Evaluation Methodology and Practical Application of Oil and Gas Well Data Asset Assessment Based on AHP-Fuzzy Mathematics

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Abstract. In response to the country's high emphasis on data asset management and the digital transformation of the energy industry, oil and gas companies are actively researching data assetization. Oil and gas well data are core to the production and operation of these companies. Assessing their value is an urgent issue in the data assetization process. This paper designs a data asset value assessment indicator system, proposes a valuation model based on the cost method, and applies hierarchical analysis, entropy weight, and fuzzy comprehensive evaluation methods for multi-dimensional value assessment of oil and gas well data assets.

Keywords: Oil and gas wells; well data resources; data asset valuation

1 Introduction

In recent years, data assets have gained significant national recognition. In August 2023, the Ministry of Finance issued the "Interim Provisions on Accounting Treatment of Enterprise Data Resources"[1], mandating the inclusion of data assets in balance sheets and providing policy guidance for their management. Simultaneously, the "Several Opinions on Accelerating Energy Digitalization and Intelligence" from the National Energy Administration emphasized leveraging digital and intelligent technologies throughout the oil and gas production, supply, storage, and sales chain[2].

Data plays a crucial role in the oil and gas industry due to the deep underground locations of resources. Geophysical data aids exploration, while reservoir simulation data supports production. Wells serve as primary sources of this critical information, encompassing geological, drilling, completion, and production data across their life cycles—from exploration to abandonment.

Despite its importance, identifying, certifying, and valuating oil and gas well data assets present numerous challenges. Given the complexity and diverse applications within the industry, establishing a robust evaluation system and method is imperative. This paper aims to explore methods for identifying, certifying, and valuating these

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assets, incorporating specific case studies to offer theoretical insights and practical guidance for managing data assets in the oil and gas sector.

2 Overview of Oil and Gas Well Data Assets

2.1 Data Asset Research

There have been several studies in academia related to data asset valuation. Christine Benesch, Christian Hess, and their colleagues[3] argue that ignoring risk components can lead to undervaluation of data assets. Thibaut Weber[4] provides a detailed method for cross-industry information valuation. Yu Yanfang et al.[5]focus on grid enterprises, highlighting the importance of data assets in enterprise digital transformation and proposing a data asset valuation method based on composite weighting. Liu Yannan[6], from the perspective of a multidimensional dynamic assessment framework, analyzes the complexity and specificity of data asset valuation. Bi Shanshan et al.[7] propose the CIME model as a new tool and method for data asset assessment.

Despite extensive discussions on the recognition and evaluation of data assets, much of the focus remains on general discussions, lacking in-depth analysis of the specific environment and characteristics of the oil and gas industry. There is a limited segmentation of data assets and constrained practical applications. This study concentrates on the identification, recognition, and valuation of data assets from oil and gas wells, providing an industry-specific framework and application cases. Additionally, based on a cost approach, this paper constructs a multidimensional valuation framework. It applies the AHP-fuzzy comprehensive evaluation method to qualitatively and quantitatively assess the value of well data assets, enhancing the accuracy and practicality of data asset valuation. This research offers theoretical and practical support for exploring the realization of data asset value in the oil and gas industry.

2.2 Current Status of Well Data Resources of a Company

An oil and gas company has developed a comprehensive data resource system over years of informatization efforts, covering exploration to development, and conventional to unconventional aspects through unified and custom-built systems. Well data, crucial as master data, is central to the company's data governance strategy. Recent initiatives have standardized well master data and governance processes, integrating managed data into a "source system collection, regional distribution" model.

Wells primarily generate economic value during exploration, development, and production, generating structured and unstructured data stored in exploration, production, and development management platforms. The key data resources across systems are shown in **Table 1**.

