Engineering Master's Thesis

Development of Ship Safety Index to Prevent Marine Accidents

Advisor Lee, Eun-Bang
Lee, Moonjin

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Department of Convergence Study on the Ocean Science and Technology
Ocean Science and Technology School
Korea Maritime and Ocean University

Bae, Jun-Ki

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Dissertation Committee :

Prof. Park, Young-Soo, Chair ____________

Prof. Lee, Moonjin, Advisor ____________

Prof. Lee, Eun-Bang, Advisor ____________

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해양사고 예방을 위한 선박안전지수 개발에 관한 연구

배 준 기

해양과학기술융합학과
한국해양대학교 해양과학기술전문대학원

초 록

선박, 항해기술 발달과 더불어 안전에 대한 교육과 법제 강화에도 불구하고 해양사고는 지속적으로 발생하여 큰 피해를 주고 있다. 사고가 발생하면 생명, 재산 그리고 환경적 재해가 수반하게 되므로 예방활동의 동기와 성과를 촉진하고 체계적인 안전관리를 위한 시각적이고 정량적인 지수를 개발하여 선순환적인 예방문화를 구축하고자 선박사고 예방지수(PIMA)와 예방수준(PGMA)을 개념화하고 정량화하였다. 선박사고 예방지수를 설계하기 위하여 지난 5년(2009~2013)간 국내에서 발생한 사고통계 자료를 4개 영역, 즉 교육, 기술, 단속, 정보영역으로 구조화하고 예방요소와 인자를 추출함으로써 지수를 정의하였다. 정의된 지수 산정에 필요한 평가모듈을 설계하였으며, 설계된 모듈을 이용하여 화물선, 여객선, 유조선, 예선, 어선을 대상으로 지수를 측정하였다. 측정된 선박사고 예방지수 결과를 통계적, 사례적으로 위험성과의 상관관계를 분석하여 유용성을 확인하고 검증하였다. 제안된 선박사고 예방지수를 인증제도 등에 활용함으로써 선박별 맞춤형 성과기반 예방활동은 물론 예방중심의 안전문화 촉진과 선박사고 저감효과가 기대된다.

KEY WORDS : 선박사고, 예방지수, 평가모듈, 예방활동

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Abstract

Despite the enforcement of marine laws, the development of improved navigation technology, and augmented educational programs, the number of marine accidents has not significantly decreased. Accident prevention is increasingly emphasized because of property damage and the environmental losses associated with marine accidents. Even though there are a variety of preventative measures in place, their performance has not been satisfactory. In order to adequately promote prevention activities and to organize safety management, a Prevention Index of Marine Accidents (PIMA) and a Prevention Grade of Marine Accidents (PGMA) which are abstracted from the statistical data of marine accidents between 2009~2013 have been proposed. The evaluation module by which these variables can be calculated is composed of methods of prevention such as: education, engineering, enforcement, and information. These methods have been applied to the prevention index measurements of cargo, passenger, tanker, tugboats and fishing vessels. The results were compared, measured, and analyzed with statistical accident rates and cases studies to confirm the index utilities. It was found that there were strong correlations between the index values and marine accident rates. It is expected that this index will become useful to evaluate the prevention of marine accidents for the culture of marine safety.

KEY WORDS : Marine accident, Safety index, Evaluation module, Prevention activity

Chapter 1. Introduction

1.1 Background and Purpose

With the development of information and communication technologies, such as: Differential Global Positioning Systems (DGPS), Electronic Chart Displays & Information Systems (ECDIS), and provisionally introduced in 2018, e-Navigation systems, great strides have been made to revolutionize travel in the shipping industry. In addition, stronger seafarer training was developed according to the revised International Convention on Standards of Training Certification and Watch-keeping for Seafarers (STCW). These programs came into effect in January of 2012 and are the driving force to promoting strict marine safety-related laws. Despite these various efforts, marine accidents cause serious damage to life and property as well as the marine environment by the countless incidents that have occurred. In particular, the increase in large-sized vessels, which can ensure reduced cost and price competitiveness, (Jeong, 2006) have caused many catastrophic accidents. A poignant example is the Sewol ferry disaster, which occurred in April of 2014. Authorized investigators said the ship’ s weight was more than double the limit. Loosely tied cargo caused the ship to capsize. Moreover, the crew did not fulfill their duty to ensure passenger safety.

The total recorded losses of the world’s registered fleet has been more than 10,000 gross tons in 2011. For the year 2011, three registered Korean ships were lost in accidents out of 2,916. This value is sixth in the world (Southampton Solent Univ., 2012). Sadly, Korean ship accidents have occurred about 2.1 times per day over the past five years. Looking at Korean marine accident statistics from 2009~2013, a total of 3,770 cases occurred (KMST, 2014). The prevalence of minor and major accidents causes serious emotional, environmental, and financial losses to everyone involved.

It is important that first responders to marine accidents follow proper protocol in a timely and efficient manner. However, proper preventative measures are an important tactic in preventing emergencies in the first place. Heinrich' s iceberg theory (Fig. 1-1) shows the correlation between the direct and indirect damage with a ratio of 1:4 in one accident case. In other words, if one accident had not occurred, four direct or indirect damages will be diminished (Kwon & Kim, 2011). To prevent accidents is to remove the potential for further damage.

After the Sewol ferry accident, the government reorganized it' s national safety policy. Among those policies, marine safety has become a top priority. As a result, the Korean Coast Guard (KCG) organization was restructured and more emphasis was placed on the marine safety of civilians. Now, new policies including public relations campaigns and stronger legislation, have been developed to create a safer Korea. These campaigns emphasize a focus on preventative actions. The Sewol crisis created strong momentum towards implementing new safety standards in Korea through sustainable and voluntary preventative action.

The purpose of this paper is to:

- Build an understanding of safety standards in Korea

- Advocate the prevention of marine accidents

- Provide methods in which systematic safety management can be utilized through Index development.

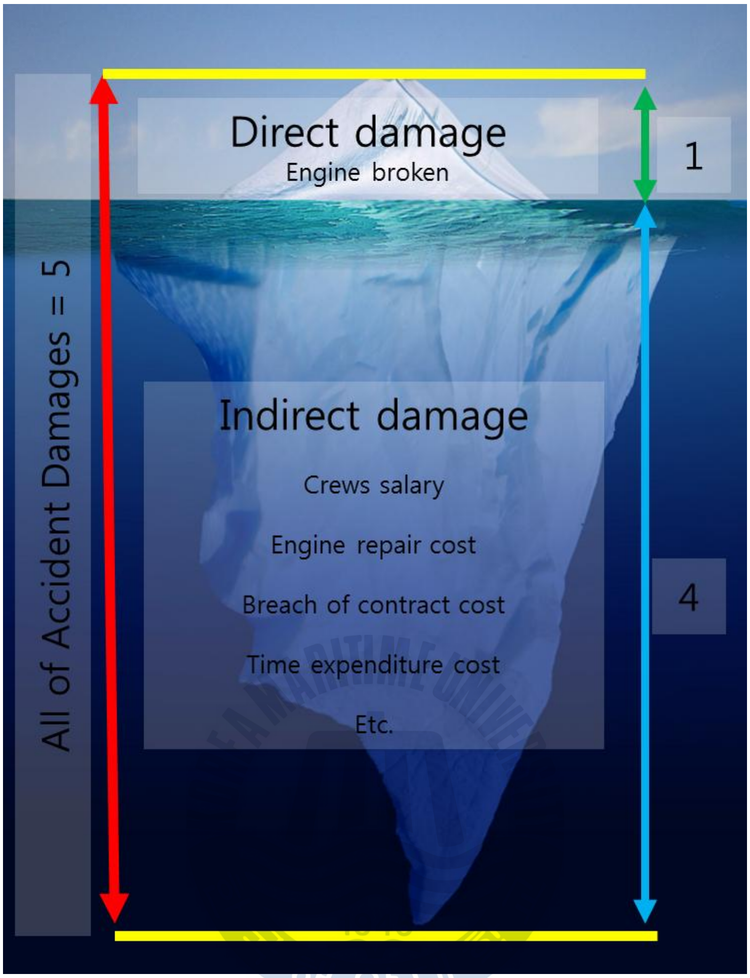


Fig. 1-1 A sample of Heinrich's iceberg theory as a mimetic diagram

1.2 Methods

The study uses statistical reviews of marine accidents in Korea from data in 2.2.1. After the analysis of that data the study used the extracted information to formulate preventive sectors and preventive factors. Each preventive sector and factor was classified through objective review by maritime professionals. Throughout this process, the Prevention Index of Marine Accidents (PIMA) is defined by remarks on how ship preventive actions were performed. The Prevention Grade of Marine Accidents (PGMA) is measured by the results of the ship's preventive actions.

PIMA and PGMA were measured with cargo ships, passenger ships, tankers, tug boats, and fishing vessels. Measured PIMA and PGMA were then compared with marine accident rates for statistical verification.

Overall, developed PIMA is the quantitative performance of activities in marine accident prevention including: effective control and customized prevention. Well developed PGMA cases can take advantage of insurance at a premium rate as part of a specialized certification program. The development of the index of preventive actions led to the development standardized techniques widely utilized by marine safety professionals.

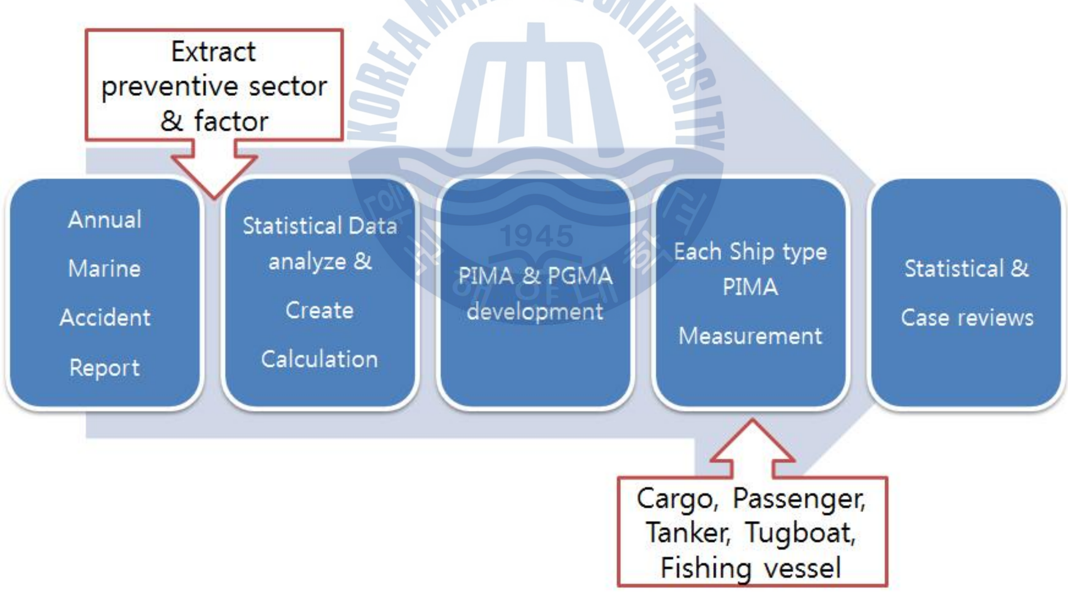


Fig. 1-2 Flow chart of study methods

Chapter 2. Analysis of Marine accidents

2.1 Concepts related to marine accidents

2.1.1 Definition of marine accidents

A marine accident is an event, or sequence of events, that has resulted in:

- the death of, or serious injury to, a person

- the loss of a person from a ship

- the loss, presumed loss, or abandonment of a ship

- material damage to a ship

- the stranding or disabling of a ship, or the involvement of a ship in a collision

- material damage to the marine infrastructure external to a ship, that could seriously endanger the safety of the ship, another or an individual

- the severe damage or the potential damage to the environment, brought about by the damage of a ship or ships.

However, a marine casualty does not include a deliberate act or omission, with the intention to cause harm to the safety of a ship, an individual or the environment (IMO, 2008).

2.1.2 Types of marine accidents

The Korea Maritime Safety Tribunal have classified ten types of marine accidents. The types of marine accidents are: collision, contact, stranding, capsizing, fire or explosion, sinking, engine damage, loss of life, hindered safety, and hindered navigation (KMST, 2014), The detailed description is as follows :

- Collision : Bumping or touching other vessels regardless of being anchored or sailing. Exclusions include collisions with a wreck under the surface of the water

- Contact : A ship or submarine bumping or touching external objects.

- Stranding : To run into shipwrecks under the surface of the water.

- Capsizing : The ship is overturned excluding those instances that occurred due to collision or stranding.

- Fire or Explosion : Accidents where fire or explosion is the first incident.

- Sinking : The immersion of a ship caused by bad weather, cracks, or holes. This excludes collision or explosion.

- Engine damage : A damaged main engine, boiler, or other auxiliary form of equipment.

- Loss of life : People killed, missing or injured in relation to the ship's structure, equipment, or operations.

- Hindered safety : The propeller could not continue to move due to hindered function.

- Hindered navigation : When the ship could not continue to sail because it sits on a shoal, but the hull is not damaged.

2.2 Statistics of marine accidents

2.2.1 Data Used and Purpose

To analyze the data of marine accidents by ship in Chapter 2 data was acquired from the Korea Maritime Safety Tribunal (KMST, 2014), and included the dates 2009 through 2013. The most recent data from a five-year period was selected because of the objective nature of official national statistics and for the abundance of current statistical cases. The KMST verdict in each accident case rated time, location, causes, types and sizes. This information has been used in the case reviews in Chapter 6.

Through marine accident analysis to grasp the situation of the domestic marine accidents, it is the object to be secured as basic data for calculating the PIMA and PGMA.

2.2.2 Status of marine accidents by year

Of Korea's registered ships the number of marine accidents are 3,770 cases in the last five years. Table 2-1 shows each year and the registered ships including their marine accident status. The marine accident rate is constantly maintained between approximately 1.0 to 1.4%.

