Nafta-Gaz 2025, no. 2, pp. 102–108, DOI: 10.18668/NG.2025.02.02

Evaluation method of water injection development effect in complex fault-block reservoirs based on the modified TOPSIS-RSR method

Metoda oceny wpływu zatłaczania wody w złożach o złożonej budowie blokowo-uskokowej oparta na zmodyfikowanej metodzie TOPSIS-RSR

Yong Zhang, Guiping Pan

School of Petroleum, Southwest Petroleum University, China

ABSTRACT: Evaluating the water-flooding development effect in complex fault-block oil reservoirs is crucial for predicting development technology and enhancing oil production. However, researchers in the oilfield development industry currently face challenges, as they rely on multi-index evaluation methods based on mathematical models used to assess water-flooding development. This paper presents a comprehensive evaluation method based on the modified TOPSIS-RSR approach and applies it to assess the water-flooding development effect in five complex fault-block oil reservoirs in the middle and high water-cut period in Southwest China. The RSR method employs a combined weighting approach to determine the probability units of each research object and its relative proximity, followed by fitting a regression equation. A subsequent fitting analysis is conducted to obtain the evaluation results for the water-flooding development of the oil reservoirs. The results obtained using the modified TOPSIS-RSR method align with those of the fuzzy comprehensive evaluation model based on the analytic hierarchy process. Compared to the fuzzy comprehensive evaluation model based on analytic hierarchy process, the modified TOPSIS-RSR method offers several advantages in evaluating the water-flooding development effect of complex fault block reservoirs. It simplifies the evaluation process, making it faster, more effective, and more accurate while allowing for clearer distinctions in reservoir development effects. Additionally, using the Lagrange method to calculate weights ensures that the results incorporate both subjective and objective information, thereby improving the reliability of the evaluation.

Key words: water injection, evaluation method of water injection development, complex fault-block reservoirs, modified TOPSIS-RSR method, Analytic Hierarchy Process (AHP).

STRESZCZENIE: Ocena wpływu zatłaczania wody w złożach ropy naftowej o złożonej budowie blokowo-uskokowej ma kluczowe znaczenie dla prognozowania technologii eksploatacji i zwiększania wydobycia ropy naftowej. Jednak z uwagi na fakt, że naukowcy zajmujący się badaniami nad eksploatacją złóż ropy naftowej opierają się na wieloindeksowych metodach oceny, opartych na modelach matematycznych wykorzystywanych do prognozowania procesów eksploatacji z wykorzystaniem zatłaczania wody, napotykają oni na szereg trudności. W niniejszym artykule przedstawiono kompleksową metodę oceny opartą na zmodyfikowanym podejściu TOPSIS-RSR, którą zastosowano do prognozowania efektów zatłaczania wody w pięciu złożach ropy naftowej o skomplikowanej budowie blokowo-uskokowej w południowo-zachodnich Chinach w fazie średniego i wysokiego zawodnienia złóż. Metoda RSR wykorzystuje łączoną metodę ważenia w celu określenia jednostek prawdopodobieństwa każdego badanego obiektu i jego względnej bliskości, a następnie dopasowania równania regresji. Następnie przeprowadzana jest analiza dopasowania w celu uzyskania wyników oceny dla zagospodarowania złóż ropy naftowej z wykorzystaniem metody zatłaczania wody. Wyniki uzyskane przy użyciu zmodyfikowanej metody TOPSIS-RSR są zgodne z wynikami modelu rozmytej oceny kompleksowej opartej na procesie hierarchii analitycznej. W porównaniu do modelu rozmytej oceny kompleksowej opartej na procesie hierarchii analitycznej, zmodyfikowana metoda TOPSIS-RSR zapewnia szereg zalet w prognozowaniu wpływu zatłaczania wody do złóż o skomplikowanej budowie blokowo-uskokowej. Upraszcza ona proces oceny, czyniąc go szybszym, skuteczniejszym i dokładniejszym, a jednocześnie pozwala na wyraźniejsze wyodrębnienie efektów zagospodarowania złoża. Dodatkowo, zastosowanie metody Lagrange'a do obliczania wag zapewnia, że wyniki zawierają zarówno subiektywne, jak i obiektywne informacje, zwiększając w ten sposób wiarygodność oceny.

