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ESTABLISHING MARINE ACCCIDENT CLASSIFICATION: A CASE STUDY IN TAIWAN

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Abstract: In this paper, we establish criterions for classifying marine accidents to integrate the navigation safety system of Taiwan. Together with unpredictable of marine accidents, the inaccuracy of maritime data in Taiwan makes marine incident information possess the characteristic of Gray message as described by Gray Theory. After analyzing the data of 107 marine incidents, we classified the accidents into four types by the Gray Clustering Method. The results revealed that the crew's negligence accounts for 93.5% for the cause of all accidents. Furthermore, 85.1% of crew's negligence is caused by senior crew. Through classifying marine accidents, this paper not only makes the port managers of port bureaus and insurance companies realize the damage levels of various kinds of marine accidents and their causes, but also provides the managers of harbor bureaus a basis to strengthen seamen's quality and management.

Key Words: Marine Accident, Gray Clustering Method, Accident Classification, Classification Criterions, Gray Theory.

1. INTRODUCTION

Taiwan is an island country, thus the economy of Taiwan is heavily depending on the ocean transportation. In such an economic system, the occurrence of marine accidents will not only bring casualties on ship, cargo and people's life, but also make a great influence on the trade. However, a marine accident is unpredictable. No one knows when or where it will happen. To avoid marine accidents, it is important to provide an effective database of marine accidents in each port to seamen for reference. Before constructing a high quality database of marine accidents, we should establish the principles of classifying marine accidents. That is why this important issue of marine transportation safety is mentioned repeatedly in the research of "Traffic Policy White Book：Transportation" which is published in 2002 by the Ministry of Communications in Taiwan.

Before discussing how the database of marine accidents should be constructed, we should plan what type of data should be included in the database. Certainly, marine accident database should include every item listed in the marine survey report; however, these data should be classified. Thus, the principles of classifying marine accidents should be established in the first place. With these classified marine accidents data, seamen can realize and will pay more attention to the frequencies and the causes of each kind of marine accident in each port. It can strengthen the capabilities of the seamen to deal with emergency accidents. In addition, it is also helpful for the admiralty court and the salvage organization to invest adequate manpower and resources when dealing with marine accidents.

The maritime organizations in some advanced maritime nations, such as Marine Accident Investigation Branch in United Kingdom, Marine Court in Mainland China, Marine Accidents Inquiry Agency in Japan, National Transportation Safety Board in the United States, and Transportation Safety Board in Canada, classify the damage cause by marine accidents into grades and give different accident investigations and the salvage range thereafter. Basing on the investigation result, the following legal responsibility can be clarified.

However, the formal admiralty court does not exist in Taiwan. The cases of marine accidents are assisted by the marine judge committee or the marine accident salvage committee of each Taiwanese port bureau. The function of the former is to arbitrate and investigate the marine accidents, while that of the latter is to offer the salvage and aids. Both of them do not have the deliberation function as the court. With differences exist in marine accident data recorded in each Taiwanese port bureau as well as lacking of classified marine accident database, thus, when ships with different flags collide in Taiwanese waters, the port bureaus do not have adequate data to exchange the information of marine accidents as required by the resolutions of International Maritime Organization (IMO). It reveals the urgency for Taiwanese authorities to establish clear rules to integrate and publish the marine accident information.

The marine accident survey reports of international commercial harbors in Taiwan offer little and incompletion information about the marine accident classifications. It corresponds to the Gray message characteristic of the Gray System Theory. After extensive applications of the Gray Clustering Method of the Gray System Theory in recent years, we find that it can help us to deal with incomplete, unsure, and little useable information, and obtain perfect conclusions and provide effective predictions and decisions as well (Deng, 1986). That is the reason that we apply the Gray Clustering Method to this research (Deng, 1999; Zeng, *et al.*, 1993; Hus and Wen, 1998).

In recent years, there are a lot of studies about the marine accidents in our country. Most documents emphasize the marine arbitration system and marine responsibility, while the rest ones devote to search and salvage at sea. Many of them mentioned and suggested to set up a systematic and standardized marine database to strengthen the navigation safety in Taiwanese waters. Chen, Y. H. (2000) has mentioned to strengthen the abilities of saving and salvage in "the Definitions of Marine Accident Types and Classifications", which is published in Transportation Planning Journal. However, these documents do not show us how to classify marine accidents in either the research processes or the results of the studies. There is no paper aimed at this issue up to the present. So, we attempt to build up the classifying standards of marine accidents for international commercial harbors in our country.

