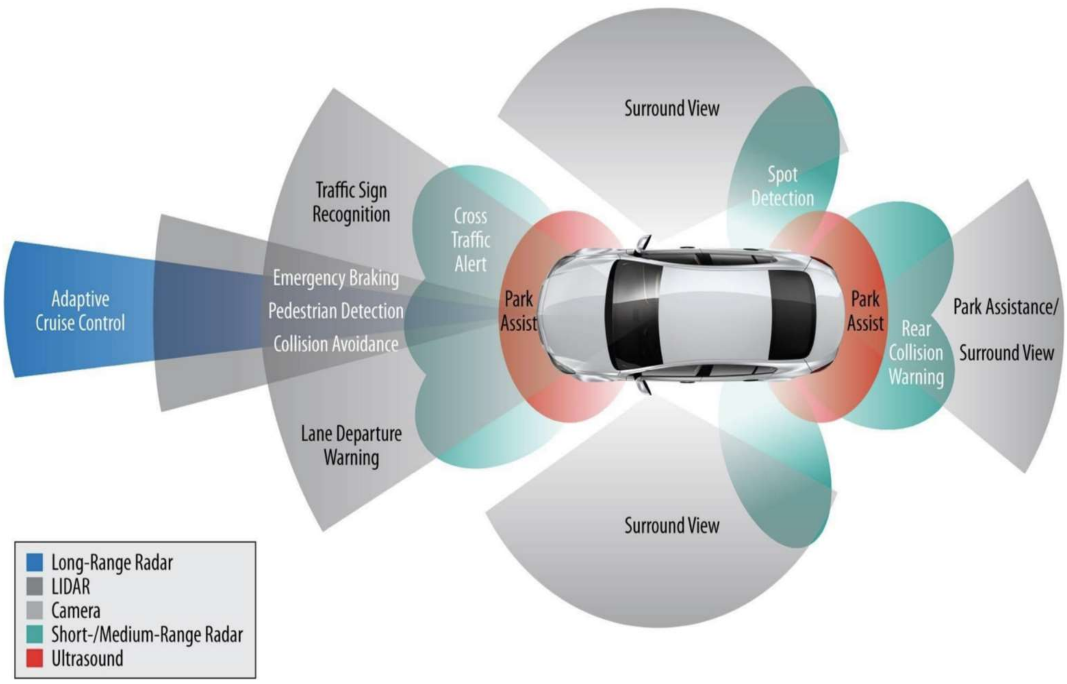


Figure 7. Technical diagram of FCA and FCW (Source from: Trends in Auto Tech)

These safety technologies in the vehicle sector are expected to make a significant contribution to accident prevention. The automotive sector has already introduced autonomous vehicles and these are expected to spread rapidly.

In the aviation field, technologies for collecting and analyzing information are being applied to prevent pilot errors as well as the application of systems to monitor pilots' operating behavior. The system collects and analyzes flight information on pilots' habits of piloting, maneuvering errors, and emergency response, and if such information is found to need to be improved, the problem is solved by providing additional training and training programs to the pilot. (Japan Aerospace Exploration Agency, 2017). This technology is very interesting in that it accumulates the behavior related to a pilot's operating habits to reduce human error, and it combines continuous education and training systems to prevent safety accidents caused by human error. Most of the large-scale casualties in the aviation sector are due to the pilot’s error and poor maintenance. Therefore, the development and application of technologies to prevent human error in the pilot monitoring and aircraft maintenance are expected to become more active.

5.3. Development status of safety technology in the maritime transportation sector

Perhaps the shipping sector is one of the slowest in applying advanced technology among other transportation means. The reason for this might be that ships are representative of the transportation sector with top priority on economics, and they have a long life cycle and the sea environment is not suitable for information communication with the shore. However, with the recent developments of related technologies, the interest of the advanced technologies to ships in the international community has increased, and as a result, e-Navigation and automated ships have been actively discussed in IMO.

In 2006, the International Maritime Organization (IMO) decided to introduce "e-Navigation" using information and communication technology (ICT) in ship navigation technology to reduce maritime accidents due to the error of ship operators and improve shipping efficiency. In accordance with the proposals of 7 countries including the UK in 2005, IMO decided to promote the introduction of e-Navigation and established an e-Navigation strategic plan in 2008. Accordingly, in 2014, the International Maritime Organization (IMO) approved the e-Navigation Strategy Implementation Plan (SIP) for the international implementation of the strategic plan, and each country continues its efforts to implement e-Navigation.

In addition, one of the most actively discussed fields in IMO is related to autonomous ships. The International Maritime Organization (IMO) is reviewing the regulations necessary for the introduction and operation of autonomous ships and is preparing countermeasures for possible security issues. IMO's 98th Maritime Safety Committee (MSC) decided to initiate the Regularly Scoping Exercise (RSE) necessary for the introduction and operation of autonomous ships, and the 99th Maritime Safety Committee discussed the regulation identification work. The system was approved, and the identification of regulations necessary for revision in 2019 was completed. In addition, discussions on the interim guideline have been initiated, and systems and regulations related to autonomous ships will be established by 2028.

5.4. The gap between maritime transportation and other sectors

Human error reduction technology can be divided into three stages.

Stage 1: Detecting an abnormal symptom of the operator and warning to the operator

Stage2: Automatically intervening in operation to reduce the risks associated with abnormal signs of the operator

Stage 3: Fully automated

In the maritime sector, the first stage of human error reduction technology is partially applied, and in the case of the automobile sector, the second stage technology is partially applied and efforts are being made for the development and practical application of the full automation stage.

5.5. The maritime safety technology in the Republic of Korea

The first safety management infrastructure based on the radio communication system promoted by the government of the Republic of Korea is the establishment of the Automatic Identification System (AIS). The AIS was adopted by the International Maritime Organization in 2000 to enhance the navigational safety and security of ships. AIS is used to prevent collisions between ships by exchanging positions between ships and transmitting ship's position to onshore facilities. The government of the Republic of Korea also ratified the international convention and established a national infrastructure for AIS operation from 2001.

To this end, 44 base stations for receiving AIS signals were installed on the coast of the Republic of Korea, and 14 VTS centers are controlling ship traffic using AIS signals. In addition, ship position information collected on the coast of the Republic of Korea through AIS is being shared by 24 national agencies including the National Crisis Management Center, Customs, and Immigration.

Another ship position-based information system is the Long Range Identification and Tracking of Ships (LRIT). In January 2009, the International Maritime Organization (IMO) was introduced to prevent maritime terrorism by ships and to take maritime security measures. It is a system that tracks the position of domestic ships around the world using satellite communication facilities to strengthen maritime security, and foreign ships entering and departing (within a maximum of 1,000 miles) in ports and coasts of the state. In order to establish the LRIT system, the Korean government established the National LRIT Information Center (NDC) in 2009, which can receive ship position information of Korean flagships around the world and foreign ships within about 300 miles off the coast of Korea.

Such AIS and LRIT are installed on ships that are engaged in international voyages or coastal voyages with a certain tonnage or more (500 tons or more in the case of cargo ships). In other words, it does not apply to small vessels such as fishing boats. For the security of these shortcomings, the Korean government has established a system to identify the position information of small ships such as fishing boats.

In this way, the Korean government has established a system for collecting position information of small ships such as fishing vessels that are not subject to international conventions. This system, called V-Pass, is a system for positioning small vessels such as fishing boats and has been built on the entire coast of the Republic of Korea since 2011. It was targeted to ships not legally subject to the AIS installation obligation, and a position transmitter was installed on fishing boats, and a land base station construction project for radio wave reception was constructed. In addition, the V-Pass system has various safety technologies suitable for small ships, such as sending an emergency rescue signals for a ship' in distress and generating a warning when the ship' demonstrates abnormal slope conditions.

These systems such as the AIS, LRIT and V-pass system provides the basic infrastructure for collecting ship’s position information and managing related data on the coast of Korea. In addition, the Korean government has established a comprehensive maritime safety management system (GICOMS, General Information Center on Maritime Safety & Security) based on the position information from various ships.

The Korean government established a maritime safety information promotion plan in 2001 and conducted a feasibility study and basic design for the establishment of a comprehensive maritime safety information system in 2002. After that, GICOMS was established through the basic construction of the first phase from 2003 to 2005, the implementation and operation of the second phase system from 2006 to 2008, and the 3rd phase upgrade project from 2009 to 2013. GICOMS is a Vessel Monitoring System (VMS) that displays real-time vessel position on an electronic chart screen by receiving ship position and information transmitted from, for example Automatic Ship Identification system (AIS) and satellite (LRIT), Ship Security Alert System (SSAS), ship registration, ship inspection and, individual business.

