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Life extension and repair decision-making of ageing offshore platforms based on DHGF method

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ABSTRACT

As platforms age, ensuring their continued integrity becomes increasingly. The current life extension and repair decision-making processes within ageing platforms are typically based on the DHGF algorithm, which was established in order to provide reasonable predictions about the lifespan of ageing platforms, make accurate repair decisions, and reduce risks related to uncertain and complicated environments. The algorithm contains 18 indicators based on the Delphi method, which together-build a complete evaluation system. In this study, the hierarchical structures were established by analyzing and adjusting four dimensions - project factors, risk factors, load factors, and structural factors, and all of them affect the ageing platform service state. The Analytic Hierarchy Process determined a weighted subset. Gray weights were calculated using the gray model theory, and fuzzy mathematics was then applied to form grade evaluation for the ageing platform. A complete evaluation criterion for life extension and repair decision-making was established, and the comprehensive score was calculated by a sequence of computational steps. Analysis showed that the decision making of this platform is 'Major repair', fatigue cracks, corrosion, and marine fouling—these factors must be addressed first. The results confirm that the proposed model accurately describes the dynamic, economic lifespan of ageing platforms.

1. Introduction

An offshore platform is the most important equipment utilized within offshore oil exploitation. They are complex in structure and costly to build, and will take with a life of approximately 15–20 years. Ageing offshore platforms in China are widely distributed throughout Bohai Bay to the South China Sea. The shallow sea platform in Bohai Bay, exceeded its design life in 2009. It is estimated that more than two-thirds of the world's ageing platforms will continue working for 5 or 10 years after their design life. Although the lengthy design life of platforms seems rather conservative, once they have been designed successfully, they will maintain a long-term, stable safety status throughout the maintenance stage. As far as life extension, the most critical issues that must be considered are the evaluation of a platform's safety conditions, and appropriate decision-making in terms of repair grades.

Previous researchers Bea and Moan built a system of re-assessment and requalification criteria for platforms, as well as probabilistic inspection planning of the jacket structures (Bea et al., 2000; Moan et al., 2000, 1999). Havbro et al. later proposed a risk monitoring method, which is applicable to structural life extension (Havbro et al., 2005). Around the same time, the research team Galbraith et al. studied platform structure integrity management, and proposed a life extension system for ageing platforms (Galbraith et al., 2005). Nielsen et al. later studied operation and maintenance of offshore wind turbine components based on risk (Nielsen et al., 2011). At present, domestic studies on life extension of ageing platforms are typically focused on defect assessment (Chen, 2001). Life extension and/or repair decision-making models have been lacking relevant research.

There is uncertainty inherent to the use, maintenance, and life extension of ageing platforms. Researchers Chang and Kaisa stated that there is a wide variation between measured results and actual results due to fuzziness (Chang et al., 1994; Kaisa, 1998). Managing this discrepancy critical within life extension and repair decision-making, and a careful balance must be maintained between cost-saving benefits and potential risk. In this study, qualitative analysis was combined with the quantitative analysis to comprehensively evaluate risk factors, which inform life extension, and repair decisions based on DHGF theory. The paper builds a decision-making model of life extension and repair based on DHGF theory, which is beneficial for leaders to make decisions by quantifying methods, improve the level of scientific decision-making and achieve the aim for prolonging the service life of offshore platform. By the comprehensive evaluation of risk factors, the model may offer valuable refereces information to the leaders.

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2. Basic thought and superiority of DHGF theory

The theoretical foundation of the DHGF comes from two sources: one is a synthesized method from qualification to quantification presented by China's keystone space scientist Qian Xuesen (Qian, 1954); another is Wuli–Shili–Renli's (WSR) approach presented by Professor Gu Jifa (Gu, 1998, 2011). Xu Wei-xiang constructed a DH model, and presented the GF algorithm in order to make comprehensive estimation for system according to the WSR approach (Xu, 2000). The DHGF algorithm is based on a combination of Delphi, Analytic Hierarchy Process (AHP), grey relational analysis, and fuzzy comprehensive assessment methods, each of which have a distinct set of disadvantages. DHGF is the combination of practical experience and scientific theory, and is a mathematics method from qualitative and quantitative view. It uses the Delphi method to construct evaluation index system, uses AHP method to obtain weighted matrix, uses Grey Interconnect to count scores of experts, and uses Fuzzy Evaluating to obtain the evaluation results (Xu et al., 2001).