Table 1. Well-related system data resources

Information System	Data Resources

Exploration and Production Management	Well master data, construction details, maps, project records, logging data, experimental reports, etc.
Development and Production Management	Well master data, deployment plans, site assessments, dynamic tracking, operational management, etc.
Oil and Gas Water Well Production Data Management	Single well, layer, reservoir, production, injection data, etc.
Oil Extraction and Surface Engineering Operations Management	Well, pump, heater, equipment details, etc.
Production Operations Management	Production plans, dynamics, daily reports, etc.

3 Well Data Asset Valuation Method

Domestic research on the valuation of data assets in China has begun to take shape. Frameworks include guidelines such as the "Asset Assessment Expert Guide No. 9 - Data Asset Assessment" published by the China Asset Appraisal Association, and the "Guidelines for Data Asset Assessment" (draft for public consultation). Additionally, the National Information Technology Standardization Technical Committee has issued the national standard "Requirements for Data Asset Management in Information Technology Services" (GB/T40685-2021), Appendix A - Reference Methods for Data Asset Valuation.

Current research findings indicate that methods for evaluating the value of data assets primarily include the cost approach, market approach, income approach, and comprehensive approach. Considering the applicability of these methods, given that data assets in the oil and gas sector are still in the developmental stage and have not yet generated economic value through market transactions, the cost approach is deemed suitable for valuing and pricing data assets.

3.1 Determine the Valuation Object

In order to conduct a comprehensive assessment of the well data assets owned by the company and determine the value of the data assets, this paper selects the conventional gas well data assets of Block A as the pilot assessment object. The data assets are mainly derived from the exploration and production management platform. After analysis and collation, they contain a large number of structured data, unstructured documents, images, etc. of the entire exploration and production process of wells, including seismic, drilling, logging, testing and well location deployment. The two-dimensional/three-dimensional display of seismic data and logging curves can be pushed to professional software for browsing.

3.2 Selecting a Valuation Method

When selecting an asset valuation method, it is necessary to consider factors such as the valuation object, value type, applicable conditions of the valuation method, and the quality and quantity of the data itself. Since the data assets of oil and gas companies are still in the development and formation stage, and have not yet generated economic value through market transactions, it is appropriate to use the cost method to value and price data assets. This paper proposes an AHP-fuzzy comprehensive evaluation method based on the cost method, establishes an indicator evaluation system including data quality, data application, and data risk dimensions, and values well data assets in the early development stage.

According to "Asset Valuation Expert Guidelines No. 9 - Data Asset Valuation", the basic calculation formula of the cost method is:

$$P=TC\times 1+R\times U \tag{1}$$

$$= HC \times S \times (1+R) \times U$$

P——Value of the data assets being assessed

TC——Replacement cost of the assessed data assets

HC——The historical cost of data assets includes the total cost incurred by data assets from the start of the statistical period to the assessment base date, including initial expenses, construction costs, operation and maintenance costs, and indirect costs.

R——The reasonable profit margin of data assets represents the reasonable income from the use of data assets. If it cannot be directly obtained, the average profit margin of similar intangible assets in the market can be used as a substitute, or it can be judged by experts in the data field combined with industry experience;

S——Data asset replacement cost coefficient

U——The value adjustment coefficient is a collection of factors that affect the realization of data value. The calculation model of the value adjustment coefficient is constructed using the hierarchical analysis method and expert scoring method. The construction of the adjustment coefficient requires comprehensive consideration of factors such as the quality, application and risk of data assets.

3.3 Cost Aggregation Method

The historical cost of well data assets is mainly considered from the data life cycle of well data from planning, collection, aggregation, storage, development, application, and maintenance. The classification includes initial expenses, construction costs, operation and maintenance costs, and indirect costs. The cost collection approach is shown in **Table 2**.

