A Method of Classifying Oilfield Benefit and Application

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Abstract. Benefit classification analysis is an important content for not only studying the benefit categories of different blocks in Oilfield, but also controlling and adjusting the negative benefit blocks. Due to the lack of comprehensive consideration of development stage and geological conditions, the classification of oil field development units has some limitations. Through comprehensive analysis of the influencing factors of oilfield development benefit, this paper classifies unit development by using system clustering method. DEA (Data Envelopment Analysis) model is used to analyze the relative validity of different development units. In the same geological and development condition units, the method of benefit classification based on validity analysis is used to realize the comprehensive classification of development and economy. Benefit classification analysis using the benefit evaluation data of a low permeability development unit in eastern oilfield shows that it can play a guiding role in benefit classification, negative effect management and operation strategy of the development unit.

Key words: DEA model; cluster analysis; benefit classification; economic evaluation; business strategy.

1. Introduction
Under the background of low oil price, low permeability oilfield needs to achieve the goal of benefit improvement and negative effect governance through classification management due to poor geological conditions and difficult development. At present, the classification of low permeability oilfield development units is determined according to the relationship between income and different costs. This method considers the development effect, economic benefit and technical and economic conditions of different units, and meets the goal of classified management of oilfield development. However, the geological conditions of low permeability oilfield are complex, the benefit difference is big, and the application of new technologies is more. How to fully consider the reserve scale, development mode, geological conditions and other factors, and establish the index and method of benefit classification evaluation is the focus of benefit promotion and negative effect treatment of low permeability oilfield. On the basis of comprehensive consideration of the existing classification methods, this paper uses the main development and geological indicators that affect the oilfield development benefits to classify the development by cluster analysis method. Then, the effectiveness of different development classification units is analyzed by using DEA analysis method, and the effective, medium and low efficiency
development units of the same development unit are determined. The combination of development and economy is realized Interest classification.

2. Determination of geological factors affecting oilfield benefit development

It is necessary to find out the main factors that affect the development effect and benefit of low permeability oilfield to classify and analyze the low permeability development units. Although the oil price directly affects the development efficiency of low permeability oilfield, it will not affect the classification results of development units. Economic indicators such as investment and cost will be considered in the effectiveness analysis based on the development classification. The determination method of influencing oilfield benefit development and geological factors is to use grey correlation analysis method to calculate and rank the correlation coefficient between development, geological indexes and benefit. At the same time, considering the correlation between the indicators, the most relevant indicators are determined as the development unit classification parameters.

The measure that affects the size of correlation is called correlation degree. The grey correlation analysis method is a quantitative method to analyze the correlation degree between various factors in the system. Its basic idea is to judge the correlation degree of the development trend of the grey process according to the similarity degree of the geometric shape of the sequence curve. It can well describe the relationship between the development of low permeability units, geological indicators and benefits [1]. The specific steps are as follows:

2.1. Selecting a Template (Heading 2)

The characteristic matrix of different influencing factors is determined. Let m-year unit profit of a unit be Xi (i = 1, 2, m) Considering n influencing factors, an index set is formed to evaluate the pros and cons of the scheme, which is recorded as xj (j = 1, 2, n). Then the eigenvalue matrix of influencing factors of annual profit in m is [2]:

\[ X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_m \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \] (1)

2.2. Maintaining the Integrity of the Specifications

Normalization of eigenvalue matrix. In order to eliminate the influence of different dimensions on decision-making results, it is necessary to normalize the factor eigenvector matrix so that \( a_{ij} = \frac{x_{ij} - x_{imin}}{x_{imax} - x_{imin}} \).

\[ A = \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \] (2)

2.3. The correlation coefficient was calculated

According to the grey correlation analysis method, the correlation coefficient of the jth influencing factor is as follows:

\[ r_j = \frac{\min_i, \min_j |a_{ij} - a^0_i| + \rho \max_i, \max_j |a_{ij} - a^0_i|}{|a_{ij} - a^0_j| + \rho \max_i, \max_j |a_{ij} - a^0_j|} \] (3)

2.4. The correlation degree was calculated

The correlation degree of the jth influencing factor was as follows:
2.5. The factors with strong correlation degree are extracted to provide basis for the classification of low permeability units.

