PERFORMANCE EVALUATION OF THE SECURITY MANAGEMENT OF CHANGJIANG MARITIME SAFETY ADMINISTRATIONS: APPLICATION WITH UNDESIRABLE OUTPUTS IN DATA ENVELOPMENT ANALYSIS

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ABSTRACT

Marine accidents would not only cause considerable loss of human life and property, but also seriously affect the safety of navigation environments. Effective security management could guarantee the prevention of marine accidents. By analysing the systematic patterns of Changjiang Maritime Safety Administration (MSA) of the People's Republic of China, this study constructed a suitable navigation security assessment model for evaluating security management performance. Our dataset was derived from the official website of Changjiang MSA, which is composed of seven MSA branches, in terms of Chongqing, Yichang, Yueyang, Wuhan, Huangshi, Anqing and Wuhu, respectively. The main research data component was focussed on marine accidents that have occurred in the Changjiang River, covering six varieties of marine accident without explicit input (WEI) variables. Data envelopment analysis (DEA) is a mathematical method for measuring the relative efficiencies of peer decision-making units (DMUs) with multiple inputs and outputs. A DEA-WEI model was implemented and applied to the evaluation in this study. According to the evaluation, we identified collision and foundering-based accidents to be the two most common varieties of marine accidents in the Changjiang River. We also observed higher safety performance in the MSAs controlling the upper and middle reaches of the Changjiang River, especially the Chongqing and Yueyang MSAs, than in those controlling the lower reaches. Therefore, Chongqing and Yueyang could be adopted as references for improving the overall security management performance in the Changjiang River area.

I. INTRODUCTION

Currently, with the development of economic globalisation, the international transportation industry has become hypercompetitive. An increase in competitive pressure stimulates the rapid and continuous employment of ships, which may engender complications in navigation environments, thereby increasing the occurrences of marine accidents. In particular, the odds of sea accidents occurring in and around ports have increased. Marine accidents pose various risks related to safety, loss of property and environmental pollution (Montewka et al., 2014). A marine accident not only causes the ship in question to incur heavy losses, but also exposes surrounding ships in the same water to the subsequent deterioration of the surrounding environment.

Improving navigation security has been pursued by several maritime organisation alliances and shipping organisations. For preserving the maritime safety of life and property, the International Maritime Organization (IMO) established its regulations and rules according to experiences of marine accidents (IMO, 2002). A high number of previous marine accidents have posed severe threats to maritime transportation safety. Chen (2002) indicated that in the waters surrounding Taiwan, at least two marine accidents occur every day, and that one life is lost as a result of such accidents every 3 days. Scholars currently pay more attention to the evaluation of navigation security (Kristiansen, 2013; Bichou, 2015; Goerlandt and Montewka, 2015; Liu et al., 2015). These studies have focussed on ensuring the security of ship navigation and for the lives of crew members. They have suggested human error, mechanical failures, and environmental factors to be the critical factors causing marine accidents. According to statistics of marine accidents derived from the Korean Maritime Safety Tribunal, human error-related marine accidents contributed to 78.7%

of all marine accidents; furthermore, 95% of these accidents involved collisions of all marine accidents occurring from 2002 to 2006 (Na et al., 2010). Among such human errors, failure to uphold appropriate lookout procedures and breaching of regulations were primary factors causing collisions (Uğurlu et al., 2015).

Although international maritime authorities have formulated several corresponding navigation laws or specifications to promote the navigation security regarding sea transportation (Hetherington et al., 2006), large-scale marine disasters have still occurred in recent years. Examples of such disasters include the Deepwater Horizon oil spill in the Gulf of Mexico in 2010 and the sinking of the MV Sewol near South Korea in 2014; both of the two marine accidents exerted a severely negative influence on the surrounding marine ecological environment, as well as causing marked loss of life and property. In 2015, the sinking of the Dong Fang Zhi Xing in the Changjiang River attracted substantial worldwide concern among the ferry transportation and shipping industry. On 30 December 2015, the State Council of China published one report of the investigation of this accident, revealing the cause to have been unprecedentedly severe weather; in total, 442 lives were lost. Consequently, security management among maritime authorities has gained considerable emphasis worldwide.