Table 2. Data asset cost collection method

Cost Classification	Secondary classification	Determining method
Initial expenses	Data Planning	The overall cost of data planning, including staff salaries, consulting fees, and related resource costs
Construction costs	data collection	Data obtained from the production and operation of enterprises

	Data aggregation	Costs incurred in the process of merging data from different data sources
	data storage	Costs of repository construction, optimization, etc.
	Data Development	Costs of information resource organization, cleaning, mining, analysis, reconstruction
	Data Application	Costs of developing, packaging and providing data applications and services
Operation and maintenance costs	data maintenance	Data backup, data redundancy, data migration, emergency response, etc.
Indirect costs	Software and hardware costs	Software and hardware procurement, R&D, and maintenance costs related to data assets
	Infrastructure costs	Including construction or rental and maintenance costs of computer rooms, sites, etc.
	Public administration costs	Including water, electricity, office and other shared expenses

3.4 Valuation Model Calculation

Based on the characteristics of well data assets and the current status of company data, factors influencing well data asset value are identified. A hierarchical model is established across dimensions of data quality, data application, and risk compliance. Relationships between these dimensions are analyzed, and a systematic hierarchical indicator structure is defined. The weights of the three main dimensional indicators sum to 1, with subordinate indicator weights aggregating to their respective higher-level weights.

(1) Construction of a Multi-Level Value Adjustment Coefficient Calculation Indicator System, as Shown in Table 3

Table 3. Well Data Asset Value Assessment System

Evaluation system	First level indicator	Secondary indicators
Well Data Asset Value Assessment System	Data quality dimensions	accuracy
		Completeness
		Normative
		Timeliness
		Uniqueness
	Data application dimension	Scope of use
		scenes to be used
		business model
		Supply and demand
		Data Relevance
	Risk compliance dimension	Data risks
		Data Compliance

(2) Construct A Judgment Matrix Based on the AHP Method And Expert Scoring Method, And Determine the Weights

Construct a judgment matrix incorporating expert experience into the hierarchical model. Utilize pairwise comparison methods to determine factor weights at each level based on *their* relative importance. Evaluate these factors on a relative scale and establish an n-order result judgment matrix. For λ_{max}, the principal eigenvalue of the judgment matrix, normalize its eigenvector to obtain weights denoted as w,These weights w represent the relative ranking importance of factors at the same level relative to those at the preceding level.

The consistency index of the matrix 为$CI = \frac{\lambda - n}{n-1}$, the *random* consistency index$RI = \frac{CI_1 + CI_2 + \cdots CI_n}{n}$

In order to test whether the judgment matrix has *satisfactory* consistency, it is necessary to introduce the test coefficientCR

$$CR = \frac{CI}{RI} \tag{2}$$

If CR＜0.1， , then the judgment matrix is considered to pass the consistency test.

(3) Establishment of Scoring Criteria for the Indicator System

After clarifying the weight of each indicator, it is necessary to assign specific scores to each indicator in the model, and finally summarize and calculate the value of the value adjustment coefficient. In order to quantify the qualitative indicators, quantitative scoring standards are formulated for the above indicators, and the fuzzy comprehensive evaluation method is used to judge the corresponding degree of membership of each indicator. Combined with the above indicator system, an evaluation and scoring standard including data quality, data application and data risk compliance is formulated, as shown in **Table 4**.

Table 4. Index evaluation scoring criteria

Evaluation indicators	0-20 points	21-40 points	41-60 points	61-80 points	81-100 points
Accuracy E_1	< 20% data describes target entity	20%-40% data describes target entity	40%-60% data describes target entity	60%-80% data describes target entity	> 80% data describes target entity
Integrity E_2	< 20% internal data open	20%-40% internal data open	40%-60% internal data open	60%-80% internal data open	> 80% internal data open
Normative E_3	20% data domains safe and compliant	20%-40% data domains safe and compliant	40%-60% data domains safe and compliant	60%-80% data domains safe and compliant	> 80% data domains safe and compliant