3. Cluster Analysis Method of Oilfield Development Unit
Cluster analysis is a method to classify samples according to the degree of correlation in nature. There are mainly k-class central clustering method and system clustering method. K-class central clustering is to divide n samples into k classes and determine K initial class centers, and then use iterative method to classify samples. The system clustering method defines the distance between classes on the basis of sample distance. Firstly, n samples are regarded as a class, and then the two classes with the smallest distance are merged each time. After merging, the distance between classes is recalculated, and the process continues until all samples are classified into one class. There are many methods to define and calculate the distance, so the system clustering method can be further subdivided into the shortest distance method, the longest distance method, the center of gravity method, the class average method, the inter class average connection method, the intra class average connection method and the sum of deviation square method. Different system clustering methods may get different results [3]. In this paper, the development units of low permeability oilfield are classified by using the system clustering method.

4. Benefit Classification Method Based on Data Envelopment Analysis
DEA analysis method is a systematic analysis method based on the concept of "relative efficiency" by famous operational research experts A. charnes and W.W. Cooper and so on, according to the concept of "relative efficiency", according to the multi index input and multi index output, the relative effectiveness or benefit of the same type of samples is evaluated and ranked [4]. DEA model uses mathematical programming method to calculate the advantages and disadvantages between samples, which is called relative efficiency. It can be used to evaluate whether a DMU with multiple inputs and outputs has "scale efficiency" and "technology efficiency". After analysis, DEA model can be applied to the benefit classification analysis of low permeability unit.

The characteristics of DEA method are as follows: 1. The linear programming model is used to compare the multi-objective decision-making methods with relative benefits between multiple input and multi output decision-making units. 2. The input and output weights of decision-making units are used as variables to avoid determining the weights of multiple indicators in the sense of priority. 3. This method does not need to determine a certain display relationship between input and output, and many subjective factors are excluded.

Suppose there are n classified samples, each sample has m input indexes and s output indexes. If the linear combination ratio of output and input of j0 classification samples is taken as the goal, and the ratio of output to input linear combination of all classification samples is less than 1 as the constraint condition, a comprehensive relative validity classification DEA model (C2R model) can be constructed.

$$r_j = \frac{1}{m} \sum_{i=1}^{m} r_{ij}$$  \hspace{1cm} (4)

$$\max_{b_0} = \frac{(U^T Y_j)}{(V^T X_j)}$$

s.t. $$(U^T Y_j) / (V^T X_j) \leq 1$$

Where, $U_j = (u_1, u_2, ..., u_l)^T \geq 0$

$$V^T = (v_1, v_2, ..., v_r)^T \geq 0$$

In the formula, $X_j$ and $Y_j$ represent the input and output of the jth evaluation sample, $X_0$ and $Y_0$ represent the input and output of the evaluated sample, and $v_i, u_i$ represent the weights of the i-th input and the r-th output, which are obtained by solving.

C2R model is a fractional programming problem. It is transformed into a linear programming problem by Charnes Cooper transformation, and then transformed into a dual programming problem by using dual theory of linear programming. Each DMU has m input indexes and s output indexes. If the linear
combination ratio of output and input of \( j_0 \) classification samples is taken as the goal, and the ratio of output to input linear combination of all classification decision samples is less than 1 as the constraint condition, then a DEA calculation model for comprehensive relative validity classification can be constructed [5].

\[
\begin{align*}
\min z &= \theta - \varepsilon (e^T S^- + e^T S^+) \\
\sum_{j=1}^{n} X_j \lambda_j + S^- &= \theta X_0 \\
s.t.
\sum_{j=1}^{n} Y_j \lambda_j - S^+ &= Y_0 \\
S^-, S^+ &\geq 0
\end{align*}
\]