2. LITERATURE REVIEW

First of all, we try to realize the current situation of countries which have implemented the classifications of marine accidents. After reviewing related studies, we try to find out some examples for our own classifications of marine accidents.

2.1 Implementing situations of the marine accident classification in other countries

IMO is the largest maritime organization in the world. The standards of the serious casualty, which must be reported from every member country, were listed in No.433 regulation of marine security committee on February thirteenth, 1986. The standards are as follow. First, ships of 1,600 gross tons or more than 1,600 gross tons is total loss (including inferential total loss) because of marine accidents. Second, ships of 500 gross tons or more than 500 gross tons involve the loss of life because of marine accidents.

To promote the marine accident investigation become the important step of improving the navigation safety and avoiding the sea pollution, IMO adopts "Code for the Investigation of Marine Casualties and Incidents" in No. A.849(20) Regulation on November twenty-seventh, 1997. In chapter 4 of this code, it defines the very serious casualty as a casualty to a ship which involves the total loss of the ship, loss of life or severe pollution. It also defines the serious casualty as a casualty which does not qualify as a very serious casualty and which involves in a fire, explosion, grounding, contact, heavy weather damage, ice damage, hull cracking or suspected hull defect, etc., resulting in structural damage rendering the ship unseaworthy, such as penetration of the hull underwater, immobilization of main engines, extensive accommodation damage etc., or pollution (regardless of quantity), and/or a breakdown necessitating towage or shore assistance. In addition, it defines the serious injury as an injury which is a person in a casualty resulting in incapacitation for more than 72 hours commencing within seven days from the date of injury.

As the marine accident investigation in the United States, the ship occurring grounding, propeller breaking, unseaworthy, loss of life, more than one seaman injury with losing the ability of sailing about 72 hours, or more than 25000 dollars of the loss in a marine accident must be taken over by the United States Coast Guard according to Rule 4 of the No. 46 Bills.

According to the "National Transportation Safety Board——United States Coast Guard Uniform Rules" in 1978, the NTSB investigates marine accidents which involve six or more than six seamen life loss, more than total 100 gross tons mobile ship loss, more than 500 thousand dollars loss in rough estimation, or harmful materials that damage the human life, properties, and the environment. Anything mentioned above is considered as the serious casualty. And it also investigates the collision between the ships of United States Coast Guard and unofficial ships, leading to more than one seaman death or more than 75 thousand dollars loss.

In the UK, MAIB sets up the Admiralty Court, and stipulates regular processes with marine accident investigations and files them according to the marine accident classification. For some minor accidents, they will be filed away and no more investigated after marking and registering on the original marine accident reports. However, if there is a serious casualty, MAIB will ask for offering the detailed report. Furthermore, MAIB will assign a maritime inspector to investigate and report the result to the court after investigation.

The sea affair bureau of the Treasury Department of Liberia decreed the standard of marine accidents according to "Regulations about Maritime Investigation and Hearing". The standards of serious casualties are as the following: (1) the practical material loss is over 50,000 dollars; (2) the casualties influence the seaworthiness and the capability of the ships; (3) grounding or stranding; (4) loss of life; (5) seamen injury or lose their abilities for more than 72 hours. (Wu, 1993)

The Bandura defines serious casualties in the "Investigation Processing of the Marine Ship Accidents" as the following: (1)the ship damages so as to lose navigability and needs fixing for more than 48 hours; (2)the ship collides the buildings and facilities of the shore and cause them out of work for more than 48 hours; (3)the cargo vessel grounds for 48 hours or more；(4)the passenger vessel grounds for 48 hours or more whether it gets any damage or not. Otherwise, it will be considered as an ordinary accident. (Huang, *et al.*, 1997)

Mainland China just set up the maritime court of the Admiralty Court to specially deal with the marine accidents. The rules and the standards of the marine accident classifications in this nation are clearer than those of any other great marine countries. In the beginning, they put the marine accident classifications of "The Interim Rules of the Investigation Processing of Marine Casualties" in force on March 29, 1989. Then, they clearly classified the degrees of the ship accident according to the classes of the ship tonnage, casualties, immediately economical loss in the "Ship Traffic Accident Statistics Rules" on June 16, 1990, and identified four degrees of ship accidents as the following: minor accidents, ordinary accidents, serious casualties, very serious casualties. The degrees of every marine accident are further divided into two classifications of the merchant ships and fishing ships. Therefore, the Mainland China classifies five levels of marine accidents in fact. That is minor accidents, ordinary accidents, major casualties, serious casualties, and very serious casualties. (Gu, 1992) Besides, Holland sets up the maritime investigation bureau under the Transportation and

Public Affair Department. The classification of marine accidents is to be decided by the seriousness of the accident and if the people learn a lesson and an experience by maritime investigation officials. It separates the levels into three parts, which are wariness, more wariness, and the most wariness. However, they don't have any clear cut to classify.

