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Research on Risk Factors of External Market-oriented Operation of Oil and Gas Enterprises

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Abstract: *Under the background of the "Double Carbon" goal was clearly put forward and the system reform of state-owned enterprises was carried out in an all-round way, China's major oil and gas enterprises generally carry out the construction of the "oil company" mode with the market-oriented operation mechanism as the core to promote themself. Therefore, to analyze external market-oriented operation risks comprehensively and identify key factors are of great significance to help oil and gas enterprises promote their own sustainable development. Firstly, we identified the risk factors of external market-oriented operation and establish an index system through the literature review and expert interview. Secondly, we applied the grey system theory to improve the DEMATEL-ISM approach to divide the hierarchical structural of risk factors and clarify their logical relationships. Thirdly, the driving force and dependence of each factors were calculated by using the MICMAC approach, so that their attribute characteristics were expressed quantitatively. We identified 18 risk factors, then divided them into 6 layers hierarchical structures, and identified 6 key risk factors among them. The analysis results show that the oil and gas enterprises should take corresponding external market-oriented operational risk prevention and control strategies from three perspectives, which of them are perfecting organizational structure, innovating management system and improving technological operation level.*

Keywords: *Oil and Gas Enterprises; "Oil Company" Mode; External Marketization Operation; Risk Factors*

1. Introduction

In order to implement the spirit of the 19th National Congress, in-depth promotion of the 14th Five-Year Plan and improve the operational efficiency of central and state-owned enterprise, the Party Central Committee and the State Council have made a major decision to reform the system of state-owned enterprises, specifying the timing and process of the reform of state-owned enterprises, which will be carried out in turn, with the oil and gas industry being the focus of this reform[1]. At the same time, in the promotion of carbon peaking and carbon neutrality goals, compared to foreign oil and gas giants such as Total, Chevron, BP, Shell and Exxon-Mobil, the systems and mechanisms of China's major oil and gas enterprises have gradually revealed the following problems: In terms of organisational structure, there are too many management levels, too many subordinate units and a high proportion of non-oil and gas assets; in terms of market-oriented operations, there is duplication of business, inefficient use of resources and low competitiveness[2]. As a result, China's major oil and gas companies are now generally reforming the "oil company"model,stimulating their internal dynamics and promoting management effectiveness through flat organizational structures, market-oriented operating mechanisms and intelligent production models.

The "oil company" model, first proposed by foreign oil and gas companies, is a new type of oil and gas enterprise management model. The core of the model is to reduce the management level, optimise the management system, build a diversified and integrated management system, rely on internal and external market-based operating mechanisms, to achieve a rational allocation of resources and efficient management operations[3]. The "oil company" model has received attention from domestic scholars, with research results emerging and focusing on the following three areas: (1) Research on the historical

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evolution of the "oil company" model. For example, Zhang[4] and Zhou[5] have reviewed the development history of the "oil company" model of Chinese characteristics in China's oil and gas enterprises, pointing out that the current management inefficiency, excessive management levels and technical innovation capacity need to be improved and other shortcomings, and the future should be strengthened through scientific planning to achieve the change from passive reform to active evolution; (2) Research on the idea of building an "oil company" model. For example, Wu[6] put forward the idea of reforming the "oil company" model with "five definitions" as the core, pointing out that the focus is on adjusting the business structure, clarifying the power and responsibility interface, reducing the management level and optimising job responsibilities. Rao[7] summarised the management and reform model of the "oil company" in the oil exploration and production business, and pointed out that future work should focus on business categorisation, streamlining of operational areas and optimisation of third-party employment; (3) Research on the practical work of the "oil company" model. For example, Chen[8] studied the integration mechanism of party building and production in state-owned enterprises under the "oil company" model; and Dong[9] proposed a method for calculating the industrial value added of shale gas production based on a whole industry chain perspective in the context of the "oil company" model.

Scholars have made a number of useful explorations of the 'oil company' model, laying a solid theoretical foundation for subsequent research. However, due to historical limitations, there has been a lack of in-depth research and quantitative analysis of the external market-based operational risks of the 'oil company' model. External marketisation is both the most distinctive external feature and the core connotation of the 'oil company' model. In practice, the various risks associated with the organisation, management systems, technology, outsourcing and government regulation of oil and gas companies will have a negative impact on external market-based operations and must be taken seriously by managers. Therefore, it is necessary to identify the risk factors for external market-based operations of oil and gas companies under the 'oil company' model, and to explore their logical relationships and attributes in depth.