Where \( X_j \) and \( Y_j \) represent the input and output of the \( j \)th DMU, \( X_0 \) and \( Y_0 \) represent the input and output of the evaluated DMU, \( \theta \) is the effective value of the sample, \( \varepsilon \) is the Archimedean infinitesimal (generally taken as \( \varepsilon = 10^{-6} \)), \( e^T \) is the unit transposition matrix, \( z \) is the objective function, \( S^- \) is the input relaxation variable, also known as the input redundancy of sample benefit; \( S^+ \) is the output relaxation variable, and the efficiency called sample benefit is insufficient. The optimal solution of the model is: \( \theta^*, \lambda^*, s^+, s^- \). DEA effectiveness analysis: (1) when \( \theta^* = 1 \) and \( s^+ = s^- = 0 \), DMUj is called DEA efficient. At this time, the efficiency of sample development is not only effective in scale, but also effective in technology. (2) When \( \theta^* = 1 \) and at least \( S^+ \) or \( S^- \) is greater than 0, the sample DMUj is called weak DEA efficient. At this time, the benefit of sample development is not the best in technical efficiency and the best in scale, which indicates that there is still an excess of input or a deficit in output. (3) When \( \theta^* < 1 \), the sample DMUj is said to be non DEA effective, indicating that the scale and technology of such projects are invalid.

5. Application analysis of benefit classification

5.1. Low permeability development unit affects benefit development and determination of geological factors

There are many development and geological factors that directly or indirectly affect the benefits of low-permeability development units, such as oil production, liquid production, total number of wells, geological reserves, etc. (Table 1).

Based on the data of 68 low permeability development units in the benefit evaluation of an oilfield in the east of China in 2017, the classification parameters of development units are determined by grey correlation analysis and multiple correlation analysis of indicators according to different geological conditions and development dynamics. Through the analysis, the average permeability, crude oil viscosity, single well controlled geological reserves, oil production rate, single well daily production, comprehensive water cut and other six indicators have the most significant impact on the development status and development benefits of low-permeability development units, which can be used as reference indicators for development classification.

Table 1. main influencing factors of unit development effect and development benefit

| influencing factors | related factors | influencing factors | related factors |
|---------------------|----------------|---------------------|----------------|
| Average permeability| directly affects oil production and liquid production | crude oil viscosity | directly affects oil production and liquid production |
| Single well controlled geological reserves | produced geological reserves, total number of wells, well pattern density | oil production rate, annual oil production and cumulative oil production |
| The daily production of a single well | related to the oil production and the number of open wells | the cumulative oil production | liquid production in the comprehensive water cut stage |
5.2. Cluster analysis results of low permeability development units

According to the six development and geological indexes which have the most significant impact on the development status and development benefits of low-permeability units, the development classification is carried out by using spss20.0 software and system clustering method. The system clustering method of the software requires that the development units are independent of each other, and each index has a certain correlation. This method can be used for classification and characteristic analysis of oilfield development units. According to the classification results, the development units can be divided into three categories, and the development status and geological conditions among different categories are also obvious. At the same time, the category with poor development and geological indicators also shows a trend of higher cost and lower benefit (Table 2).

| Table 2. Comparison of different classification development, geology and benefit indexes |
|-----------------------------------------------|----------------|----------------|----------------|
| Category                                      | Type I | Type II | Type III |
| unit number                                   | 20     | 22      | 26         |
| Oil production rate (%)                       | 0.7    | 0.6     | 0.5        |
| daily production of single well(t)            | 1.9    | 1.2     | 1          |
| Comprehensive water content(%)                | 68.3   | 62      | 52.1       |
| operating cost (USD / barrel)                 | 30.5   | 35.7    | 38.7       |
| depreciation                                  | 37.9   | 48.3    | 57.8       |
| annual profit                                 | -16.2  | -25.8   | -41.2      |

5.3. Benefit classification analysis based on DEA evaluation

Taking unit depreciation and operating cost as input index and crude oil output as output index, the relative effectiveness of each type of development evaluation unit is analyzed by deap version 2.1, and the analysis results are as follows (Table 3).

| Table 3. Results of DEA Analysis for some development units |
|------------------------------------------------------------|
| number sample                                             | 1 | 2 | 3 | 4 | 5 | 6 |
| 0                                                          | SFT | W11 | XX | LHP | CCL | BDTQ |
| λ                                                           | 1  | 1  | 0.8 | 1.0 | 0.2 | 0.5 |
| output S_1^+                                               | 0  | 0  | 524.5 | 0.0 | 0.0 | 0.0 |
| S_2^+                                                      | 0  | 0  | 0.0 | 243.2 | 0.0 | 52833 |
| input S_1^+                                                | 0  | 0  | 0.0 | 0.0 | 0.0 | 2.9 |
| S_2^+                                                      | 0  | 0  | 143.6 | 0.0 | 22.7 | 0.0 |

*Note: the total number of valid samples is 68, and the DEA analysis results of some samples are listed above.