During sailing, the security of a ship can be affected by internal equipment structures, external navigation environment, and human-based factors. Such influences may engender an increase in risk levels related to maritime activities. Effective security management can robustly ensure a ship's navigation security, as well as contributing to maintaining a safe navigation environment in port waters. The most effective measure for controlling navigation security entails focusing on port management systems and the causes of previous marine accidents. In this paper, we present the first step to evaluating the security management performance of Maritime Safety Administrations (MSAs) overseeing the Changjiang River in China, and with the objective of providing a reference to facilitate maritime authorities around the Changjiang River in improving their security management levels. Furthermore, the results of this study may assist MSA managers in effectively preventing marine accidents from occurring in their port waters.

The remainder of this paper is organised as follows: Section 2 introduces previous studies regarding the main influencing factors of marine accidents, as well as several studies concerning the data envelopment analysis (DEA) model applied in marine security management or port operation. Section 3 describes the DEA model employed in the present study, which could deal with the undesirable data for this research in detail. Section 4 presents the empirical results of research regarding security management performance evaluation of the Changjiang MSA in 2015, with a view to examining the overall navigation security management level in and around the Changjiang River. Finally, concluding remarks based on the results of this study are provided in Section 5.

II. LITERATURE REVIEW

The objective of any maritime-related authority, especially the IMO, is to maintain the effective security of maritime transportation. Examining the correlation between marine accidents and their main influencing factors could provide vital information for MSA managers to appropriately adjust corresponding countermeasures to accidents. Conventional practices for achieving the goal of internal correlation are usually characterised by investigating the causes of marine accidents in detail and subsequently conducting a thorough analysis to determine the main intrinsic causes (Soares and Teixeira, 2001).

Scholars have conducted studies exploring the main influencing factors that may directly engender marine accidents. Li and Zheng (2008) identified six factors: ship management, current state of the ship, ship classification, ship history, ship type, and ship age. They revealed that improving the security level of ships based on these factors can effectively improve the navigation security of ships. The International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL 73/78) suggested that port state managers should increase standards related to the control and inspection of substandard ships. Baniela and Ríos (2011) determined that substandard ships could constitute a critical factor in marine accidents. Furthermore, based on the previously identified factors, several scholars have paid attention to evaluating the security levels of different bodies of water through a variety of mathematical models. Arslan and Turan (2009) analysed the maritime disaster incidents in the Istanbul channel by SWOT analysis. They assumed that the most common types of marine accidents in the Istanbul channel were stranding- and collision-based accidents. Baniela and Ríos (2010) selected data regarding marine accidents of cargo carrying occurring worldwide in 2005 and 2006 related to the following: weather, grounding, fire/explosion, collision/contact, hull damage, and machinery. Then, the authors established a security assessment system to explore the relationship between security levels and the occurrence of marine accidents based on risk homeostasis theory.

DEA is an efficient approach for exploring the internal relationships between output and input variables. The main contribution of this approach is to provide quantitative data regarding methods of improvement. Jiang et al. (2012) employed DEA to analyse the efficiency of 24 major Asian container ports to identify both potential opportunities and potential competitive disadvantages of these ports. Wang and Lee (2012) employed the DEA model to evaluate the security of international commercial harbours in Taiwan. These authors have asserted that their research results could reveal the correlation between the conditions of their investigation and practical scenarios. Lee et al. (2014) developed a slacks-based measure of efficiency in the DEA model to assess the environmental efficiency of several emerging port cities.

In the current study, we attempted to provide a scientific and reasonable method for the performance evaluation of security management in the Changjiang MSA, with the objective of assisting maritime authorities in adjusting their management strategies, as well as improving security management levels. Our study established a DEA model for the evaluation of security management performance based on undesirable output data.