Słowa kluczowe: zatłaczanie wody, metoda zarządzania procesem zatłaczania wody, skomplikowane złoża o budowie blokowo-uskokowej, zmodyfikowana metoda TOPSIS-RSR, Analityczny Proces Hierarchiczny (AHP).

Corresponding author: P. Guiping, e-mail: *2546212926@qq.com*

Article contributed to the Editor: 24.09.2024. Approved for publication: 24.01.2025.

Introduction

Water injection development is a widely used and intricate method for developing fault-block reservoirs, significantly enhancing crude oil recovery rates. Evaluating the impact of water injection on reservoir development is essential, as it helps technicians identify factors affecting oil field development and analyses potential technical issues related to extraction. This evaluation facilitates the timely implementation of measures to address these issues, leading to improvements in development technology and ultimately achieving greater benefits (Li, 2015).

Domestically and internationally, there are six categories of methods for evaluating the effectiveness of reservoir water injection development: the state comparison method, recoverable reserves evaluation method, comprehensive evaluation method, analogy method, numerical simulation evaluation method, and the application of the fluid potential principle to study potential areas for water flooding. Among these, the comprehensive evaluation method is one of the primary approaches used to assess the impact of reservoir water injection development both domestically and abroad. Huang et al. (1999) proposed a technique for calculating weights using the analytic hierarchy process and the “fuzzy comprehensive evaluation method” to determine the effectiveness of reservoir water flooding. However, due to its subjective nature in determining index weight vectors and further calculation through AHP (*Analytic Hierarchy Process*), which leads to increased subjectivity in weight determination, it may result in low credibility and accuracy of results. Additionally, this approach is only suitable for the qualitative assessment of a single reservoir. Moreover, when numerous assessment indicators are present, super-ambiguity may arise, leading to poor resolution or even evaluation failure. Song et al. (2004) extensively utilized grey system theory to evaluate water flooding uniformity and its developmental potential. The similarity between the calculation process and fuzzy mathematics lies in the fact that the parameter selection and indicator formulation significantly impact evaluation results. However, grey system theory focuses on researching objects with a “clear extension but unclear connotation” (Zhao, 2011). Guo et al. (2018) introduced a methodology that combines fuzzy evaluation with an unknown measure model to assess reservoir water flooding's developmental effects. Unlike previous approaches, this technique enables ranking multiple same-type reservoirs based on developmental effect assessments. Nevertheless, it involves complex calculation processes requiring custom-designed measure functions for indices which lack standardization, thereby reducing applicability. Liu et al. (2008) contributed to this field by providing a comprehensive approach to evaluating reservoir water flooding's developmental effects.

Among the above methods, fuzzy comprehensive evaluation, which is a comprehensive evaluation method, is the most widely used. In this method, establishing a judgment matrix and calculating the membership degree are the main problems. A large literature review found that scholars did not elaborate on how to establish the judgment matrix, but based on previous experience, or did not mention it at all. However, there is no systematic and perfect criterion for selecting the membership function. The oilfield development degree classification document issued by China National Petroleum Corporation (SY/T 6219-1996) covers 7 types of reservoir development degree classification, including complex fault-block reservoirs. However, this document was designed to evaluate all development methods for such reservoirs and does not specifically consider its applicability to delineating boundaries for combined water cut growth rate, remaining recoverable reserves, recovery efficiency, and other indicators in waterflood development. Furthermore, it does not detail the importance and internal relationships of each indicator.

In terms of evaluation methods, the modified TOPSIS-RSR (*Technique for Order Preference by Similarity to Ideal Solution-Rank Sum Ratio*) method was used to rank and evaluate solutions. Subjective weight was established using AHP (*Analytic Hierarchy Process*), while objective weight was determined using the entropy weight method. Additionally, the Lagrange multiplier method was employed to optimize both subjective and objective weights in order to obtain a combined weight. The calculation results highlighted several advantages of combining the TOPSIS and RSR method, including simplicity, flexibility in calculation, and objective analysis. However, it is important to note that while the TOPSIS method effectively utilizes data, its Si value only reflects relative proximity to an object's interior rather than its proximity to an optimal solution (Yue et. al., 2024).