According to the documents review stated as above, we find that death or injury of seamen become the main judging principles to classify marine accidents. The others are the gross tonnage of the ships, the economical loss of the accident, the seaworthiness of the ship, the loss or total loss of the ship, and so on. That's why this research will use the number of casualties and the tonnage of the ship to classify marine accidents.

In this research, we combined the number of casualties and the number of the ship damaged into a new index, because there may not be only one ship damaged in a marine accident. For example, the ships in dock floated and collided with each other because of a strong typhoon in Port Keelung last year. The ships were damaged, but nobody got hurt or died. Including only the number of casualties to classify this marine accident, the index cannot reflect the real situation and may be not perfect. It's real useful to deal with this kind of marine accidents impartiality by the new classification of casualties and the damage of ships.

There is no detail economical loss of the accidents in the marine accident reports in every harbor of Taiwan now. Only ship owners and the insurers know the information about the real loss and the compensation. So we cannot clearly know the detailed economic loss of accidents because of the business benefits. So, we reference the highest compensation, which followed the Convention on Limitation of Liability for Maritime Claims, 1976 to classify the accidents.

2.2 Pertinent Researches of the Marine Accidents in Nowadays

The documents related to marine accidents in Taiwan or Cross-Strait can be divided into four parts, which are marine safety policy and technology (R.O.C. Marine Transportation Research Association, 1994, 1996; The Ministry of Communications, 2002; Chen, 1991; Chen, *et al.*, 1998), maritime arbitration (Lin, 1995; Zhang, 1999), casualty salvage and responsibility (Chen, 1996, 1997, 1998; Zhou, 2000; Qi, 2002), and marine accident investigation (Chen, 1999; Guo, 2000; Hong, 2000). And the results of casualty salvage are the majority. Limited maritime arbitration and marine safety policies are carried out because of political factors and the transfer of managers of shipping and harbor administrations.

We also find that most of these studies suggest to set up the classification of marine accidents but they do not provide the detail about how to implement it at all. That's the main difference between our research and the pertinent studies.

The related papers about every kind of traffic accidents only explore the accident classifications of the land transportation and the air transportation in our nation. There is nothing mentioned about the classification of marine accidents.

Furthermore, while reviewing the classifications of marine accidents in international journals, we only found that Qui (1992) classified the vessel traffic management system using in every harbor in Mainland China by the Fuzzy Mathematical Model. He made no mention about how to classify the marine accidents. Huang, *et al*. (1997) classified the levels of vessel traffic accidents by the mathematical model of the Fuzzy Theory. What they suggested can reduce the disadvantages of the classifications of the single index based on law. Since we cannot find that any other pertinent papers discussing the same issues with us, the classifications of Huang, *et al.* could be a good reference for this research.

3. METHODOLOGY

The Gray System Theory, based on the concept of interval analysis, was developed in 1982 by Professor Ju-Long Deng in China to deal with incomplete information and uncertain causality. This theory includes four parts: Gray Relational Analysis, Gray Decision, Gray Evaluation, and Gray Predication. In the Gray System, all messages can be divided into three categories—white, Gray, and black. The white category shows completely clear messages in a system, the black category contains completely unknown characteristics, and the Gray category occurs in between and covers both known and unknown messages. The Gray Clustering Analysis (GCA), also proposed by Ju-Long Deng in 1982, is one of foundations in Gray Evaluation. Since a marine accident is unpredictable and uncontrollable as well as incomplete data provided, it possesses the characteristic of a Gray message. For this reason, we choose the GCA as the tool in this article.

3.1 Obtaining the Gray Clustering Category

Allow $x_{ij}, i = 1,2,...,m; j = 1,2,...,n$, to be the observation value of the j^{th} evaluation criterion attained by the i^{th} evaluation object. Then, the degree of closeness, denoted by d_{ij}, of x_{ij} to an ideal value can be defined as:

$$d_{ij} = \frac{x_{ij}}{x_j^{\max}}, \tag{1}$$

Where $x_j^{\max} = \max_i \{x_{ij}\}$.