This paper proposes to use grey systems theory to improve the Decision making Trial and Evaluation Laboratory (DEMATEL) and the Interpretive Structural Modeling (ISM) approach to analyse the logical relationships and relative importance of risk factors,and the attributes of each factor are quantitatively explored by the Matrix Impacts Cross-reference Multiplication Applied to a Classification (MICMAC) method.The study aims to provide technical support for the formulation of targeted risk control measures and sustainable development of enterprises.

2. Identifying External Market-based Operational Risk Factors for Oil and Gas Companies Under the "Oil Company" Model

Table 1: Experts' information

Source of experts	Expertise	Experts' Title	Number of experts	Average oil and gas industry research and work experience (Working years)
Petroleum universities	Teaching/ Research Staff	Professor	5	12
		Associate professor	7	
Oil and gas enterprises	Management/ Technical staff	Professor-level senior engineer	1	24
		Professor-level senior economist	1	
		Professor-level senior political engineer	1	
		Senior engineer	2	15
		Senior economist	2	
		Senior political engineer	1	
Oil and gas companies affiliated Research Institutes	Researchers	Professor-level senior engineer	2	27
		Professor-level senior economist	2	

The core of the "oil company" model is the marketisation of business operations, and external

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marketisation is at the heart of this marketisation, namely the "business outsourcing"[10]. In the context of the "oil company" model, external marketisation can effectively help oil and gas companies to to smash the shackles,make up for deficiency and stimulate the market's vitality.Firstly,we refer to the relevant systems and documents on service outsourcing management of CNPC, SINOPEC and CNOOC, search and sort out relevant literature, and start from four aspects, including "management system of oil and gas enterprises", "technical operation management of oil and gas enterprises", "management of service outsourcing companies" and "market environment"[11]. The risk factors were systematically identified to form a risk list; secondly, 24 experts from Petroleum universities, oil and gas enterprises and research institutes affiliated to oil and gas enterprises were invited to screen the risk list based on their research and working experience through the Delphi method, and finally four categories of 18 risk factors were derived. The information of the experts involved in the study is shown in Table 1 and the results of the risk factor analysis are as shown in Figure 1.

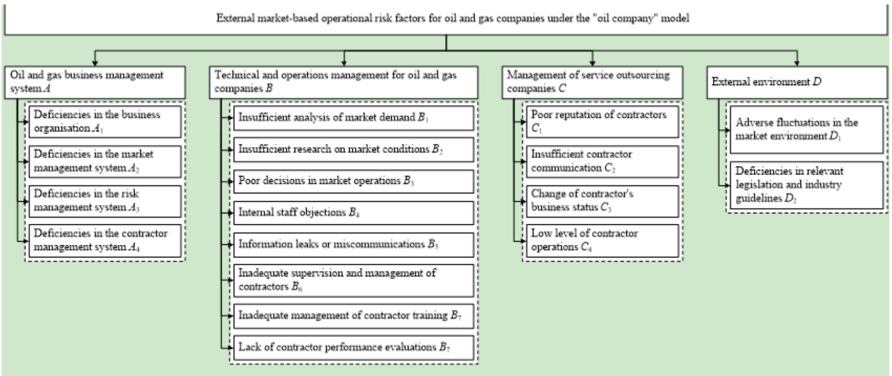

Figure 1: Index System of risk factors

3. Quantitative Analysis of External Market-based Operational Risk Factors for Oil and Gas Companies Under the "Oil Company" Model

3.1 Grey DEMATEL-ISM-MICMAC Integration Method

On the basis of the identification and selection of risk factors, the "quantitative-directed cognitive mapping approach" based on structural methodology is integrated with the DEMATEL and ISM methods to dig deeper into the logical relationships between risk factors[12]. The DEMATEL method can effectively portray the complex non-linear relationships between elements within a system with the help of matrix tools, while the ISM is effective in delineating the hierarchy of factors within a complex system, and the combination of the two can effectively overcome the shortcomings when used alone; to make up for the shortcomings of the traditional DEMATEL-ISM method which makes it difficult to represent ambiguous information contexts and reflect differences in expert opinions, grey system theory is introduced for improvement[12]. The specific steps are as follows:

1) Establish the set of influencing factors C, $C=\{C_i|i=1,2,\dots,n\}$; then invite experts and evaluate the degree of influence between factors according to Table 2 and convert them into grey numbers to establish a direct grey relationship matrix.