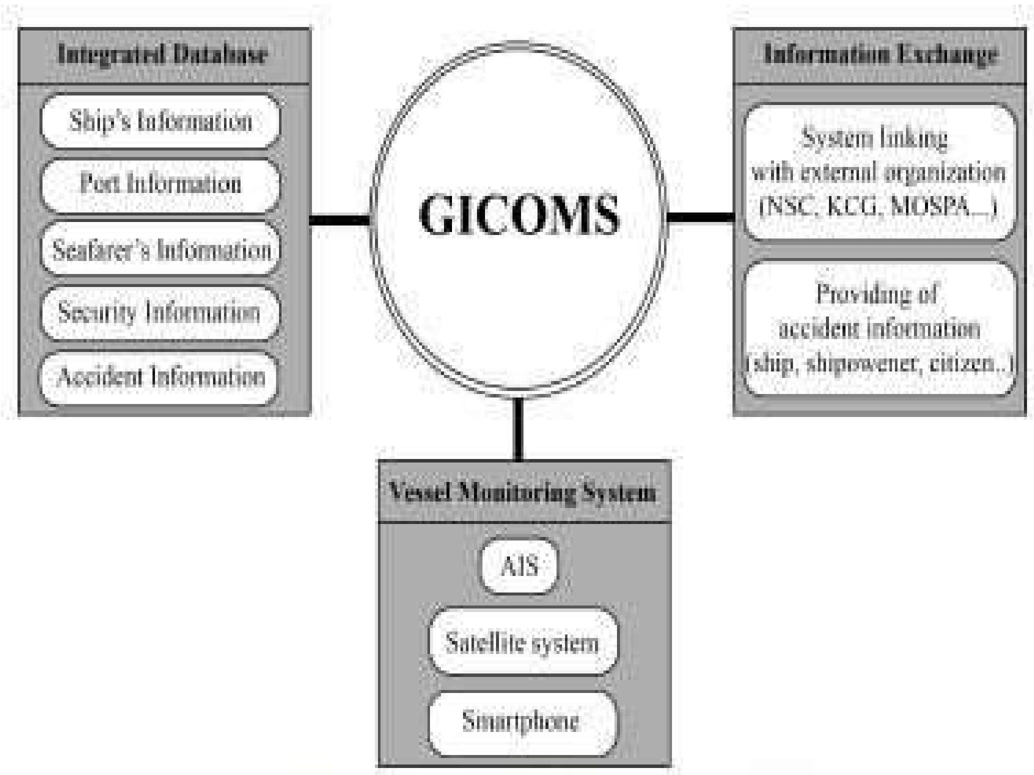


Figure 8. GICOMS configuration diagram

It is composed of a ship-related integrated DB that enables collective information inquiry for each ship by linking the system, and an information-sharing system for sharing ship position information and ship-related integrated DB and providing services to the public with related organizations such as the Coast Guard, Navy, and Shipping Association.

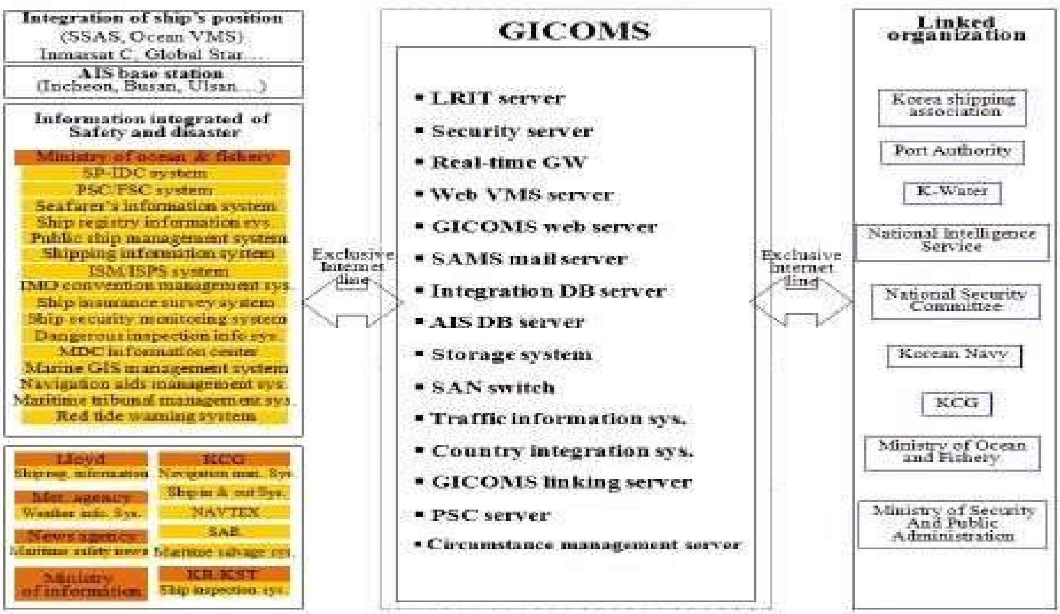


Figure 9. GICOMS data connection diagram

Up to now, this dissertation has briefly examined the outline of the information system for ship safety management established in Korea. Such a system is of value as a system that is the basis for the development and application of human error reduction technology using information technology. In addition, such an information system will support the use of complex and extensive related data to improve the efficiency of technology to reduce human error by continuously developing, and not remaining in the current function.

As briefly mentioned earlier, e-Navigation is one of the most actively discussed internationally among maritime safety-related technologies using information technology. The definition of e-navigation is shipping through better organization of data on ships and onshore, and better data exchange and communication between ships and the ship and shore. The Republic of Korea has invested about 180 million USD to promote a Korean e-Navigation project for 2016-2020.

Table 17. Korean e-Navigation research and development major tasks

Korean e-Nav. The core technology for service R&D and e-Nav. Operation system construction	Comprehensive situational awareness and Response technology development	Accident Vulnerable Ship Monitoring Support Service
	Korean e-Nav. service development	Onboard system remote monitoring service
		Optimal Safe Route Support Service
		Electronic chart service for small ships
	IMO e-Nav. essential service development	Leading/qualifying support service
		Maritime Safety Information Service
Expansion of maritime digital infrastructure		Establishment of e-Nav. comprehensive (regional) operation system
		High-speed maritime wireless communication (LTE-Maritime) construction
		Digital maritime wireless communication system establishment
International standard technology research and development		Maritime data exchange standard
		Maritime information sharing system development (S-10X)
		Maritime wireless communication (standard) technology development
		Ship navigation facility standardization mode (S-Mode)

If Korean e-Navigation is established, high-speed wireless communication will be possible up to 100 km off the coast of Korea, and an e-Navigation Information center will be able to provide digital safety information to all ships within the coast of the Republic of Korea. The most important human error prevention technology is to monitor and analyze the ship's operating conditions such as the ship's route and abnormal sign monitoring and provide it to the ship to support the operator's decision making (Ministry of Oceans and Fisheries of Republic of Korea, 2016).