3.2 Determining the Gray Whitening Function

Let f_{jk} , $j = 1,2,...,n; k = 1,2,..., p$, denote the whitening function of the k^{th} Gray category in the j^{th} evaluation criterion. Then, the membership function of all Gray categories can be defined as:

(a) If $d_{ij} \geq c_{j1}$, then the $f_{j1}(d_{ij})$ of Gray category 1 in the j^{th} evaluation criterion is 1. And $f_{j1}(d_{ij})$ is linearly decreasing on the left side of c_{j1}. That is,

$$f_{j1}(d_{ij}) = \begin{cases} d_{ij} / c_{j1} \ , & if \ d_{ij} \in [0, c_{j1}) \\ 1 \ , & if \ d_{ij} \in [c_{j1}, \infty) \end{cases} \tag{2}$$

Where c_{j1} is the threshold value of $f_{j1}(d_{ij})$.

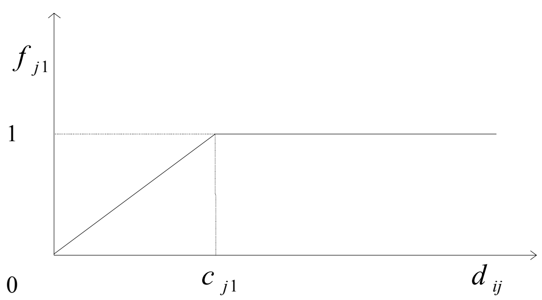

Figure 1. the 1^{st} whitening function in the j^{th} evaluation criterion

(b) If $d_{ij} = c_{jt}$, $1 < t < p$, then the $f_{jt}(d_{ij})$ of Gray category t in the j^{th} evaluation criterion is 1. And $f_{jt}(d_{ij})$ is linearly decreasing on the both sides of c_{jt}. That is, define $f_{jt}(d_{ij})$ as

$$f_{jt}(d_{ij}) = \begin{cases} d_{ij} / c_{jt} \ , & if \ d_{ij} \in [0, c_{jt}) \\ (2c_{jt} - d_{ij}) / c_{jt} \ , & if \ d_{ij} \in [c_{jt}, 2c_{jt}) \\ 0 \ , & if \ d_{ij} \in [2c_{jt}, \infty) \end{cases} \tag{3}$$

Where c_{jt} is the threshold value of $f_{jt}(d_{ij})$.

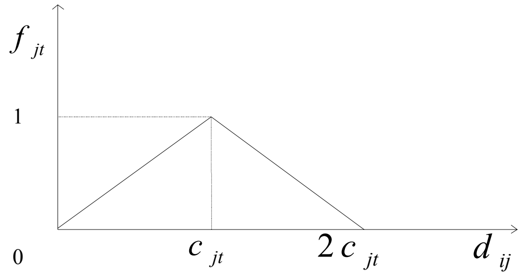

Figure 2. the t^{th} whitening function in the j^{th} evaluation criterion

(c) If $d_{ij} \geq c_{jp}$, then $f_{jp}(d_{ij})$ of Gray category p in the j^{th} evaluation criterion is 1. And $f_{jp}(d_{ij})$ is linearly decreasing on the right side of c_{jp}. That is, define $f_{jp}(d_{ij})$ as

$$f_{jp}(d_{ij}) = \begin{cases} 1 & , \quad if \quad d_{ij} \in [0, c_{jp}) \\ \dfrac{2c_{jp} - d_{ij}}{c_{jp}} & , \quad if \quad d_{ij} \in [c_{jp}, 2c_{jp}) \\ 0 & , \quad if \quad d_{ij} \in [2c_{jp}, \infty) \end{cases} \tag{4}$$

Where c_{jp} is the threshold value of $f_{jp}(d_{ij})$.

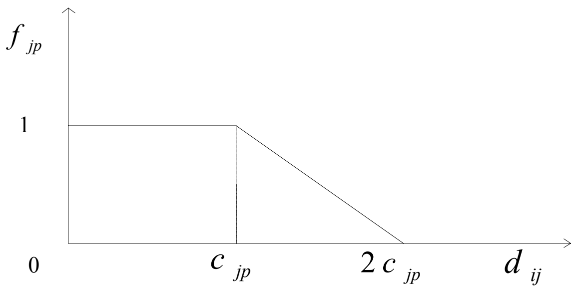

Figure 3. the p^{th} whitening function in the j^{th} evaluation criterion

3.3 Gray Clustering Analysis

Let d_{ij}, $i = 1,2,...,m; j = 1,2,...,n$, denote the degree of closeness of x_{ij} to ideal value $x^{\max}_{j}$. And, let f_{jk}, $j = 1,2,...,n; k = 1,2,..., p$ be the whitening function of the k^{th} Gray category in the represented GCC of i^{th} observation objects in the j^{th} evaluation criterion. Define the Clustering Weight Coefficient (CWC) η_{jk} of f_{jk} as

$$\eta_{jk} = \frac{c_{jk}}{\sum_{j=1}^{n} c_{jk}} \tag{5}$$

Where c_{jk} is the threshold value of $f_{jk}(d_{ij})$, and $\sum_{j=1}^{n} c_{jk}$ represents the sum of threshold values of all evaluation criteria versus k^{th} Gray category.