Table 2: Grey language evaluation scale

Grey language	Rating	Number of grey system
No impact	0	0
Extremely low impact	1	>0~0.25
Low impact	2	>0.25~0.5
High impact	3	>0.5~0.75
Extremely high impact	4	>0.75~1

2) Clarification of the grey number by means of equations (1) to (3).

$$\bar{\otimes}\overline{x_{ij}^k}=(\bar{\otimes}x_{ij}^k-\min\bar{\otimes}x_{ij}^k)/\Delta_{\min}^{\max} \tag{1}$$

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$$\underline{\otimes}\overline{x_{ij}^k} = (\underline{\otimes} x_{ij}^k - \min \underline{\otimes} x_{ij}^k) / \Delta_{\min}^{\max} \tag{2}$$

$$\Delta_{\min}^{\max} = \max \bar{\otimes} x_{ij}^k - \min \underline{\otimes} x_{ij}^k \tag{3}$$

In which, k is the number of experts, $\bar{\otimes}\overline{x_{ij}^k}$ and $\underline{\otimes}\overline{x_{ij}^k}$ is the standard value of the upper and lower limits of the grey number. $\Delta_{\min}^{\max}$ is the result of subtracting the maximum and the minimum value of the grey number.

3) Calculation of normalised clarity values y_{ij}^k and final clarity values z_{ij}^k by means of equations (4) and (5).

$$y_{ij}^k = \frac{\underline{\otimes}\overline{x_{ij}^k}(1 - \underline{\otimes}\overline{x_{ij}^k}) + (\bar{\otimes}\overline{x_{ij}^k} \times \bar{\otimes}\overline{x_{ij}^k})}{1 - \underline{\otimes}\overline{x_{ij}^k} + \bar{\otimes}\overline{x_{ij}^k}} \tag{4}$$

$$z_{ij}^k = \min_j \underline{\otimes} x_{ij}^k + y_{ij}^k \Delta_{\min}^{\max} \tag{5}$$

4) Calculate the weighted clarity grey direct impact matrix Z by using equation (6).

$$z_{ij} = w_1 z_{ij}^1 + w_2 z_{ij}^2 + \cdots + w_k z_{ij}^k \tag{6}$$

In which, zij are the elements of the matrix Z and wk are the weights.

5) The direct influence relationship matrix Z is normalized by equations (7) to (9) to create a standardized influence relationship matrix X and a combined influence relationship matrix T.

$$M = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} z_{ij}}, (i, j = 1.2, \ldots, n) \tag{7}$$

$$x_{ij} = M z_{ij} \tag{8}$$

$$T = X(I - X)^{-1} \tag{9}$$

In which, xij and zij are elements of the matrix X and Z respectively, I is unit matrices of the same order as the matrix Z .

6) Calculate the overall impact relationship matrix H through equation (10); then calculate the threshold value λ based on the mean and standard deviation of all elements within the integrated impact relationship matrix T[12], then we could calculate the reachability matrix K through equation (11).

$$H = I + T \tag{10}$$

$$k_{ij} = \begin{cases} 1, h_{ij} \ge \lambda (i, j = 1,2, \ldots, n) \\ 0, h_{ij} < \lambda (i, j = 1,2, \ldots, n) \end{cases} \tag{11}$$

In which, kij is the element inside the matrix K.

7) Calculate the reachable set Ri and prior set Si of each factor by equations (12) and (13).

$$R_i = \{ c_j \mid c_j \in C, k_{ij} \ne 0 \}, j = 1,2, \ldots, n \tag{12}$$

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$$S_i = \left\{c_i \middle| c_i \in C, k_{ij} \neq 0\right\}, i = 1,2,\ldots,n \tag{13}$$

Each factor is verified to be satisfied $R_i = R_i \cap S_i, (i = 1,2,\ldots,n)$. If it is satisfied, the factor is the first level factor, then the row corresponding to that factor is removed from the reachable matrix and the process is repeated until all factors have been assigned, thus building a multi-level recursive hierarchy model.

