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Evaluation of safety monitoring scheme for offshore floating platform based on the multiple connection numbers

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Abstract. To accurately evaluate the safety monitoring scheme of offshore floating platform, a five-element connection number analysis method for evaluating the safety monitoring scheme of offshore floating platform was developed in this paper. According to the characteristics of safety monitoring of offshore floating platform, an index system was constructed. Considering the complexity and uncertainty in the evaluation of safety monitoring schemes, the Set Pair Analysis based on the five-element connection number was used to establish the similarity, difference and reverse evaluation model of safety monitoring schemes for offshore floating platforms. In addition, entropy weight method was employed to calculate the objective weights. Taking an offshore floating platform project in Guangdong, China as an example, a case study was carried out. The study showed that the evaluation grade of this monitoring program was good and the scientificity of the programming method is the most important influencing factor. The research results provided a theoretical basis for the safety monitoring scheme management of offshore floating platform.

1 INTRODUCTION

With the deepening of ocean development and researches, the number and types of offshore floating platforms are increasing. Safety monitoring is very important owing to the complex working environment of offshore floating platforms. Accurately evaluating the safety monitoring plan and quantitatively analyzing the risk state of offshore floating platform operation have laid a solid foundation for reducing the safety accidents of offshore floating platform.

At present, relevant scholars have done a lot of research on the safety of offshore floating platforms, but the related research mainly focuses on structural safety or structural performance design, and few scholars pay attention to the safety monitoring scheme of offshore floating platforms. Based on hydrological analysis and dynamic time history analysis, Ren et al. [1] determined the ultimate safety state of offshore floating wind turbines. To accurately evaluate the influence of ocean current on offshore floating platform structure, Chen and Basu [2] proposed a nonlinear hydrodynamic model of multi-cable mooring system, which considered geometric nonlinearity, seabed contact and ocean current effect. Wu et al. [3] emphasized the important influence of weld safety on the safety of offshore floating platform structure, and proposed a new calculation method of weld stress of offshore floating platform structure.

Set Pair Analysis (SPA) is a novel research method in the field of system evaluation, which has been widely used in recent years. Guo et al. [4] constructed a flood disaster risk assessment model based on the SPA. The case study showed that SPA was able to effectively deal with fuzziness in system evaluation. Plugge et al. [5] constructed a feasibility evaluation model of South-South cooperation based on the SPA. To the best of the authors' knowledge, there is no research on the application of the SPA to the safety monitoring scheme evaluation of offshore floating platform.

In view of this, the SPA, entropy weight method, and five-element connection number were introduced to establish the evaluation model, and static analysis of safety monitoring scheme through situation function was made. The research purpose of this paper was to provide theoretical basis for safety risk management of offshore floating platform.

2 EVALUATION INDEX SYSTEM

There is no national or industrial standard for safety monitoring of offshore floating platforms. Therefore, the first-level index of safety monitoring program evaluation was constructed from three dimensions: scientificity, rationality and adaptability. Through on-the-spot investigation and questionnaire survey, the secondary indicators under three dimensions were analyzed [6-7]. The questionnaire was aimed at 20 experts with rich experience in offshore engineering. The final scheme evaluation index system was shown in the Table 1.

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Table 1. Program evaluation index system.

Primary index	Secondary index
x_1 : Scientificness	x_{11} : Comply with the requirements of laws
	x_{12} : Scientificity of the programming method
	x_{13} : Adequacy of personnel and materials
x_2 : Rationality	x_{21} : Clear objectives of monitoring measures
	x_{22} : Clear implementers of monitoring measures
	x_{23} : Reasonable monitoring and management system
x_2 : Rationality	x_{31} : Adaptability to sudden natural disasters
	x_{32} : Adaptability of rapid consumption of materials
	x_{33} : Adaptability of changing monitoring content

3 PROPOSED EVALUATION MODEL

SPA is a mathematical method to deal with certain and uncertain problems in research system through connection number analysis. Two sets of the object to be evaluated and the ideal scheme were established, so the set pairs were formed. The connection degree was calculated from the same but different angles, and the identity, difference and opposition of the uncertain system were quantitatively analyzed. The core steps of introducing the SPA into safety monitoring scheme evaluation of offshore floating platform were as follows.