Timeliness E_4	Last updated 2 years ago	Last updated 1 year ago	Last updated within 1 year	Last updated within 6 months	Last updated within 3 months
Uniqueness E_5	> 80% datasets are repeated	60%-80% datasets repeated	40%-60% datasets repeated	20%-40% datasets repeated	< 20% datasets repeated
Range of use A_1	Data application limited	Few industries, fields, regions applied	Many industries, fields, regions applied	Extremely diverse industries, fields, regions	Very diverse industries, fields, regions
Use scenario A_2	Very few data access interfaces	Fewer data access interfaces	Medium data access interfaces	High data access interfaces	Extremely high data access interfaces
Business Model A_3	Extremely poor product and financial models	Poor product and financial models	Medium product and financial models	Relatively high product and financial models	Extremely high product and financial models
Supply and Demand A_4	Extremely poor data scarcity, very small market	Poor data scarcity, small market size	Medium data scarcity, medium market size	High data scarcity, high market size	Extremely high data scarcity, large market size
Data Relevance A_5	Extremely poor business-data correlation	Poor business-data correlation	Moderate business-data correlation	Highly correlated with businesses	Extremely highly correlated with businesses
Data Risk C_1	Extremely high safety risks	Relatively high safety risks	Moderate safety risks	Relatively low safety risks	Extremely low safety risks
Data Compliance C_2	Extremely low compliance	Low compliance	Moderate compliance	High compliance	Extremely high compliance

(4) Summarize and Calculate the Value Adjustment Coefficient

Use the AHP-fuzzy comprehensive evaluation method to determine the weights and specific values of the detailed indicators under each dimension, and obtain the adjustment coefficient U value through weighted average.

$$U = \frac{1}{100} \times \sum_{i=1}^{n} w_i \left(q_i + a_i + c_i\right) \qquad (3)$$

w_i is the weight of the ith evaluation indicator, q_i is the quality evaluation score, a_i is the application evaluation score, and c_i is the risk compliance assessment score.

In summary, after obtaining the historical cost $HC$and value adjustment coefficient of data assets U, the cost reset coefficient can be determined in combination with $S$the CPI and industry wage growth rate Rduring the statistical period, and the assessed value of the data assets can be calculated in combination with the industry profit margin.

3.5 Valuation Model Optimization

Due to the subjective nature of determining weights using the Analytic Hierarchy Process (AHP), it is advantageous to combine the Entropy Weight Method (EWM) with AHP in decision models. This approach balances subjective judgment with objective data, enhancing the scientific and rational basis of the model. In practical applications, AHP is first used to establish initial weights, followed by the introduction of EWM to optimize these weights. This method preserves the advantages of expert experience while leveraging the objectivity of data, thereby improving the reliability and accuracy of the model.

The process of applying EWM to optimize weight calculation is as follows:

(1) Standardization of Decision Matrix

Normalize the original data to obtain a standardized matrix.

(2) Calculation of Information Entropy

Compute the information entropy for each indicator using the standardized matrix.

Let $P_{ij} = \frac{R_{ij}}{\sum_{i=1}^{m} R_{ij}}$, $k = \frac{1}{\ln(m)}$, and m is the number of evaluation objects.

$$E_j = -k \sum_{i=1}^{m} P_{ij} \ln P_{ij} \quad (4)$$

(3) Determination of Indicator Weights

Calculate the weights of each indicator based on its entropy value.

$$W_j = \frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \quad (5)$$

(4) Integration of Weights

Combine the weights obtained from AHP and EWM. Assuming an equal weighting ratio (α = 0.5) between the two methods.

$$W_{combined} = \alpha W_{combined} + (1-\alpha) W_{AHP} \quad (6)$$

4 Well Data Asset Valuation Practice

4.1 Calculation of Replacement Cost

Firstly, calculate the historical cost (HC) of conventional gas well data assets in Block A for the period from January 1, 2019, to January 1, 2023. Due to security and confidentiality requirements for cost data, sample data is used in this case.

Analysis of the entire process of oil and gas well design, drilling, testing, and completion indicates that the acquisition cost of conventional gas well data in Block A C_0 is stored in the exploration and production management platform. Costs such as data aggregation (C_1), storage (C_2), data development (C_3), data application (C_4), data maintenance (C_5), and management (C_6) are calculated based on expenses generated by the platform. Considering that the platform's original data is not limited to the development of conventional gas well data assets in Block A but also used for other data assets, costs (C_1, C_2, C_3, C_4, C_5) are allocated according to the storage ratio in related systems. Detailed historical cost statistics are shown in **Table 5**.

