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Risk Analysis Model of Offshore Engineering Project Management Based on Fuzzy Membership Function

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ABSTRACT

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As a high-risk and high-cost project for offshore engineering (OE), the risk assessment and risk management of such project are necessary measures to reduce project economic losses. Based on a fuzzy membership function and a probability analysis method, this article analyzes the possible risks in OE projects, calculates the risk values of various factors, and establishes a risk analysis model for project management (PM) of the OE based on the fuzzy membership function. The research results show that in the offshore engineering PM (OEPM), external factors are the most risky, and the PM organization needs to increase attention on them; the organizational management structure is well organized in aspects such as clear divisions of labor, reasonable distribution of powers and responsibilities, and sound project operation; the key to risk management countermeasures is reducing the possibility of risk occurrence and preventing the occurrence of risks as much as possible by precontrol on one hand and by lowering the degree of risk loss and ensuring the risk consequences no longer deteriorate on the other. These research findings provide theoretical support for risk management and risk control in the OEPM.

ADDITIONAL INDEX WORDS: *Offshore engineering (OE), project management (PM), risk analysis, fuzzy membership function, r-isk countermeasure.*

INTRODUCTION

In view of the rich petroleum resources in the ocean, its exploration and development require advanced technical support and reasonable PM strategies (Carr and Tah, 2001; Ren *et al.,* 2006). In the relatively complex marine environment, oil extraction is susceptible to weather and various environments in the ocean, so offshore oil engineering (OE) has been a high-risk and high-cost project (Carbone and Tippett, 2004; Denas, 2015; Senesi, Javernick-Will, and Molenaar, 2015). In addition, the offshore oil engineering is complex in production, requires a lot of manpower and material resources, and has high professional and technical requirements. There are many randomness and fuzziness factors in the exploitation process. In addition, safety risks may occur in the operation of such engineering projects (Killick *et al.,* 2010; Liu *et al.,* 2010; Simister, 1994). Therefore, risk management and risk control are required for OE projects.

Project risk management can reasonably predict the risks that may occur in the project, then identify, evaluate, analyze, and manage the different risk issues and even take proper measures to avoid those risks (Athanasatos, Michaelides, and Papadakis, 2014; de Gouveia Souza, 2009). During the OE project management (PM), the whole process of project establishment, design, construction, completion, and production requires project risk management to reduce economic losses and casualties caused by possible risks and to avoid some risks in the project (Herroelen, 2013; Ward and Chapman, 1991). Risk management is the basis for reducing the possible risks of the project and for ensuring the project's smooth operation. It is also one of the most economical and effective measures for reducing the probability of engineering accidents and various losses during project implementation (Enyinda, 2017; Nassa and Yadav, 2013). In short, for high-risk, high-investment, and high-return OE projects, project safety management is required to prevent engineering safety problems (Lin, Wang, and Liu, 2012).

Based on existing research and survey data, this article uses the fuzzy membership function and fuzzy analysis method to analyze the possible risks in OEPM and then applies the probability analysis method to calculate various risk factors. Finally, the risk analysis model of the OEPM, based on the fuzzy membership function, is established. This study lays a theoretical foundation for risk management and effective control of OE projects.

RISK ASSESSMENT MODELS BASED ON THE FUZZY MEMBERSHIP FUNCTION

Fuzzy Membership Function and the Risk Assessment Method

In fuzzy set theory, fuzziness is one of the basic concepts, and the membership parameter is used to describe the intermediate transition, that is, the fuzziness is expressed by more-precise mathematical language. When determining the membership function, it is first necessary to sum up the experience and attach importance values to the experience of experts and technicians in the relevant professional fields. Next, in some

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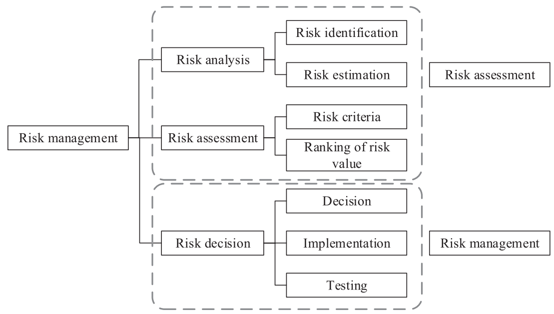

Figure 1. Hierarchical graph of risk management.

cases, the membership function is determined by the fuzzy statistic test, and the membership function is finally obtained by probability statistics and a fuzzy operation.

Risk management generally includes three parts: risk analysis, risk assessment, and risk decisions. Effective management of risks can control the risk within the scope of the manager's estimate, providing guarantees for the smooth implementation and cost savings of the project. Figure 1 shows the hierarchy chart of risk management.