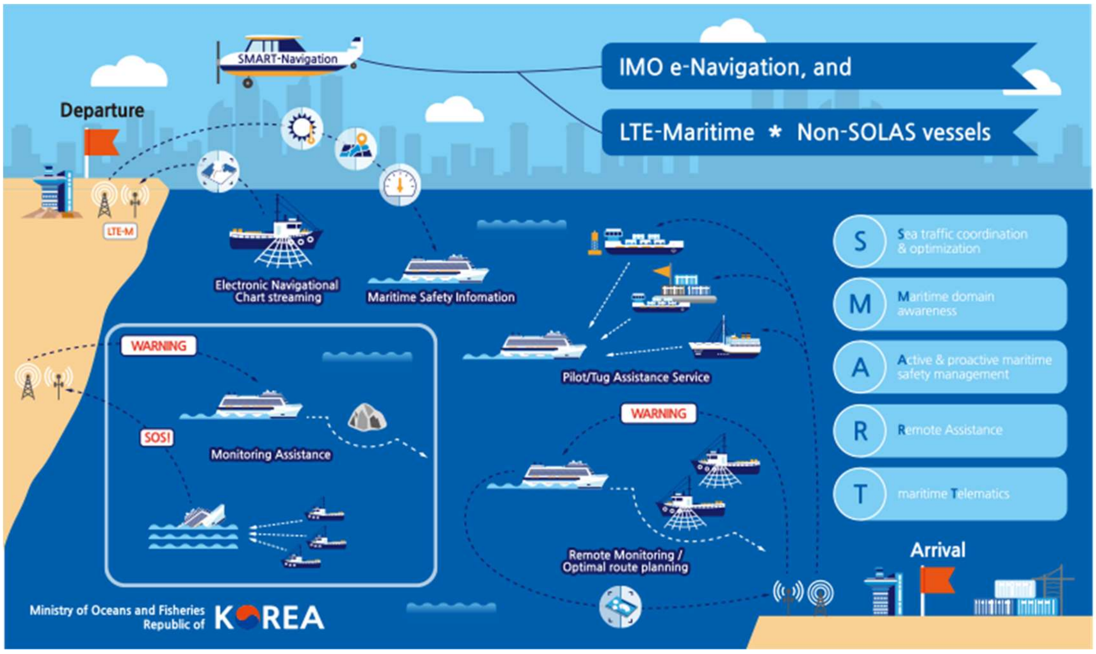


Figure 10. Korea e-Navigation at a glance

The most notable task in Korea's e-Navigation development project is the construction of an LTE communication network extending 100 miles from the coast. This means that maritime wireless communication, which used to be dependent on low-capacity and low-speed communication, can receive the same level of communication service as on land. This is expected to bring innovation in the use of maritime safety information by making various pieces of maritime traffic safety information collected on land available to ships.

The Republic of Korea is also promoting R & D on autonomous vessels. The R & D projects, including pilot ship construction, will be underway in 2020. This R & D includes several projects related to the development and introduction of technologies to prevent accidents caused by human error such as operator inshore base system. The R&D project is expected to be implemented from 2020 to 2025, in four areas including intelligent navigation system development, engine automation system development, autonomous ship performance verification center establishment, the autonomous ship operating technology development, and standardization technology development. It is planning to carry out 13 detailed case tasks. This project aims to develop autonomous ships that have secured the technology of 3 levels of degrees of autonomy defined by the International Maritime Organization (IMO) and 2 levels for coastal vessels.

So far, this dissertation has briefly reviewed the development status and plans of Korea's maritime safety technology. These marine safety applications are the upper-level classification of human error reduction technologies, targeting a broader range of marine safety and logistics efficiency areas. However, the level of human error reduction technology can be further elaborated by such a high-level technology frame, so it must be carefully examined.

As might be expected, in the maritime sector, there are various barriers to the introduction of automation technology. The biggest of these is probably about economic profits. However, the introduction of human error reduction technology is necessary not only for the prevention of accidents but also for the cost reduction due to ship transportation accidents. In particular, the development of maritime communication means and technologies discussed and developed in e-Navigation will be utilized as an important base technology to secure the sophistication and reliability of human error reduction technologies.

Chapter 6. Discussion on the human error reduction technology in the Republic of Korea

In this chapter, to select the priority for deriving the most suitable human error reduction technology on the coast of the Republic of Korea, the implications and conclusions are drawn based on the data such as the maritime accident statistics, the maritime traffic environment, and the development status of related technologies analysed in the previous chapter. Further, through the risk assessments, the priority of human error reduction technology is to be derived. Case studies were additionally implemented to compensate for the limitations of statistical and data analysis.

6.1. Risks Assessments of safety technology caused by human error

So far, this dissertation has examined the definition of human error reduction technology, international discussion trends of related technologies, Korea's maritime accident statistics and current status of maritime safety technology, seafarer’s statistics, and coastal maritime traffic environment. This analysis data is the basic data to derive the development plan of human error reduction technology.

This chapter attempts to categorize the top five types of accidents and causes of high importance based on the statistical data of Korean maritime accidents analyzed earlier. In addition, it is intended to categorize the types of ships in which such accidents occur, and to classify the types of seafarers. Through this procedure, this dissertation intends to derive the priority of the types of accidents for safety technology development.

In this way, the level of causes that cause maritime accidents due to human error is firstly defined, the components of each level are classified, and the linkage between each level is analyzed to derive the necessary human error reduction technology. The levels and components of accidents caused by human error are classified as follows:

Level 1. Maritime Accident

- Category 1. Type of maritime accident (chapter. 3.2)
- Category 2. Cause of maritime accident due to human error (chapter. 3.3)
- Category 3. Type and size of the ship (chapter. 3.2)

Level 2. Maritime environment

- Category 1. Maritime Safety technologies (chapter. 5.2, 5.3, 5.5)
- Category 2. Maritime traffic environment (chapter. 4.2)
- Category 3. Increase of ships subject to maritime safety policy (chapter. 4.3)

Level 3. Human resources

- Category 1. Age of Seafarers (chapter. 4.4)

- Category 2. Composition of seafarers (chapter. 4.4)
- Category 3. Seafarers supply and demand (chapter. 4.4)

Analyzing the types of maritime accidents in the Republic of Korea, Level 1, as mentioned in Chapter 3.2 of this dissertation, collisions account for the largest proportion. Since then, groundings, fires, for example, have taken up a high proportion. Most of such ship collision accidents are caused by human error, such as improper look-out, error in situation judgment, unfamiliarity with related regulations, and errors in communication between ships. In addition, a ship collision accident is the most significant accident because it causes a lot of damage economically or leads to loss of life, and it is one of the most likely types of accidents that can reduce the number of accidents through human error reduction technology.

Level 1. - Category 1.

Based on such statistical data analysis results, it can be concluded that the development of technology to prevent a human error that causes collisions between ships is the most significant.

When analyzing the type of maritime accidents caused by human error, the second category of Level 1, maritime accidents due to improper look-out account for the highest percentage of about 45%.

Level 1. - Category 2.

Based on such statistical data analysis results, it can be concluded that the development of technology to prevent a human error that causes collisions between ships is the most significant .

When analyzing the type of ships involved in maritime accidents, the third category of Level 1 can be classified into two types as mentioned in chapter 3.1. Looking at the first ship type, of the 8,404 maritime accidents that occurred from 2012 to 2016, fishing boat accidents accounted for 6,598 cases, accounting for 78.5%. Second, when analyzing the tonnage of the ship, more than 81% of accidents occurred in ships with a gross tonnage of fewer than 100 tons. In addition, the number of ships registered in the Republic of Korea is about 75,000, of which fishing boats account for 87.9%. In addition, considering that most of these fishing boats are engaged fishing within 60 miles from the coast, it can be concluded that fishing boats have a very high impact on the maritime traffic environment along the coast of the Republic of Korea.

Level 1. - Category 3.

The results of this statistical analysis show that most maritime accidents occur frequently in small vessels less than 100 tons, and are particularly concentrated on fishing boats. Therefore, it can be concluded that the data show which ship types will be subject to the application of human error reduction technology to prevent maritime accidents.

Next, the status of safety technology development in the maritime sector, the first category of Level 2, was analyzed. In addition to the maritime safety information system stipulated in international convention such as AIS, the Republic of Korea is establishing a fishing boat position monitoring system, and the integrated vessel monitoring system (GICOMS) based on the vessel position information. In addition, it is actively promoting R&D and infrastructure construction for the introduction and operation of e-Navigation and autonomous ships.

Level 2. - Category 1.

The Republic of Korea has established a maritime safety information system based on the nationwide IT infrastructure. Therefore, it can be concluded that the infrastructure for providing improved service of human error reduction technology using information technology was relatively well established. In particular, the position information system for fishing boats has already been established and the construction of the Long Term Evolution (LTE) communication system within 100 km of the coast, which will be implemented in e-Navigation, is for the efficient and economic application of human error reduction technology. This is the most substantial technical advantage.

The following analyzed the matters related to the maritime transportation environment in Korea mentioned in Chapter 4.2. There are a total of 31 trading ports and 29 coastal ports, 109 fishing harbors on the coast of the Republic of Korea. In addition, the Republic of Korea, which has virtually island-like geographic features, relies on shipping for 98% of its whole trade volume. On the coast of the Republic of Korea, it shows a complex maritime transportation environment with 16,600 ships operating every day. Geographically, the west and south seas of the Republic of Korea constitute a rias coast and have low depths. For this reason, it is also noteworthy that most of the ports are located here, and most fishing activities are also conducted in this sea area.

Level 2. - Category 2.

The coastal waters of Korea have a large number of port facilities and show a very high sea utilization rate due to a large number of fishing boats and cargo ships. In particular, the west and south seas have a complex coastline and relatively low water depth. Due to this, most of the port facilities are located in this area, and many fishing boats are engaged in fishing activities. Therefore, it is necessary to develop and apply human error reduction technologies or services in consideration of such geographic characteristics.