Define the Gray clustering value σ_{ik} of i^{th} evaluation object belongs to k^{th} Gray category as

$$\sigma_{ik} = \sum_{j=1}^{n} f_{jk}(d_{ij})\, \eta_{jk} \tag{6}$$

By using equation (6), we can obtain the Gray clustering series of i^{th} observation object as below

$$\sigma_i = (\sigma_{i1},\ \sigma_{i2},\ \ldots,\ \sigma_{ik},\ \ldots,\ \sigma_{ip}) \tag{7}$$

Furthermore, if $\sigma_{it} = \max\{\sigma_{i1}, \sigma_{i2}, \ldots, \sigma_{ik}, \ldots, \sigma_{ip}\}$, then the i^{th} observation object belongs to t^{th} Gray category.

4. CASE STUDY ANALYSIS

The main resource of our marine accidents data is collected from the Ministry of Communications and port authorities in Taiwan. The research content covers all damages occurred within Taiwanese territorial waters. We focus on the damage of marine accidents which involve in the damage or loss of the ship itself, the cargo, or the human life even. However, the damage caused by the marine accident, such as environment pollution, poisoning, etc., is not included in our research, because this kind of damage is unpredictable or uneasy to be controlled.

We collect related documents and the various kinds of marine accident classification indicators in the beginning. Next we interview with officials of each port authorities, managers of maritime department of insurance companies, college professors of related study field, and managers of insurance department or vessel affair department of famous shipping companies in Taiwan. We make a questionnaire which combines the forgoing comments, and test them again with this questionnaire to construct the criteria of the marine accident classification in our study. The marine accident reports in each international commercial harbor are short of the actual damage level and the value of the loss cargoes on the ship; the compensation decided by maritime arbitration makes no mention of the compensation for damaged cargoes. The carrier of the accident vessel refuses to provide the related accident information and the amount of compensation because of business secrets; the insurer rejects to tell the detail information about the accident vessel for protecting the privacy of clients and themselves. All above are the reasons why we cannot apply the damage level and the loss value of damaged cargoes to the criteria of the Gray Clustering Method.

Besides, there is no record about the fixing time of the accident vessel and the disability time of seamen in marine accident reports of port authorities or maritime arbitration. The carrier of the accident vessel and the insurer refuse to provide the information. So we cannot apply the fixing time of the accident vessel and the disability time of seamen to the criteria of the Gray Clustering Method, either.

We collect thousands of original data of marine accidents in each harbor from 1978 to 1996. During the collecting process, we find that most file papers have been lost with the time passing or hard to identity what the word describe, the transfer of personnel of port authorities lead the information uncompleted, or the descriptions of foreign captains or agents are too condensed far simpler in marine accident reports. So only 111 data remain to be the useful for this study.

So we eliminate 4 data that is unsuitable for the Gray Clustering Analysis within 111 data of marine accidents. The rest 107 data is used to be the analysis objects of the Gray Clustering Method.

We compare the actual conditions of all countries that put the marine accident classification into practice, and find that they all view it as the serious or very serious casualty once the loss of life occurs. We also interview specialists and scholars for suggestions about the marine accident classification. They all agree that life in distress is superior to ships in distress when considering the classification of the serious casualty. They also advise us dealing with them separately before conducting the Gray Clustering Analysis. The main setting of calculating classification for each region of data in Table 1. Grey Category 1, 2, 3, 4 are defined as especially important accident, important accident, ordinary accident, minor accident, respectively. With repefitive trial and error, we obtain all the threshold values of all regions and gray categories which are shown in Table 1.

Table 1. The Threshold Values of All Regions and Gray Categories

Data types	Gray Category 1 Especially important accident		Gray Category 2 Important accident		Gray Category 3 Ordinary accident		Gray Category 4 Minor accident	
	Threshold value	CWC	threshold value	CWC	threshold value	CWC	threshold value	CWC
1st region	0.250	1/4	0.056	1/4	----	----	----	----
2nd region	0.500	1/4	0.333	1/4	0.032	1/4	----	----
3rd region	0.667	1/4	0.500	1/4	0.265	1/4	0.099	1/4

Note: "----" represents not applicable.
CWC: stands for the clustering weight coefficient mentioned in section 3.3.