In addition, the selected DMUs considered all the main MSAs that control the Changjiang River. This empirical research aimed to truthfully reflect security management performance in the Changjiang MSA at the present stage. Furthermore, we hope this study can provide the direction for security management agencies in managing their respective regulatory waters.

III. RESEARCH METHODOLOGY

Charnes, Cooper, and Rhodes (1978) proposed a model, called the Charnes-Cooper-Rhodes (CCR) model, to analyse the data efficiency of each DMU, which is assumed to comprise m inputs and s outputs. Let y_{rj} and x_{ij} (both positive) be the outputs and inputs of the jth DMU, respectively, and let u_r and v_i be variable weights to determine the solution of the evaluation model. E_k is the CCR input-oriented efficiency of the k th DMU. In a more precise form, when the target is translated into a linear programming formulation, the standard DEA-CCR model can be expressed as follows:

$$\text{Max} \quad \sum_{r=1}^{s} u_r y_{rk}$$

$$\text{s.t.} \quad \sum_{i=1}^{m} v_i x_{ik} = 1, \ i = 1, 2, \ldots, m;$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \ j = 1, 2, \ldots, n; \quad (1)$$

$$u_r \geq \varepsilon > 0, \ r = 1, 2, \ldots, s;$$

$$v_i \geq \varepsilon > 0, \ i = 1, 2, \ldots, m.$$

where ε denotes a non-Archimedean infinitesimal epsilon. As a special assumption, all DMUs occupy the same multiple outputs ($\mathbf{y} = y_{1j}, y_{2j}, \ldots, y_{sj}$) as model (1) does; concurrently, the number of input variables are reduced to one, and a constant value can be assumed for a single input with all $x_j = 1$ ($j = 1, 2, \ldots, n$). Subsequently, a new variable $d_j (j = 1, 2, \ldots, n)$ can be added to alter the second constraint of model (1) to serve as an equation. The evaluation model is expressed as follows:

$$\text{Max} \quad \sum_{r=1}^{s} u_r y_{rk}$$

$$\text{s.t.} \quad \sum_{r=1}^{s} u_r y_{rj} + d_j = 1, \ j = 1, 2, \ldots, n; \quad (2)$$

$$u_r \geq \varepsilon > 0, \ r = 1, 2, \ldots, s;$$

$$d_j \geq 0, \ j = 1, 2, \ldots, n.$$

Model (2) is an efficient approach for dealing with n DMUs (DMU $- j, j = 1, 2, \ldots, n$) that occupy multiple outputs without explicit inputs (WEIs), especially when the input of a database cannot easily be measured. However, model (2) should select a set of variables with weights of $u_r (r = 1, \ldots, s)$ based on the

final target of maximising the efficiency of DMU-k. Naturally, with the fluctuation of the evaluated DMU, the selection of variables with weights of $u_r (r = 1, \ldots, s)$ should present a variety of solutions. Karsak and Ahiska (2005) proposed a minimax-based approach for exploring the most efficient DMUs with a common set of weights, from which each DMU was evaluated through a common set of criteria. Based on the model of Karsak and Ahiska (2005), the target can be altered to maximise the efficiency of the weakest inefficient DMU. Suppose that there exist s outputs ($\mathbf{y} = y_{1j}, y_{2j}, \ldots, y_{sj}$) and a single input x_j for all DMUs, and that u_r and $\mathbf{v}$ are variable weights to determine the solution of the evaluation model; the described approach can be presented as follows:

$$\text{Min} \quad d_{\max}$$

$$\text{s.t.} \quad d_{\max} \geq d_j, \ j = 1, 2, \ldots, n;$$

$$\sum_{r=1}^{s} u_r y_{rj} + d_j = 1, \ j = 1, 2, \ldots, n; \quad (3)$$

$$u_r \geq \varepsilon > 0, \ r = 1, 2, \ldots, s;$$

$$d_j \geq 0, \ j = 1, 2, \ldots, n.$$

where d_j denotes the deviation from the efficiency of DMU-j. Toloo (2013) researched nine different aspects of the service and in-game performance of tennis players WEI variables; however, this approach ultimately selected an inefficient player as the most efficient player, and thus, an illogical conclusion was obtained, thereby severely decreasing the validity of model (3). To overcome this issue, Toloo (2013) innovatively proposed an extended mixed integer linear programming DEA (MILP-DEA) model for reducing the number of efficient units WEIs, from which a new approach was developed that integrated an auxiliary binary variable into the constraints of model (4) to strictly control the efficient DMU, allowing it to be unique. Toloo's approach is presented as follows:

$$\text{Min} \quad d_{\max}$$

$$\text{s.t.} \quad d_{\max} \geq d_j, \ j = 1, 2, \ldots, n;$$

$$\sum_{r=1}^{s} u_r y_{rj} + d_j = 1, \ j = 1, 2, \ldots, n;$$

$$\sum_{j=1}^{n} \theta_j = n - 1, \ j = 1, 2, \ldots, n;$$

$$d_j \leq \theta_j, \ j = 1, 2, \ldots, n; \quad (4)$$

$$\theta_j \leq M d_j, \ j = 1, 2, \ldots, n;$$

$$\theta_j \in \{0, 1\}, \ j = 1, 2, \ldots, n;$$

$$u_r \geq \varepsilon > 0, \ r = 1, 2, \ldots, s.$$

where M is a sufficiently high positive number and θ_j is an auxiliary binary variable. Based on the fourth and fifth constraints for the variable θ_j, $d_j = 0$ if and only if $\theta_j = 0$. Consequently, for any efficient DMU-k, only the binary variable θ_k would be zero, which thus leads to $d_k = 0$. Moreover, $\theta_{j \neq k} = 1$ can be obtained, leading to $d_{j \neq k} > 0$. Specifically, in model (4), a zero deviation from the efficient unit can be achieved if and only if a zero auxiliary binary variable is available. Consequently, for finding the most efficient DMU, Toloo (2013) proposed the third constraint, which compels the sum value of all auxiliary binary variables to be n-1. Therefore, a single efficient unit can be chosen; furthermore, the only selected unit is evidently the most efficient DMU. From a set of real data of 40 professional tennis players, nine different competition performances were obtained WEIs, and they were subsequently utilised to examine the model (4).

Combined with the concept of sustainable design efficiency proposed by Chen et al. (2012), assuming a set of n different designs of a particular product as the DMUs denoted by DMU$_j$($j = 1, 2, \ldots, n$), there exist s performance attributes as desirable outputs and s' undesirable outputs. Let r represent the index of desirable outputs and r' represent the index of undesirable outputs. The r th desirable output of the k th DMU is denoted by y_{rk}, and the r th undesirable output of the k th DMU is denoted by $y_{r'k}^u$. We modified model (4) to handle the WEI issue. Our new model under the output oriented can be rewritten as the following non-linear programming problem:

$$\text{Min} \quad d_{\max}$$
$$\text{s.t.} \quad d_{\max} \geq d_j, j = 1, 2, \ldots, n;$$
$$d_{\max} \geq d_j^u, j = 1, 2, \ldots, n;$$
$$\sum_{r=1}^{s} u_r y_{rj} + d_j = 1, j = 1, 2, \ldots, n;$$
$$\sum_{r=1}^{s} u_{r'} y_{r'j}^u - d_j^u = 1, j = 1, 2, \ldots, n;$$
$$\sum_{j=1}^{n} \theta_j = n-1, \sum_{j=1}^{n} \theta_j^u = n-1, j = 1, 2, \ldots, n; \quad (5)$$
$$d_j \leq \theta_j, d_j^u \leq M\theta_j^u, j = 1, 2, \ldots, n;$$
$$\theta_j \leq Nd_j, \theta_j^u \leq Nd_j^u, j = 1, 2, \ldots, n;$$
$$\theta_j \in \{0, 1\}, \theta_j^u \in \{0, 1\}, j = 1, 2, \ldots, n;$$
$$u_r \geq \varepsilon > 0, r = 1, 2, \ldots, s;$$
$$u_{r'} \geq \varepsilon > 0, r' = 1, 2, \ldots, s'.$$