Referring to the statistics in Chapter 4.2, it can be seen that the number of registered and users of leisure boats on the coast of the Republic of Korea is increasing significantly. In the past, the coastal areas of Korea accounted for a high proportion of logistics and fishing activities. However, as the marine leisure population increased with the development of the economic level, leisure vessels such as yachts emerged as an important component of the maritime traffic environment.

Level 2. - Category 3.

In the case of leisure vessels such as yachts, the purpose of this vessel is to enjoy the leisure time of passengers, unlike commercial vessels such as fishing boats and cargo ships, so it is necessary to approach it from a different perspective in terms of safety management. In particular, in the case of operators of small ships such as leisure boats, the level of expertise related to maritime safety is relatively low, and thus the introduction of human error reduction technology is further required.

The last level for risk analysis is the human factor. As mentioned in Chapter 4.4, a total of 37,000 seafarers are employed on the Korean flag's ships. Of these, the number of seafarers engaged in cargo ships excluding fishing boats was 17,155, accounting for 46.3%. In other words, the number of seafarers on fishing boats accounts for more than 50%.

Level 3. - Category 1.

Such seafarer statistics is one of the important factors to be considered in selecting the most important targets for human error reduction technology. In particular, it should be considered that fishing boat seafarers, who account for more than 50% of the total number of seafarers do not have sufficient expertise compared to seafarers covered by international conventions. Therefore, it is more important for these seafarers to respond to emergency situations and to apply human error reduction technology for decision making.

Also, a noteworthy fact is the increasing number of older and foreign seafarers. As of 2015, 59.5% of seafarers aged 50 or older accounted for this trend, which is increasing. In addition, the proportion of foreign seafarers accounts for 39.9% of all seafarers.

Level 3. - Category 2.

Considering that most of the seafarers are aged 50 years or older with relatively weak adaptation and utilization capabilities to IT systems, it can be concluded that the interface of the human error reduction system should be simplified. In addition, a system that can be easily used by foreign seafarers is needed.

Analyzing the aforementioned data on the forecast of seafarers' demand in the Republic of Korea, as of 2015, Korea's seafarer's demand was 18 thousand, but the supply was 14.5 thousand, which was about 3.5 thousand seafarers short[6]. This is closely related to the increase in ship operations due to the aging of the seafarers and the increase in maritime traffic. In conclusion, Korea's seafarer's demand is expected to increase in the future, but supply is expected to be insufficient, and such shortage demand is expected to be filled by foreign seafarers.

[6] (Demand) International voyage 11,000 persons, domestic voyage 7,000 persons, (Supply) international voyage 8,000 persons, domestic voyage 65,000 persons

Level 3. - Category 3.

This seafarer shortage phenomenon does not occur only in the Republic of Korea. Due to the lack of seafarer demand, shipping companies will increasingly invest more in ship automation. However, in the case of small ships such as fishing boats and leisure boats, a lot of investment is required to achieve a high level of automation in consideration of the size and economy of the ship. For this reason, the role of human error reduction technology is important in the transitional period for the development and application of small ship automation technology.

In addition, when considering the increase in the number of foreign seafarers and the number of ships onboard multinational seafarers, it is important to develop and apply internationally standardized human error reduction technologies and simple interfaces.

So far, nine categories in three levels have been analyzed for the development of human error reduction technologies. From now on, this dissertation attempts to derive the priorities of human error reduction technologies through interrelationship analysis for each level to determine what kind of connection these elements have and what development plans can be suggested.

Table 18. Risk assessment for human error reducing technologies

LEVEL 1 (Accident)

		Priority
C.1	Type of maritime accident	(P1) Collision (P2) Human casualties (P3) Rollover (P4) Grounding
C.2	Cause of maritime accident due to human error	(P1) Improper look-out (P2) Non-compliance with ship safety regulations (P3) Poor handling of machinery (P4) Improper ship operating
C.3	Type and size of the ship (Registered ships)	(P1) Less than 100tons (P2) Fishing boat (P3) Towing vessel

LEVEL.2 (Traffic environment)

		Priority
C.1	Maritime Safety technologies	(P1) LTE-M (P2) e-Navigation (P3) GICOMS (P4) Autonomous vessel
C.2	Maritime traffic environment	(P1) Various type of ship (P2) South and West Sea (Port & Fishing boat) (P3) Ship & Cargo operation volume
C.3	Increase of ships subject to maritime safety policy	(P1) Leisure boat (P2) Ferry boat (P3) Small fishing boat (without engine)

LEVEL.3 (Human factor)

		Priority
C.1	Age of Seafarers	(P1) Over 60 year (P2) All of the ages
C.2	Composition of seafarers	(P1) Seafarers of fishing boat (P2) Seafarers of international voyage (P2) Seafarers of domestic voyage
C.3	Seafarers supply and demand	(P1) Korean seafarers (P2) Foreign seafarers

Related Technologies
Collision avoidance technology
Operator decision support technology
Operator drowsiness prevention/monitoring technology
Single window interface (Simplified operating interface)
Lane Keeping System (LKS)
Operator behavior pattern analysis technology
Warning technology when entering a dangerous area
Safe route analysis technology

Based on the statistical data of maritime accidents, the maritime traffic environment, and the analysis results of related technologies, priorities were selected for which human error reduction technologies are needed on the coast of the Republic of Korea.

The main findings of the analyses are summarized as follows:

Level 1. Related with Accident Statistics

- Accident type: Prevention of the collision between ships
- Causes of Human Error: Improper lookout
- Ship Type: Less than 100 tons

Level 2. Related with the maritime traffic environment

- Maritime Safety technologies: LTE-M
- Maritime traffic environment: Various types of ships
- Increase of ships subject to maritime safety policy: Leisure boats

Level 3. Related with the human factor

- Age of Seafarers: Over 60 years
- Composition of seafarers: Seafarers on fishing boats
- Seafarers supply and demand: Korean seafarers

So far, an analysis has been conducted to select priorities for the development and application of human error reduction technologies suitable for the Korean coast.

The priorities derived in this chapter were used in the proposal for technology development to reduce human error in the Republic of the Korean coast in Chapter 6.3.

6.2. Case Analysis of the maritime accidents caused by human error

The previous chapter investigated what kind of human error reduction technology is necessary based on the overall statistical data and analysis data in the maritime sector. However, such statistical data may have limitations in reflecting the detailed situation and cause of the accident. For this reason, this chapter aims to discover additional data to derive measures to develop human error reduction technologies through a detailed case analysis of human error accidents that occur with the highest frequency.

Case 1. Collision accident of ‘Sunchang No.1’: On December 3, 2017, around 6:02 am, a fishing boat ‘Sunchang No.1’ (9.77 tons) and a tanker ship Myungjin 15 (366 tons) collided in the waters of Yeongheung Island, Incheon. In this accident 15 people lost their lives, including fishers. The fishing boat ‘Sunchang No.1’ hurriedly ran without avoiding the approaching tanker to reach the good fishing spot, and the tanker also thought that small fishing boats would be avoided and did not take avoidance action. According to the fisheries industry, some fisheries believe that fishing boats openly cross the bows of large ships because of the myth that fishing boats pass by the front of a large ship and the fishing performance is good that day.

If the captain of one of the two ships had known the risk of collision and taken an active change or positive action early, it would have prevented the loss of life.

The above accident was a collision between a fishing boat and an oil tanker. The cause of the accident was the unreasonable operation of the fishing boat and improper avoidance action of the oil tanker. In particular, in the case of the fishing boat and other vessels, it is difficult to communicate, so the ship operator must understand the intention of operation and perform the avoidance action. Collision avoidance operation caused by such inappropriate information can lead to a major maritime accident. As mentioned above, the maritime traffic environment is not only affected by a specific ship type but is determined by the interrelationship of various ships. Therefore, there is a need for communication and information exchange between different ship types and a decision support system based on this case study.

Case 2. Fishing boat S grounding accident: In October 2004, fishing boat ‘S’ was sailing for fishing. The ship was approaching the Dokdo island coastal reef out of the planned route due to the influence of strong winds and ocean currents. At the time of the accident, the captain was on duty alone in the wheelhouse. The captain neglected to check the situation and confirm the ship's position using radar during the voyage due to fatigue from fishing work. In this accident, 1 in a total of 6 seafarers died and the ship was sinking.