The DHGF model is widely involved in various fields, including Ma Zhi-qiang's application for it in performance evaluation of university teachers (Ma and Bo, 2011); Feng You-ling's application for it in international influence of the Shanghai World Exposition in quantitative analysis (Feng et al., 2011); Tang Qiu-sheng's application for it in risk evaluation of international logistics park (Tang et al., 2010); Zhang Jian's application for it in comprehensive evaluation of ship maneuverability (Zhang et al., 2010); Wang Wen's application for it in command and control performance evaluation of armored forces (Wang et al., 2009); Liu Kai's application for it in supportability evaluation of torpedo power system (Liu et al., 2009).

Advantages and disadvantages of each method are presented as follows (Table 1).

The evaluation method first sets up a bridge between the qualitative and quantitative analysis, and then abstract description of the system uncertainty by using scientific calculation methods in order to reveal the nature of things and laws. Its expert groups, the data along with a variety of information and computer is combined organically to mesh scientific theoretical knowledge and practical experience together to play their respective advantages and the comprehensive positive effect.

3. Modeling procedure

General uncertainty regarding the use, maintenance, and risks inherent to the life extension and repair of the existing ageing platforms poses a serious problem. Research must focus on managing these complex factors and more effectively gathering and analyzing relevant data. Essentially, life extension and repair decisions for ageing platforms are very precarious, and require careful balance between cost-saving benefits and risk. This study adopted the DHGF theory to build a risk management system for ageing platforms, as mentioned above.

The Delphi method establishes the risk assessment system's index, the AHP method weights each index appropriately, then the expert evaluation results undergo grey relational analysis, and finally overall conclusions are obtained by fuzzy comprehensive assessment method. Basically, the algorithm utilizes a panel of experts, relevant data theories, and practice to build a comprehensive evaluation system with all possible advantages, in which all four methods complement each other.

The main steps in the decision-making process are as follows:

Step 1: Determine the evaluation index set.

According to WSR thought, one must use the Delphi method, invite a panel of experts to participate in the project team, each expert will then put forward to a series of evaluation indices independently while collecting and analyzing data, and then screen out some unimportant indices (Gu, 1998, 2011). In this step, a scientific and reasonable evaluation index system is built.

$O = [O_1, O_2, \cdots, O_n]$ (n is the number of index)

Step 2: Determine the weighted subset using AHP method.

The Analytic Hierarchy Process (AHP) is a structured multi-attribute decision-making method (Satty, 1994). The main goal of the AHP is to decompose a complex system into goals, principles, and programs, thus making quantitative and qualitative decisions. The primary advantage of this method is its capability to identify and reduce inconsistencies within expert judgments. The AHP has been used extensively to solve problems that have multiple criteria (Satty, 2005).

In general, the AHP contains the following several steps:

(1) Define problems.

(2) Construct hierarchical structure. Construct decisions that can be decomposed into independent elements within a hierarchy comprised of goals, criteria, sub-criteria, and alternatives.

(3) Construct judgment matrix and invite experts fill in it. Determine the importance of attributes, sub-attributes, and pairs of attributes, and evaluate them on a nine-point scale (Table 2). Place each element in its corresponding level and calibrate them on the numerical scale; from this, the judgment matrix $A = (a_{ij})_{m \times n}$ can be obtained.

Table 1
Comparison in the advantage and disadvantage of different evaluation models.

Methods	Advantage	Disadvantage
Delphi method	1. Simplicity 2. It has broadly representative.	1. Subjectivity is too strong. 2. Responses are too hasty. 3. Time of consultation is longer.
AHP method	1. It has theoretic foundation. 2. Plan sort can be obtained.	1. Subjectivity is strong. 2. The process of comparison and judgment is rough. 3. Cannot do hierarchical plans.
Grey theory	1. The request of sample size is small. 2. Computation complexity is small. 3. It can reduce subjectivity.	1. It is difficult to completely analyze question due to lower-resolution. 2. Do not take into account qualitative indices.
Fuzzy evaluation	1. It offered the quantitative description method for obscure phenomenon.	1. Subjectivity is strong. 2. There are problems with judgment is inexact or results are not comparable.
DHGF model	1. It can reduce subjectivity. 2. Evaluation results are more accurate. 3. Plan sort can be obtained. 4. Plan can be graded.	1. The request of sample size is more. 2. A great deal of calculation is needed.