In order to combine these three parts of accidents and analyze them altogether, we build up four Gray Clustering categories for accident classification, and that is the Gray Clustering index set $k \in K = \{1, 2, 3, 4\}$ = {especially important accident, important accident, ordinary accident, minor accident}. The Gray Clustering index set of the first part is $k \in K = \{1,2\}$ = {especially important accident, important accident}, that of the second part is $k \in K = \{1,2,3\}$ = {especially important accident, important accident, ordinary accident}, and that of the third part is $k \in K = \{1,2,3,4\}$ = {especially important accident, important accident, ordinary accident, minor accident}.

For the reasons mentioned before and the premise of life being beyond price, the accident is classified to the first region if there are casualties regardless of the damaged level of vessels. There are 26 data in the first region. The accident is classified to the second region if there is no casualty but the ship is sunk. There are 29 data in the second region. The accident is classified to the third region if there is no casualty and no sinking ship but there are damages of ship. There are 52 data in the third region. After Gray Clustering analysis, the number of data under each region and category is shown in Table 2.

Table 2. The Results after the Gray Clustering Analysis of Each Region and Each Category

Data types	Gray Category 1 Especially important accident	Gray Category 2 Important accident	Gray Category 3 Ordinary accident	Gray Category 4 Minor accident
1st region	13	13	----	----
2nd region	14	1	14	----
3rd region	5	13	12	22

No marine accident classification has been established by the Ministry of Communications and port authorities, and there is no study achievement about the marine accident classification in Taiwan, either. Therefore, according to the result of the Gray Clustering Analysis and combining with the original data of marine accidents, this research tries to summarize classification criteria of the marine accident classification in the following Table 3.

Table 3. The Classification Criteria of the Marine Accident Classification for Each Region(1)

	Gray Category 1											
The gross tonnage of ship damaged					700 ≤		1000 ≤			40001 ≤	20001 ≤	30001 ≤
Regardless of the ship damaged	*	*		*					*			
No ship damaged												
The number of ships damaged			3 ≤									
The gross tonnage of the sinking ship						1501 ≤						
Regardless of the sinking ship	*	*	*						*			
No sinking ship										*	*	*
The number of the sinking ship				2 ≤	2			1 ≤				
The number of the accident ship		4 ≤				1	1	2~3		1	2	3
The gross tonnage of the accident ship									60001 ≤			
Regardless of the number of the accident ship	*		*	*					*			
The number of the casualty and missing	3 ≤				1~2		1~2					
No casualty and missing						*		*		*	*	*
Regardless of the casualty and missing		*	*	*					*			

Based on classification criteria development in Table 3, we have classified the original 107data once again. There are 9 data which do not matched with classification criteria. It shows that the classification criteria in this paper reach 91.59% accuracy.

There are 12 columns in Table 3, which are 12 scenarios under Gray category 1. Under each column in Table 3, as doing as all “*” conditions and the other conditions (for example, in the leftmost column, 3≤ stands for the other condition. It requires that the number of the casualty and missing is more than or equal to 3.) are satisfied, this scenarios will be classified as Gray category 1.

Table 3. The Classification Criteria of the Marine Accident Classification for Each Region(2)

	Gray Category 2							
The gross tonnage of ship damaged		≤700		≤1000		15001~40000	6701~20000	15000~30000
Regardless of the ship damaged					*			
No ship damaged	*							
The number of ships damaged								
The gross tonnage of the sinking ship			501~1500					
Regardless of the sinking ship					*			
No sinking ship	*					*	*	*
The number of the sinking ship								
The number of the accident ship		2	1	1		1	2	3
The gross tonnage of the accident ship					30001~ 60000			
Regardless of the number of the accident ship	*							
The number of the casualty and missing	1	1~2		1~2				
No casualty and missing			*	*		*	*	*
Regardless of the casualty and missing					*			

Table 3. The Classification Criteria of the Marine Accident Classification for Each Region(3)

	Gray Category 3					Gray Category 4		
The gross tonnage of ship damaged			3001~15000	3201~6700	≤15000		≤3000	≤3200
Regardless of the ship damaged		*				*		
No ship damaged								
The number of ships damaged								
The gross tonnage of the sinking ship	≤500							
Regardless of the sinking ship		*				*		
No sinking ship			*	*	*		*	*
The number of the sinking ship								
The number of the accident ship	1		1	2	3		1	2
The gross tonnage of the accident ship		9001~30000				≤9000		
Regardless of the number of the accident ship		*				*		
The number of the casualty and missing								
No casualty and missing	*		*	*	*		*	*
Regardless of the casualty and missing		*				*		

In Table 4, the occurrence ratio of vessel collision accidents is 51.4%, while that of machinery failure is 1.9% only. This means that most causes of marine accidents result from man-made carelessness. From Table 4, we can observe that the collision accidents account for major portion of especially important accident and important accident.