Table 2-1. Status of marine accidents by year

Year / No.	2009	2010	2011	2012	2013
No. of registered ships(A)	86,087	86,015	85,025	84,466	80,360
No. of marine accident ships(B)	915	961	1,197	941	818
No. of marine accident	723	737	946	726	638
marine accident rate(B/A)	**1.06%**	**1.12%**	**1.41%**	**1.11%**	**1.02%**

* The number of registered ships in 2013 are represented by a provisional number

2.2.3 Marine accidents by ship type

In looking at marine accidents by ship type (Fig. 2-1, Table 2-2), most cases were involving fishing vessels at 71% with 3,474 cases. Then, tanker ships at 10% with 465 cases, tugboats at 6% with 294 cases, tanker ships at 4% with 185 cases, and passenger ships at 2% with 84 cases. Each case was analyzed in order.

In contrast, when compared to the overall results, analysis showed cargo ship at 11.51% and had the most frequently occurring accidents. See Table 2-3. After that, passenger ships at 7.92%, tanker ships at 5.08%, tugboats at 4.64%, and fishing vessels at 0.92%. Each were analyzed in order. The frequency of cargo ship accidents causes a profound impact on the national economy and it is thought to be highly desirable to develop opportunities for future research (Seo & Bae, 2002).

In particular, apart from other types of ships, fishing vessels were concentrated in 2011. This tendency is due to bad weather, such as typoons. In particular, typhoon 'MUIFA' wreaked havoc on the maritime industry in 2011. Consequently, the weather is an important safety consideration in fishing vessel accidents.

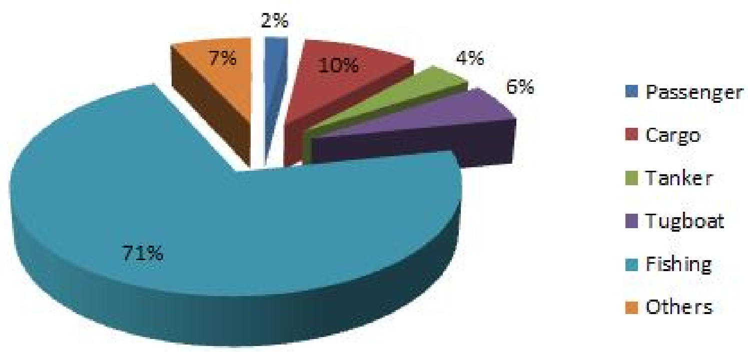


Fig. 2-1 Marine accident by type of ship

Table 2-2. Marine accidents by type of ship

Type / Year	Passenger	Cargo	Tanker	Tugboat	fishing	Others	Total
2009	7	83	18	35	725	47	915
2010	18	107	42	65	672	57	961
2011	17	96	37	75	888	84	1197
2012	24	86	39	65	653	74	941
2013	18	93	49	54	536	68	818
Total	84	465	185	294	3474	330	4832
Ratio	2%	10%	4%	6%	71%	7%	100%

Table 2-3. Number of ships registered compared with marine accidents (5 year average)

Type of ship / Division	Passenger	Cargo	Tanker	Tugboat	fishing	Others	Total
No. of ship registered (a)	212	808	728.4	1267	75269.4	6105.8	84390.6
No. of marine accident ships (b)	16.8	93	37	58.8	694.8	66	966.4
Marine accident rate (b/a)	7.92%	11.51%	5.08%	4.64%	0.92%	1.08%	1.15%

2.2.4 Marine accidents by causes

Table 2-4 shows number of marine accidents by causes according to 2009~2013 KMST verdict results. The main cause of marine accidents was operational failure at 82.1% with 1,153 cases. It was followed by the neglect of equipment maintenance at 10.1% with 142 cases, and other forms of failure at 7.8% with 109 cases.

After analysing the main cause of operational failure the results showed that neglecting watch-keeping duties were at 46.4% with 652 cases. It was followed by the violation of navigation rules at 11.5% with 161 cases, and hazardous ship-maneuvering at 5.7% with 80 cases. Accounting for the top causes in marine accident is human error. Results show that about 80% of marine accidents are caused by mistakes in judgement. The factor of human error and our tendency to make chains of mistakes is mentioned by Yang et al. (2004), Na et al. (2012).

Therefore, in order to prevent marine accidents caused by factors of human error, the need for safety advocacy among the crew on board ships is a necessity. Crew should promote a culture of voluntary marine safety and should be provided with a system of checks and balances that can intuitively determine the ongoing safety grade during a voyage.

Table 2-4. Number of Marine accidents by causes and type

Causes \ Type		Collision	Contact	Stranding	Capsizing	Fire & Explosion	Sinking	Engine damage	Loss of life	Others	Total	Ratio
Operational fault	A	0	0	0	2	0	3	0	0	0	5	0.4%
	B	0	1	2	0	0	0	0	0	0	3	0.2%
	C	5	1	0	2	0	0	0	0	0	8	0.6%
	D	2	4	42	0	0	2	0	0	0	50	3.6%
	E	43	12	7	9	0	5	0	4	0	80	5.7%
	F	638	7	5	0	0	0	0	2	0	652	46.4%
	G	9	1	9	15	1	17	0	1	0	53	3.8%
	H	0	0	1	0	0	0	0	0	1	2	0.1%
	I	159	1	0	1	0	0	0	0	0	161	11.5%
	J	1	0	1	0	0	0	0	1	0	3	0.2%
	K	7	2	6	2	1	0	0	0	1	19	1.4%
	L	16	7	5	5	1	7	0	5	1	47	3.3%
	M	0	0	1	5	3	2	0	57	2	70	5.0%
	Sub-total	880	36	79	41	6	36	0	70	5	1153	82.1%
Equipment maintenance	N	1	0	3	2	14	5	1	1	3	30	2.1%
	O	2	3	0	0	21	2	43	0	7	78	5.6%
	P	0	0	0	0	34	0	0	0	0	34	2.4%
	Sub-total	3	3	3	2	69	7	44	1	10	142	10.1%
Other	Q	0	0	0	9	0	3	0	1	2	15	1.1%
	R	0	0	0	2	1	5	0	0	0	8	0.6%
	S	0	0	0	0	0	0	0	0	0	0	0.0%
	T	0	0	0	1	0	1	0	0	0	2	0.1%
	U	12	0	2	3	8	2	0	0	1	28	2.0%
	V	18	7	5	4	8	4	1	5	4	56	4.0%
	Sub-total	30	7	7	19	17	15	1	6	7	109	7.8%
Total		913	46	89	62	92	58	45	77	22	1404	100.0%

A	Poor departure preparation	L	Operational fault (Other)
B	Poor fairway research	M	Neglect of safety rules
C	Poor selected course	N	Poor quality of hull and engine equipment
D	Unidentified ship position	O	Poor repair of engine equipment
E	Hazardous ship-maneuvering	P	Poor quality of fire and electric wire
F	Neglect of watch keeping	Q	Neglect of cargo and passengers
G	Poor bad weather preparation & response	R	Neglect of shipping service control
H	Lack of anchoring	S	Neglect of on board crews
I	Violation of navigation rules	T	Neglect of aids to navigation
J	Poor duty control	U	Neglect of meteorological conditions
K	Poor watchkeeping	V	Others

2.2.5 Marine accidents by type

Table 2-5 shows number of marine accidents by type. The main type of marine accident is engine damage at 28.1% with 1056 cases. The most forms of engine damage to ships were reported on fishing vessels. It was followed by collisions at 22.5% with 848 cases, hindered safety & navigation at 11.9% with 447 cases, and stranding at 7.5% with 282 cases.

Excluding the engine damage of fishing vessels, marine traffic accidents include: colliding, contacting, stranding, capsizing, and sinking. These accidents may cause further types of incidents including 38.6% with 1455 cases resulting in greater threats to life and property. Preventative measures are the best solution for ensuring these accidents do not exacerbate.

Table 2-5. Number of Marine accidents by type

type / year	Collision	Contact	Stranding	Capsizing	Fire& Explosion	Sinking	Engine damage	Loss of life	Hinder safety & navigation	Others
2009	160	10	43	18	34	22	253	21	94	68
2010	174	22	64	17	25	22	236	33	91	53
2011	208	23	64	38	57	27	261	82	101	85
2012	157	21	53	25	55	26	178	57	68	86
2013	149	21	58	20	43	13	130	42	93	69
Total	848	97	282	118	214	110	1058	235	447	361
Ratio	22.5%	2.6%	7.5%	3.1%	5.7%	2.9%	28.1%	6.2%	11.9%	9.6%

2.3 Marine accident (Sewol Ferry disaster)

The Sewol Ferry disaster occurred on the morning of 16 April 2014 en route from Incheon Port to Jeju island Port. The Sewol Ferry capsized while carrying 476 people, mostly school students from Danwon High School. The sinking of the Sewol has resulted in widespread social and political criticism within Korea (Wikipedia, 2014a). The Sewol Ferry disaster is a somber reminder of the importance of preventative measures and diligence in ensuring marine safety on Korean waterways.

2.3.1 Ship specifications & operating status

The Sewol Ferry had been regularly operating from Incheon Port to Jeju Port as a coastal passenger ship. This ship was 5,997 tons and was constructed in the Hayashi shipyard of Japan on April 1, 1994. After one month, the ship was increased to 6,782 tons. Later CHEONGHAEJIN Marine Corps imported the ship to Korea on October 22, 2012, and then removed the stern. Part of B deck was repaired and modified. Repairs included: removing the car ramp and making a new cabin and rooms in A deck (KR, 2014).

Table 2-6. Specifications of Sewol Ferry

Ship Name	SEWOL	
Port of Registry	Incheon	
Owner	CHEONGHAEJIN Marine Corps.	
Gross Tons	6,825 tons(Built : 5,997 tons. Built after 1 month increase 650 tons in Japan)	
Specifications	Length OverAll(L_{OA})	145.61m
	Length Between Perpendiculars(L_{BP})	136.00m
	Breadth MouLDed(B_{MLD})	22.00m
	Depth MouLDed(D_{MLD})	14.00m
Full Draft	6.264m	
Built	1994.4.1. Launched(Japan)	
Main Engine	9,000PS(6,619.5KW) × 2	
Registered	2012.10.22. New(imported) Registered 2013. 1.25. Remodeling(increase 178 tons)	

Boarding personnel increased to 116 people while gross tonnage increased 239 tons through extension remodelling. The weight of the vertical distribution also increased, resulting in weakened ship stability. For safety, this reduced loadable cargo to 1,450 tons and increased the ballast water to 1,333 ones. Cargo capabilities became set at 1,077 tons (Lee, 2014).

2.3.2 Timeline of events

On April 15^{th} , 2014, the Sewol should have set sail on its regular overnight journey from Incheon to Jeju at 18:30. It was delayed by fog and eventually departed at about 21:00. There were 476 people on board, 443 of whom were passengers, including a school party of 325 students and their teachers from Danwon High School. However, due to inconsistencies in the passenger manifest, the number of total passengers may have been higher.

On the morning of April 16th, the ship sailed through a treacherous area of water near Jindo Island, following the Mangol passage, when it made a sharp turn and began to severely list. It is not clear why this sudden turn was made. The Automatic Identification System (AIS) data was released later by authorities, and showed that as the ferry turned, it lost control and began drifting sideways. The Sewol quickly began to capsize.

At approximately 08:52 the ship began to lean over. The first distress call came not from the crew but from a teenage boy who dialed the national emergency number.

At approximately 08:55 the crew calls for help by contacting Jeju Harbour affairs. Transcripts reveal an increasingly desperate interchange between the ship and shore. Meanwhile, announcements are broadcast telling passengers to stay where they are. Mobile phone footage retrieved from the victims later showed frightened students in life vests discussing whether to obey orders or try to escape.

Between 08:55 and 9:37 Harbor Affairs at Jeju and Jindo island, began to coordinate rescue efforts while moving to the ferry's location, and urged crew to get passengers ready for evacuation. The captain sought assurance that the rescue was at hand. He later says he was concerned that people would be swept away by the strong current if they entered that swift cold water. The crew were also trapped in the bridge by the angle at which the ship was tilted and by fallen containers, so they could not reach the passengers.

At 09:30 Coast-Guard boats and helicopters began arriving. The captain said the ferry was now tilted at 60 degrees.

At 09:37, in the final communication, the crew said the evacuation order had been given and some passengers were escaping on the port side. Over the next two hours, a total of 172 passengers and crew were rescued but many more were trapped inside as the ship slipped beneath the waves (BBC, 2014).

2.3.3 Suspected factors

- Overloaded : According to investigators, the Sewol ferry was carrying more than double the ship's limit when it capsized. Since CHEONGHAEJIN Marine Corps. started the Incheon to Jeju route in March 2013, 57% of its trips carried excess cargo. According to prosecutors excessive cargo was carried 139 times out of 241 trips. Investigators say, the company profited from overloading the ferry, earning an extra profit of $ 2.9 million since March 2013.

-Improperly secured cargo : Investigators have been probing the possibility the ship overturned because of a sharp turn that may have shifted the cargo, knocking the vessel off-balance. Witnesses have described how several containers fell over and made booming sounds as they tumbled off-balance. Loosely tied cargo contributed to the Sewol's sinking because weight distribution determines a ship's position in the water.

- The crew insisted passengers stay put : The instruction to remain in place, instead of getting into lifeboats. It's unclear why the crew made this determination, which remains one of the most haunting and perplexing questions surrounding the accident.

- The captain abandoned ship, while passengers were told not to move : The Captain has come under heavy criticism for abandoning the ship while hundreds of passengers remained on board.

- An inexperienced crew member steered the ship : Authorities have questioned why an inexperienced third mate was guiding the ship at the time of the accident. That third mate is also facing charges for not abiding by emergency safety laws, negligence which led to the ship sinking, and causing injuries leading to numerous deaths. The captain was not at the helm at the time of the accident. There is no law requiring the captain to be on the bridge when the third mate is steering, but the fact that an inexperienced member of the crew was navigating in one of the most treacherous stretches of the trip has raised questions.

- Delays on notifying proper authorities of the accident : The first distress call came not from the ship's crew, but instead from a boy on board who used a cell phone to contact emergency services at 8:52 a.m. His call to emergency services gave rescuers a few extra minutes to get to the stricken Sewol as it is listed dangerously before capsizing. Three minutes later, the ship's crew made a distress call to authorities in Jeju. The miscommunications may have caused delays.