7) The driving force DRi and dependency DSj of each factor are calculated from the reachability matrix by using equations (14) and (15); then all factors are classified into four categories, including autonomous, dependent, associated and independent, based on the values of driving force and dependency. The driving force and dependency of the autonomous factors are low, the driving force of the dependent factors are low and the dependency are high, the driving force and dependency of the associated factors are high and the driving force of the independent factors are high and the dependency are low.

$$DR_i = \sum_{j=1}^{n} k_{ij}, i = 1,2,\ldots,n \tag{14}$$

$$DS_j = \sum_{i=1}^{n} k_{ij}, j = 1,2,\ldots,n \tag{15}$$

3.2 Analysis of Calculation Results

Twenty-four experts were invited to evaluate the relationship between risk factors by means of a questionnaire survey. To ensure the accuracy and consistency of the study results, the evaluation results were averaged, and the Cronbach' α coefficient test was applied to the questionnaire results using SPSS, and the solution was α=0.879 (>0.800), with good reliability of the questionnaire and strong persuasive power of the study results. The specific analysis steps are as follows.

Firstly, the opinions of the 24 experts were collected in aggregate, their evaluation scores were converted into grey numbers through Table 1, and the weighted clarified grey direct influence relationship matrix was calculated through equations (1) to (6). Secondly, the standardised influence relationship matrix and the comprehensive influence relationship matrix were calculated through equations (7) to (9). Thirdly, the reachability matrix was established through equations (10) and (11), and then the hierarchical structure model was established through equations (12) and (13) to establish the recursive hierarchy model, and the results are shown in Figure 2. Finally, the driving force and dependency of each factor is calculated by equation (14) and equation (15) one by one and presented in the form of Descartes coordinate system, and the results are shown in Figure 3.

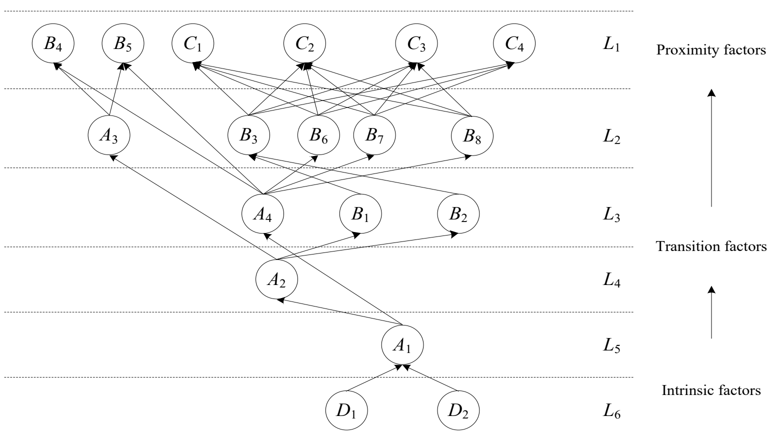

Figure 2: Hierarchical structure model of risk factors

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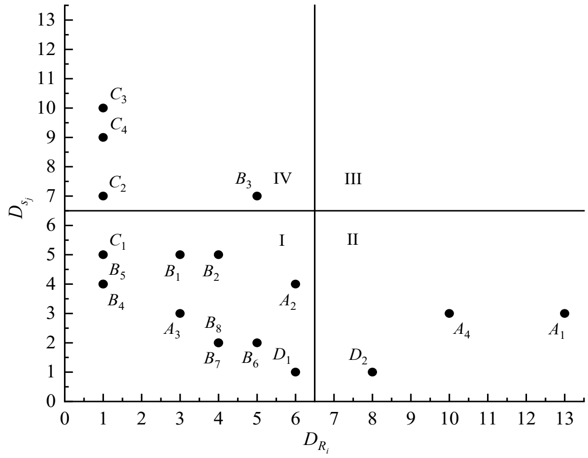

Figure 3: Analysis results of driving force - dependence of risk factors

4. Analysis of Modelling Results

4.1 Progressive Hierarchy Analysis of Risk Factors

Analysis of Figure 2 shows that the 18 risk factors are divided into a six-level hierarchy. There is a complex non-linear relationship between the various risk factors, and the closer the factors are to the bottom, the more important they are in the risk system; effective control of essential and transitional factors is the key to preventing coupling between the various factors, leading to the emergence of proximity factors and system failure.