Step 1. Forming a set pair.

Because of the complexity of safety monitoring scheme evaluation of offshore floating platform, all secondary indicators constructed in this paper were qualitative indicators. The evaluation scheme was divided into five grades, very good (I), good (II), fair (III), poor (IV), and very poor (V). The scores of each index were expressed as very good [0,20), good [20,40), fair [40,60), poor [60,80), and very poor [80,100).

Make each secondary index score of the object to be evaluated and the sustainability grade standard into a set pair:

$$\mu = \sum_{i=1}^{n} \omega_i a_i + \cdots + \sum_{i=1}^{n} \omega_i b_{i,K-2} e_{K-2} + \sum_{i=1}^{n} \omega_i c_l f \tag{1}$$

where ω_i is the weight of the i-th index, which is calculated by entropy method in this paper. The n is the number of indexes, a is the same degree of the set, b is the difference degree of the set, and c is the opposition degree of the set.

Step 2. Calculating the weight of each index.

Entropy method was used to determine the weight of indexes by measuring the amount of effective information. The entropy value indicated the probability and order degree of events. The greater the probability and order degree of events, the greater the entropy value of the system, the less the effective information contained and the smaller the weight.

According to the calculation principle of entropy, the entropy value was as follows:

$$\begin{cases} H_i = q\sum_{j=1}^{n} p_{ij} \cdot \ln p_{ij} \\ p_{ij} = \dfrac{r_{ij}}{\sum_{j=1}^{n} r_{ij}} \\ q = -\dfrac{1}{\ln n} \end{cases} \tag{2}$$

Where p_{ij} is the characteristic proportion, $i = 1, 2, \ldots, m$, and $0 \le H_i \le 1$.

The weight calculation equation of the evaluation index i was:

$$w_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \tag{3}$$

Step 3. Calculating the connection degree of each secondary index.

Referring to the previous research results [4], the connection degree of each secondary index was as follows:

$$\mu_i = \begin{cases} 1 + 0e_1 + 0e_2 + \cdots + 0e_{k-2} + 0f & x_i \ge s_1 \\ \dfrac{2x_i - s_1 - s_2}{s_1 - s_2} + \dfrac{2s_1 - 2x_i}{s_1 - s_2} e_1 + 0e_2 + \cdots + 0e_{K-2} & \dfrac{s_1 + s_2}{2} \le x_i < s_1 \\ \dfrac{2x_i - s_2 - s_3}{s_1 - s_3} e_1 + \dfrac{s_1 + s_2 - 2x_i}{s_1 - s_3} e_2 + \cdots + 0e_{K-2} & \dfrac{s_2 + s_3}{2} \le x_i < \dfrac{s_1 + s_2}{2} \\ \vdots & \vdots \\ 0e_1 + \cdots + \dfrac{2x_i - 2s_{K-1}}{s_{K-2} - s_{K-1}} e_{K-2} + \dfrac{s_{K-2} + s_{K-1} - 2x_i}{s_{K-2} - s_{K-1}} f & s_{K-1} \le x_i < \dfrac{s_{K-2} + s_{K-1}}{2} \\ 0 + 0e_1 + 0e_2 + \cdots + 0e_{K-2} + 1f & x_i < s_{K-1} \end{cases} \tag{4}$$

Step 4. Determining the evaluation level of the monitoring program.

The connection degree of the object to be evaluated to the five evaluation grades was as follows:

$$\begin{cases} f_1 = \sum_{i=1}^{n} \omega_i a_i \\ f_2 = \sum_{i=1}^{n} \omega_i b_{i,1} \\ f_3 = \sum_{i=1}^{n} \omega_i b_{i,2} \\ f_4 = \sum_{i=1}^{n} \omega_i b_{i,3} \\ f_5 = \sum_{i=1}^{n} \omega_i c_i \end{cases} \quad (5)$$

In this paper, confidence λ was used to determine the sustainability level:

$$h_k = \left(f_1 + f_2 + \cdots + f_k\right) > \lambda \quad (6)$$

where λ is the preset confidence level, generally taking 0.6 indicates that the decision maker's risk attitude is neither extreme nor conservative.

The minimum value of k satisfying equation (6) was the sustainability evaluation grade of urban road engineering.