The grounding accident of the fishing vessel 'S' is a typical human error accident caused by improper lookout due to seafarers’ fatigue of fishing work. In the case of seafarers on fishing boats, the rate of night work is high and the intensity of work is strong. Because of this, it is in an environment that is highly exposed to fatigue. Fatigue decreases the seafarers' ability to concentrate on safe navigation and increases the risk of maritime accidents.

In case 2, there was an accident that could have been prevented if the seafarers had periodically checked the ship position. Because the ship sailed in a dangerous area, the equipment should have been installed to identify the danger in advance. If this equipment had actively intervened in the ship's operation, the accident would have been avoided. In addition, it would be helpful to prevent the recurrence of such an accident if a system that informs or warns about the vessel entering the dangerous area through the onshore monitoring system.

The results derived through the case study are as follows.

- The necessity of a system for information exchange between fishing boats and other vessels
- Development of human error reduction technology to prevent collisions between different types of ships
- Development of ship's equipment and notification system to check ship position of small ships such as fishing boats
- Position notification service for small ships from shore
- Development of a system that can actively intervene in the operation of a ship when a ship enters a dangerous area
- Introduction of a monitoring system to prevent improper look-out of navigators

6.3. The development suggestion of human error reduction technology considering the coastal traffic environment of maritime transportation and the characteristics of the seafarers

So far, through analysis of Korea's maritime accident statistics, maritime traffic environment analysis, and the current status of maritime safety technology, the priorities of the development and application of human error reduction technologies to prevent maritime accidents have been derived. In addition, through a case study, the technologies needed to prevent accidents caused by human error were analyzed. Based on the results of this analysis, this chapter intends to propose the necessary technologies for reducing human error to prevent maritime accidents in the coastal waters of the Republic of Korea.

First, the development of human error reduction technology to prevent collisions between ships should be improved. Such efforts have been around for a long time. ARPA radar and AIS are representative examples of such efforts. However, these technologies have a very limited scope of information exchange between ships. In addition, the delivery of risk information was also very passive. However, due to the development of sensor technology mentioned above, ships have been able to collect more detailed maritime traffic information, and due to the development of information technology, more detailed traffic information from land can be used. It is necessary to develop a system that allows the system to more actively intervene in the operation when a dangerous situation occurs by using such technology to analyze in more detail about collision information between ships and using such reliable information. In the development of such a system, it must be considered that all or part of the system should be applied to small ships such as fishing boats. The decision of the ship's avoidance operation is not only the problem between ships in which a collision is expected but also the relationship with the ships operating around it. Therefore, if all ships do not operate such a system, reliability will not be secured.

Second, the development of human error reduction technology suitable for small vessels (Less than 100 tons) should be enhanced. In the case of fishing boats, the size of the vessel is small, and in particular, the navigation room (Bridge) is narrow. Because a fishing vessel is made for fishing purposes, there is a limit to the loading space of navigation and communication equipment for vessel safety. In addition, it must be taken into account that most of the small ship's seafarers do not have high navigational knowledge or the utilization of IT equipment. Therefore, in the case of human error reduction equipment to be installed in small ships, it should be able to provide only necessary information based on a simple user-interface for older seafarers and with a minimized size.

Third, the software of human error accident prevention technology should be developed. In the case of the coast of Korea, sufficient maritime safety infrastructure such as AIS, e-Navigation, and LTE-M is established and will be installed. Such a hardware infrastructure for communication between ships and land, enables more useful maritime traffic information to be exchanged. However, despite such infrastructure, the service of human error reduction technology utilizing it is insufficient. In other words, the development and efforts of navigator-centered software technology are still in the beginning stage. Therefore, it is possible to check whether the ship's operation is safe through the analysis of the ship's position information. To provide safety route information through the analysis of the surrounding maritime traffic environment (ship traffic, weather, fishing boats operation information, etc.), and collision risk information between different ship types (fishing boat-cargo ship) various software-like human error reduction technologies should be developed.

Fourth, human error reduction technology to prevent maritime accidents due to improper lookout should be developed. There are many reasons for improper look-out. These include drowsiness due to fatigue, work in other tasks, and decreased concentration. These various causes are difficult to control with one technique. Particularly, due to the characteristics of the ship's operation, the size of the bridge being wide, and the very long periods of duty. Because of the nature of the maritime route, it is difficult to apply the drowsiness prevention technology or Lane Keeping System (LKS) applied in the automobile field. Considering such characteristics of ship operations, a certain area of the bridge is set as an area for securing voyage safety, and the working pattern of navigators in this area is analyzed. However, such a system will be able to play a role as an auxiliary system as a means to increase the concentration of observation by analyzing the algorithm of human behavior.

Lastly, the aims of human error reduction technology are to preventing human error, and should not be a means to control humans. The purpose of this is to minimize errors in human decision-making processes and to prevent maritime accidents through support for optimal decision-making. Therefore, such technology should not control humans or restrict human behavior and right but should develop as a system for providing information for accurate decision making.

6.4. Tasks other than human error reduction technology

The human error reduction technologies mentioned in this dissertation so far is a technical support method to minimize human error. Such a technology does not fundamentally eliminate human error but aims to technically prevent errors that may occur in the overall process and decision-making and to provide support to improve the completeness of decision-making.

As mentioned above, IMO has already established and is implementing international conventions such as the ISM Code and STCW Convention for standardization of human factors and verification of qualifications. However, these efforts are limited to the seafarer of ships under international conventions engaged in international voyages. For this reason, seafarers of small ships such as fishing boats are in the blind spot of the standardized system to reduce human error. Furthermore, seafarers of the small ship have a relatively low level of expertise and education. In addition, since seafarers of a fishing boat are engaged in fishing work and ship operation at the same time, it makes it difficult to focus on the safety of ship operation due to fatigue from hard work. Therefore, the introduction of an education and training system considering the characteristics of fishing boat seafarers is required.

Chapter 7. Conclusions and Suggestions

7.1. Conclusions

In the procedure of the ship's operation, ship operators sense and perceive a variety of information, use their knowledge to judge the situation, make decisions, and take action. If a human error occurs in any part of this process, the ship operator makes a mistake, and sometimes this mistake leads to an accident. Human errors cannot be eliminated but can be reduced with effort. As mentioned in this dissertation, a technical approach such as designing a ship to prevent human error, establishing a decision support system, or establishing accident prevention or alarm/monitoring device can be effective. Since enormous costs are incurred to build such a system or equipment, the state or shipping company may face financial limitations and will remain at an economically appropriate level. For this reason, measures to control human behavior must be devised to fill the gap between investment limitations and accidents.

However, no matter how much technology to reduce human error is introduced and education and regulations for seafarers are strengthened, human errors such as mistakes, flickering, and errors arising from human nature cannot be eliminated. Therefore, it is necessary to strengthen the professionalism of seafarers to minimize deviations in individual behavior and to secure knowledge through education and training. In addition, shipping companies and the state should make more drastic investments in safety for the sustainable development of shipping, rather than focusing on short-term profits.

7.2. Suggestions

The Republic of Korea has been focusing on the construction of a hardware system to secure maritime safety, such as the establishment of maritime wireless communication and ship monitoring systems. In other words, it means that the infrastructure for the development and realization of human error reduction technology using IT has already been established. However, even though such an efficient infrastructure has already been established, the software development and implementation of applications for reducing maritime accidents are still insufficient.

Maritime accidents due to human error account for more than about 90% of all maritime accidents, and the proportion is expected to increase further due to the development of shipbuilding technology and the acceleration of the aging of the seafarers. In particular, small ships that are not subject to international conventions such as fishing boats require special attention as a blind spot for maritime safety. In the development of the application, not only the cost for development is high in the early stage, but the size of the market for dissemination and utilization of the technology is limited, making it difficult to develop related technologies led by the business sector.

The prevention of maritime accidents is the state's duty to protect the safety and life of the people and the foundation for sustainable development of the shipping industry. For this reason, to develop and implement effective human error reduction technology, investment, and efforts led by the state are required in the early stages. In particular, in the case of small vessels such as fishing boats, relatively drastic investment is required because the commercial scale is small and the ability to invest in safety management is insufficient.

Therefore, at the beginning of the development of human error reduction technology, the government should lead the development of software, such as platforms, which are essential elements of it, and the expansion of related services should be supported by the business sector.