Among the 18 risk factors, we can concluded that: Firstly, the intrinsic factors include three items such as deficiencies in the business organisation, adverse fluctuations in the market environment D1 and deficiencies in relevant legislation and industry guidelines D2, which are the internal subjective key and external deep-rooted root causes of external market-oriented operational risks of oil and gas enterprises and can produce adverse interference with transitional and proximate factors through coupling. Secondly, the transitional factors include deficiencies in the risk management system A3, deficiencies in the contractor management system A4, insufficient analysis of market demand B1, insufficient research on market conditions B2, Poor decisions in market operations B3, Inadequate supervision and management of contractors B6, Inadequate management of contractor training B7 and lack of contractor performance evaluation B8, etc. As can be seen from Figure 2, under the influence of external risk factors and oil and gas enterprises' own organisational structure defects, oil and gas enterprises' market management system and Contractor management system will be the first to be impacted, which in turn will affect market demand analysis, market situation research, market decision making and contractor management in the enterprise's technical and operational management system. Thirdly. proximity factors include internal staff opposition B4, information leaks or miscommunications B5, poor reputation of contractors C1, Insufficient contractor communication C2, change of contractor's business status C3 and low level of contractor operations C4 and other 6 items are the surface presentation and practical portrayal of external market-oriented risks of oil and gas enterprises, which should be focused on in practical work.

4.2 Risk Factor Driver-dependency Analysis

Analysis of Figure 3 shows that the 18 factors are divided into four quadrants and fall under three of them. Quadrant I is for autonomous factors, including A2, A3, B1, B2, B4, B5, B6, B7, B8, C1, D1; Quadrant II is for independent factors, including A1, A4 and D2; Quadrant IV is for dependent factors, including B3, C2, C3, C4. Considering that the external market-based operational risk factors of oil and gas companies under the "oil company" model tend to have distinctive characteristics and close relationships, it is normal that no factors fall into the quadrant of related factors with high driving forces and dependencies.

The autonomy factors have relatively low driving forces and dependencies, but they have an important role to play in the risk factor system, and therefore cannot be ignored. As can be seen from the analysis of Figure 3, among the 11 autonomous factors, A2 and D1 have relatively high driving forces, indicating that they play a relatively more prominent role in the risk system; B4, B5, C1 have relatively low driving forces and the highest degree of dependence, indicating that these factors may both influence and be influenced by other factors; in the future, emphasis should be placed on strengthening the prevention of these factors and curbing the emergence of external market-based operational risks by interrupting the risk evolution chain. In the future, the focus should be on strengthening the prevention of such factors and curbing the emergence of external market-based operational risks by interrupting the risk evolution chain.

Among the three independent factors, the driving force of A1 is much higher than that of the other factors, indicating that this factor is the key core of the entire risk system; the driving force of A4 is second only to A1, as contractor management is the basis for the smooth operation of the external market, and defects in the management of contractors of oil and gas enterprises are the main reason for contractors' failure to perform as required; deficiencies in relevant legislation and industry guidelines D2 are external objective risk factors, which may lead to the possibility of unscrupulous contractors or poor/unqualified contractors "exploiting loopholes". Deficiencies in relevant legislation and industry guidelines D2 are external objective risk factors, which may lead to the possibility of unscrupulous contractors or less qualified/unqualified contractors "exploiting" the loopholes, and may also lead to a lack of legal basis and policy support in the market-based operation of oil and gas enterprises.

Dependency elements include four factors such as poor decisions in market operations B3, Insufficient contractor communication C2, Change of contractor's business status C3 and Low level of contractor operations C4,. These factors are less driven and more dependent, more influenced by other quadrant factors and are external manifestations of risk, which is consistent with the results of the progressive hierarchy model analysis.

4.3 Risk Prevention and Control Measures for External Market-based Operations of Oil and Gas Companies

Based on the results of the hierarchy of risk factors and their drivers-dependencies, it can be seen that the key factors of external market-based operational risk for oil and gas companies under the "oil company" model are four subjective factors, namely deficiencies in the business organisation A1, deficiencies in the market management system A2, deficiencies in the risk management system A3 and deficiencies in the contractor management system A4 and the two objective factors, namely the adverse fluctuations in the market environment D1 and deficiencies in relevant legislation and industry guidelines D1. Therefore, it is proposed to propose risk prevention and control countermeasures from three perspectives, including improving the organisational structure, innovating the management system and enhancing the level of technical operation and management, as explained below.