For the risk management of some projects, the expert-survey method is often used to evaluate the relevant factors in risk management or risk assessment, thereby objectively evaluating the relevant states of the fuzzy factors. With reference to the opinions of experts, the comprehensive fuzzy evaluation method was adopted to reasonably assess the project described in this article. The specific steps used expert opinions to establish a fuzzy evaluation matrix in the form of a membership evaluation function, as shown in Equation (1). Next, according to each expert's professional ability, experience, familiarity with the project, and other factors, the weights of the experts' opinions were determined and normalized to form the corresponding weight set $C = (c_1, c_2, \ldots, c_n)$, and the corresponding evaluation result was $D(d_1, d_2, \ldots, d_n) = C(c_1, c_2, \ldots, c_n) \times R$. Finally, according to the Hamming distance calculation, the proximity of the evaluation result and the evaluation set were obtained, as shown in Equation (2). The comprehensive evaluation results of the expert had the maximum proximity, further achieving the fuzzy interval for the occurrence possibility of various risks:

$$R = (\mu_m) \tag{1}$$

$$N(C, D) = 1 - \frac{1}{n}\sum_{i=1}^{n} |C(u_i) - D(u_i)| \tag{2}$$

where, $i = 1, 2, \ldots, i$ is the serial number of the fuzzy interval of the occurrence probability for each risk event; and $n = 1, 2, \ldots, n$ is the serial number of the experts who participated in the evaluation.

Establishing A Risk Assessment Model of Risk Value

In the process of risk management, it is necessary to calculate the risk value of the influencing factors in the subsystems and then manage and control the possible risks.

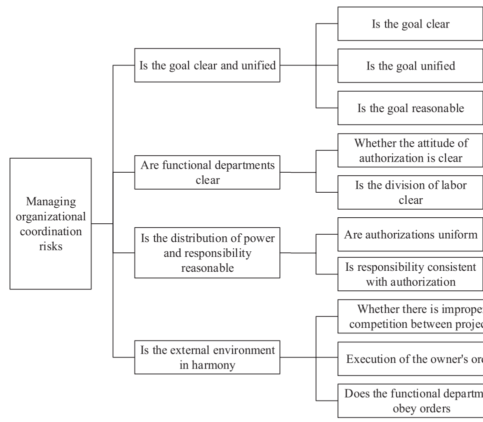

Figure 2. Risk-accident tree for project organizational coordination.

The relative risk value Rr_i was calculated as shown in Equations (3) and (4), where Cr_i is the severity index of the consequences for an event or factor, $P_i(\text{or } Poss_i)$ is the probability value of an event or risk, and $r_i (i = 1, 2, \ldots, n)$ is the interval of occurrence possibility for the event. The calculation of the absolute risk value Ra_i takes into account the direct economic loss to the project and the indirect loss caused by the risk event, as shown in Equation (5), where Ca_i is the economic consequence after the occurrence of a certain risk events:

$$Rr_i = P(\text{or } Poss_i) \times Cr_i \tag{3}$$

$$P_i(\text{or } Poss_i) = \mu_i(\omega) \times r_i \tag{4}$$

$$Ra_i = P_i(\text{or } Poss_i) \times Ca_i \tag{5}$$

RISK ANALYSIS MODEL OF OEPM

Risk Assessment of OEPM

The risk assessment of OE projects mainly involves the project organization, the comprehensive level of management personnel, the procurement of the functional departments and branch offices, and construction safety, *etc*. The OE project organization needs to develop a set of job structures according to the requirements of the task to rationally allocate human resources and accomplish project objectives more efficiently. In addition to establishing one suitable job system, it should also develop realistic goals, clarify the responsibilities of each department, construct a complete system, and establish a risk-factor accident tree based on the risk source, as shown in Figure 2.

As the core of management, the comprehensive level of management personnel is crucial to the PM. The risk analysis should be performed from the manager's management ability, comprehensive factors, and management experiences, which is also very important for the efficient operation of the company. Thus, managers' risk assessments were performed in three levels: management decision, organization implementation,

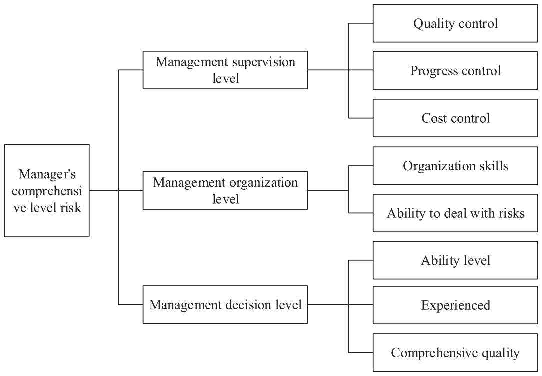

Figure 3. Manager risk-assessment accident tree.

and management supervision. Figure 3 shows the risk-assessment accident tree.

The installation and construction process is one part of the construction in the PM process. During the construction, different processes need to be arranged reasonably according to the actual construction schedule. When the construction progress lags or the output ratio deviates from the plan, it is necessary to adjust the construction period or formulate the work-crash plan. Construction is a dynamic management process. The management content of construction and installation mainly includes quality management, schedule management, material management, and expense management, *etc*. Figure 4 shows the accident tree of installation and construction risk assessment.