- The ship's modifications raise questions : The Sewol had been renovated in 2013 to expand the top floor to make room for more passengers. The 20-year-old ship was originally used in Japan, until CHEONGHAEJIN Marine Corp. purchased the ferry in 2012 and refurbished it. CHEONGHAEJIN added extra passenger cabins on the third, fourth and fifth decks, raising passenger capacity and altering the weight and balance of the vessel. Investigators want to know if the renovations may have made the ferry more likely to capsize or raised the ship's center of gravity. The Ministry of Oceans and Fisheries announced in late April that it would ask lawmakers to consider legislation prohibiting modifications to ships to increase passenger capacity. The government plans to take away the company's licenses for all it's routes, including the one on which the Sewol sank, according to an official at the ministry (CNN, 2014).

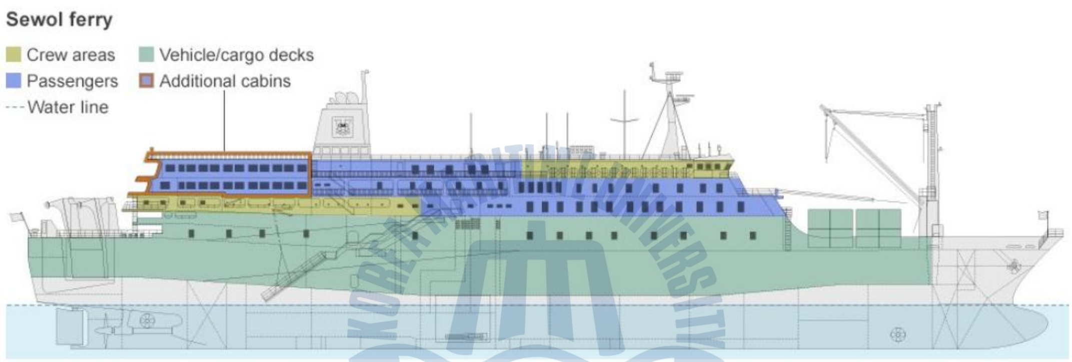


Fig. 2-2 The Sewol's blueprint

2.3.4 Sewol ferry disasters problems

When viewed by examining the cause of the accident, which is above suspected factors, the accident prevention lack of activities and human negligence is determined to be the main cause.

In particular, not properly secured cargo, overloaded, delays on notifying proper authorities of the accident and captain abandoned ship while passengers were told not to move such main suspected factors are sufficiently prevent or reduce the accidents to a minimum at the stage of prevention activity, is a pity in that could be so as not to occur.

Chapter 3. Marine accident prevention sector & statistical organization

3.1 Marine accident prevention sector

Numerous countries have gone to great lengths to innovate road traffic safety policies. A policy known as "3E" has been implemented in many countries including the United States and Europe. The 3E policy is separated into three major areas: Education, Engineering, and Enforcement. Firstly, traffic safety education and public relations are used to introduce innovative new safety campaigns. Secondly, traffic safety workshops and engineering facilities are used to provide arenas for further development of the program. Thirdly, traffic enforcement is used as a means of combatting rogue offenders (Kang & Bae, 2011).

Representative examples of the 3E policy are known as traffic calming. Traffic calming consists of the physical design of roadways and other measures including narrowed traffic patterns and speed bumps. These tactics are put in place on roads with the intention of slowing down or reducing motor-vehicle traffic to improve the safety for pedestrians and cyclists. Traffic engineers using the 3E policy, use education in reducing speed limits near institutions such as schools and hospitals, and publicity campaigns with targeted road user training. Engineering tactics are then implemented including narrowed traffic lanes, curb extensions, speed bumps, speed cushions, and the blocking or restricted access to facilities. Finally, the enforcement campaign utilizes law enforcement to set up speed cameras, vehicle activated signs, or traffic lights triggered by traffic exceeding a preset speed threshold (Wikipedia, 2014b).

In Korea, the National Policy on Road Safety is divided into a similar 3E fashion. Korea conducted ongoing research to develop the policy in the area of road safety. The policies have been implemented and major changes have been decided upon using the 3E strategy (KEC, 2009). In order to utilize the widespread reduction of accidents, 3E is considered an objective method that is widely used in the field of ground transportation.

In addition to considering the specific nature of maritime education, maritime engineering, and maritime enforcement within our globalized world, sensitivity to the specificity of maritime educational information is essential (KMA, 2013). The parameters of ideal flow, port information, and shipping traffic is of paramount importance for collection, processing, transmission, and decision making purposes (MLTM, 2010). The above characteristics combined with marine engineering activities and maritime law enforcement can allow rapid changes to the dismal state of safety standards in Korea (Lee & Jeong, 2012). Consequently, the Korean marine accident preventative sectors set four viable parameters including: Education, Engineering, Enforcement and Information.

3.2 Utilized statistical data

Statistics of marine accidents not only infer preventive factors but also find the causes and provide valuable clues to establishing preventive measures. Taking place over the course of five years, from 2009 to 2013, the program developed the relationship between the causes and the prevention of accidents. The program used the analysis of marine accident statistics and marine safety investigations by the Korea Maritime Tribunal in over 1,348 cases. The verdicts by KMST provide an objective administrative document that has legal force to show the transparent results of marine accident investigations. The causes of accidents are determined by multiple objective angles and highly professional analysis.

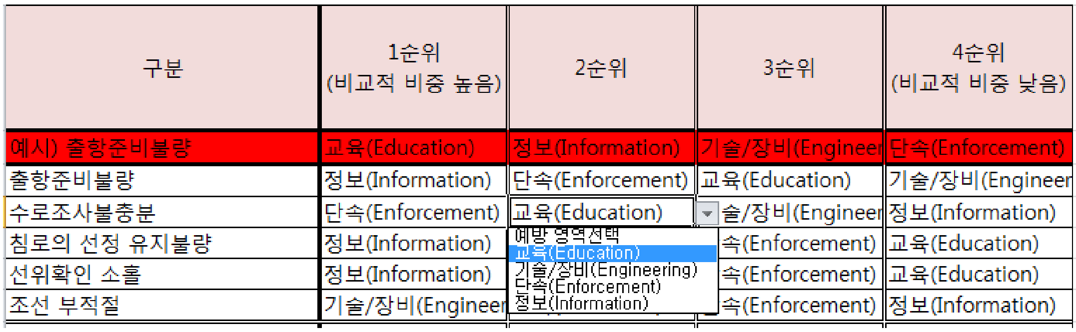
3.3 Statistical data organize

3.3.1 Classification of cause of marine accident by prevention sector (3EI)

The classification created by KMST marine accident statistics include 22 different prevention sector types of marine accidents. Advanced ship operators consisting of professors and expert officers included twelve people. The group conducted an plenary session for discussion. After a brain-storming phase, the group used a questionnaire designed to classify the causes of marine accidents by prevention sector methods. Twelve were examined, and then their details were analyzed for results shown in Fig. 3-1. According to analysis: the Education prevention sector data included 8 causes, the Engineering prevention sector data included five causes, the Enforcement prevention sector data included five causes, and the Information prevention sector data included five causes and Other included one cause as shown in Table 3-1.

Table 3-1. Classification of causes of marine accidents by prevention sector(3EI)

Division	Main cause of accident	No. of selected response				Results
		Edu.	Eng.	Enf.	Info.	
A	Poor departure preparation	**9**	1	1	1	Edu.
B	Inferior fairway research	3	1	1	**7**	Info.
C	Inferiority of selected course	**8**	1	1	2	Edu.
D	Unidentified ship position	**7**	2	2	1	Edu.
E	Hazardous ship maneuvering	2	**9**	0	1	Eng.
F	Neglectful watch-keeping	**10**	0	1	1	Edu.
G	Poor bad weather preparation & response	**8**	0	2	2	Edu.
H	Poor anchoring	**7**	2	1	2	Edu.
I	Violation of navigation rules	1	0	**11**	0	Enf.
J	Poor duty control	2	0	**10**	0	Enf.
K	Neglect to keep watch	**9**	1	2	0	Edu.
L	Operational fault (Other)	2	2	1	**7**	Info.
M	Ignorance of safety rules	2	0	**10**	0	Enf.
N	Poor hull and engine equipment	2	**9**	1	0	Eng.
O	Inferior repair of engine equipment	**6**	4	2	0	Edu.
P	Inferiority of fire and electrical wire	3	**7**	2	0	Eng.
Q	Neglect of cargo and passengers	3	**6**	2	1	Eng.
R	Neglect of shipping service control	3	1	**7**	1	Enf.
S	Neglect of on-board crews	2	0	**10**	0	Enf.
T	Neglect of aids to navigation	2	**8**	0	2	Eng.
U	Neglect of meteorological conditions	1	0	0	**11**	Info.



구분	1순위 (비교적 비중 높음)	2순위	3순위	4순위 (비교적 비중 낮음)
예시) 출항준비불량	교육(Education)	정보(Information)	기술/장비(Engineer	단속(Enforcement)
출항준비불량	정보(Information)	단속(Enforcement)	교육(Education)	기술/장비(Engineer
수로조사불충분	단속(Enforcement)	교육(Education)	술/장비(Engineer	정보(Information)
침로의 선정 유지불량	정보(Information)	예방 영역선택 교육(Education) 기술/장비(Engineering) 단속(Enforcement) 정보(Information)	속(Enforcement)	교육(Education)
선위확인 소홀	정보(Information)		속(Enforcement)	교육(Education)
조선 부적절	기술/장비(Engineer		속(Enforcement)	정보(Information)

Fig. 3-1 Example of questionnaire response result screen

3.3.2 Prevention sector organization

Table 3-2. Statistical data organized according to prevention sector

Prevention Sector	Main cause of accident	Cases		Ratio (%)	
Education (8causes, 36%)	Poor departure preparation	5	867	0.4	64.5
	Poor preparation of selected course	8		0.6	
	Unidentified ship position	50		3.7	
	Neglected watch-keeping	652		48.5	
	Poor bad weather preparation & response	53		3.9	
	Poor anchoring	2		0.1	
	Neglect to keep watch	19		1.4	
	Inferiority repair of engine equipment	78		5.9	
Engineering (5causes, 23%)	Hazardous ship maneuvering	80	161	5.8	11.7
	Inferior repair of engine equipment	30		2.2	
	Inferior fire and electrical wire	34		2.5	
	Neglect of cargo and passengers	15		1.1	
	Neglect of aids to navigation	2		0.1	
Enforcement (5causes, 23%)	Violation of navigation rules	161	242	12	18
	Poor duty control	3		0.2	
	Neglect of safety rules	70		5.2	
	Neglect of shipping service control	8		0.6	
	Neglect of on-board crews	0		0	
Information (3causes, 14%)	Inferiority of fairway research	3	78	0.2	5.8
	Operational fault (Other)	47		14	
	Neglect of meteorological conditions	28		2.1	

Table 3-2 shows statistical data organized according to the prevention sector and substituted for each main cause of accident 1,348 cases. These cases are KMST 2009~2013 main cause of each verdicts Looking at the ratio of each prevention sector, education accounts for 64.5%. Preventive education actions can stop marine accidents. Education was followed by enforcement prevention sectors at 18%, engineering prevention sectors at 11.7%, and information prevention sectors at 5.8%. The organized results show that most of the domestic marine accidents are caused by human error such as the lack of education. In order to augment prevention activities there should be ample opportunities amongst crew members to promote education, public relations, and develop the teamwork of the crew.

Chapter 4. Definition of Prevention Index & Grade of Marine Accidents

4.1 Concept of index

4.1.1 Definition of index

Statistical measurements are often used to gauge changes in economic and securities markets. In the case of financial markets, an index is a portfolio of securities representing a particular market or a portion of it. Each index has its own calculation methodology and is usually expressed in terms of change from a base value. Thus, the percentage of change is more important than the actual numeric value (INVESTOPEDIA, 2014).

4.1.2 An Example of traffic safety index

As mentioned above in 4.1.1, a variety of fields have introduced the concept of index use and it provides the quantification of specific targets on the scale. The evaluation of traffic safety index data, both domestically and overseas, is a profound method to determine the merits of using the index system for maritime safety.

(1) Traffic safety evaluation index in Korea

Section 29 of the traffic safety article provides an evaluation method useful for index standards. If the operator of a vehicle exceeds the index standards then the results can forecast the potential for a particular index rating (KMGL, 2014).

$$(Traffic\,safety\,evaluation\,index) = \frac{(No.\,of\,accident \times 0.4) + (No.\,of\,accident\,casualties \times 0.6) \times 10}{(No.\,of\,registered\,operating\,cars)} \tag{4-1}$$

Equation 4-1 shows the traffic safety evaluation index calculations. Accidents are based on the previous year and accident casualties are divided by death, serious injury, and slight injury. The number of traffic accidents and casualties can be estimated on slight injury accidents with 0.3 cases, serious injury accidents with 0.7 cases, and accidents causing death with 1 case. If several people suffered death or injury in an accident, the most highly weighted accident applied.

(2) Traffic culture index in Korea

In section 57 of the traffic safety act article, the index shows high levels of safety conscious driving which objectively measures the levels of Korean traffic culture. The research topics for the traffic culture index include: driving behavior, road safety, and pedestrian behavior. Detailed research topics are crosswalk stop line compliance rates, fastened seat belt rates, speed limit compliance rates, signal violation rates, the number of accident casualties, the number of pedestrian casualties, the number of accidents, the number of hit and run accidents, pedestrian environment, public transportation satisfaction, and illegally parked vehicles (KMGL, 2014).

As quantified by an index of 100, the research topics were surveyed by local authorities. Therefore, it is possible to determine the level of traffic safety and awareness in a local understanding through the traffic culture index.

(3) Air transportation culture index in Korea

The main purpose of this study is to develop an air transportation index capable of estimating approximate levels. Generally speaking, air transportation culture, a compound word of 'air transportation' and 'culture', is a substantial entity consisting of knowledge, morality, legality, cultivation, and customs which originate in the aviation sector. The aviation sector encompasses flight operation, airport operation and management, and passengers. They are classified in a primary scope, as the aircraft operation sector relates to flight operation, airport operation, and how management relate to passengers (Lee, 2005).

$$\sum_{i=1}^{n}(X_i - \min_i) \times 100 \times \frac{W_i}{\max_i - \min_i} \qquad (4\text{-}2)$$

Equation 4-2 shows the air transportation culture index calculations. X_i signifies each sectors point, $\min_i$ represents each sectors minimum point, $\max_i$ shows each sectors maximum point, W_i represents each sectors weight, and n denotes the number of sectors.