(1) Improve the organisational structure, with the business leader at the core. A reasonable organisational structure will have a direct and negative impact on the management systems and technical and operational management practices of an oil and gas company. The "oil company" model requires oil and gas companies to change their original multi-level vertical management structure and overcome the disadvantages of excessive levels of organisation and long chains of command. By streamlining and improving the organisational structure, gradually reducing management levels and optimising resource allocation strategies, the 'oil company' reform process is steadily progressing, providing top-level support for high-quality corporate development. It is recommended that a "two-tier structure system" and a "virtualised operation model" be developed. The construction of a two-tier structure includes three tasks: dynamic optimisation of the management system, adjustment and upgrading of the management system and quality benchmarking management; the virtualised operation model needs to be realised by sorting out business links and transforming the business into a virtualised one, and is supported by three major support teams, including technology, management and services.

(2) The key to an innovative management system is the business manager. The core management system should cover three categories, including market management, risk management and contractor management system. Firstly, establish the working principle of service outsourcing as the core; secondly, take cost reduction and efficiency enhancement as the criterion, build the foundation of market-oriented operation mechanism by dividing the business list and rationalizing the attribution of responsibilities, and use the business list as the basis to classify and steadily implement at each level; thirdly, take risk control as the guide, establish a "five-in-one" supervision pattern and risk prevention and control system covering finance, internal control, audit, information and confidentiality. "Thirdly, with the guidance of risk control, we should establish a five-in-one supervision pattern and risk prevention and control system covering finance, internal control, audit, information and confidentiality,

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and jointly prevent and control risks from three aspects, including the enterprise's internal, outsourcing service providers and the market environment; finally, we should take the process management as the grasp, and optimize the management system guarantee mechanism from four aspects, including the market management system, the HSE management system of outsourcing units, the contract management system and the performance assessment system.

(3) Promote the progress of technology and operation, the main body is the enterprise employees. Technology and operation management is the practical application of the enterprise management system, and requires the joint efforts of all employees. Firstly, we must pay attention to market management, strengthen market research, deepen market demand analysis, optimise market decision-making solutions, and lay a good foundation for outsourcing business division, contractor selection and management; secondly, we must do a good job of promoting and educating internal staff on market-oriented reform to avoid damage to their core interests and resistance; thirdly, we must strengthen supervision, training and performance assessment of contractors to ensure Finally, oil and gas companies should always pay attention to changes in the domestic and international market environment and adjust their business strategies in a timely manner; and through enhanced communication with higher authorities and local governments, revise and improve the inadequacies of the existing legal system and industry norms in a timely manner.

5. Conclusion

(1) Based on the existing literature and the opinions of experts in the industry, the system engineering method was applied to identify 18 external market-based operational risk factors of oil and gas enterprises under the "oil company" model; the integrated DEMATEL-ISM-MICMAC method was improved through grey theory to quantitatively portray the logical relationship between risk factors, hierarchical structure and attribute characteristics.

(2) The results of the study show that the 18 risk factors form a six-level hierarchy and can be classified into three categories according to their driving force-dependency; deficiencies in the business organisation A1, deficiencies in the market management system A2, deficiencies in the risk management system A3 and deficiencies in the contractor management system A4, and the two objective factors, namely the adverse fluctuations in the market environment D1 and deficiencies in relevant legislation and industry guidelines D2, and loopholes in relevant laws and industry regulations are the external objective depth root causes; emphasis should be placed on strengthening the prevention and control of the above risk factors.

(3) From three perspectives, including improving organisational structure, innovating management systems and improving technical and operational management, we propose countermeasures to prevent and control external market-based operational risks of oil and gas enterprises under the "oil company" model. Firstly, to improve the organisational structure, the core of which is the enterprise leader, it is recommended that this be achieved through the "two-tier structure supporting system" and the "virtualised operation model", etc. Secondly, to innovate the management system, the key is the enterprise manager, and it is recommended that the focus be on revising and improving three types of systems: market management, risk management and contractor management. Finally, to improve the level of technical operation management, the main body is all employees of the enterprise, and the focus should cover three aspects, such as market analysis, market research and contractor management. Through the above-mentioned measures and practices, we can jointly build a solid barrier for the prevention and control of external market-oriented operation risks.

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