In addition, during the project implementation, acquisition is also the core of the PM. It is a key part of ensuring smooth progress for the project. Three sensitive issues affect the acquisition, namely, cost, quality, and the shipping period. The reasons for tardy delivery mainly include objective factors and human subjective factors. Figure 5 shows the acquisition risk-assessment accident tree.

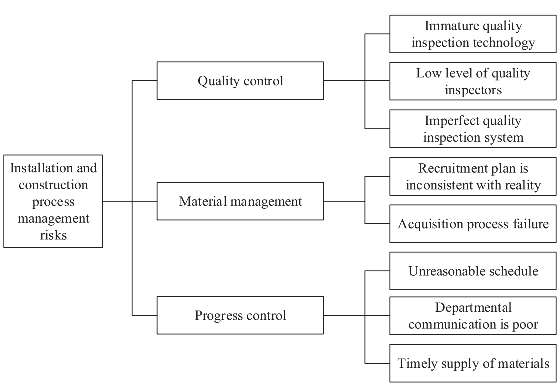

Figure 4. Installation and construction of risk-assessment accident tree.

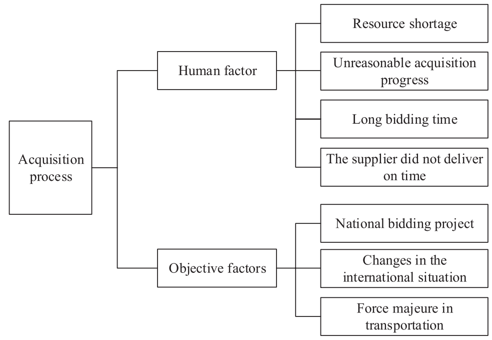

Figure 5. Acquisition risk-assessment accident tree.

Risk Analysis of an Offshore Engineering Project Example

Through survey of the management structure and personnel of an OEMP, risk assessment results for the project were obtained, as listed in Table 1.

Analysis of the results in Table 1 show that, in terms of overall project results, external factors are the most risky, and the PM organizations need to focus more on them; otherwise, external factors will affect the operation of the entire project. The organizational management structure is well organized in aspects such as the clear division of labor, a reasonable distribution of powers and responsibilities, and sound project operation. From the perspective of local risk factors, the main risks are a shortage of human and material resources, low decision-making efficiency, in-executability of decision-making, repeated and complicated tasks, unclear project objective, and biased understanding of the commands.

PM Risk Countermeasures

In view of that evaluation, this article proposes corresponding risk management countermeasures for improving the management efficiency of the project. Specifically, the PM personnel should be rationally allocated to ensure clear responsibilities and improve *per capita* efficiency; system control of procurement materials should strictly limit the use of personnel, eliminate extravagance and waste, reduce material waste, and achieve resource optimization; the division of powers and responsibilities should be clearly defined to strictly implement the company's regulations and enforce the orders issued by the superiors; the decision-making priorities of the functional managers and project managers should be clearly defined; the assigned goals and tasks need to be tracked regularly, and their completion status should be updated in a timely manner, with any deviation from the plan and the objectives being corrected in a timely manner; and it should be made clear that the transmission of information is based on knowledge rather than job position.

Project risk management should first grasp the degree of risk loss and the occurrence probability of risks and conduct a grade assessment of various risks. The key to risk management countermeasures is first, to reduce the possibility of risk occurrence and to avoid risk as much as possible by precontrol, and second, to lower the degree of risk loss and to prevent risk

Table 1. *Organizational risk table for ocean engineering management.*

Risk Categories	Factor	Value at Risk
Is the goal clear and unified?	Is the goal clear?	0.025
	Is the goal unified?	1.273
	Is the goal reasonable?	1.452
Are functional departments clear?	Is the attitude of authorization clear?	0.302
	Is the division of labor clear?	0.007
Is the distribution of responsibility reasonable?	Are authorizations uniform?	0.147
	Is responsibility consistent with authorization?	0.135
Is the external environment in harmony?	Is there improper competition among projects?	0.229
	Are the owner's orders executed?	0.053
	Does the functional department obey orders?	0.264

consequences from deteriorating. Through risk avoidance, risk control, risk transfer, and risk retention, the risks can be effectively controlled, to reduce losses and maximize profit returns.

CONCLUSIONS

Using the fuzzy membership function, fuzzy analysis method, and the probabilistic analysis method, this article analyzed the risk factors that may occur in the OEPM and established the related risk-analysis model based on the fuzzy membership function. The main conclusions were as follows:

(1) In the OEPM, environmental factors and other external factors have the greatest degree of risk, so PM organizations need to focus on the risk events that may arise in the external environment;
(2) The coordination of external factors by decision makers and management teams will affect the operation of the entire project, so increased attention should be focused on the management risk of the team; and
(3) The key to risk management countermeasures is reducing the possibility of risk occurrence, avoiding risk as much as possible by prior precontrol, and lowering the risk loss after the risk occurs, thus, ensuring the consequences of the risk do not deteriorate further.

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