(4) Traffic safety culture index in the United states of America

This index is similar to the Traffic culture index in Korea. Since 2006, the AAA foundation for traffic safety has been sponsoring research to better understand traffic safety. The foundation's long-term vision is to create a "social climate in which traffic safety is highly valued and rigorously pursued." In 2008, the AAA foundation conducted the first annual Traffic Safety Culture Index, a nationally representative survey, to begin to assess a few key indicators of the degree to which traffic safety is valued and is being pursed (AAA Foundation, 2012).

The detailed research of topics are: personal exposure to crashes, drinking and driving, cell phone use and texting, speeding, the running of red lights, driving while drowsy, seatbelts, and helmets. The data reported was collected by AAA was a web-enabled, nationally-representative, probability-based survey of U.S. residents 16 years of age and older by GfK[1] for the AAA foundation.

(5) The Personal Security Index of Safety on the Road in Canada

The Personal Security Index consists of national social economy, health, physical safety, and security sectors. The health security sector is used to monitor the safety of Canada's motor vehicle crash victim rates. They analyze the number of motor vehicle injuries by year and include the number of motor vehicle injuries by age group. Such various traffic safety index contributions build a safe society by showing quantitative data.

4.1.3 The Advantage of the index

The index focuses on safety grade classifications by semi quantitative methods. The following three are the advantages of indexes (Chung et al., 2008).

(1) Multiattribute & Multicriteria evaluation

The most effective decisions make complex systems simple but firm models through multiattribute and multicriteria evaluations. Risk index facilitates evaluations that are reflected in various hazards or risks including: assessment plans, the reduction of information technology costs, the determination of priority, and the use of technology.

1) GfK : Market research specialty company[http://www.gfk.com]

(2) Simplicity

In the process of selecting the proper prevention sector, removing improper data assessments and the reduction of cost by the coordination of qualitative properties can be carried out to compare predictions quickly and simply.

(3) Practicability

Risk index is relative to absolute risk and based on comparable risk. Relative risk can be used to check various populations relative to risk by using practical alternatives.

When introduced into the marine accident prevention field, index contributes to the substantial reduction of marine accidents as well as performance-based prevention activities. These activities build an autonomous marine safety conscious culture.

4.2 Advantage of Grading system

According to McComick, from a 2014 study, a pass or fail grading system is an accurate ranking of success. This type of grading system has been shown to have several advantages.

(1) Less stress : Subjects in a traditional grading systems often experience stress to perform exceptionally well on tests, papers, and other assignments. When they receive only a pass or fail grade, they do not gave to worry about their grade point average, which causes less perceived stress.

(2) Group cohesion : Under a pass or fail grading system, subjects do not see other subjects as competition. Competition among subjects makes

subjects less likely to work together. In a pass or fail system, subjects can freely work with other students.

(3) More academic risks : Some subjects will avoid subjects that they may not excel in because they are afraid that a bad grade will negatively affect their grade point average. Under a pass or fail system, students feel safer trying new things and may be more willing to take academic risk.

(4) Fairness : Under a pass or fail grading system subjects know that if they complete the work in a satisfactory manner, they can pass many forms of tests.

By utilizing the strengths and weaknesses of this grading system, it is applicable to the study of PIMA and PGMA.

4.3 Definition of PIMA & PGMA

4.3.1 Definition of PIMA

PIMA or the Prevention Index of Marine Accident allows for the quantifiable evaluation of marine accident prevention activities. PIMA is varied according to the degree of prevention activities and has value of 0 to 100. The high value of PIMA shows greater prevention activities than the lower values.

4.3.2 Definition of PGMA

PGMA or the Prevention Grade of Marine Accidents is based on PIMA values. PIMA values are divided at regular intervals to determine the grade of prevention activities in 'A~D' resulting in four applicable grades. An "A" grade denotes the highest prevention activities and a grade of "D" represents the lowest of prevention activities.

4.4 Concept of prevention index based on marine accidents statistics

The study of traffic accident statistics allows researchers to identify the symptoms and problems associated with traffic accidents. Moreover, accident prevention policy decisions, execution, and evaluations take advantage of accident statistics to provide objective evidence for researchers (Lee & Kim, 1955). As mentioned, accident statistics are a valuable resource for accident prevention, preparedness, and response based on statistical analysis and case studies. When analysis is looked at in reverse order it becomes possible to guess the prevention sectors and factors that will be evaluated for the prevention grade.

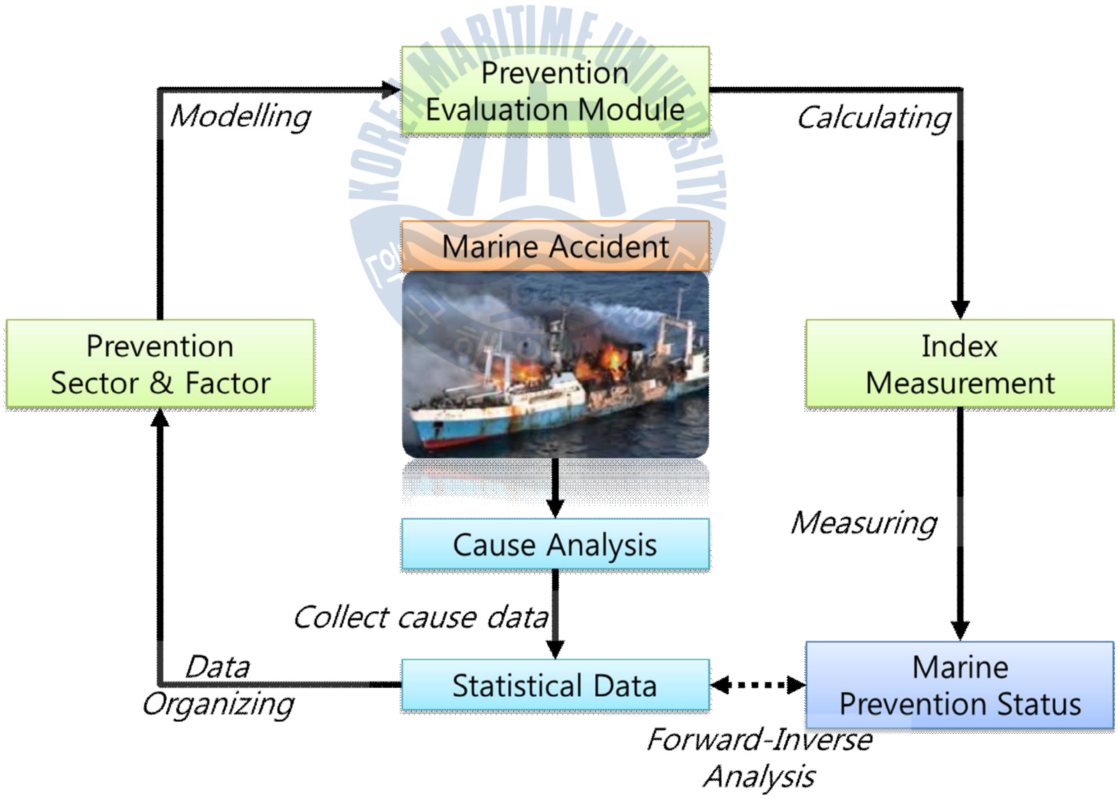


Fig. 4-1 The diagram to measure the prevention status of marine accidents by PIMA

As shown in Fig. 4-1, the marine statistics were created by researching the causes of marine accident investigation results. Using the organization of data, a prevention evaluation module was derived from the prevention sector & factor modelling. Consequently, the Created Prevention Evaluation Module calculates the index value and measurements through the index. This marine prevention status review uses statistical data with forward-inverse analysis.

PIMA was designed to develop a module that displays the status of marine accidents through the above process. PIMA is configured based on the statistics of marine accidents in the Korea. PIMA reflects the current state of Korea and it's safety education, safety engineering, safety enforcement, and safety information attributes. Therefore, a database of methods for preventing accidents matches information accurately related to Korea. PIMA utilizes prevention activities tailored to the prevention sector that is insufficient in each unique marine setting.

4.5 Method of PIMA & PGMA calculation

PIMA is described in terms of the sector value I_n and weight value in W_n. I_n is defined as a prevention sector and represents an evaluated value. W_n is a numerical value that reflects how this sector impacts prevention activities. Equation 4-1 shows an overview of the PIMA calculation.

$$(PIMA) = \sum_{n=1}^{4} (I_n \times W_n) \qquad (4\text{-}1)$$

In equation 4-1, n value shows 1 for the Education sector, 2 for the Engineering sector, 3 for the Enforcement sector, and 4 for the Information sector.

As shown in Equation 4-2 and Equation 4-3, the value of the prevention sector and the weight of the prevention sector consists of Education, Engineering, Enforcement and Information values.

$$I_n = (i_1, i_2, i_3, i_4) \quad (4\text{-}2)$$

$$W_n = (w_1, w_2, w_3, w_4) \quad (4\text{-}3)$$

Equation 4-2 values are the basis for the module created in chapter 4, and it is measured in chapter 5. The weight value of Equation 4-3 includes Education, Engineering, Enforcement, and Information, the value of the accident rate which was organized through marine accident statistics in Chapter 3 by Table 4-1 as 0.645, 0.117, 0.180, and 0.058.

Table 4-1. Weight of prevention sector

Prevention sector	Education (w_1)	Engineering (w_2)	Enforcement (w_3)	Information (w_4)
Weight value (W_n)	0.645	0.117	0.180	0.058

The PIMA value was based on the statistics of marine accidents in Korea and shows results from Equation 4-4.

$$(PIMA) = 0.645 \cdot i_1 + 0.117 \cdot i_2 + 0.180 \cdot i_3 + 0.058 \cdot i_4 \quad (4\text{-}4)$$

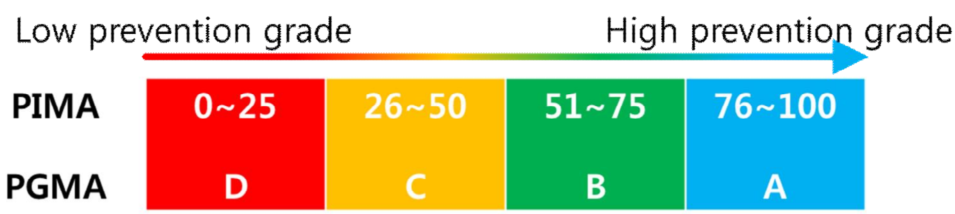


Fig. 4-2 Conceptual diagram of PIMA & PGMA

PGMA was created to augment reliability due to subtle variations of PIMA. An attempt was made to raise awareness and motivation of prevention activities by displaying the four tiered grade system which includes the standardized system of A(100~76), B(75~51), C(50~26), and D(25~0).

Chapter 5. Design of PIMA evaluation module

5.1 Composition of PIMA evaluation module

The PIMA evaluation module is highly quantifiable and objective. It enables continued prevention and management through self-assessment and the external accident prevention preparation of a ship. As shown Table 4-2, the Composition of the module is a Likert scale which incorporates factors of the primary prevention sectors including: Education, Engineering, Enforcement and Information to quantify the degree of prevention.

The PIMA evaluation module adopts the Likert scale. A Likert scale is a psychometric scale commonly involved in research that employs questionnaires. It is the most widely used approach to scaling responses in survey research, and is often used interchangeably with the phrase rating scale. Likert distinguished between a proper scale, which emerges from collective responses to a set of items, and the format in which responses are scored along a range. The difference between these two concepts has to do with the distinction Likert made between the underlying phenomenon being investigated and the means of capturing variation that points to the underlying phenomenon. When responding to a Likert questionnaire item, respondents specify their level of agreement or disagreement on a symmetric agree-disagree scale for a series of statements. Thus, the range captures the intensity of their feeling for a given item (Wikipedia, 2014c).

Table 4-2. Example of PIMA evaluation module

<table>
<tr><th colspan="10">Prevention Index of Marine Accident Evaluation Module</th></tr>
<tr><td colspan="10">Ship name: Date: Assessor: int./ext assessment</td></tr>
<tr><td>Prevention sector</td><td colspan="4">Prevention factor</td><td>Evaluation item</td><td colspan="5">Likert scale</td></tr>
<tr><td rowspan="12">i_1
(Education)</td><td colspan="4" rowspan="5">Factor. 1-1</td><td>item. 1-1-1</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>item. 1-1-2</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>item. 1-1-3</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>item. 1-1-4</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>item. 1-1-5</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="4" rowspan="5">Factor. 1-2</td><td>item. 1-2-1</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
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<tr><td colspan="4">…</td><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
<tr><td>i_2</td><td colspan="4">Factor. 2-1</td><td>⋮</td><td>⋮</td><td>⋮</td><td>⋮</td><td>⋮</td><td>⋮</td></tr>
<tr><td rowspan="2">i_4</td><td colspan="4">⋮</td><td>⋮</td><td>⋮</td><td>⋮</td><td>⋮</td><td>⋮</td><td>⋮</td></tr>
<tr><td colspan="4">Factor. 4-4</td><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
<tr><td rowspan="2">PIMA</td><td colspan="4" rowspan="2">92</td><td>$i_1 \cdot w_1$</td><td colspan="5">64</td></tr>
<tr><td>$i_2 \cdot w_2$</td><td colspan="5">11</td></tr>
<tr><td rowspan="2">PGMA</td><td rowspan="2">A</td><td rowspan="2">B</td><td rowspan="2">C</td><td rowspan="2">D</td><td>$i_3 \cdot w_3$</td><td colspan="5">13</td></tr>
<tr><td>$i_4 \cdot w_4$</td><td colspan="5">4</td></tr>
</table>

To perform effective prevention activities tailored to assess specific sectors, targeted prevention scores are needed. This makes it possible to fuse data by making up for the weak points of the absolute evaluation recorded together in PIMA with PGMA factors.