By combining the TOPSIS and RSR methods, we can leverage their respective strengths while compensating for their individual limitations, resulting in more objective and reasonable evaluation outcomes. Furthermore, using the Lagrange multiplier method to obtain the combined weights ensures that the results incorporate both subjective and objective perspectives.

Methods

Yu and Fu (2004) applied the TOPSIS concept to multi-objective decision-making in planning in 1994, evaluating the relative superiority and inferiority of existing objects. The principle of TOPSIS involves several steps. First, the maximum and minimum vectors are calculated using normalized original matrix. Next, the distance between each evaluation unit and the maximum value is obtained, as well as the distance between each evaluation unit and the minimum value. Finally, the relative closeness of each evaluation unit to the maximum value is calculated, which is then used for quality evaluation. The advantages of TOPSIS include the absence of strict requirements for data distribution, sample size, or the number of indicators. It also features simple calculations, and sufficient use of raw data. Therefore, it has intuitive geometric significance and is widely used in academic research.

The steps of TOPSIS are as follows:

1. Selecting required indicators, collecting raw data, and establishing the original matrix x as:

$$x = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \tag{1}$$

$$Z = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1m} \\ z_{21} & z_{22} & \cdots & z_{2m} \\ \vdots & \cdots & \vdots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nm} \end{bmatrix} \tag{2}$$

$$Z_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} \left(X_{ij}\right)^2}} \tag{3}$$

where:
x – original matrix,
x_{nm} – the element in the n-th row and m-th column of the original matrix x,
Z_{ij} – standardized matrix,
X – forward matrix,
X_{ij} – the element in the i-th row and j-th column of the forward matrix x.

2. Determining the maximum and minimum values based on the Z-matrix, and defining the maximum and minimum vectors, respectively:

$$Z^+ = (Z_1^+, Z_2^+, \cdots, Z_m^+) \tag{4}$$

$$Z^- = (Z_1^-, Z_2^-, \cdots, Z_m^-) \tag{5}$$

$$Z_j^+ = \max\left\{Z_{1j}, Z_{2j}, \cdots, Z_{nj}\right\} \tag{6}$$

$$Z_j^- = \min\left\{Z_{1j}, Z_{2j}, \cdots, Z_{nj}\right\} \tag{7}$$

where:
Z^+ – maximum vector,
Z^- – minimum value vector.

3. Calculate the distance between each evaluation object and the maximum and minimum values, and then obtain the normalized scores Si for each object:

$$D_i^+ = \sqrt{\sum_{j=1}^{m} (Z_j^+ - Z_{ij})^2} \tag{8}$$

$$D_i^- = \sqrt{\sum_{j=1}^{m} (Z_j^- - Z_{ij})^2} \tag{9}$$

$$D_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{10}$$

where:
D_i^+ – normalized maximum distance of item i,
D_i^- – normalized minimum distance for item i,
D_i – score for the i-th item.

In the formula, D_i^- is the normalized maximum distance of item i and D_i^- is the normalized minimum distance for item j, which is usually used as the dependent variable.

Finally, the evaluation objects are ranked based on their scores, where a higher the score indicates greater proximity to the maximum value.

Based on the above two calculation results, the weighted combination of TOPSIS methods was carried out (Hu and Li, 2019). Subjective weights are determined using the analytic hierarchy process, while objective weights are determined using the entropy weight method (Sun, 2022). Finally, combined weights are obtained by optimizing subjective weights and objective weights using the Lagrange multiplier method. The specific process for determining subjective and objective weights can be found in this literature (Hu and Ge, 2019) and will not be repeated in this paper.

The Lagrange multiplier method is used to optimize the subjective weight (W_1) and objective weight (W_2) to obtain the formula of combination weight calculation (Yang et al., 2022):

$$W_{ki} = \frac{(W_{1i}W_{2i})^{1/2}}{\sum_{i=1}^{n} (W_{1i}W_{2i})^{1/2}} (k = 1,2,3,4,\cdots,n;\ i =,2,3,4,\cdots,n) \tag{11}$$

$$S_i = D_i W_{ki} \tag{12}$$

The relatively close distance can be achieved by applying the weighted processing of the normalized distance of the i-th item.