Table 5. Historical cost statistics

Cost Type	use	2019	2020	2021	2022	202 3	Value (ten thousand yuan)
Construction costs	data collectionC_0	60000	60000	—	—	—	120000
	Data aggregationC_1	—	—	3.2	2.2		5.4
	data storageC_2	—	—	—	4	2	6
	Data DevelopmentC_3	—	—	—	3.5	1.5	5
	Data ApplicationC_4	—	—	—	2	1	3
Operation and maintenance costs	data maintenanceC_5	—	—	—	0.5	0.5	1
Indirect costs	Management costsC_6	6	8	10	12	15	51
total	120,071.4						

The price replacement coefficient is the annual average CPI within the statistical period, which is used to calculate the replacement cost of construction costs and operation and maintenance costs. The manpower replacement index is obtained by investigating the average growth rate of the salary level of the entire bank in the IT industry in the past 10 years, which is used to calculate the replacement cost of indirect costs.

Table 6. Reset coefficient table for 2019-2023

statistical period	Price growth rate	Price reset factorS_1	Average salary growth rate of IT industry employees	Manpower reset factorS_2
2023	100.20%	1	105.10%	1
2022	102%	1.002	109.40%	1.09
2021	100.90%	1.022	113.10%	1.23

2020	102.50%	1.03	121.55%	1.49
2019	102.90%	1.05	119.36%	1.77

The asset replacement cost is obtained by multiplying the historical cost of each part in previous years by the replacement coefficient of the corresponding year. According to **Table 6**, it can be seen that the total to obtain the replacement cost TC of RMB 124883.41 ten thousand yuan.

4.2 Calculation of Value Adjustment Coefficient

(1) Use the Analytic Hierarchy Process to Determine the Weight of Each Indicator

Through the expert scoring method, the following judgment matrix as shown in **Table 7**,**Table 8**,**Table 9**,**Table 10.** Risk Compliance Assessment Judgment Matrix was constructed and the weights and consistency ratios were calculated.

Table 7. Data asset value evaluation matrix

Dimensions	Data quality	Data Application	Risk Compliance	W i
Data quality	1.0000	3.0000	0.5000	0.3338
Data Application	0.3333	1.0000	0.3333	0.1416
Risk Compliance	2.0000	3.0000	1.0000	0.5247

The matrix calculation $CR = 0.0517 < 0.1$, $\lambda_{max} = 3.0538$, is verified.

Table 8. Data quality evaluation matrix

Dimensions	accuracy	Completeness	Normative	Timeliness	Uniqueness	W i
accuracy	1.0000	3.0000	2.0000	2.0000	2.0000	0.3373
Completeness	0.3333	1.0000	2.0000	2.0000	2.0000	0.2175
Normative	0.5000	0.5000	1.0000	3.0000	3.0000	0.2194
Timeliness	0.5000	0.5000	0.3333	1.0000	0.5000	0.0970
Uniqueness	0.5000	0.5000	0.3333	2.0000	1.0000	0.1288

The matrix calculation $CR = 0.0912 < 0.1$, $\lambda_{max} = 5.4084$, is verified.

Table 9. Data application evaluation matrix

Dimensions	Scope of use	scenes to be used	business model	Supply and demand	Data Relevance	W i
Scope of use	1.0000	2.0000	3.0000	0.5000	2.0000	0.2514
scenes to be used	0.5000	1.0000	2.0000	0.3333	2.0000	0.1637
business model	0.3333	0.5000	1.0000	0.5000	2.0000	0.1307
Supply and demand	2.0000	3.0000	2.0000	1.0000	3.0000	0.3601
Data Relevance	0.5000	0.5000	0.5000	0.3333	1.0000	0.0941

The matrix calculation $CR = 0.0493 < 0.1$, $\lambda_{max} = 5.2210$, is verified.