4 CASE STUDY

An offshore floating island project in Guangdong Province, China was selected for analysis to verify the effectiveness of the proposed method. The environmental monitoring of this project mainly monitored the wind and wave load, adopted the five-parameter integrated machine to measure the wind speed and direction, and adopted the Acoustic Doppler Wave Velocity Profiler (AWAC) to measure the wave height, wave direction and velocity profile.

According to the established evaluation index system, a questionnaire was designed, and a total of 30 questionnaires were distributed to front-line operators (A), technicians (B), safety managers (C) and safety management experts (D). Considering the differences of academic level and working experience, the four types of appraisers were given as $w' = \left[w'_A, w'_B, w'_C, w'_D\right] = [0.19, 0.28, 0.25, 0.28]$.

According to the evaluation model constructed in the Section 3, the evaluation data were brought into equations (2)-(3) in turn, and the secondary weight of each index was obtained and shown in Table 2. According to the five-level risk comments of various personnel on the safety monitoring scheme of this offshore floating island project, the five-element connection number expression of the safety monitoring scheme of this project was calculated by using equation (4), and the results were shown in Table 2.

Table 2. Calculation results of weights and five-element connection numbers.

Secondary index	Weight	Five-element connection number
x_{11}	0.0946	$0.249 + 0.215i + 0.132j + 0.195k + 0.209l$
x_{12}	0.1685	$0.196 + 0.311i + 0.271j + 0.114k + 0.108l$
x_{13}	0.1036	$0.143 + 0.248i + 0.260j + 0.172k + 0.177l$
x_{21}	0.0905	$0.078 + 0.252i + 0.375j + 0.167k + 0.128l$
x_{22}	0.0473	$0.199 + 0.285i + 0.327j + 0.141k + 0.048l$
x_{23}	0.1546	$0.268 + 0.298i + 0.249j + 0.099k + 0.086l$
x_{31}	0.1336	$0.176 + 0.252i + 0.260j + 0.177k + 0.135l$
x_{32}	0.1265	$0.115 + 0.273i + 0.252j + 0.140k + 0.220l$
x_{33}	0.0808	$0.284 + 0.294i + 0.168j + 0.128k + 0.126l$

The x_{12} (Scientificity of the programming method) has the greatest weight. This shows that the managers of safety monitoring scheme evaluation for offshore floating platforms should focus on the rationality of the monitoring scheme compilation method. According to the calculation results in Table 2, the five-element connection number of this project was

$\mu = 0.244 + 0.363i + 0.137j + 0.107k + 0.149l$.

$0.244+0.363>0.6$ indicated that the evaluation grade of the safety monitoring scheme of this project was good (II).

Combined with the actual situation of the project, the following suggestions were put forward to improve the safety monitoring level of the project.

The equipment must be put in place before the start of monitoring. Before the start of the monitoring work, the project department should arrange the storage place of the instruments in a unified way, and the environment and facilities of the instrument storage warehouse should meet the general requirements of the measuring instrument room. If the equipment needs to be sent for inspection according to the regulations, it can only be put into use after it has passed the verification. If it does not need to be submitted for inspection, the project department should arrange self-inspection, and the whole inspection process should be recorded in writing, which can be used as the basis for tracing responsibility in case of abnormal use or man-made damage of instruments and equipment in the future. The project department should regularly check the health of all staff to prevent malignant diseases and infectious diseases from participating in the monitoring work, and the project department should regularly report to the head office. During the construction period, the relevant functional departments and management personnel of the project department are responsible for the personal safety of all staff, so as to prevent accidental casualties.

5 CONCLUSION

In this paper, the safety monitoring scheme evaluation model of offshore floating platform was established by five-element connection number, and the evaluation grade of safety monitoring scheme was comprehensively analyzed, which provided theoretical guidance for safety monitoring scheme management of offshore floating platform. An example of a floating platform project in Guangdong Province was analyzed. The research showed that the evaluation grade of the monitoring scheme was good, and the scientificity of the programming method was the most important influencing factor. The research results provided a basis for the follow-up safety monitoring and management of offshore floating platforms. The main limitation of this paper is that it fails to analyze the influence of different offshore floating platform structures on the evaluation results of safety monitoring scheme.

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