5.2 Selection of prevention factor & assessment items

In order to properly select prevention factors and assessment items, the first analysis was used to search each prevention sectors for trends. Through the internet and literature research, results were tabulated for each prevention sector including evaluation items. To validate such organized evaluation prevention factors and assessment items, experts incorporated methods of pier review and group discussion. As in the first step, maritime experts examine whether the organized factors and items were properly selected. Four prevention factors were selected in each prevention sector by experts. Each of the prevention factors have 5 assessment items that were selected and used to evaluate the Likert scale by a question to quantify the status.

As for the organized evaluation modules, the categories of the marine accident prevention programs were classified into four prevention sectors such as: Education, Engineering, Enforcement and Information, including detailed evaluation factors and assessment items by sectors.

5.2.1 Education prevention sector

The Education prevention sector was created with reference to a study of the safety evaluation indexes of industrial education programs in a 2007 thesis by Oh. This thesis developed four evaluation categories including pre-evaluation, education personnel and organizations, education environment, and regulations. Each evaluation category has detailed indicators which are pier reviewed by groups of experts.

For the Education prevention sector, twenty assessment items were organized into four prevention factors such as education systems and resources, education programs, training programs, and evaluations. The education system and resources include: 'equipped with a safety education plan and procedures', 'training according to the education plan', 'equipped with a tools and materials' and 'whether there is a passion for education by the captain or chief engineer'. The education program includes: 'safety program planning according to the characteristics of the work', 'graded educational program', 'education assistance to prevent accidents', 'faithful answers to the questions' and 'education programs are been continuously updated'. The training program includes: 'safety program planning according to the characteristics of the work', 'graded training program', 'training help to prevent accidents', 'faithful answers to the questions' and 'training programs have been continuously updated'. The evaluation program includes: 'actively participates in education or training', 'satisfied with education or training', 'evaluations performed', 'continuous evaluation results and feedback' and 'provides incentives based on results'.

5.2.2 Engineering prevention sector

The Engineering prevention sector was a thesis written by Catherine et. al., in 2006. This thesis was used to identify research articles on human errors in shipping by using the following search terms : maritime, shipping, stress, fatigue, situation awareness, decision making, communication, teamwork, safety, and shipping/maritime accidents. The engineering prevention sector brain-stormed and organized each of the assessment items.

For the engineering prevention sector, twenty assessment items were organized into 4 prevention factors such as: configuration, maintenance, operating, and management. The configuration included: 'bridge material resources for safe navigation are equipped', 'engine room material resources for safe navigation are equipped', 'material resources for seaworthiness are equipped', 'material resources for emergency response are equipped' and 'corresponding systems with outside assistance are operated'. The maintenance criteria included: 'resource maintenance repair plan developed', 'maintenance repair is done on the basis of the plan', 'owns the technology required to maintain and repair', 'supplies required to carry out maintenance and repair' and 'possesses external support systems for maintenance and repair'. Operating includes: 'familiar with the use of equipment and systems for safe navigation', 'use of equipment and systems in accordance with the manual', 'equipment and system operation check', 'equipment and system updating' and 'possesses equipment and system backup device during failure'. Management includes: 'use of a daily log for equipment and systems', 'appropriate replacement of the latest equipment and systems', 'measurement of errors on the system used periodically on major equipment', 'limitations of major equipment and systems' and 'equipped with major equipment and system manuals'.

5.2.3 Enforcement prevention sector

The Enforcement prevention sector was created with reference to the study of regulations and enforcement on safety in a thesis by DNV in 2011. This thesis shows the methodology of marine safety. It consists of investigative processes, site preparation, material evaluation, and damage assessments. These were brain-stormed by groups of experts.

For the enforcement prevention sector, twenty assessment items were organized into four prevention factors such as: regulation, examination, direction, and enforcement. The regulation included: 'following the Convention on the International Regulations for Preventing Collisions at Sea (COLREG)', 'following watch-keeping regulations', 'following the Safety of Life at Sea

(SOLAS)', 'following labor standard laws', and 'following the open port act'. The examination includes: 'getting regular examinations', 'the request of an examination if necessary', 'error factors at Port State Control(PSC)', 'error factors in the examination of the institution' and 'findings of the examination to improve quickly'. The direction includes: 'direction of the ship complies with regulations', 'direction of the company complies with regulations', 'ship provides direction processes', 'the company provides direction processes' and 'direction result feedback'. The enforcement includes: 'safe operation enforcement by the Coast guard', 'regulatory enforcement by authorities', 'procedure for reporting violations', 'impact of enforcement authorities' and 'improvement of enforcement requirements'.

5.2.4 Information prevention sector

The Information prevention sector was created with reference to studies on ship casualties in the marine environment in a thesis by Touvinen in 1984. This thesis uses information processes including data collection to evaluate of causal factors and their relationship.

For the information prevention sector, twenty assessment items were organized into four prevention factors such as a collection, provision, analysis and utilization. Collection included: 'collection of weather and sea status information', 'collection of port and passage status information', 'collection of surrounding marine traffic information', 'collection of sailing position, speed and course information' and 'collection of real-time information about accidents and dangerous environments'. Provision included: 'authorities constantly provide weather and sea status information', 'authorities constantly provide port and passage status information', 'provide real-time hazard information', 'provide necessary remote information', and 'provide a variety of ways such as voice, text, and signal information'. The analysis includes: 'analysis of arrival and departure information', 'analysis of narrow channel information', 'analysis of anchoring information', 'analysis of coastal navigation information' and 'analysis of emergency response information'. Utilization includes: 'the utilization of search and rescue information', 'the utilization of vessel monitoring information', 'the utilization of collision prevention information', 'the utilization of emergency response information' and 'the utilization of risk reduction information'.

5.3 Utilization of evaluation modules

Utilization of evaluation modules makes it is possible to easily determine the prevention factor and prevention sector. At the ship level, it is possible to diagnose the prevention of autonomous activities. At the company level, it may be helpful information for the distribution of resources and determining effective cost.

Even at the government level, it is possible to take advantage of the evaluation module for prevention activities and certification systems introduced for the reduction of ship accidents. By changing the weight coefficient and the evaluation group for the evaluation module, other marine fields including beaches and water leisure resorts can also can be used as a network for safety management.

Chapter 6. Measurement & Application of PIMA

6.1 Measurement method & subject

For the study, the evaluation module was used to be able to reflect the nature of accidents that occurred in Korea, using the analysis of domestic ships. A total of 50 people including captains and officers with a limit of ten coastal cargo ships, ten coastal passenger ships, ten coastal tanker ships, ten coastal tugboats, ten coastal fishing vessels were engaged to be measured. To raise the response rate of the evaluation module, measurement was conducted by a private evaluator. The measurements were completed from July to October in 2013 and from March to April in 2014 by distributing the evaluation module on-site or by e-mail.

Fig. 6-1 Picture of the on-site measurement

6.2 Result of Measurement

6.2.1 Coastal Cargo ships

Figure 6-2 shows the results of the measurement of a coastal cargo ship with PIMA by 6.1 using ten coastal cargo ships. The average value of prevention sector results were education at 45.89/64.50, engineering at 8.25/11.70, enforcement at 11.97/18.00, and information at 4.06/5.80. The total PIMA is 70.16/100. Each of the prevention sectors used transformed percentage scoring. Education was 71.1/100, engineering was 70.5/100, enforcement was 66.5/100, and information was 70.0/100. When looking at the results, the sector with a relatively high prevention state is the education sector at 71.1. However, the sector showing a low prevention state is the enforcement sector at 66.5.

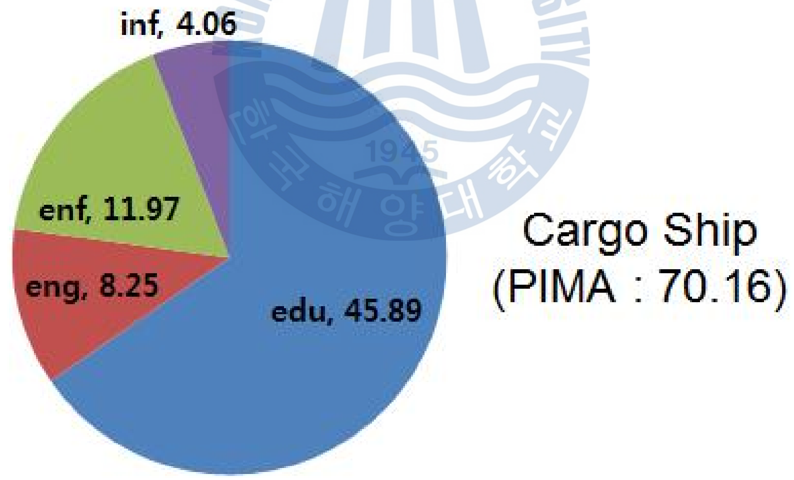

Fig. 6-2 Results of Measurement (Coastal cargo ships)

6.2.2 Coastal passenger ships

Figure 6-3 shows the results of the measurement of coastal passenger ships using PIMA in 6.1 with ten coastal passenger ships. The average value of the prevention sector for education was 48.10/64.50, engineering at 8.81/11.70, enforcement at 12.42/18.00, information at 4.47/5.80. The total PIMA score was 73.80/100. Each of the prevention sectors used transformed percentage scoring. Education was 74.6/100, engineering was 75.3/100, enforcement was 69.0/100 and information was 77.1/100. When looking at the results, the sector with a relatively high prevention state is the information sector at 77.1, and the sector showing a low prevention state is the enforcement sector at 69.0.

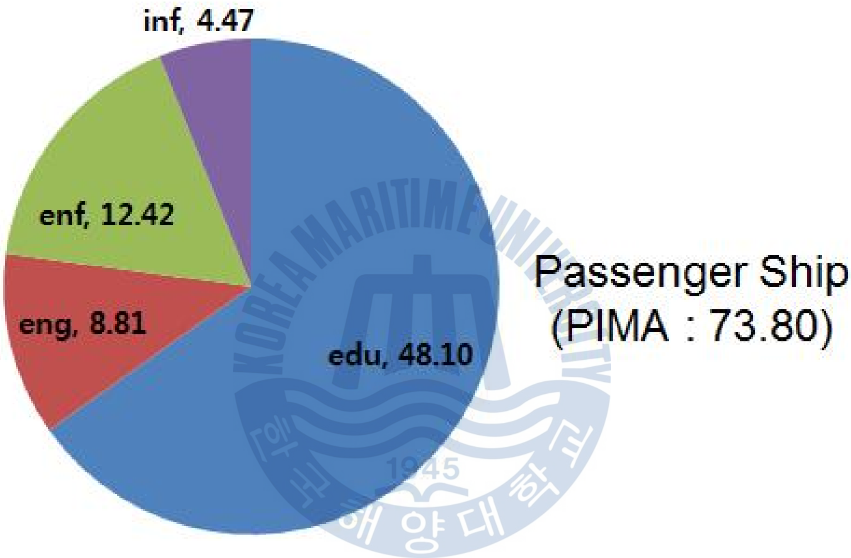

Fig. 6-3 Results of Measurement (Coastal passenger ships)

6.2.3 Coastal tanker ships

Figure 6-4. shows result of measurement of coastal tanker ships using PIMA in 6.1 for ten coastal tanker ships. The average value of the prevention sectors were education at 49.25/64.50, engineering at 8.91/11.70, enforcement at 12.87/18.00, information at 4.55/5.80. The total PIMA score was 75.58/100. Each prevention sector used transformed percentage scoring. Education was 76.4/100, engineering was 76.2/100, enforcement was 71.5/100 and information was 78.4/100. When looking at the results, the sector with a relatively high prevention state is the information sector at 78.4, the sector showing a low prevention state is the enforcement sector at 71.5.

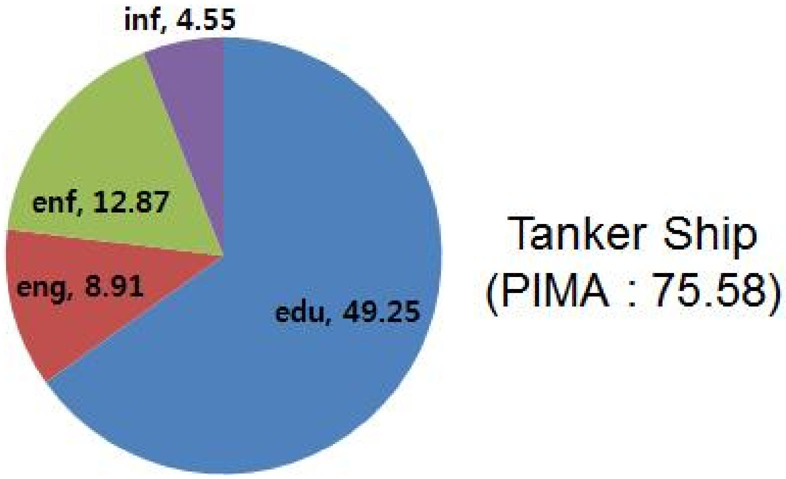

Fig. 6-4 Results of Measurement (Coastal tanker ships)

6.2.4 Coastal tugboats

Figure 6-5. shows result of the measurement of coastal tugboats PIMA by 6.1 with ten coastal tugboats. The average value of the prevention sector were education at 50.17/64.50, engineering at 9.01/11.70, enforcement at 13.76/18.00, information at 4.59/5.80. The total PIMA score was 77.53/100. Each prevention sector used transformed percentage scoring. Education was 77.8/100, engineering was 77.0/100, enforcement was 76.4/100 and information was 79.1/100. When looking at the results, the sector that has a relatively high prevention state is the information sector with 79.1, and the sector showing a low prevention state is the enforcement sector at 76.4.