Table 10. Risk Compliance Assessment Judgment Matrix

Dimensions	Data risks	Data Compliance	W_i
Data risks	1.0000	1.0000	0.5000
Data Compliance	1.0000	1.0000	0.5000

The matrix calculation $CR = 0.5247 < 0.1$, $\lambda_{max} = 2.0000$, is verified.
In summary, the weight ratio of each indicator is shown in **Table 11**.

Table 11. Data value evaluation index weights(AHP)

WAE_1	WAE_2	WAE_3	WAE_4	WAE_5	WAA_1	WAA_2	WAA_3	WAA_4	WAA_5	WAC_1	WAC_2
0.1126	0.0726	0.0732	0.0324	0.043	0.0356	0.0232	0.0185	0.051	0.0133	0.2623	0.2623

(2) Using Entropy Weight Method to Determine Indicator Weights

To optimize the weights determined by AHP mentioned above, we introduce the Entropy Weight Method (EWM) for auxiliary calculation to reduce subjectivity and enhance objectivity. According to Table 7, preliminary weights for three dimensions are obtained. Applying the Entropy Weight Method to matrices in Tables 8, 9, and 10 allows us to calculate the weights of the indicators as shown in **Table 12** below.

Table 12. Data value evaluation index weights(Entropy)

WJE_1	WJE_2	WJE_3	WJE_4	WJE_5	WJA_1	WJA_2	WJA_3	WJA_4	WJA_5	WJC_1	WJC_2
0.074	0.0723	0.0727	0.0645	0.0503	0.0318	0.0306	0.0266	0.0315	0.021	0.2623	0.2623

(3) Determination of Integrated Weights

The final weights are determined by combining the AHP weights and the weights from the Entropy Weight Method with a ratio of α=0.5, as shown in **Table 13** below.

Table 13. Data value evaluation index weights(Entropy)

WFE_1	WFE_2	WFE_3	WFE_4	WFE_5	WFA_1	WFA_2	WFA_3	WFA_4	WFA_5	WFC_1	WFC_2
0.0933	0.0725	0.0730	0.0485	0.0467	0.0337	0.0269	0.0226	0.0413	0.0172	0.2623	0.2623

(4) Using Fuzzy Comprehensive Evaluation Method for Data Asset Scoring

Experts were invited to score the conventional gas well data assets in Block A in combination with the data asset scoring table, and the scores for each item are shown in **Table 14**.

Table **14.** Data value evaluation index scores

E_1	E_2	E_3	E_4	E_5	A_1	A_2	A_3	A_4	A_5	C_1	C_2
60	65	75	70	90	80	80	60	70	60	70	80

(5) Calculate the Value Adjustment Factor

In summary, the value adjustment coefficient of the data asset can be calculated:

$$U = \frac{1}{100} \times \sum_{i=1}^{n} w_i \left(q_i + a_i + c_i\right) = \frac{1}{100} \times 72.86 = 0.7286 \quad (7)$$

4.3 Data Asset Value Assessment

After obtaining the data asset replacement cost $TC$and value adjustment coefficient U, the reasonable profit rate $R$is taken as the company's benchmark rate of return of 6%, and we can get:

$$P = HC \times S \times (1 + R) \times U = 124883.41 \times 1.06 \times 0.7286 = 96{,}449.46 \quad (8)$$

From this we can see that the valuation of block A's data assets is 96,449.46 ten thousand yuan.

5 Conclusion

This study constructs and practices a set of identification, recognition and valuation methods for oil and gas well data assets, which not only provides a solid theoretical basis and practical operational tools for the quantitative evaluation and management of data assets in the oil and gas industry, but also highlights the important value of well data assets in oil and gas companies through in-depth case analysis. The research results provide decision-making support for oil and gas companies in the identification, evaluation and transaction of data assets in the future, and demonstrate the key role of data assets in promoting enterprise digital transformation and value creation.

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