Professor F.T. Tian (1994), a Chinese scholar, proposed the Hierarchical Clustering Ratio Method in 1988. This method is a statistical analysis technique that combines the advantages of classical parametric statistics and modern non-parametric statistics. The principle of the Hierarchical Clustering Ratio Method involves calculating dimensionless statistics, followed by calculating the probability unit and regression equation to study its distribution. The final result of this method is used to rank the strengths and weaknesses of the evaluation object, allowing for a comprehensive evaluation.

This method has several advantages. There are no special requirements for object or indicator selection. It has the ability to eliminate the interference from outliers. It also provides more accurate results. The accuracy exceeds that of using non-parametric methods alone. Therefore, it can be directly sorted or graded and has a wide range of applications. The steps of the method are as follows:

1. Selecting appropriate indicators and categorizing them as high performance indicators and low performance indicators (high performance indicators refer to indicators with larger values indicating better evaluation or results, while low performance indicators refer to indicators with smaller values indicating better evaluation or results), and creating the original matrix C:

$$C = \begin{bmatrix} C_{11} & C_{12} & \cdots & C_{1p} \\ C_{21} & C_{22} & \cdots & C_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ C_{f1} & C_{f2} & \cdots & C_{fp} \end{bmatrix} \quad (13)$$

where:
C – original matrix,
f – number of samples to be evaluated,
p – number of rating indicators.

2. Allocating all samples to be evaluated in an orderly manner based on the rank-first principle and determining the rank order set:

$$R = \begin{bmatrix} R_{11} & R_{12} & \cdots & R_{1p} \\ R_{21} & R_{22} & \cdots & R_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ R_{f1} & R_{f2} & \cdots & R_{fp} \end{bmatrix} \quad (14)$$

3. Using the non-integer rank method to compute the ranks of high and low optimal indicators:

$$R_{ij} = 1 + (f-1)\frac{C_{ij} - C_{min}}{C_{max} - C_{min}} \quad (15)$$

$$R'_{ij} = 1 + (f-1)\frac{C_{max} - C_{ij}}{C_{max} - C_{min}} \quad (16)$$

where:
R_{ij} – rank of high-quality indicators,
R'_{ij} – rank of low-quality indicators.

In the formula, R_{ij} represents the rank of high-quality indicators, while R'_{ij} represents the rank of low-quality indicators, which is usually used as the dependent variable.

4. Sorting the Hierarchical Clustering Ratio Method values in ascending order. Fist, the frequencies of these values (RSR) are listed and the distribution based on the sorted values and their frequencies is determined. RSR represents the dimensionless statistic obtained by averaging the ranks. Next, the average frequency for each object is calculated and the downward cumulative frequency is computed. Then, the cumulative frequency is converted to a probability unit value. Finally, the standard normal distribution table for this conversion is used.

$$RSR_i = \frac{1}{f \cdot p}\sum_{i=1}^{p} C_{ij} \quad (17)$$

$$Downward\ cumulative\ frequency = \bar{R}/f \times 100\% \quad (18)$$

$$Downward\ cumulative\ frequency^{*} = Downward\ cumulative\ frequency \times (1 - \frac{1}{4}f) \times 100\% \quad (19)$$

where:
RSR – a dimensionless statistic ranging from 0 to 1, with higher values indicating a better evaluation object.

The cftool toolbox of MATLAB was used to fit a linear regression equation, with Probit as the independent variable and the relatively close distance F_i as the dependent variable. Probit is the probability unit value converted from the down-cumulative frequency in the standard normal distribution table (Department of Mathematics, 2017).

$$F_i = a + b \times Probit \quad (20)$$

where:
$Probit$ – probability unit value.

Model establishment

The study focuses on a complex fault-block reservoir located in southwest China. The oil reservoirs in this region are generally complex fault-blocks characterized by multiple small oil-bearing areas, small reserve scales, low permeability, low reserve abundance, and low connectivity of small layers.