Based on the assumption that the optimal solution weight of model (5) is u_r^* and $u_{r'}^*$, the efficiency score of each DMU can be calculated as follows:

$$e_j^* = \sum_{r=1}^{s} u_r^* y_{rj}$$
$$+ \frac{1}{\sum_{r=1}^{s} u_{r'}^* y_{r'j}^u} (j = 1, 2, \ldots, n; r = 1, 2, \ldots, s; r' = 1, 2, \ldots, s')$$

IV. EMPIRICAL STUDY

1. Input and Output Variables

Marine accidents can occur in many forms such as foundering, collision, stranding, fire, capsizing, explosion, ship missing and others (Li, 1998). Nielsen and Roberts (1999) divided the reasons for loss of life at sea into five categories: deaths caused by occupational accidents; deaths caused by marine accidents; deaths related to crew members not being present; deaths resulting from illness at sea; and deaths from suicide, homicide, and reasons not accounted for. Akten (2004) also extended the varieties of marine accidents, indicating that marine accidents resulting in the loss of a ship include contact or collision, foundering, capsizing, fire or explosion, sinking, grounding, breaking up, breakdown of the ship underway, stranding, missing of the ship, and adverse weather conditions.

MSAs in different countries and regions provide diverse definitions for the classification of marine accidents. Our dataset covered six varieties of accident defined by the Changjiang MSA: collision, contact, grounding, stranding, fire, and foundering, respectively. In the current study, the research data regarding marine accidents were collected from the official website of the Changjiang MSA. All accident types were considered as undesirable output variables in the current study, and were derived from seven websites of the primary MSAs in charge of the Changjiang River in 2015. No explicit input variables were considered in the current study. Therefore, model (5) was suitable for conducting our research, as well as for handling WEI issues and undesirable output variables.

2. Data Analysis

Descriptive statistics of output variables selected for the current study are summarised in Table 1. For understanding the distribution of output variables related to each DMU, this study integrated statistical analysis (Table 2) linked with the statistical data in terms of the maximum, minimum, average, and standard deviation for each accident type.

Table 1 presents the main varieties of marine accidents in the Changjiang River: collision, grounding, and foundering. Collisions constitute nearly half of all marine accidents in the Changjiang River, particularly in the parts of the river under the control of the Huangshi, Anqing, and Wuhu MSAs. In 2015, grounding and stranding revealed low-quality security management performance in the Chongqing MSA. The Yichang and Yueyang MSAs must also pay more attention to security management

Table 1. Descriptive statistics of output variables.

Changjiang MSA	Outputs					
	Collision	Contact	Grounding	Stranding	Fire	Foundering
Chong Qing	1	0	5	7	1	2
Yi Chang	4	0	3	1	3	0
Yue Yang	2	0	0	0	0	0
Wu Han	3	4	3	0	0	3
Huang Shi	12	2	1	1	1	2
An Qing	6	0	0	0	1	1
Wu Hu	7	3	0	0	1	3

Table 2. Statistical analysis of output variables.

Changjiang MSA	Outputs					
	Collision	Contact	Grounding	Stranding	Fire	Foundering
Maximum	12	4	5	7	3	3
Minimum	1	0	0	0	0	0
Average	5.00	1.29	1.71	1.29	1.00	1.57
Standard deviation	3.74	1.70	1.98	2.56	1.00	1.27

Table 3. The security management performance of Changjiang MSA.

Changjiang MSA	Efficiency score	Ranking
Chong Qing	1.0000	1
Yue Yang	0.9999	2
Wu Han	0.6667	3
Yi Chang	0.4828	4
An Qing	0.3333	5
Wu Hu	0.2857	6
Huang Shi	0.1647	7

related to the occurrence of collisions. However, the probability of contact-based accidents was high for the Wuhan MSA. Overall, the risks of collision and grounding were determined to rank highest among the marine accident varieties in the Changjiang River. This conclusion is confirmed in Table 2.