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Appendices 1. Dissertation process summery

1. Background

When you are in a hurry to drive your car, you sometimes forget to wear a seat belt. What happens if you start your car without wearing a seat belt? Perhaps a loud alarm will continue to sound until you wear the seatbelt, and in some cases the car may not start. This is one of the technology devices to reduce human error to prevent accidents and to minimize the damage of accidents by informing you when you forget to wear a seat belt. This technology is very simple but very efficient. Since the introduction of seat belt alarm technology, the wearing rate of seat belts in front seats has increased by 95% and the death rate of traffic accidents has decreased by 45% (Fildes, Fitzharris, Koppel & Vulcan, 2014).

There are many reasons for maritime accidents. However, they can roughly be divided into four factors such as the defects of the ship itself, human error, the environment of the ship-transportation and lack of regulations. Among these, human error accounts for the greatest proportion of maritime accidents. Maritime accidents caused by human error account for more than 80% of all accidents, which result in, for example, ship collisions and marine pollution. Since the 1912 Titanic accident, the international community has continued efforts to strengthen the ship's structure and equipment standards to prevent maritime accidents. Nonetheless, maritime accidents are occurring constantly, which shows that there is a limit to the accident prevention effect only by strengthening regulations on the structure and equipment standards of ships. For this reason, the IMO adopted the International Maritime Safety

Management Code (ISM) in 1990 in order to reduce accidents caused by human error. This is a code for international unification standards for the organization and procedures of shipping companies and ships, and IMO also established the International Convention on Standards of Training, Certification, and Watch-keeping for Seafarers (STCW 1978). Nevertheless, maritime accidents caused by human error continue to be an issue, proving that more diverse approaches are required to reduce human error.

For this reason, the introduction of advanced technology to reduce human error is effective as a means to prevent maritime accidents caused by human error and minimizing the mistakes of seafarers. In addition, due to the advancement of related technologies and the Fourth Industrial Revolution, interest and necessity have increased to introduce advanced technologies such as e-Navigation and autonomous shipping to increase maritime safety and efficiency.

2. Aims and objectives

The objective of the dissertation has three main purposes. The first objective is to identify the types of maritime accident reduction techniques caused by human error and the direction and prospects for the development of related technologies. Second, it is to examine what kinds of human error reduction technologies are applied in the aviation and automobile sectors and to investigate the possibility of applying these technologies to the maritime sector. Lastly, what these technologies need to be considered for effectively contributing to the reduction of maritime accidents caused by human errors occurring off the coast of the Republic of Korea, and what kind of development plan is needed.

3. Research hypothesis

Existing international conventions for reducing human errors, such as ISM and STCW, have a limited impact on accident reduction. Human error reduction techniques will be effective in reducing such accidents. In addition, these technologies could be effective not only for seafarers of international conventions but also for seafarers of non-conventional vessels not covered by the convention.

4. Methodology, Data collection and schedule

4.1 The research will be carried out in five steps using qualitative and quantitative methodology depend on the content of the research as follows.

4.1.1 The current statistics and causes of maritime accidents caused by human error in the Republic of Korea will be identified. A quantitative research methodology is applied to prove the necessity of applying related technologies by analyzing the number and causes of maritime accidents caused by human errors through analysis of the number of maritime accidents and their causes. Due to the diversified sampling of maritime accidents, it will suggest the necessity of human error reduction techniques based on objective numerical values based on the results of analysis through quantitative research methods.

4.1.2 The research will review the contents of the ISM and STCW Conventions established by the International Maritime Organization to reduce accidents caused by human error. In order to prevent maritime accidents caused by human errors, relevant regulations introduced by the International Maritime Organization and data on the quantified effects will be conducted according to qualitative research methodology with a focus on literature research.

4.1.3 The current status and prospects of technology development to reduce human error in the aviation, automobile, and maritime fields will be investigated. Qualitative research methodology such as literature data survey and expert group questionnaire will be applied for investigated that the current status and prospects of related technologies for reducing human error in various transportation fields such as aviation and automobile as well as ships. In particular, the research will focus on a prime example of human error reduction technologies in the similar transportation sector and the prospects for technological development. Based on this, it will identify which technologies are applicable or useful to the shipping sector.

4.1.4 The characteristics of the maritime traffic environment and crew working environment will be analyzed in the Republic of Korea for the application of related technologies. In order to apply effective human error reduction technology, it is important to understand the current status of the maritime traffic environment. In order to analyze the maritime traffic environment in the coastal waters of the Republic of Korea, the quantitative research methodology will be used for statistical data on ship traffic volume and port operation status. In addition, human error reduction technology is applied to the seafarer, so it is important to first understand the characteristics of the seafarer 's working environment. Therefore, if possible, a survey will be conducted to identify the characteristics of the working environment of the seafarer.

4.1.5 Based on the above findings, the applicability and development plan of technology for reducing human error will be proposed.

5. Expected results

The dissertation will attempt to provide a development plan that the effective introduction of technology for reducing the maritime accident caused by human error. In particular, it hopes that the research to contribute to the reduction of accidents by suggesting the application and development plan of human error reduction technologies for not only convention vessel but also non-conventional vessels such as fishing vessels and leisure boats, which account for a high proportion of maritime accidents in the Republic of Korea.

6. Key assumptions and potential limitations

The fundamental assumption is that human error reduction techniques are applied to both Conventional and Non-Conventional vessels and, in particular, to all human errors that may occur during voyages, such as seafarer's improper lookout and misjudgment. The human error reduction techniques mentioned in this dissertation do not apply to the seafarers of machinery parts, and for non-convention vessels with a gross tonnage of less than 500 tonnes, the application of human error reduction techniques may be limited depending on the size or purpose of the vessel.

Appendices 2. Theory of human error and marine safety

Human Error and Marine Safety

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Over the last 40 years or so, the shipping industry has focused on improving ship structure and the reliability of ship systems in order to reduce casualties and increase efficiency and productivity. We've seen improvements in hull design, stability systems, propulsion systems, and navigational equipment. Today's ship systems are technologically advanced and highly reliable.

Yet, the maritime casualty rate is still high. Why? Why is it, with all these improvements, we have not significantly reduced the risk of accidents? It is because ship structure and system reliability are a relatively small part of the safety equation. The maritime system is a *people* system, and human errors figure prominently in casualty situations. About 75-96% of marine casualties are caused, at least in part, by some form of human error. Studies have shown that human error contributes to:

- 84-88% of tanker accidents[i][1]
- 79% of towing vessel groundings[ii][2]
- 89-96% of collisions[iii][3],[iv][4]
- 75% of allisions[3]
- 75% of fires and explosions[3]

Therefore, if we want to make greater strides towards reducing marine casualties, we must begin to focus on the types of human errors that cause casualties.

One way to identify the types of human errors relevant to the maritime industry is to study marine accidents and determine how they happen. Chairman Jim Hall of the National Transportation Safety Board (NTSB) has said that accidents can be viewed as very successful events. What Chairman Hall means by "successful" is that it is actually pretty difficult to create an accident (thank goodness!). Accidents are not usually caused by a single failure or mistake, but by the confluence of a whole series, or chain, of errors. In looking at how accidents happen, it is usually possible to trace the development of an accident through a number of discrete events.

A Dutch study of 100 marine casualties[v][5] found that the number of causes per accident ranged from 7 to 58, with a median of 23[vi][6]. Minor things go wrong or little mistakes are made which, in and of themselves, may seem innocuous. However, sometimes when these seemingly minor events converge, the result is a casualty. In the study, human error was found to contribute to 96 of the 100 accidents. In 93 of the accidents, multiple human errors were made, usually by two or more people, each of whom made about two errors apiece. But here is the most important point: *every human error* that was made was determined to be a *necessary condition* for the accident. That means that if just one of those human errors had *not* occurred, the chain of events would have been broken, and *the accident would not have happened*. Therefore, if we can find ways to prevent some of these human errors, or at least increase the probability that such errors will be noticed and corrected, we can achieve greater marine safety and fewer casualties.

Types of Human Error

What do we mean by "human error"? Human error is sometimes described as being one of the following: an incorrect decision, an improperly performed action, or an improper lack of action (inaction). Probably a better way to explain human error is to provide examples from two real marine casualties.

The first example is the collision of the M/V SANTA CRUZ II and the USCGC CUYAHOGA[6][7], which occurred on a clear, calm night on the Chesapeake Bay. Both vessels saw each other visually and on radar. So what could possibly go wrong? Well, the CUYAHOGA turned in front of the SANTA CRUZ II. In the collision that ensued, 11 Coast Guardsmen lost their lives. What could have caused such a tragedy? Equipment malfunctions? Severe currents? A buoy off-station? No, the sole cause was human error.