Among them, effective development unit: unit θ = 1 and S_1=S_2=0 is DEA effective. This kind of unit is scale effective and technologically effective; medium development unit: unit θ = 1 and at least S_1 or S_2 is greater than 0, it is weak DEA effective, and this kind of unit has more input or less output than the overall average level; low efficiency development unit: when unit θ < 1, it is non DEA effective, which indicates that this kind of unit has invalid scale and technology.

From the classification results, development units with the same geological conditions and development stages can also be divided into benefit categories with different development efficiency according to the results of DEA analysis, which is more in line with the actual division of unit benefits, and the treatment of low efficiency development units will be more targeted (Table 4).
Table 4. Benefit classification results of low permeability development unit

| Effectiveness Development classification | Type I | Type II | Type III |
|----------------------------------------|--------|---------|----------|
| effective development unit             | SFT, W11, M11, XZ, GNN, Z15 | XJWZ, AGL, CYG, YSHL | P47, YL, XD, GX |
| medium development unit                 | SP, LHP, QI, SCH, Y13, BZCA, SR, WDXD | A9, ZZH, LHPPY, LN, TLH, FST, ZY, YSLD, Z25, HEW, T105 | M801, PNFY, GN, QJB, DYSQ, YSLN, YSXL, J251, SX, G172 |
| low efficiency development unit         | G23, XX, CYG, CCL, T1, BDTQ | Z212, YDCZ, S9, S22, M401, M8_M10, WMD | X7686, AN, PX, XZ, BHT, X25, X30, BMG, G137, HHNR, HDMR, XALQ |

4.5 Analysis of negative effect governance and management strategy

5.4 Analysis of negative effect governance and management strategy

According to the relationship between the operating cost and depreciation of the unit and the overall average level of the oilfield, the inefficient development units are divided into three categories: operation, planning and comprehensive, and the corresponding governance objectives are determined. Governance direction of low efficiency development unit

Table 5. Low efficiency category governance direction

| Low efficiency category | development classification | low efficiency development unit | governance direction |
|-------------------------|----------------------------|---------------------------------|----------------------|
| business                | Type I                     | /                               | to control the decline of oil fields, strengthen the treatment of ineffective wells, and achieve cost reduction |
|                         | Type II                    | YDCZ, S22                       |                      |
|                         | Type III                   | AN, BMG, J51, SX                |                      |
| planning                | Type I                     | /                               | optimize the production capacity, use the incremental benefit to drive the stock benefit |
|                         | Type II                    | M8_M10                          |                      |
|                         | Type III                   | PX, XZ                          |                      |
| comprehensive class     | Type I                     | G23, XX, CYG, CCL, T1, BDTQ     | new well productivity construction, old well stimulation and negative effect well treatment |
|                         | Type II                    | Z212, M401, WMD                 |                      |
|                         | Type III                   | X7686, BHT, XALQ                |                      |

Among them, the operating cost is higher than the average level, the depreciation is lower than the average level, and the unit efficiency is due to the high production and operation costs. In the planning category, the operating cost is lower than the average level, and the depreciation is higher than the average level. The low efficiency of the unit is due to the large initial investment. In the comprehensive category, the operating cost and depreciation are higher than the average level, and the unit investment and production and operation costs are high.
6. Conclusion
(1) The development and classification of low permeability development units is based on the systematic clustering method of six factors, which truly reflects the development and geological conditions of different units, and is the basis of benefit classification of development units.

(2) Through the application of DEA model, this paper evaluates the effect of development unit classification from the effectiveness of development unit benefit classification, scale income and other aspects, considers the economic efficiency of unit development as a whole, and improves the comprehensiveness of unit classification.

(3) Benefit classification analysis is an important research content of oilfield economic evaluation and benefit evaluation. The method of benefit classification of development units with similar geological and development conditions has realized the comprehensive classification of development and economy. At the same time, it is also a powerful measure to control the negative effect unit and improve the overall benefit of the oilfield, which can provide reference for the economic evaluation and benefit evaluation of low permeability oilfield.

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