Table 4. Marine Accident Types of Each Gray Category

	Gray Category 1 Especially important accident	Gray Category 2 Important accident	Gray Category 3 Ordinary accident	Gray Category 4 Minor accident	Total
Collision	19	16	7	13	55（51.4%）
Goundering	5	1	3	0	9（8.4%）
Stranding	1	2	5	5	13（12.2%）
Machinery Failure	1	1	0	0	2（1.9%）
Fire	2	2	8	0	12（11.2%）
Leaking	0	0	1	0	1（0.9%）
Others	6	3	2	4	15（14.0%）
Total	34	25	26	22	107（100%）

Table 5 shows another advantage of marine accident classification. It makes port authorities and insurance companies realize the causes of different accident damage levels. For example, Table 5 shows marine accident caused by 'complete man-made carelessness' is the prime accident cause among all the Gray Clustering categories. The aggregate value of complete man-made carelessness among these four accident categories is 86.9%. If accidents of man and the weather or man and machinery are included, the aggregate value of accidents about man-made carelessness reaches 93.5%.

Table 5. Marine Accident Cause-type of Each Gray Category

Category / Cause type	Gray Category 1 Especially important accident	Gray Category 2 Important accident	Gray Category 3 Ordinary accident	Gray Category 4 Minor accident	Total
Complete personnel carelessness	25	24	24	20	93（86.9%）
Complete weather defect	3	0	1	0	4（3.7%）
Personnel and weather defect	4	1	0	0	5（4.7%）
Complete machine defect	2	0	0	1	3（2.8%）
Personnel and machine defect	0	0	1	1	2（1.9%）
Total	34	25	26	22	107（100%）

Table 6 shows the third advantage of marine accident classification. It provides port authorities to strengthen management of seaman quality. Table 6 shows the carelessness ratio of officers in deck (including master, chief mate, second mate, and third mate) is 85.1%, while that of officers in engine room is 13.1% among ignore of all the seaman classes. The ratio of negligence of the master is the most serious. It reaches 63.6%. That of chief mate and chief engineer is the next. They reach about 11.2%. That of pilot reaches 7.5%. In other words, the navigation technique and ability to deal with emergency of pilots, captains, chief engineers, and chief mates should be strengthened, and all classes of education organizations that foster staffs in deck and engine room should implement accurate and strict training in order to reduce both the occurrence and the damage of marine accidents in Taiwanese international harbors as low as possible.

Table 6. Negligent Causers of Each Gray Category

Category / Negligent causer	Gray category 1 Especially important accident	Gray category 2 Important accident	Gray category 3 Ordinary accident	Gray category 4 Minor accident	Total
Master	19	18	16	15	68（63.6%）
Chief Mate	7	3	2	0	12（11.2%）
Chief Engineer	3	2	5	2	12（11.2%）
Second Mate	3	2	2	2	9（8.4%）
Pilot	1	3	3	1	8（7.5%）
Third Mate	1	1	0	0	2（1.9%）
First Engineer	1	0	0	1	2（1.9%）

5. CONCLUSION

The main purpose of this research is to establish marine accident classification criteria which are helpful for constructing information related to navigation safety and helpful for enhancing navigation safety system, so it is an important and basic research for improving navigation safety. The result of this research can make the seaman realize the frequency and the cause of marine accidents and strengthen the seaman's ability to deal with an emergency accident. Furthermore, the result proposed in this study is also helpful for organizations, such as the admiralty court and the salvage organization, in optimizing the level of resources to invest in.

Our research suggests that there should be modifications and amendments to the classification of marine accident code. Furthermore, more explanations about the legal basis of the marine accident classifications and promotions to traffic safety code should be made in order to increase the effectiveness of the marine accident classification.

To sum up, we summarize the advantages of our proposed marine accident classification as follows:

(a) Due to different definitions of the marine accident classification, different qualities of the marine accident information, and different characteristics of water, it results in many types of marine accident classifications. After comparing to every country's marine accident classification system, we find that our classification should be the most suitable mechanism for Taiwan and can be put into practice easily.

