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Application of HFACS Model in Marine Traffic Accident Field

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Abstract

Accidents are caused by the interaction of various factors. Due to the complexity and uncertainty of the research object, a structured and scientifically effective framework and an appropriate data analysis method are needed for the research. In order to study Marine Traffic accidents quantitatively and take corresponding preventive measures, this paper proposed the Human Factors Analysis and Classification System for Marine Traffic accidents based on HFACS, HFACS-MTA), first of all, the human error factors of maritime traffic accidents are classified, then the obvious and hidden factors that lead to the accidents are scored by the expert subjective scoring method, and the factors are quantitatively ranked by the gray relational analysis method. Finally, the validity of the proposed concept is verified by the analysis of a maritime traffic accident.

Keywords

Marine Traffic; Accident Analysis; Human Factor Analysis and Classification System; Expert Score; Grey Relational Analysis.

1. Introduction

In recent years, the global maritime transport trade volume has continued to grow. Research based on accident data shows that more than 80% of maritime accidents are related to human factors. Among marine traffic accidents, ship collisions have the highest incidence, and over 95% of them are caused by human factors. As a type of marine accident with a higher incidence, more than 90% of ship stranding/reefing accidents are also caused by human factors. Therefore, human error has become the main cause of maritime traffic accidents. Many research scholars also hope to systematically analyze and identify human factors in accidents by establishing relevant framework models. Among them, the HFACS model has been recognized by many industries and has become a The most powerful tool for human factors analysis of various accidents.

Zhang Xinxin et al. [2] proposed a human error analysis and classification system for maritime traffic accidents. Based on the HFACS model, a classification discussion was carried out from the perspectives of crew factors, ship factors and environmental factors that affect maritime safety; Shih-Tzung Chen et al. [5] The human factors analysis and classification system for maritime accidents adds a new level of external factors on the basis of the traditional HFACS model. At this level, it emphasizes that legislation, management, and system component design are not sufficient for accident analysis in the maritime industry. However, the existing research lacks sufficient consideration of the "premises of unsafe behavior" and the sub-factors of "unsafe behavior" and their interactions and constraints. This is not conducive to the grasp of the classification of unsafe actions, and it cannot The system analyzes unsafe actions. This paper will combine the human factor dimension in marine traffic accident investigation to propose a human factor classification system suitable for marine traffic accident investigation. Through the subjective scoring method of experts, we will analyze the human explicit and implicit factors in marine traffic accidents, and use grey relational analysis to analyze marine traffic accidents. The influencing factors of human factors in traffic accidents are quantified and sorted, and the sequence of the human factors is obtained, which

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provides support for the investigation of human factors in maritime traffic accidents.Organization of the Text

2. HFACS-MTA

2.1 HFACS

The human factor analysis and classification system model was proposed by behavioral scientists Wiegmann and Shappell [1] of the US Navy. In the early 1990s, due to the extremely high rate of aviation accidents in the U.S. Navy, the naval forces were turbulent. The task of Wiegmann and Shappell was to determine why these accidents continued to occur and how to reduce the accident rate. Therefore, they established the basic framework of the HFACS model based on James Reason's famous "Swiss Cheese" model [4]. The "Swiss Cheese" model includes four levels: organizational management impact, unsafe supervision, preconditions for unsafe behavior, and unsafe behavior. In addition to these levels, the HFACS model also creates causal categories to identify and classify hiddenness within the organization. With explicit factors, the reasons for the four levels of the "Swiss Cheese" model are deepened, and more specific reasons are proposed for each level. The goal of the HFACS model is not to blame responsibility, but to understand the potential cause and effect of the accident. The organizational influence, the supervision of unsafe behaviors, and the premise of unsafe behaviors in the framework are hidden factors and potential causes of accidents; unsafe behaviors are explicit factors that directly lead to accidents.

The research of the HFACS model originated in the aviation field, so at first the model was only applied to the analysis of aviation accidents. With the continuous development and deepening of research, more and more researchers apply the HFACS model to other fields, such as the mining industry[6]-[8], construction[9]-[10], shipping[11]-[13], railway[14]-[15], medical[16], etc.