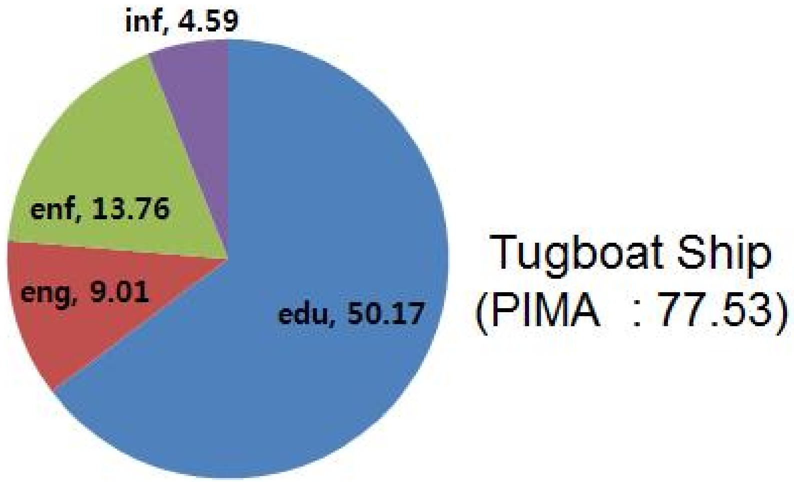

Fig. 6-5 Results of Measurement (Coastal tugboat)

6.2.5 Coastal fishing vessels

Figure 6-6 shows the results of measurements for coastal fishing vessels using PIMA in 6.1 with ten coastal fishing vessels. The average value of the prevention sector were education at 58.52/64.50, engineering at 9.44/11.70, enforcement at 15.00/18.00, and information at 4.70/5.80. The total PIMA score was 87.66/100. Each prevention sector used transformed percentage scoring. Education was 90.7/100, engineering was 80.7/100, enforcement was 83.3/100, and information was 81.0/100. When looking at the results, the sector with a relatively high prevention state was the education sector at 90.7. The sector showing a low prevention state was the engineering sector at 80.7.

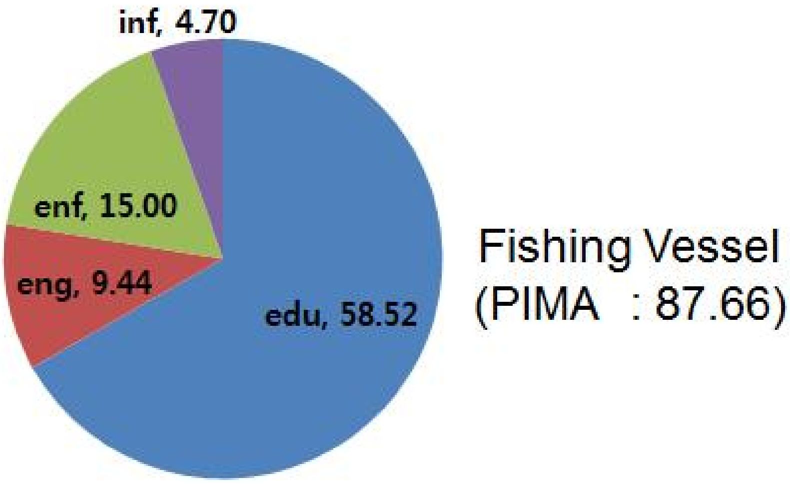

Fig. 6-6 Results of Measurement (Coastal fishing vessels)

6.2.6 Conclusion of the results of measurement

Looking at the average value of PIMA by the type of ship in order of highest to lowest included fishing vessels, tugboats, tanker ships, passenger ships, and cargo ships. When evaluating percentage scoring for each of the ship types it' s important to note that ships with a relatively high score have a lower enforcement sector.

Conversion of PIMA into PGMA average values for each type of ship, are shown in Fig. 6-7. The PGMA 'A' graded ship types are fishing vessels with a PIMA score of 87.66, tugboats with a PIMA score of 77.53, and tanker ships with a PIMA score of 75.58. PGMA 'B' graded ship types are passenger ships with a PIMA score of 73.80 and cargo ships with a PIMA score of 70.16.

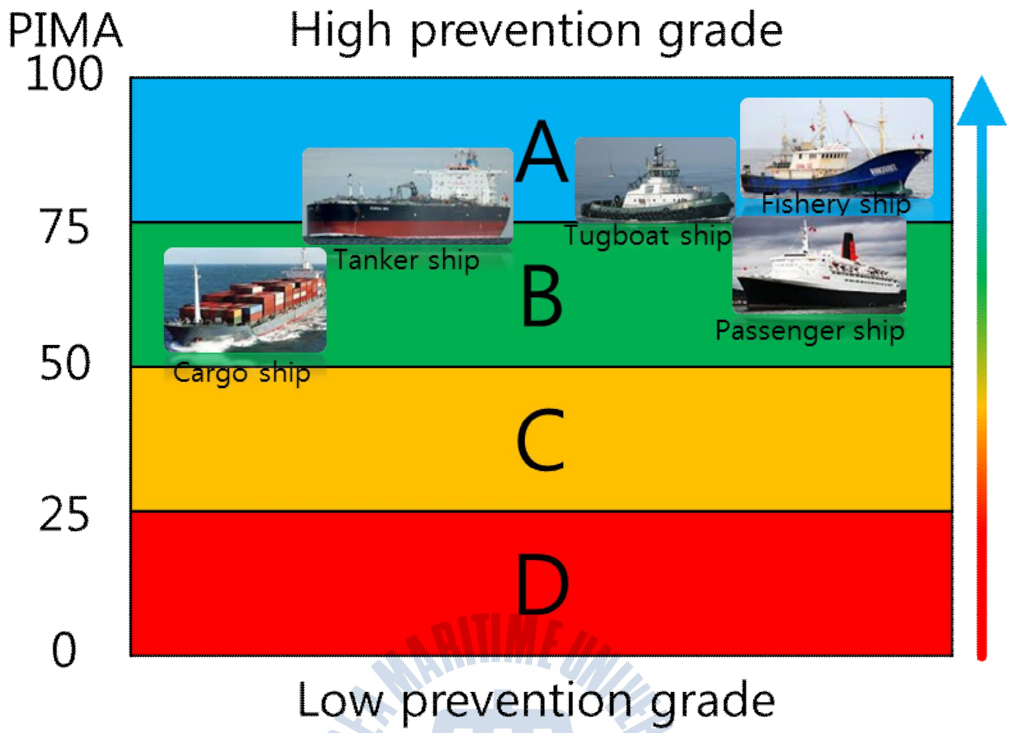

Fig. 6-7 Results of conversion from PIMA into PGMA

6.3 Statistical review of measured PIMA

Utilizing statistical data for the consideration of validity as an indicator to evaluation and prevention effects. Accident rates can be represented by the following Equation in 6-1.

$$(Accident\,Rate) = \frac{(Number\,of\,Marine\,accident)}{(Number\,of\,Registered\,ship)} \times 100 \qquad (6\text{-}1)$$

Fig. 6-8 shows the average rate of accidents for five years from 2009 to 2013 for cargo ships, passenger ships, tanker ships, tugboat ships and fishing vessels . Cargo ships show the highest accident rates.

Type of ship / Division	Passenger	Cargo	Tanker	Tugboat	Fishery
No. of ship registered(a)	212	808	728.4	1267	75269.4
No. of marine accident ships(b)	16.8	93	37	58.8	694.8
Marine accident rate(b/a)	7.92%	11.51%	5.08%	4.64%	0.92%

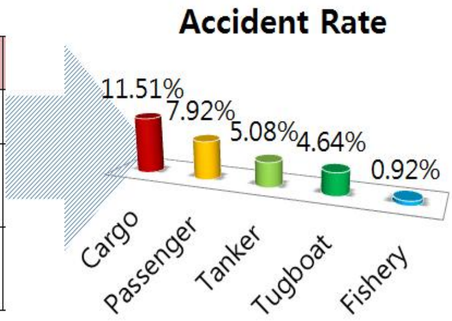

Fig. 6-8 Accident Rates by Ship type

The table(6-1) shows each ship type of PIMA and Accident rate values.

Table 6-1. PIMA & Accident Rate value by Ship type

x \ y	PIMA(y_{PIMA})	Accident Rate(y_{AR})
Cargo ships($x=1$)	70.16	11.51
Passenger ships($x=2$)	73.80	7.92
Tanker ships($x=3$)	75.58	5.08
Tugboat ships($x=4$)	77.53	4.64
fishing vessels($x=5$)	87.66	0.92

Convert to the equation in Table 6-1, to Equation 6-2, and Equation 6-3.

Switching bv substituting each ship of the type PIMA value quartic function, it is possible to check the score at a glance. Further, when differentiating the quartic function, and exhibits a ship type PIMA trend using the value of the gradient, are summarized the values.

$$y_{PIMA} = 0.2492x^4 - 2.1533x^3 - 5.9608x^2 - 2.3067x + 68.6100 \quad (6\text{-}2)$$

$$y_{AR} = -0.3054x^4 + 3.3292x^3 - 11.9646x^2 + 13.5808x + 6.8700 \quad (6\text{-}3)$$

These equations show PIMA and Accident Rate values but a differential shows a correlation between the function. The equation in 6-4 and 6-5 should be utilized.

$$y'_{PIMA} = 0.9968x^3 - 6.4599x^2 + 11.5216x - 2.3067 \quad (6\text{-}4)$$

$$y'_{AR} = -1.2216x^3 + 9.9876x^2 - 23.9292x + 13.5808 \quad (6\text{-}5)$$

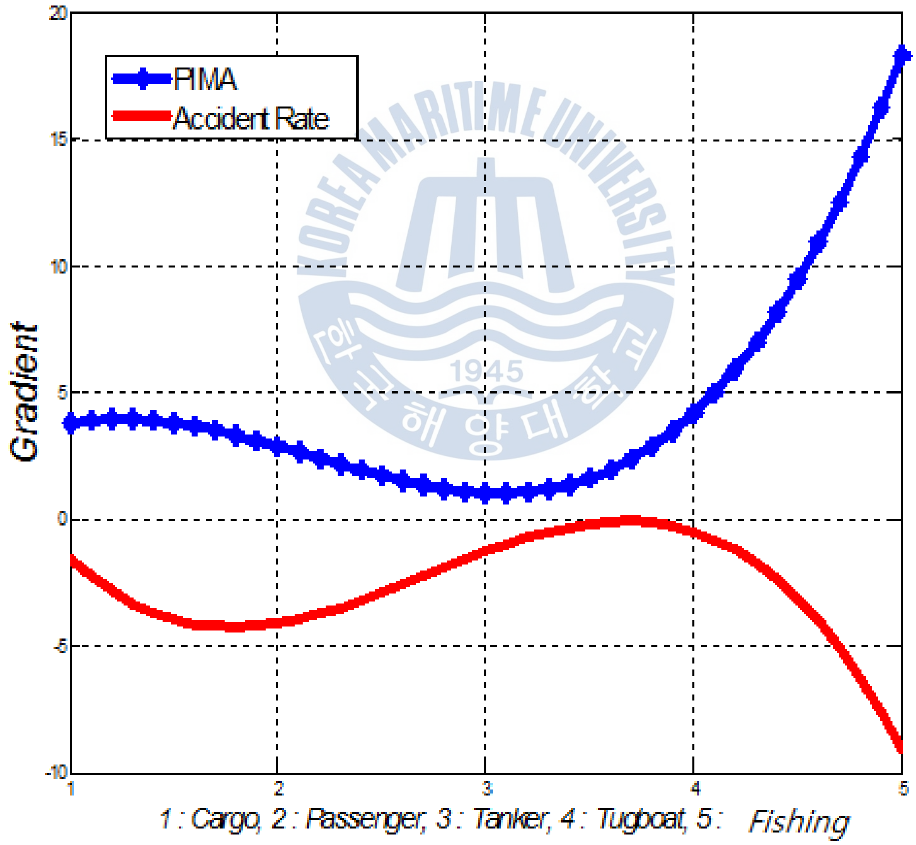

Fig. 6-9 Comparing accident rate gradients with PIMA gradients

The accident rate equation and PIMA equation show the results by ship type illustrating an inverse relationship. There were differences in the degree, but it was confirmed statistically to prevent a low accident rate by ship type with high PIMA values. PIMA displays the risk of accidents through the inter-comparison of accident rates.

6.4 Case review of measured PIMA

Case reviews are used to try to confirm that case studies used by PIMA have an effect in terms of the prevention of marine accidents. Of the accidents that have occurred in the past five years, by analyzing the fault tree analysis data, one must analyze the representative type of ship, and confirm it by utilizing the FTA. In case reviews, fault trees were removed by PIMA assessment items that have been derived from the Fault Tree Analysis (FTA) technique. As a result, it is possible to ascertain the extent by which the fault tree was removed to find the determined PIMA effects of prevention activities.

6.4.1 Fault Tree Analysis (FTA)

(1) History

FTA was originally developed in 1962 at Bell Laboratories by H.A. Watson, under a U.S. Air Force Ballistics System Division contract to evaluate the Minuteman International Ballistic Missile (ICBM) launch control system (Ericson, 1999). The use of fault trees has since gained widespread support and is often used as a failure analysis tool by reliability experts (Martensen, 2011). In the 1960s and 1970s, U.S. Military applications of FTA were for use with fuses. The U.S. Army material command incorporated FTA into an Engineering Design Handbook on Design for Reliability. In the 1980s and 1990s, the United States Department of Labor Occupational Safety and Health Administration (OSHA) published a standard Process Safety Management (PSM) by recognized

FTA data as an acceptable method for hazard analysis.

Today, FTA is widely used in system safety, reliability engineering, and in all major fields of engineering (Wikipedia, 2014d).

(2) Analysis process

Many different approaches can be used with FTA, but the most common and popular way can be summarized in a few processes. A single fault tree is used to analyse one and only one undesired event, which may be subsequently fed into another fault tree as a basic event. FTA analysis involves five brief steps (Wikipedia, 2014c).