The study evaluates the development effect of 5 complex fault-block water injection reservoirs with medium water content in the oil region. The study comprehensively analyzes factors influencing oilfield water drive development decisions and selects seven indicators for comprehensive evaluation. The first indicator is the comprehensive decline rate. The second indicator is the natural decline rate. The third indicator is the water drive reserve utilization degree. The fourth indicator is the water drive reserve control degree. The fifth indicator is the water content rise rate. The sixth indicator is the oil recovery rate. The seventh indicator is the pressure maintenance level.

Table 1. Basic data of evaluation indicators for complex fault- block water injection reservoir

Tabela 1. Podstawowe dane wskaźników oceny dla złoża o skomplikowanej budowie blokowo-uskokowej eksploatowanego metodą zatłaczania wody

Reservoir	Comprehensive decline rate [%]	Natural decline rate [%]	Water drive reserves [%]		Water content increase rate [%]	Oil recovery rate [%]	Pressure maintenance levels [%]
			utilization degree	control degree			
1	14.20	19.30	91.0	96.0	–2.0	0.70	75
2	17.20	20.40	86.0	86.0	5.5	1.50	84
3	–0.60	13.70	90.0	100.0	5.5	3.58	75
4	10.51	38.31	85.0	90.0	–1.9	0.76	95
5	22.90	25.10	85.0	95.0	4.8	1.30	90

The basic data of evaluation indicators for the complex fault-block water injection reservoirs are shown in Table 1.

Subsequently, the oil reservoir data were analyzed using three different methodologies to derive the final evaluation results. These methodologies included the fuzzy comprehensive evaluation method based on the analytic hierarchy process, oilfield development level classification as outlined by the China National Petroleum Corporation (SY/T 6219-1996), and the TOPSIS-RSR method. These methodologies include several approaches. One approach is the fuzzy comprehensive evaluation method, which is based on the analytic hierarchy process. Another approach uses the oilfield development level classification. This classification is outlined by China National Petroleum Corporation, whose standard for this classification is SY/T 6219-1996.The third approach is the TOPSIS-RSR method.

Results and discussion

The subjective weights calculated by AHP and the objective weights calculated by the entropy weight method are presented in Table 2.

The results of TOPSIS method and RSR method are presented in Table 3.

Table 2. Individual weights

Tabela 2. Poszczególne wagi

Subjective weight	Objective weight	Combined weight
0.6261	0.0991	0.1977
0.6261	0.0682	0.2045
0.1628	0.1911	0.0855
0.1628	0.0840	0.0403
0.0762	0.2113	0.0262
0.1031	0.1916	0.0185
0.3827	0.1547	0.0197

Table 3. Results

Tabela 3. Wyniki

Reservoirs	S_i	RSR	Probit
1	0.3716	0.6408	5.8416
2	0.2250	0.4131	4.1584
3	0.5322	0.7524	6.6449
4	0.1617	0.5223	5.2533
5	0.1568	0.4550	4.7467

With relative proximity distance F_i as the dependent variable and probability unit Probit b as the independent variable, a linear regression equation was fitted using MATLAB:

$$F_i = 0.1412b - 0.4631$$

Table 4. Evaluation results based on modified TOPSIS-RSR method

Tabela 4. Wyniki oceny w oparciu o zmodyfikowaną metodę TOPSIS-RSR

S_i	F_i	Evaluation result	Rank
0.3716	0.4558	0.41370	II
0.2250	0.2310	0.22800	V
0.5322	0.5632	0.54770	I
0.1617	0.3772	0.26945	III
0.1568	0.3096	0.23320	IV

According to SY/T 6219-1996, the oilfield development level classification document released by China National Petroleum Corporation, and the actual situation of the studied block, the water drive development effect indicators are classified as high or low optimization indicators, as presented in Table 5.

According to the SY/T 6219-1996, the oilfield development level classification document issued by the China National Petroleum Corporation, and the actual situation of the studied block, as well as the research of Zhang et al. (2005), the evaluation index of oilfield development effect was established, as shown in Table 6.