Table 1 Survey dimension table of human factors in marine traffic accidents

Problems on board	Safety measures
	Activities before the accident
	Liability in the event of an accident
	Actual actions in the event of an accident
	Training/education/certification/professional experience
	health condition
	Psychology, emotion, consciousness and employment situation
	Work pressure/task complexity
	Working time limit / rest time limit / rest method
	Relationship with other crew members and subordinates
	Living conditions and environment on board
	Staffing level
	Captain's Executive Order
	Equipment automation/reliability level
	Ship design and maneuvering/cargo characteristics
Company management issues	Work plan and rest period
	Staffing level
	Duty practice
	Job designation
	Shore-ship-shore support and communication
	Management policy
	Voyage plan and port plan
	Recreational facilities
	Contracts and labor agreements
	National/International Requirements

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2.2 Dimensions of human factors in maritime traffic accidents

To study human factors, it is necessary to analyze the design of equipment, the interaction between operators and equipment, as well as the rules and regulations that the crew and managers abide by, that is, fully consider the mutual restraint relationship between man, ship and environment. The process of investigating human factors is divided into 6 steps: collecting accident information, determining the process of accident occurrence, confirming unsafe operations/decisions and conditions, confirming the types of errors and violations, confirming the potential factors of the accident, and confirming the potential safety issues And formulate safety measures. Among them, steps 3 to 5 are the main steps of the investigation. The scope of human factors investigation on ships generally includes but is not limited to the following 25 scopes. According to the characteristics of factors, they are mainly divided into two parts: shipboard issues and company management issues, as shown in Table 1.

2.3 Establishment of HFACS-MTA

HFACS-MTA consists of four levels in sequence: organizational influence, unsafe supervision, preconditions for unsafe behavior, and unsafe behavior. Combining the HFACS model and the characteristics of maritime traffic accidents, the overall framework of the model is compiled,. Considering the interaction of "people-ship-environment", the secondary factor indicators of the third level "preconditions for unsafe behavior" mainly include environmental factors, ship factors, crew factors and company factors. In order to understand the structure of the cause model, the model is divided into two parts, the hidden cause and the explicit cause.

The model focuses on the third-level “preconditions for unsafe behavior” and the fourth-level “unsafe behavior”, respectively listing the sub-factor indicators of each second-level causal factor, and detailed the negligence factors of the fourth-level crew. The specific categories of man-made technical negligence on board are listed in detail.

3. Grey Relational Analysis of HFACS-MTA Model

3.1 Cause analysis of maritime traffic accidents

The subjective scoring method is to use the experience of experts to intuitively judge the explicit and implicit reasons related to the accident, and assign the corresponding weight to each factor, and then analyze and process the corresponding results. The specific steps are as follows:

Table 2 Experts' subjective score sheet on the cause of the accident

Serial number	Dominant factor	The level of hidden factors	Hidden factors	influence level	Probability of occurrence
1	Improper loading management	Prerequisites for unsafe behavior(L3)	Improper loading and securing of cargo	0.96	0.62
2	Improper loading management	Prerequisites for unsafe behavior(L3)	Defects of ship securing equipment	0.87	0.92
3	Unskilled crew	Prerequisites for unsafe behavior(L3)	Insufficient training experience	0.82	0.65
4	Lack of crew professional ethics	Organizational impact(L1)	Lack of organizational culture	0.71	0.34
5	Poor ship maneuverability	Prerequisites for unsafe behavior(L3)	Excessive modification of hull structure	0.77	0.35
6	Poor ship maneuverability	Unsafe regulation(L2)	Insufficient shore-based supervision	0.41	0.74
7	Load exceeds the limit	Unsafe regulation(L2)	Did not correct the problem	0.82	0.54
8	Rescue operation lags behind	Prerequisites for unsafe behavior(L3)	Shore-ship-shore support and communication	0.58	0.57

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3.1.1. Making a questionnaire for maritime traffic accidents

Analyze the accident situation with the HFACS-MTA model, and make a questionnaire for experts in maritime traffic accidents based on this. The questionnaire lists the obvious and hidden errors that may lead to the accident.

3.1.2. Scoring by experts

Experts are invited to score possible human errors listed in the questionnaire based on the degree of influence and probability of occurrence of maritime traffic accidents. The scoring range consists of numbers between 0-1. 0 means no effect on the occurrence of the accident (the probability of occurrence is the smallest), 1 means the degree of influence is the greatest (the probability of occurrence is the greatest).

Experts' subjective scores of the causes of maritime traffic accidents are shown in Table 2.

3.2 Grey relational analysis

The results of the questionnaire survey are sorted and analyzed, and the mean value of the evaluation indicators for each hidden cause is selected as the behavior sequence of each dominant cause as the comparison sequence of the gray correlation analysis. The comparison sequence is expressed in the form of formula (1):

$$X_i = (x_i(1), x_i(2), \ldots, x_i(n)) \tag{1}$$

Where represents the i-th explicit cause and the n-th recessive cause respectively,represents the m related factors of the nth hidden cause, corresponding to the evaluation index of the nth hidden cause in the article: the degree of influence and the probability of occurrence.