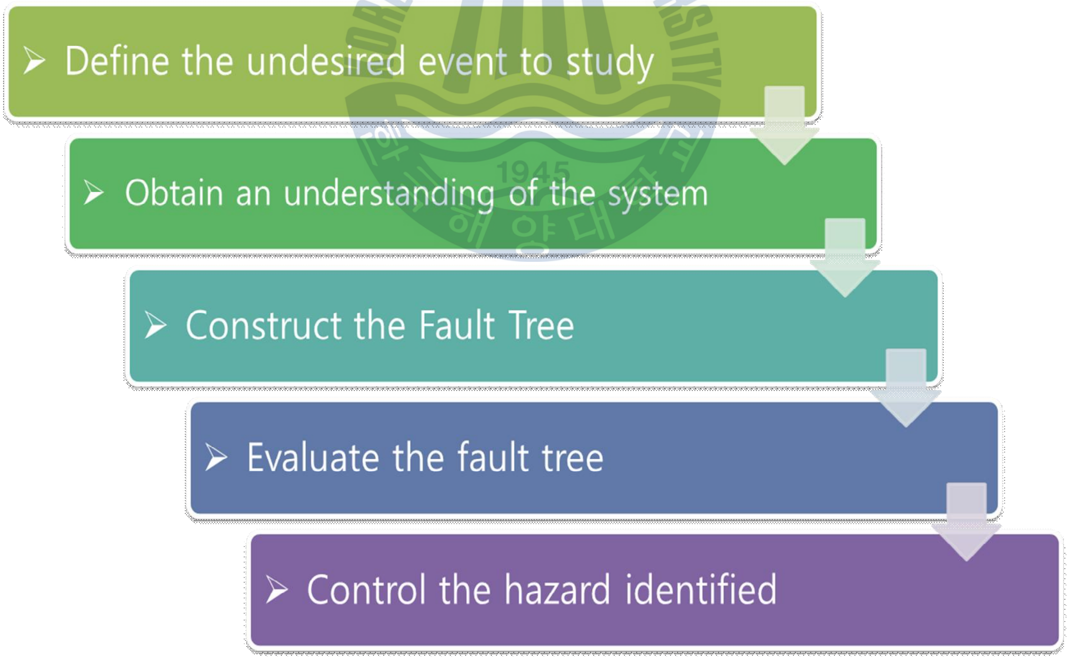

Fig. 6-10 Diagram of the FTA process

(3) Advantages of FTA

Through using FTA, analyzing the accident visually and with case studies for the possibility of accidents allows for prevention activities with the possibility of declining probabilities of occurrence.

The advantages of the FTA are as follows:

- Possible to easily investigate the cause of accidents with the creation of a Fault Tree and allows users to easily grasp the cause of the accident.

- Generalized analysis of the cause of the accident which can be seen at a glance in the fault tree.

- Analysis quantification of the accident cause using statistical processing, computer processing, and quantitative analysis of the causes of the accident by the FTA is possible.

- Through the reduction of time and effort it is possible to know results quickly and with high probability. Through the analysis of important causes it saves time and effort.

- It is possible to make a safety checklist by systematically organizing parts that focus on safety.

6.4.2 Fault Tree Analysis of Cargo ship

A Fault Tree was created by selecting the case of a cargo ship accident which occurred over the past five years. The case that was selected is the VEGA ROSE accident which was recorded in the Korea Maritime Tribunal, Donghae branch verdict No. 2012-001 and was classified based on the four prevention factors using FTA methods. The causes of the VEGA ROSE accident were described in the verdict. The results have been classified in Fig. 6-11.

The cause of the accident has been identified in the verdict over the

VEGA ROSE accident and is confirmed in the Fault Tree. The fault tree for the education sector has four faults, the engineering sector has four faults, the enforcement sector shows six faults, and the information sector reported three faults. Faults are specified in section 5.2 in the fault tree including: education, engineering, enforcement, and information factors.

Fault tree data cannot be deleted from the evaluation factors specified in section 5.2. One is included in each of the education, enforcement, engineering, and information factors. It is possible to erase fourteen faults with the exception of three unremovable faults forming a fault tree total of seventeen. Through the case analysis of the cargo ship there is a removal of 82% of the analyzed causes.

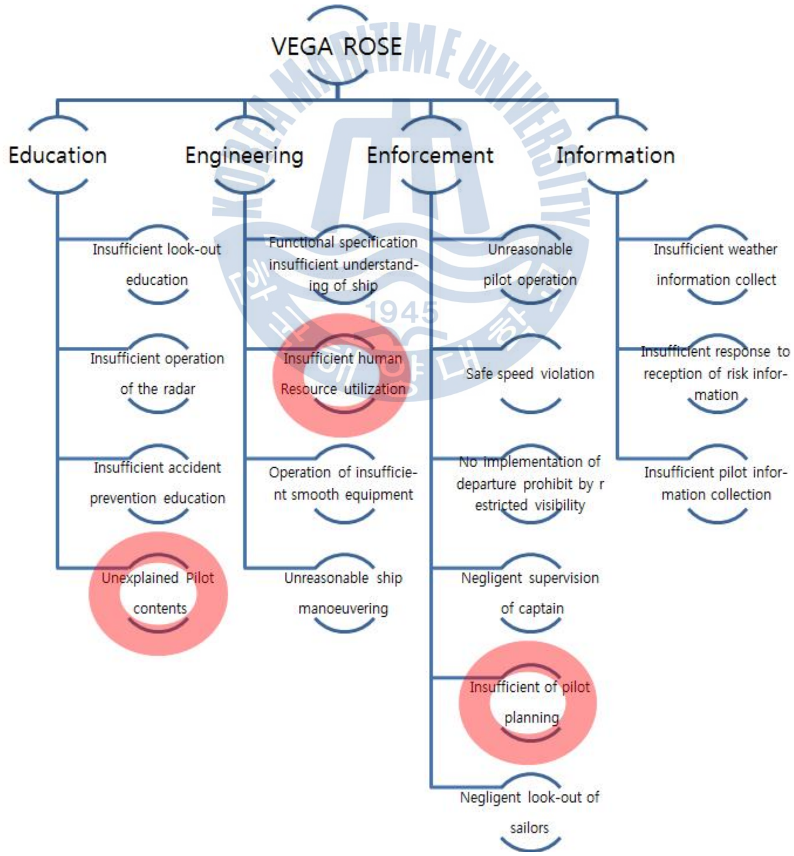

Fig. 6-11 Diagram of VEGA ROSE (Cargo ship) Fault tree

6.4.3 Fault Tree Analysis of Passenger ship

A Fault Tree was made by selecting the case of passenger ship accident from the accident cases over the past five years. The case selected was the Woo-Sung Ferry accident which was recorded in the Korea Maritime Tribunal, Donghae branch verdict No. 2012-015 and was classified based on the four prevention factors by using FTA methods. The the cause of Woo-sung Ferry accident was described in that verdict. The results that have been classified, are shown in Fig. 6-12.

The cause of the accident has been identified in the verdict of the Woo-Sung Ferry accident and is confirmed in the Fault Tree. The education sector consisted of five faults, the engineering sector had three faults, the enforcement sector had four faults, and the information sector also had four faults.

Fault tree data cannot be deleted from the evaluation factors specified in section 5.2. One is noted in the education and enforcement factors. It is possible to erase fifteen faults with the exception of three unremovable faults forming a fault tree total of seventeen. Through the case analysis of the passenger ship there is a removal of 88% of the analyzed causes.

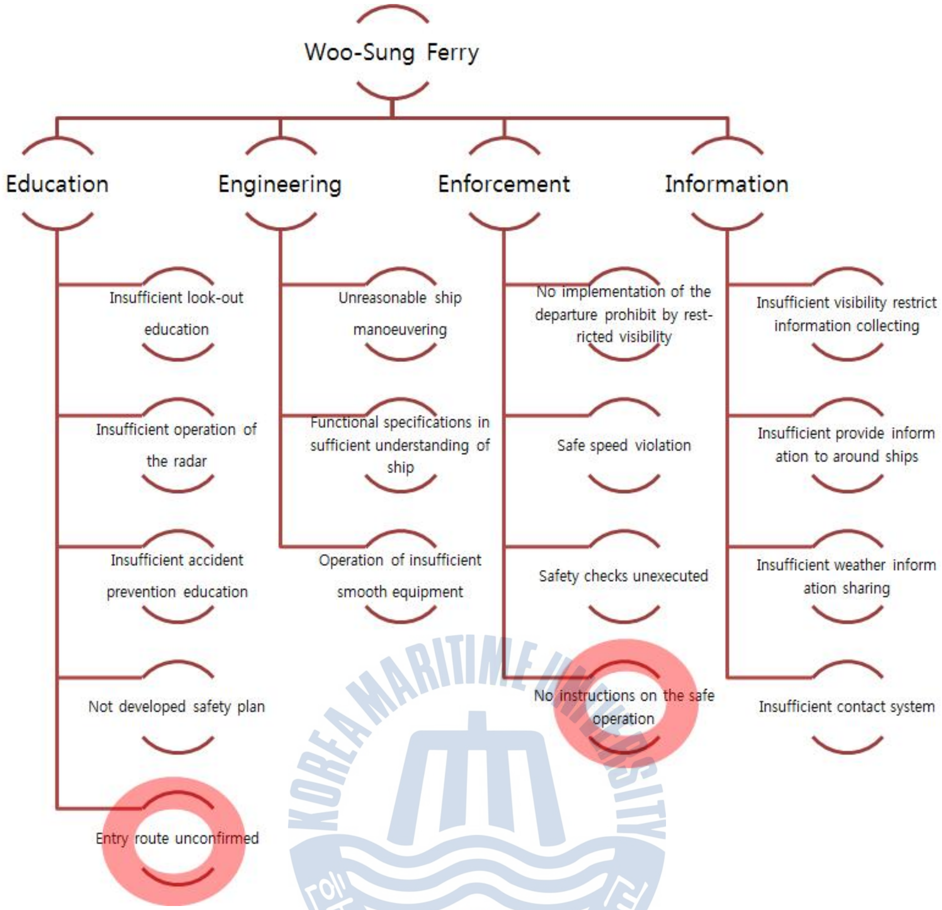

Fig. 6-12 Diagram of Woo-Sung Ferry(Passenger ship) Fault tree

6.4.4 Fault Tree Analysis of a Tanker ship

A Fault Tree was made by selecting the case of a tanker ship accident which occurred over the past five years. The case that was selected was the Sam-Young accident. It was recorded in the Korea Maritime Tribunal, Busan branch verdict No. 2013-041. It was classified based on the four prevention factors by using FTA methods. The cause of the Sam-Young accident is described in the verdict. The results have been classified and shown in Fig. 6-13.

The cause of the accident has been identified in the verdict of the Sam-Young accident, and is confirmed by the Fault Tree. The education sector consists of two faults, the engineering sector has three faults, the enforcement sector has two faults, and the information sector has one fault.

Fault tree data cannot be deleted from the evaluation factors specified in section 5.2. One is included for the information factor. It is possible to erase seven faults with the exception of three unremovable faults forming a fault tree total of eight. Through the case analysis of the tanker ship there is a removal of 87% of the analyzed causes.

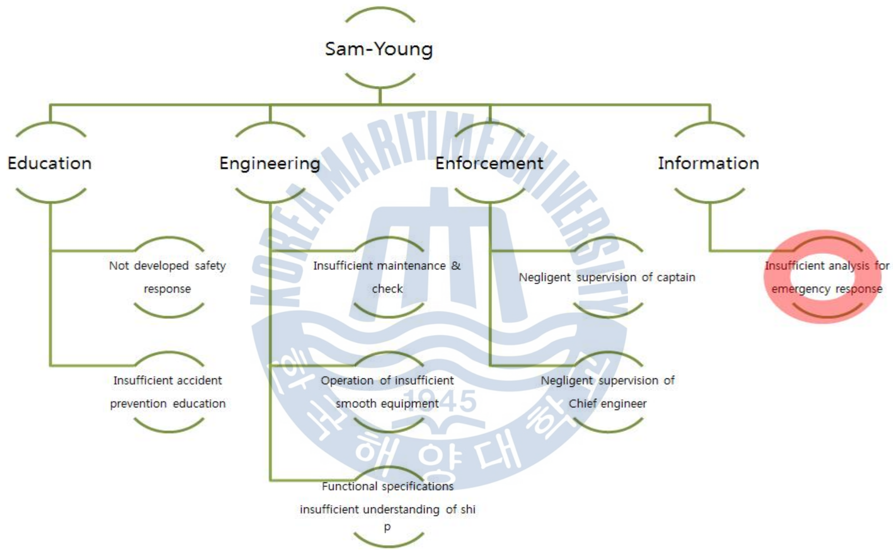

Fig. 6-13 Diagram of Sam-Young (Tanker ship) Fault tree

6.4.5 Fault Tree Analysis of a Tugboat

A Fault Tree was made by selecting the case of a Tugboat accident in the past five years. The case that was selected is the 303 Goryo accident which was recorded in the Korea Maritime Tribunal, Busan branch verdict No. 2010-052. It was classified based on the four prevention factors by using FTA methods. The cause of the 303 Goryo accident was described in the verdict. The results that have been classified, shown in Fig. 6-14.

The cause of the accident is confirmed in the Fault Tree. The education sector consists of four faults, the engineering sector has three faults, the enforcement sector has three faults, and the information sector has two faults.

Fault tree data cannot be deleted from the evaluation factors specified in section 5.2. One is included for the information factor and two in the enforcement factor. It is possible to erase nine faults with the exception of three unremovable faults forming a fault tree total of twelve. Through the case analysis of the tugboat there is a removal of 75% of the analyzed causes.