Table 3 presents the evaluation results of the security management performance of the MSA in charge of the Changjiang River, as evaluated by our modified DEA-WEI model (model (5)). The evaluation conclusion of each projection can provide quantitative reference information that can serve as guidance for improvement. For DEA, the efficiency scores represent the performance levels of each evaluated DMU. The higher the efficiency score is, the more satisfactory the performance of the DMU is. However, with the exception of the highly efficient DEA model, the efficiency score cannot be higher than 1. Therefore, a value of 1 denotes that the DMU is efficient and can serve as a benchmark.

Table 3 presents a clear ranking of all DMUs based on model (5). The evaluation solution indicated that the performance of the Chongqing MSA was the most satisfactory regarding security management of the Changjiang River, obtaining an efficiency score of 1; the Chongqing MSA was closely followed by the
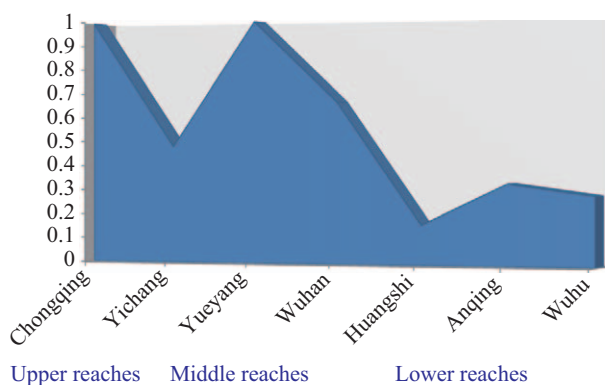
Yueyang MSA, which obtained an efficiency score of 0.9999, also extremely close to the efficient production indicator. The other DMUs all exhibited low performance levels in 2015, all achieving an evaluation efficiency score of less than 1. This specifically indicates that for most of the major Changjiang River MSAs, there exists the potential for danger in the waters under their control, particularly for the Huangshi, Wuhu, and Anqing MSAs, of which a common feature is that all of them are located around the lower reaches of the Changjiang River. The evaluation results indicate that among MSAs based in different regions around the Changjiang River, the security management levels are uneven. Along with an increase in the volume of shipping traffic in the river, the navigation environment is becoming increasingly complicated and unpredictable. Effective navigation security management could contribute to preventing loss of property, as well as to protecting the lives of crew members.

Fig. 1 presents the security management performance of all the evaluated MSAs, representing the overall navigation security environment of the Changjiang River.

According to priority, the performance of all the evaluated MSAs can be ranked in the following order: Chongqing, Yueyang, Wuhan, Yichang, Anqing, Wuhu, Huangshi. Fig. 1 clearly

Table 4. Projections and change rates of each output variable.

Changjiang MSA	Outputs											
	Collision	Change rate	Contact	Change rate	Grounding	Change rate	Stranding	Change rate	Fire	Change rate	Foundering	Change rate
Chong Qing	0.50	-50.00%	0	0.00%	0	-100.00%	0.50	-92.86%	0	-100.00%	0	-100.00%
Yi Chang	2.00	-50.00%	0	0.00%	0	-100.00%	0.07	-92.86%	0	-100.00%	0	0.00%
Yue Yang	1.00	-50.00%	0	0.00%	0	0.00%	0.00	0.00%	0	0.00%	0	0.00%
Wu Han	1.50	-50.00%	0	-100.00%	0	-100.00%	0.00	0.00%	0	0.00%	0	-100.00%
Huang Shi	6.00	-50.00%	0	-100.00%	0	-100.00%	0.07	-92.86%	0	-100.00%	0	-100.00%
An Qing	3.00	-50.00%	0	0.00%	0	0.00%	0.00	0.00%	0	-100.00%	0	-100.00%
Wu Hu	3.50	-50.00%	0	-100.00%	0	0.00%	0.00	0.00%	0	-100.00%	0	-100.00%
Average		**-50.00%**		**-42.86%**		**-57.14%**		**-39.80%**		**-71.43%**		**-71.43%**