Since the standard sequence reflects the ideal expected level of the relevant causative factors, the standard sequence can be selected as a zero sequence. The format of the standard sequence is generally as shown in formula (2):

$$X_0 = (x_0(1), x_0(2) \ldots, x_0(n)) \tag{2}$$

Calculate the difference sequence between the comparison sequence and the standard sequence:

$$\Delta X_i = X_i - X_0 \tag{3}$$

Calculate the correlation coefficient between each evaluation index of each explicit (implicit) reason and the standard sequence, as shown in formula (4):

$$\gamma(x_0(k), x_i(k)) = \frac{\min_i \min_k |x_i(k) - x_0(k)| + \xi \max_i \max_k |x_i(k) - x_0(k)|}{\Delta_i(k) + \xi \max_i \max_j |x_i(k) - x_0(k)|} \tag{4}$$

Calculating the gray correlation degree between the comparison sequence and the standard sequence can be obtained by formula (5):

$$\gamma(X_0, X_i) = \sum_{k=1}^{n} \delta_k \gamma(x_0(k), x_i(k)) \tag{5}$$

The final gray correlation degree obtained by formula (5) reflects the relationship between the cause of an accident and the ideal value of each factor (zero accident). The greater the correlation degree, the higher the safety of the corresponding maritime traffic safety; the greater the correlation degree Smaller, it indicates that the causal factor poses a greater threat to maritime traffic safety.

4. Case study

The HFACS-MTA model and the grey correlation analysis method were used to analyze the human factors in the sinking of the "Seyue" in Korea in 2014.

After preliminary investigation, the main causes of human error in this accident are as follows: (1) The crew's lack of professional ability and experience caused the ship to turn too much due to the excessive rudder efficiency; (2) The crew's pre-job and emergency training were insufficient,

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resulting in The entire ship's personnel missed the best time to escape; (3) the hull was over-modified; (4) overloaded and the cargo was not fastened or lashed; (5) the crisis response and emergency rescue mechanism was not perfect.

The steps of human error analysis of the accident are as follows:

1) Invite experts to score the cause of the accident, and take the average of the index scores of each factor in the hidden cause. The results are shown in Table 2, so the comparison sequence is obtained:

$$X = \begin{pmatrix} x_1 \\ x_2 \\ \dots \\ x_8 \end{pmatrix} = \begin{pmatrix} 0.96 & 0.62 \\ 0.87 & 0.92 \\ 0.82 & 0.65 \\ 0.71 & 0.34 \\ 0.77 & 0.35 \\ 0.41 & 0.74 \\ 0.82 & 0.54 \\ 0.58 & 0.57 \end{pmatrix}$$

2) In order to facilitate the calculation, the standard sequence is selected as the zero sequence:

$$X_0 = (0,0)^T$$

3) Calculate the gray correlation coefficient corresponding to each cause by formula (4);

4) Bring the gray correlation coefficient corresponding to the hidden cause into formula (5) to obtain the gray correlation degree corresponding to each hidden cause.

5) Sort the obtained gray correlation degree of each hidden factor, as shown in Table 3.

Table 3 Accident Causes Grey Relational Degree Ranking Table

Serial number	Hidden factors	Gray correlation	Relevance ranking
1	Improper loading and securing of cargo	0.8802	5
2	Defects of ship securing equipment	0.9819	2
3	Insufficient training experience	0.9277	3
4	Lack of organizational culture	0.8263	7
5	Excessive modification of hull structure	0.8182	8
6	Insufficient shore-based supervision	0.8514	6
7	Did not correct the problem	0.8861	4
8	Shore-ship-shore support and communication	0.9942	1

According to the calculation results in Table 3, it can be seen that the gray correlation degree is low for reasons such as the excessive transformation of the hull structure and the lack of organizational culture of the shipping company, which poses a greater threat to maritime traffic safety; while the gray correlation degree for reasons such as the defects of ship securing equipment and the communication between ship and shore is relatively low High, less threat to maritime traffic safety. Therefore, in order to prevent accidents, the competent authority should strengthen the safety supervision of the company and its fleet, improve the safety management system, and appropriately strengthen the internal audit system; shipping companies should focus on improving their corporate safety culture and make it effective To every crew member.

5. Conclusion

This paper combines the HFACS model to classify the human factors in maritime traffic accidents, constructs the HFACS-MTA model, divides it into two parts, explicit factors and recessive factors, and studies in detail the "preconditions for unsafe behavior" and "unsafe behaviors". The contributing factors of each sub-item covered under "Safety Behavior". The final processing result is obtained by combining the subjective scoring method of experts and grey relational analysis, and relevant suggestions are put forward for the result. This article also has shortcomings. The expert's score contains too many subjective components, which will inevitably lead to a certain deviation in the final

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result. It is necessary to combine more theoretical systems to improve the HFACS-MTA model in the future to provide information for marine traffic accident investigations. convenient.

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