Table 5. Water drive development effect indicators
Tabela 5. Wskaźniki efektywności eksploatacji metodą załączania wody

Indicators	Number	Property
Comprehensive decline rate	X1	Low
Natural decline rate	X2	Low
Degree of water drive reserve utilization	X3	High
Degree of water drive reserve control	X4	High
Water cut increase rate	X5	Low
Oil recovery rate	X6	High
Pressure Maine-nance level	X7	High

Table 6. Oilfield development effect index
Tabela 6. Wskaźnik skuteczności eksploatacji złóż ropy naftowej

Item number	Index [%]	Rank		
		Good	Medium	Poor
1	Comprehensive decline rate	≤7	>7 – ≤10	<10
2	Degree of utilization	≥50	<50 – ≥40	<40
3	Degree of control	≥60	<60 – ≥50	<50
4	Water content increase rate	≤1	>1 – ≤3	>3
5	Oil recovery rate	≥6	<6 – ≥5	<5
6	Maintain pressure levels	≥95	<95 – ≥85	<85

Note: When 4 of the 5 indicators in item numbers 1, 2, 3, 4 and 6 meet the standard or the previous standard, the reservoir is classified accordingly. Since SY/T 6219-1996 oilfield development level classification document does not classify the natural decline rate index, it is not included in the above table.

The evaluation results obtained by the fuzzy comprehensive evaluation method combined with good and bad intercept and Hierarchical Clustering Ratio Method fuzzy are compared in Table 7.

The ranking obtained using the modified TOPSIS-RSR method is consistent with the fuzzy comprehensive evaluation method based on analytic hierarchy process (using the geometric mean method for weight calculation). However, it differs from those obtained using the arithmetic mean or eigenvalue methods for weight calculation. Some scholars often use the eigenvalue method to calculate weights in fuzzy comprehensive evaluation (Zhang et al., 2005). While this method considers the significance of various factors, it does not account for numerical magnitude or proportional relationship in the samples (Zhang et al., 2005). Due to the small difference between the calculation results using AHP and fuzzy mathematics, the difference in reservoir evaluation scores based on AHP is not obvious. In contrast, the composite scores calculated using the modified TOPSIS-RSR method vary considerably. Therefore, TOPSIS-RSR can make composite scores more objective and reliable, effectively reducing the probability of obtaining identical scores.

Table 7. Comparison of development effect
Tabela 7. Porównanie wyników eksploatacji

Reservoir	Fuzzy comprehensive evaluation method	Modified TOPSIS-RSR method	Traditional evaluations
1	□	□	Poor
2	□	□	Poor
3	□	□	Poor
4	□	□	Poor
5	□	□	Poor

The SY/T 6219-1996 (1996) document, issued by the China National Petroleum Corporation (CNPC), evaluates water injection development effects in complex fault-block oilfields. However, the results indicate that the development effect of this group of oilfields remains consistently poor. As a result, the intended purpose of grading the development effect cannot be realized.

Conclusions

This paper discusses three methods for evaluating the effect of oilfield development in complex fault-block reservoirs. Additionally, the TOPSIS-RSR method, based on the entropy weight method, was applied to evaluate reservoir development effect for the first time. The main conclusions are as follows:

1. The improved TOPSIS-RSR method utilizes the combination weight method to calculate weights. It effectively reflects the discrimination ability of both TOPSIS and RSR methods. The weight calculation in this method is more scientifically rigorous, resulting in more reliable reservoir evaluation results.
2. In the fuzzy comprehensive evaluation method based on the analytic hierarchy process, scholars often fail to provide detailed explanations for establishing the judgment matrix. Instead, they rely on prior experience or omit this step altogether. Furthermore, this research field lacks both systematic and definitive criteria. These criteria are needed to select appropriate membership degree functions used to compute membership degrees. This leads to difficulties in using this method to evaluate reservoir development effects. Additionally, this method often results in similar or even identical scores when evaluating the development effects of multiple reservoirs, hindering effective ranking.
3. The CNPC (China National Petroleum Corporation) has issued a document classifying oilfield development grades.