(b) Setting up standard operation procedures to collect the information of marine accidents can offer a united statistics of marine accidents to every harbor bureau and the Ministry of Communications also can build up the marine accident database corresponding to the international maritime codes.

(c) Based on the classification of different types of accidents, the salvage organizations can realize the seriousness of the accidents and assign proper manpower, facilities and resources to avoid wasting unnecessary resources.

(d) It offers the official salvage organizations a reference index to decide how many resources of the salvage material and manpower they should invest in.

(e) It can offer the information for the schools or the training institutions to strengthen the abilities of the seamen to deal with an emergency situation. And the shipping department of the Ministry of Communications should strengthen on the job of training of the captains, pilots, chief officers, and chief engineers regularly.

(f) Better understanding of the types and the causes of the marine accidents in Taiwanese waters can reduce the operational negligence of the seamen when they are sailing.

(g) With more information about the flag and type of accident ships, the insurers can establish more reasonable insurance premium and compensation.

At last, we hope all shipping companies, insurers, and related associations can offer the information of practical compensation and loss amount to improve the navigation safety in the future. We also hope them can offer the information about the recovery time of the injured seamen and the repairing time of the ship to make the system become perfect so as to promote the transportation safety of the people, the ships, and the cargoes.

REFERENCES

The R.O.C. Marine Transportation Research Association. (1996) **The study on the technology of safety at sea in cross-strait**, The Ministry of Communications Press.

Gu, W.X. (1992) **Ship transportation safety**, Dalian Maritime University Press.

The Ministry of Communications (2002) **The White Book of Traffic Policy: Transportation**, The Ministry of Communications Press.

Chi, M. (2002) **The study of salvage system in Taiwan**, Master Thesis, Institute of Shipping Transportation Management, National Taiwan Ocean University, Taiwan.

Wu, Z.L. (1993) **Maritime investigation and assay**, Dalian Maritime University Press.

Lin, G.M. (1995) The study of maritime consideration system, **Journal of Shipping Transportation, Vol. 361**, 29-39.

Chou, Y.H. (2000) **The study of the responsibility for sinking and grounding in cases of shipwreck in Taiwan**, Master Thesis, Institute of Shipping Transportation Management, National Taiwan Ocean University, Taiwan.

Hong, B.L. (2000) **The analyzing study of research and rescue handling of shipwreck and evidence investigation**, Master Thesis, Institute of Maritime Police, Central Officer University, Taiwan.

Guo, J.L. (2000) **The study on the current condition of marine accident investigation in Taiwan**, Master Thesis, Institute of Maritime Technology, National Taiwan Ocean University, Taiwan.

Chen, Z.L. (1991) **The study of an analyzing model for marine accident** ,Master Thesis, Institute of Maritime Technology, National Taiwan Ocean University, Taiwan.

Chen, Y.H. (2000) **The preliminary study on the maritime casualty identification techniques**, Highest Level of the Executive Branch.

Chen, Y.H. (1999) **The study on the marine traffic accident investigation**, Highest Level of the Executive Branch.

Chen, Y.H. (1998) **The experimental study for the integration of marine search and rescue information**, Highest Level of the Executive Branch.

Chen, Y.H. *et al*. (1997) **A study on the marine rescue simulation to the ship in distress**, Highest Level of the Executive Branch.

Chen, Deng, J.L. et al. (1998) **Shipping safety and management**, Dalian Maritime University Press.

Deng, J.L. (1999) **Gray system theory and application**, China.

Deng, J.L. (1986) **Gray prediction and decision**, Huazhong Institute of echnology Press, Wuhan, China.

Huang, Y.P., Zheng, Z.Y. and Wu, Z.L. (1997) Fuzzy model for quantitative determination of casualty levels, **Journal of Dalian Maritime University, Vol. 23, No. 4**, 29-33.

Hus, C.I. and Wen, Y.H. (1998) Applying gray clustering and multiobjective programming on airline network design, **Proceedings of the Second Asia Pacific Decision Science Institute Conference**, Taipei, Taiwan.

Qiu, Z. (1992) Quantitative determination of VTMS levels, **Journal of Navigation, Vol. 45, No. 2**, 285-291.

Zeng, B.Y., Li, Q.Q., Li, A.F., Zhang, C.Q. and Chen, H.B. (1993) Gray clustering for wheat parent crosses, **The Journal of Gray System, Vol. 3**, 235-242.