Fig. 1. **Overall navigation security environment of the Changjiang River.**

Upper reaches   Middle reaches   Lower reaches

indicates that the navigation environments of both the upper and middle reaches of the Changjiang River are subject to higher safety management performance, compared with the environments of the lower reaches. Among all the MSAs, Huangshi was identified to have the lowest performance in terms of navigation security management. Among the remaining DMUs, Yichang, Anqing, and Wuhu also obtained unsatisfactory efficiency scores. These evaluation results reveal that all the inefficient MSAs around the Changjiang River have considerable room for improvement in terms of security management. In addition, more concrete and quantifiable adjustment recommendations may provide more effective help.

To facilitate the inefficient MSAs in improving their security management performances, Table 4 presents a summary of the objectives and appropriate improvements regarding each variable in this study. The summarised information in Table 4 could provide some quantitative information serving as a reference to guide the improvements for each inefficient unit.

Table 4 shows that the change rates are equal to the gap between the actual operating values and objective goals. A negative value represents the corresponding decrement of each variable, whereas a positive value denotes the corresponding growth rate. As presented in each row in Table 4, the evaluated MSAs were determined to have optimal projections of each undesirable output variable and the corresponding change rates. Moreover, the quantitative information may facilitate each inefficient MSA in effectively improving its management performance.

The last row in Table 4 presents the average change rate of each output variable. The higher the absolute value is, the more critical is the variable represented. Specifically, an undesirable variable, denoted by the highest absolute value in the last row of Table 4, can be considered the most urgent issue requiring resolution. It is evident that with an average change rate of -71.43%, marine accident types related to fire and foundering are far more prevalent than the other undesirable variables. The next most prevalent is grounding, with an average change rate of -57.14%.

V. CONCLUDING REMARKS

According to the empirical research results, the Chongqing and Yueyang MSAs were observed to be relatively efficient under security management performance evaluation. Furthermore, marine accident types related to collision and grounding were determined to be the most frequently occurring types in the Changjiang River. From an overall perspective of observing the entire navigation environment of the Changjiang River, the MSAs in charge of the upper and middle reaches exhibited higher safety performance levels than did those in charge of the lower reaches.

Currently, for each main MSA in charge of the Changjiang River, authorities should continue to focus on preventing fire- and foundering-related accidents. However, the highest security risk in the river was observed to be collisions. Last year, collisions occupied the largest market share of marine casualties, covering all Changjiang River MSAs. Therefore, enhancing methods of collision prevention could play a key role in improving security management performance levels.

The main factors causing marine accidents can be divided into two categories: human factors and environmental factors. Human factors include physical fatigue, mental fatigue, highly dangerous work practices, and professional burnout, all of which could be viewed as factors that interfere with the routine work of ship crews. According to observations of previous marine accidents, being unconscious of danger in any given situation may lead to a lack of awareness of the most suitable methods for self-preservation among crew members, potentially resulting in crew members making unsuitable choices that could result in collisions in emergency situations. As for environmental factors, along with developments in the globalisation of the commerce industry, shipping traffic in the Changjiang River continues to

present an increasing trend: A wide variety of ship types converging in the same bodies of water simultaneously, which evidently exacerbates the complicated nature of the navigation environment.

Other corresponding suggestions can also be summarised, but not limited to the following: strengthening the structure of ships, establishing more effective aids for navigation, and strictly monitoring the transportation environment in the Changjiang River. This study explored the current situation of the security management performance of MSAs around the Changjiang River by establishing an evaluation model for navigation security including data regarding undesirable outcomes. We hope this paper provides useful suggestions that can serve as a reference for inefficient maritime authorities in improving their management performance levels, as well as in maintaining safe navigation environments in their respective regulatory waters.

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