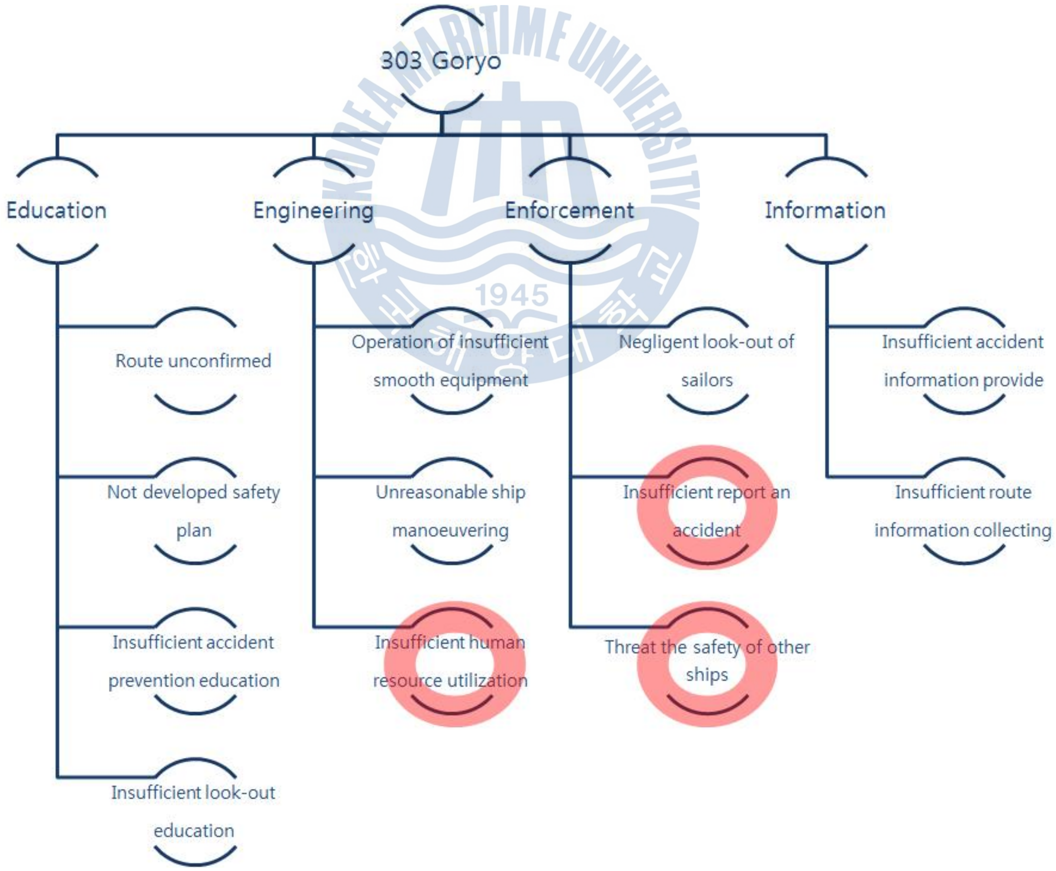

Fig. 6-14 Diagram of 303 Goryo (Tugboat) Fault tree

6.4.6 Fault Tree Analysis of a fishing vessel

A Fault Tree was made by selecting the case of an accident with a fishing vessel occurring over the past five years. Case that was selected is the Sung-Beok accident that was recorded in the Korea Maritime Tribunal, Incheon branch verdict No. 2012-015. It was classified based on the four prevention factors by using FTA methods. The cause of the Sung-Beok accident is described in the verdict. The results that have been classified, and shown in Fig. 6-15.

Fault tree data cannot be deleted from the evaluation factors specified in section 5.2. One is included in each of the education, enforcement and information factors and two in the engineering factor. It is possible to erase nine faults with the exception of three unremovable faults forming a fault tree total of fourteen. This confirms that through the case analysis of the fishing vessel there is a removal of 64% of the analyzed causes.

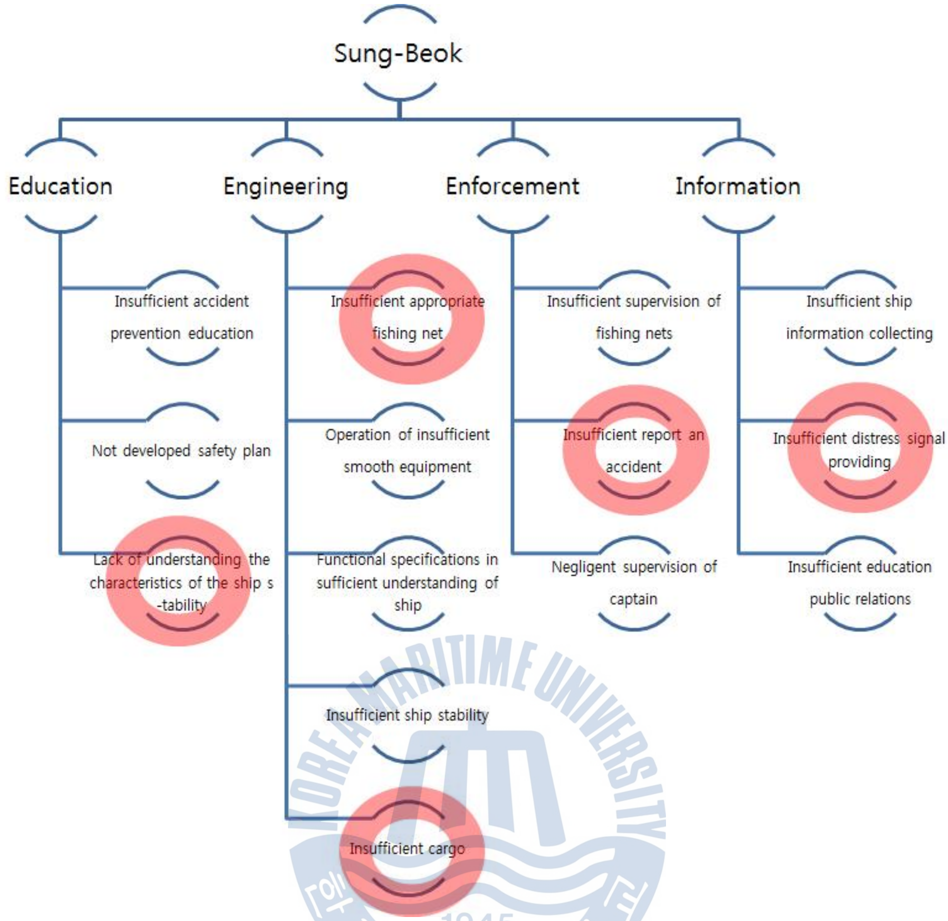

Fig. 6-15 Diagram of Sung-Beok (fishing vessel) Fault tree

6.4.7 Conclusion of case review

Table 6-2 shows the total results of representative accident cases and fault trees. Removal rates of all marine accidents by ship type in the fault tree showed a rate of 79% to that shown in the following Table 6-2. In particular, it showed a high removal rate for tankers and passenger ships. Confirming the removal rate in each prevention sector, education is the highest, while enforcement had lowest. It shows the fishing vessel was the lowest by fault removal rate for this type of ship. This result, in the case of the fishing vessel was thought to be due to accidents in which fishing vessels are categorized by complex and convoluted evaluation processes. Through a discussion of these processes, and potential future study and reasearch the type of ship and it's characteristics will be better matched to the design of the index evaluation method.

Table 6-2. Total result of Representative accident cases and fault tree

Case	Type	Edu.	Eng.	Enf.	Inf.	Total
		(Removed fault tree)/(Fault tree)				
VEGA ROSE (2012)	Cargo	3/4	3/4	5/6	3/3	14/17 82%
Woo-Sung (2012)	Passenger	4/5	3/3	3/4	4/4	14/16 88%
Sam-Sung (2013)	Tanker	2/2	3/3	2/2	0/1	7/8 87%
303 Goryo (2010)	Tug boat	4/4	2/3	1/3	2/2	9/12 75%
Sung-Beok (2012)	fishing	2/3	3/5	2/3	2/3	9/14 64%
Total	-	15/18	14/18	13/18	11/13	53/67 79%
		83%	78%	72%	84%	-

Chapter 7. Conclusion

7.1 Conclusion

Over time, public interest in the ocean has increased while awareness of safety is also increasing. Therefore, an attempt to make a method capable of reflecting such an atmosphere is of great importance.

This paper has defined PIMA as a strong candidate for organizing the statistics of marine accidents in the Korea, analyzing marine accident prevention sector information, and assessing the extent of prevention activities. In addition, it has developed a prevention sector for evaluation so that it ca be used to calculate PIMA.

PIMA was verified for usefulness and as an indicator to the degree of prevention achieved. Through the use of statistical methods and case review PIMA measurement provides the best results.

PIMA and PGMA verification are frequently used as a measurement result target for actual ships. Through statistical review, it was possible to check the tendency of index values for accident rates that were inversely proportional.

As a result, it was possible to confirm that the PIMA evaluation module is configured in a rational manner.

7.2 Application plan & Expected effect

PIMA, which has been proposed in this paper, is expected to take advantage of the most useful indicator for obtaining results effective to customized marine prevention activities and the establishment of accident reduction measures for the marine environment in Korea.

In conclusion, planning needs to be complemented by prevention indexes to expand the amount of evaluated ships. Possible expansion includes: the accident prevention readiness and specialized indexation processes by type of ship. Furthermore, it is possible to promote marine safety by applying the same widespread approach and extending it to all areas of the marine environment.

Fig. 7-1 Applicable areas of PIMA

References

- AAA Foundation for Traffic safety, 2012. *2012 Traffic Safety Culture Index.* AAA Foundation:Washinton, D.C.
- Bae, J.K., Lee, E.B., 2014. *A Study on the Development of a Preventive Index Based on the Statistical Data of Ship Accidents.* Journal of Korean Navigation and Port Research. Vol.38(3). pp. 247-252.
- BBC NEWS ASIA. 2014. *South Korea Sewol ferry : What we know.* [Available at : http://www.bbc.com/news/world-asia-27342967]
- Catherine. Hetherington, Rhona. Flin, Kathryn. Meams, 2006. *Safety in shipping : The human element.* Journal of Safety Research. Vol.37. pp-401-411.
- Chung, E.S, Yang, K.M, Ha, J.H, Kang, K.S, 2008. *A Study on Fire Risk analysis & Indexing of Builidings.* Korea Safety Management & Science, Vol.10(4). pp. 93-104.
- CNN International, 2014. *What went wrong on Sewol?.* [Available at : http://edition.cnn.com/2014/05/15/world/asia/sewol-problems/]
- Det Norske Veritas(DNV). 2011. *Final Report for United States Department of the Interior Bureau of Ocean Energy Management, Regulation, and Enforcement.* Det Norske Veritas.
- Ericson. Clifton, 1999. *Fault Tree Analysis-A History.* Proceedings of the 17th International System Safety Conference.
- International Maritime Organization(IMO), 2008, *Resolution MSC.255(84)*

(adopted on 16 May 2008), International Maritime Organization

- Jeong, B.M, 2006. *The limit of large container ships*. Monthly Ocean and fishing. August, pp. 1-6.
- Kang, S.C, Bae, H, 2011. *Analysis of the Effect of Safety Investment on Traffic Accident Reduction Using Panel Data.* Journal of Korea Transportation Research Society, Vol.29(5). pp. 19-42.
- Korea Expressway Corporation. 2009. *Development of Traffic Safety Policies for Halving Casualties on Korean Expressways.* Korea Expressway Corporation
- Korea Maritime Safety Tribunal, 2014. *Annual Marine accident statistics report*, Korea Maritime Safety Tribunal.
- Korea Meteorological Agency. 2013. *A Study on Policy development financial climate weather information for the creation of complex economies.* Pshon Partners:Seoul
- Korea Ministry of Government Legislation, 2014.
 [Available at : http://www.law.go.kr]
- Korean Register of Shipping, 2014. *Ship Information*
 [Abailable at : http://www.krs.co.kr/kor/main/main.aspx]
- Kwon, Y.K., Kim, C.O., 2011. *Safety Engineering of Smartphone Age*. Hyungseul press:Seoul
- Lee, E.B, Jeong, T.G, 2012. *Maritime Safety System*, Sejong Press:Busan
- INVESTOPEDIA, 2012. INVESTOPEDIA Dictionary.
 [Availabe at : http://www.investopedia.com/terms/i/index.asp]
- Lee, K.S, 2005, *A study on the development for an air transportation cultural index.* Journal of the Korean society for aeronautical science and flight operation, Vol.13(3). pp. 61-72.

- Lee, K.S, Kim, M.B, 1995. The Evaluation of Traffic Accident Prevention Policy. Journal of Transportation safety research. Vol.14. pp. 1-12.
- Lee, Y.C, 2014. *A Study on Legislation specific issues and domestic ship safety management measures of Sewol Ferry sinking accident.* Proceeding of the Korea Institute of Maritime Law conference on 2014 Autumn, pp. 59-78.
- Martensen. Anna L, Butler. Ricky W, 2011. The Fault-Tree Compiler. Langely Research Center. NTRS
- McCormick, Maggie, 2014. *The Advantages of a Pass/Fail Grading system.* [Available at : http://classroom.synonym.com], Demand Media
- Ministry of Land, Transport and Maritime Affairs. 2010. *Traffic Safety Annual Report*. Ministry of Land, Transport and Maritime Affairs.
- Na, S, Kim, H.T, Yum, C.W, Park, J.H, 2012. *A Study on marine accidents human factor investigation analysis model application*. Proceeding of Korean Institution of Navigation an Port Research Conference on 2012 Spring, pp. 466-468.
- Oh. Y.A, 2007. *Development of Evaluation Indicator on Industrial Safety and Health Education Program.* Ewha Womans University Dissertation of Doctor degree. Graduate School of Ewha Womans University.
- P. Tuovinen, V. Kostilainen, A. Hamalainen, 1984. Studies on Ship Casualties In the Baltic Sea. Baltic Sea Environment Proceedings No.11. Helsinki University of Technology Ship Hydrodynamics Laboratory Otaniemi : Finland
- Seo, M.S., Bae, S.J. 2002. *The Study on the Analysis of Marine Accidents and Preventive Measures*. Journal of Fisheries and Marine Sciences Education. Vol. 14(2). pp. 149-160.
- Southampton Solent University, 2012. *15 Years of Shipping Accidents : A*

review for WWF, Southampton Solent University [Available at : http://awsassets.panda.org/downloads/15_years_of_shipping_accidents_a_review_for_wwf_.pdf]

- Yang, W.J, Kwon, S.J, Keum, J.S, 2004. *An Analysis of Human Factor in Marine Accidents -Collision Accidents-*. Proceeding of The Korean Society of Marine Environment & Safety Conference on 2004 Spring, pp. 7-11.
- Wikipedia. 2014a. *Sinking of the MV Sewol*
  [Abailable at : http://en.wikipedia.org/wiki/Sinking_of_the_MV_Sewol]
- Wikipedia. 2014b. *Traffic calming.*
  [Available at : http://en.wikipedia.org/wiki/Traffic_calming]
- Wikipedia, 2014c. *Likert scale.*
  [Avaiable at : http://en.wikipedia.org/wiki/Likert_scale]
- Wikipedia, 2014d. *Fault Tree Analysis(FTA).*
  [Avaiable at : http://en.wikipedia.org/wiki/Fault_tree_analysis]