It is used to evaluate the development effect of complex fault-block reservoirs. However, the evaluation results using this document are not satisfactory.
4. The TOPSIS method makes full use of the available data. Its Si value indicates the relative proximity within the object, but it does not measure proximity to the optimal solution. On the other hand, the RSR method reflects the rank size but does not capture the relationship between objects, potentially leading to information loss during computation.
To address this issue, a new approach called TOPSIS-RSR, based on combined weighted reconstruction, is proposed after comparing with other improved TOPSIS methods. This method incorporates statistical scoring and uses relative posting progress instead of RSR value for qualitative scoring. It extends the evaluation results of the TOPSIS method, making qualitative evaluation more objective. The proposed method is suitable for situations where index information is random and where many schemes need to be classified, ensuring that evaluation results are more reasonable and credible.

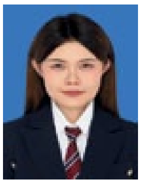
References

Department of Mathematics, Tongji University, 2017. Probability Theory and Mathematical Statistics. *Posts and Telecommunications Press*, 1: 252.
Guo W.Y, Mei W.H., Fang G.L., Ye Z.S., Guo W.W., 2018. Comprehensive evaluation of operation management of a hospital by fuzzy combination of TOPSIS method and RSR method. *Chinese Health Statistics*, 35(5): 729–732.
Huang B.G., Fu Y.Q., Tang H., Wang N.T., Zhang X.P., 1999. Fuzzy comprehensive evaluation method to determine the water drive difficulty of water drive reservoir. *Journal of Southwest Petroleum Institute*, 4: 1–5.
Hu G.Q., Ge S.C., 2019. Teaching quality evaluation of university teachers based on analytic hierarchy process and entropy weight method: Taking students evaluating teachers as an example. *Journal of Inner Mongolia Normal University (Education Science Edition)*, 32(8): 62–66.
Li S.L., 2015. Research on development law and remaining oil distribution of L17 fault block reservoir, *Master's thesis, Yunshan University, Qinhuangdaodao, 066004, China*.
Liu X.T., Yang C.D., Yang J., Guan Z.T., Wang S.Y., Guan P.F., Li X.W., 2008. New discussion on comprehensive evaluation system of development effect of complex fault-block reservoir. *Fault-block Oil & Gas Field*, 1: 80–83.
Song Z.Q., Zhao L., Wang R.F., et al. 2004. Application of a water drive development effect evaluation method in Liao he Oilfield. *Journal of Xi'an Petroleum University (Natural Science Edition)*, 3: 17–22.
Sun Y., 2022. Research on entropy of directed complex networks based on degree and feature roots. *Master's thesis, Qinghai Normal University, Xining, China*.
Tian F.T., 1994. Application of rank sum ratio method in hospital statistics. *Chinese Hospital Statistics*, 1: 41–46.
Yang H.S., Zheng K.W., Tan J.Y., 2022. Application of Improved TOPSIS-RSR Method in Quality Evaluation of CNC Machine Tools. *Automation Technology and Application*, 41(4): 4–7.
Yu X.F., Fu D., 2004. A review of multi-index comprehensive evaluation methods. *Statistics and Decision*, 11: 119–121.
Yue Y., Zheng J. R., Cheng L., Zhu Y.N., Wu H., 2024. Comprehensive Evaluation of Distributed PV Grid-Connected Based on Combined Weighting Weights and TOPSIS-RSR Method. *Energy Engineering*, 121(3): 703–728.
Zhang X.F., Zhang L.H., Xiong Y., Sun W.Q., Li Y.L., 2005. Research on evaluation method and application of development effect of high water cut oilfield. *Daqing Petroleum Geology and Development*, 3: 48–50.
Zhao X.F., 2011. Overview of grey system theory. *Journal of Jilin Provincial Institute of Education*, 27(3): 152–154.

Legislative acts and normative documents

SY/T 6219-1996. Classification of oilfield development level. China National Petroleum Corporation, Beijing,1996.

Yong ZHANG, Ph.D.
Associate Professor at the School of Petroleum and Natural Gas Engineering
Southwest Petroleum University
No. 8 Xindu Avenue, Xindu District, Chengdu City, Sichuan Province, China
E-mail: *zhangyongsc@126.com*



Guiping PAN, M.Sc.
Postgraduate student at the School of Petroleum and Natural Gas Engineering
Southwest Petroleum University
No. 8 Xindu Avenue, Xindu District, Chengdu City, Sichuan Province, China
E-mail: *2546212926@qq.com*