There were two primary errors that were made. The first was on the part of the CUYAHOGA's captain: he misinterpreted the configuration of the running lights on the SANTA CRUZ II, and thus misperceived its size and heading. When he ordered that fateful turn, he thought he was well clear of the other vessel. The second error was on the part of the crew: they realized what was happening, but failed to inform or question the captain. They figured the captain's perception of the situation was the same as their own, and that the captain must have had a good reason to order the turn. So they just stood there and let it happen. Another type of human error that may have contributed to the casualty was insufficient manning (notice that this is not an error on the part of the captain or crew; rather, it is an error on the part of a "management" decision-maker who determined the cutter's minimum crew size). The vessel was undermanned, and the crew was overworked. Fatigue and excessive workload may have contributed to the captain's perceptual error and the crew's unresponsiveness.

The second example is the grounding of the TORREY CANYON[8][9]. Again we have clear, calm weather--this time it was a daylight transit of the English Channel. While proceeding through the Scilly Islands, the ship ran aground, spilling 100,000 tons of oil.

At least four different human errors contributed to this accident. The first was economic pressure, that is, the pressure to keep to schedule (pressure exerted on the master by management). The TORREY CANYON was loaded with cargo and headed for its deep-water terminal in Wales. The shipping agent had contacted the captain to warn him of decreasing tides at Milford Haven, the entrance to the terminal. The captain knew that if he didn't make the next high tide, he might have to wait as much as five days before the water depth would be sufficient for the ship to enter. This pressure to keep to schedule was exacerbated by a second factor: the captain's vanity about his ship's appearance. He needed to transfer cargo in order to even out the ship's draft. He could have performed the transfer while underway, but that would have increased the probability that he might spill a little oil on the decks and come into port with a "sloppy" ship. So instead, he opted to rush to get past the Scillies and into Milford Haven in order to make the transfer, thus increasing the pressure to make good time.

The third human error in this chain was another poor decision by the master. He decided, in order to save time, to go *through* the Scilly Islands, instead of *around* them as originally planned. He made this decision even though he did not have a copy of the *Channel Pilot* for that area, and even though he was not very familiar with the area.

The final human error was an equipment design error (made by the equipment manufacturer). The steering selector switch was in the wrong position: it had been left on autopilot.

Unfortunately, the design of the steering selector unit did not give any indication of its setting at the helm. So when the captain ordered a turn into the western channel through the Scillies, the helmsman dutifully turned the wheel, but nothing happened. By the time they figured out the problem and got the steering selector back on "manual", it was too late to make the turn, and the TORREY CANYON ran aground.

As these two examples show, there are many different kinds of human error. It is important to recognize that "human error" encompasses much more than what is commonly called "operator error". In order to understand what causes human error, we need to consider how humans work within the maritime system.

The Maritime System: People, Technology, Environment, and Organizational Factors

As was stated earlier, the maritime system is a *people* system (Fig. 1). People interact with technology, the environment, and organizational factors. Sometimes the weak link is with the people themselves; but more often the weak link is the way that technological, environmental, or organizational factors influence the way people perform. Let's look at each of these factors.

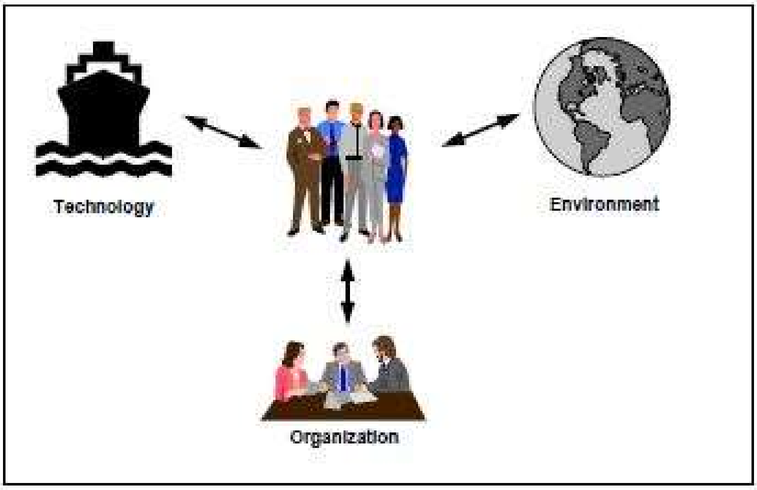

Fig. 1. The Maritime System Is A *People* System

First, the people. In the maritime system this could include the ship's crew, pilots, dock workers, Vessel Traffic Service operators, and others. The performance of these people will be dependent on many traits, both innate and learned (Fig. 2). As human beings, we all have certain abilities and limitations. For example, human beings are great at pattern discrimination and recognition. There isn't a machine in the world that can interpret a radar screen as well as a trained human being can. On the other hand, we are fairly limited in our memory capacity and in our ability to calculate numbers quickly and accurately--machines can do a much better job. In addition to these inborn characteristics, human performance is also influenced by the knowledge and skills we have acquired, as well as by internal regulators such as motivation and alertness.

Fig. 2. The Maritime System: People

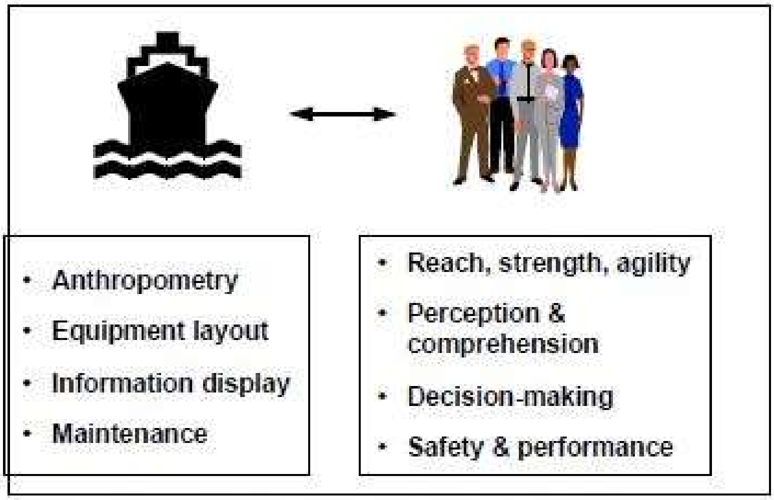

Fig. 3. The Maritime System: Effect of Technology on People

The design of technology can have a big impact on how people perform (Fig. 3). For example, people come in certain sizes and have limited strength. So when a piece of equipment meant to be used outside is designed with data entry keys that are too small and too close together to be operated by a gloved hand, or if a cutoff valve is positioned out of easy reach, these designs will have a detrimental effect on performance. Automation is often designed without much thought to the information that the user needs to access. Critical information is sometimes either not displayed at all or else displayed in a manner which is not easy to interpret. Such designs can lead to inadequate comprehension of the state of the system and to poor decision making.

The environment affects performance, too (Fig. 4). By "environment" we are including not only weather and other aspects of the physical work environment (such as lighting, noise, and temperature), but also the regulatory and economic climates. The physical work environment directly affects one's ability to perform. For example, the human body performs best in a fairly restricted temperature range. Performance will be degraded at temperatures outside that range, and fail altogether in extreme temperatures. High sea states and ship vibrations can affect locomotion and manual dexterity, as well as cause stress and fatigue. Tight economic conditions can increase the probability of risk-taking (e.g., making schedule at all costs).

Finally, organizational factors, both crew organization and company policies, affect human performance (Fig. 5). Crew size and training decisions directly affect crew workload and their capabilities to perform safely and effectively. A strict hierarchical command structure can inhibit effective teamwork, whereas free, interactive communications can enhance it. Work schedules which do not provide the individual with regular and sufficient sleep time produce fatigue. Company policies with respect to meeting schedules and working safely will directly influence the degree of risk-taking behavior and operational safety.

As you can see, while human errors are all too often blamed on "inattention" or "mistakes" on the part of the operator, more often than not they are symptomatic of deeper and more complicated problems in the total maritime system. Human errors are generally caused by technologies, environments, and organizations which are incompatible in some way with optimal human performance. These incompatible factors "set up" the human operator to make mistakes. So what is to be done to solve this problem? Traditionally, management has tried either to cajole or threaten its personnel into not making errors, as though proper motivation could somehow overcome inborn human limitations. In other words, the human has been expected to adapt to the system. *This does not work.* Instead, what needs to be done is to *adapt the system to the human.*

The discipline of human factors is devoted to understanding human capabilities and limitations, and to applying this information to design equipment, work environments, procedures, and policies that are compatible with human abilities. In this way we can design technology, environments, and organizations which will work *with* people to enhance their performance, instead of working *against* people and degrading their performance. This kind of *human-centered* approach (that is, adapting the system to the human) has many benefits, including increased efficiency and effectiveness, decreased errors and accidents, decreased training costs, decreased personnel injuries and lost time, and increased morale.

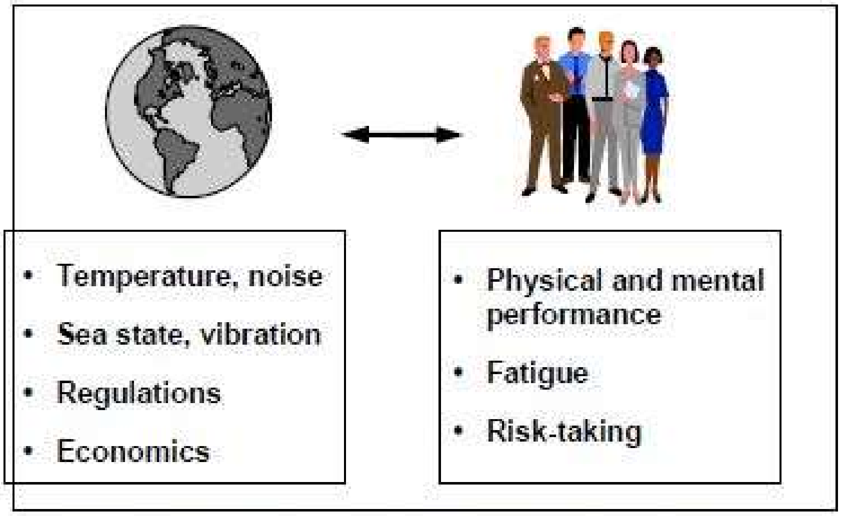

Fig. 4. The Maritime System: Effect of Environment on People

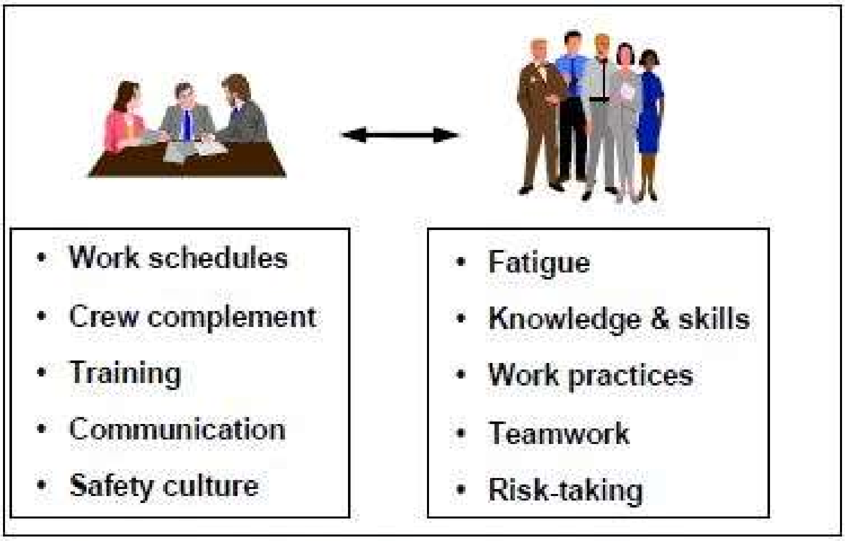

Fig. 5. The Maritime System: Effect of Organization on People

Human Factors Issues in the Marine Industry

What are some of the most important human factors challenges facing the maritime industry today? A study by the U.S. Coast Guard[ix][9] found many areas where the industry can improve safety and performance through the application of human factors principles. The three largest problems were fatigue, inadequate communication and coordination between pilot and bridge crew, and inadequate technical knowledge (especially of radar). Below are summaries of these and other human factors areas that need to be improved in order to prevent casualties.

Fatigue. The NTSB has identified fatigue to be an important cross-modal issue, being just as pertinent and in need of improvement in the maritime industry as it is in the aviation, rail, and automotive industries. Fatigue has been cited as the "number one" concern of mariners in two different studies[x][10],[xi][11]. It was also the most frequently mentioned problem in a recent Coast Guard survey[9]. A new study has objectively substantiated these anecdotal fears: in a study of critical vessel casualties[xii][12] and personnel injuries, it was found that fatigue contributed to 16% of the vessel casualties and 33% of the injuries[xiii][13]. More information on fatigue and how to prevent or reduce it can be found in subsequent chapters in this book.

Inadequate Communications. Another area for improvement is communications--between shipmates, between masters and pilots, ship-to-ship, and ship-to-VTS. An NTSB report[xiv][14] stated that 70% of major marine collisions and allisions occurred while a State or federal pilot was directing one or both vessels. Better procedures and training can be designed to promote better communications and coordination on and between vessels. Bridge Resource Management (BRM) is a first step towards improvement.

Inadequate General Technical Knowledge. In one study, this problem was responsible for 35% of casualties[5]. The main contributor to this category was a lack of knowledge of the proper use of technology, such as radar. Mariners often do not understand how the automation works or under what set of operating conditions it was designed to work effectively. The unfortunate result is that mariners sometimes make errors in using the equipment or depend on a piece of equipment when they should be getting information from alternate sources.

Inadequate Knowledge of Own Ship Systems. A frequent contributing factor to marine casualties is inadequate knowledge of own ship operations and equipment. Several studies and casualty reports have warned of the difficulties encountered by crews and pilots who are constantly working on ships of different sizes, with different equipment, and carrying different cargoes. The lack of ship-specific knowledge was cited as a problem by 78% of the mariners surveyed[11]. A combination of better training, standardized equipment design, and an overhaul of the present method of assigning crew to ships can help solve this problem.

Poor Design of Automation. One challenge is to improve the design of shipboard automation. Poor design pervades almost all shipboard automation, leading to collisions from misinterpretation of radar displays, oil spills from poorly designed overfill devices, and allisions due to poor design of bow thrusters. Poor equipment design was cited as a causal factor in one-third of major marine casualties[8]. The "fix" is relatively simple: equipment designers need to consider how a given piece of equipment will support the mariner's task and how that piece of equipment will fit into the entire equipment "suite" used by the mariner. Human factors engineering methods and principles are in routine use in other industries to ensure human-centered equipment design and evaluation. The maritime industry needs to follow suit. This topic is discussed further in a subsequent chapter.

Decisions Based on Inadequate Information. Mariners are charged with making navigation decisions based on all available information. Too often, we have a tendency to rely on either a favored piece of equipment or our memory. Many casualties result from the failure to consult available information (such as that from a radar or an echo-sounder). In other cases, critical information may be lacking or incorrect, leading to navigation errors (for example, bridge supports often are not marked, or buoys may be off-station).

Faulty standards, policies, or practices. This is an oft-cited category and covers a variety of problems. Included in this category is the lack of available, precise, written, and comprehensible operational procedures aboard ship (if something goes wrong, and if a well-written manual is not immediately available, a correct and timely response is much less likely). Other problems in this category include management policies which encourage risk-taking (like pressure to meet schedules at all costs) and the lack of consistent traffic rules from port to port.

Poor maintenance. Published reports[3,11] and survey results[9] expressed concern regarding the poor maintenance of ships. Poor maintenance can result in a dangerous work environment, lack of working backup systems, and crew fatigue from the need to make emergency repairs. Poor maintenance is also a leading cause of fires and explosions[3].

Hazardous natural environment. The marine environment is not a forgiving one. Currents, winds, and fog make for treacherous working conditions. When we fail to incorporate these factors into the design of our ships and equipment, and when we fail to adjust our operations based on hazardous environmental conditions, we are at greater risk for casualties.

Summary

This chapter has introduced the concept of "human error". We have seen that human error (and usually multiple errors made by multiple people) contributes to the vast majority (75-96%) of marine casualties, making the prevention of human error of paramount importance if we wish to reduce the number and severity of maritime accidents. Many types of human errors were described, the majority of which were shown not to be the "fault" of the human operator. Rather, most of these errors tend to occur as a result of technologies, work environments, and organizational factors which do not sufficiently consider the abilities and limitations of the people who must interact with them, thus "setting up" the human operator for failure. Human errors *can* be reduced significantly. Other industries have shown that human error can be controlled through *human-centered design*. By keeping the human operator uppermost in our minds, we can design technologies, work environments, and organizations which support the human operator and foster improved performance and fewer accidents.

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