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Ecological environment governance in mining areas in the process of urbanization based on fuzzy comprehensive evaluation

This paper studies the situation of the ecological environmental governance in mining areas. By selecting indices from the perspectives of economic, ecological and social efficiencies, this paper establishes a comprehensive efficiency evaluation index system for the ecological environment governance in mining areas in the process of urbanization. Based on the index weights determined, this paper applies the fuzzy comprehensive evaluation model to perform empirical analysis on Xuzhou mining area as a whole. According to the analysis results, the comprehensive efficiency of ecological environment governance in the mining area has a total score of 77.8545, which is rated as "medium" and is developing towards "good", indicating that the environmental governance has gained some comprehensive efficiencies but still needs to be improved.

Keywords: *Ecological environment of mining areas, fuzzy comprehensive evaluation, governance efficiencies, urbanization.*

1. Introduction

Mineral resources are the basic resources in national economy and the indispensable material basis for the survival and development of modern human society. In mining areas, the development and utilization of mineral resources is the main factor that drives the formation and adjustment of the industrial structure and promotes the economic and social development there. However, during the process, external problems such as environmental pollution and ecological environment destruction are very prominent in these resource-based areas. The key to the supply-side reform is to promote the structural adjustment of supply side, including emission structure, industrial structure and regional structure. Urbanization is an important engine that drives the supply-side reform under the new normal. At present, the hard constraints on the ecological environment in urban mining areas are being strengthened, so the adjustment of emission structure is particularly important, and efforts should be strengthened in ecological environment governance. The ecology principle, with Geddes and Park as the representative, has been applied in the urban construction and development, which has laid the foundation for the study of urban and ecological relations in the early 20th century. B. Commoner and G. Grossman [1] used the IPAT model to simulate the evolution of the relation between urban development and environment in developed countries to establish a link between urbanization and ecology. Former Soviet Ecologist O. Yanitsy formally proposed the concept of eco-city. Relevant research started late in China. New urbanization was put forward and ecological civilization was given great attention in the Eighteenth National Congress of CPC; the ecological civilization philosophy and principles were officially incorporated into the urbanization process for the first time at the Central Economic Working Conference in 2012. J.C. Huang and C.L. Fang [2] performed quantitative identification of the coupling relationship between the urbanization and ecological environment in the Three Gorges reservoir area; K. J. Zhao [3] took Pingshuo mining area in Shanxi province as an example, studied the ecological environment governance and the protection of peasants' interest in the mining area and proposed a solution to the ecological environment problems in this area; H. Y. Zhao, J. li [4] adopted the fuzzy comprehensive evaluation method to evaluate the ecological security problems existing in the urbanization development of Daqing city; D.Q. Zhu [5] took the smog governance in the Yangtze river delta as an example, and studied the cross-domain coordinated governance over environmental pollution; B.Z. Feng [6] studied the collaborative governance on the ecological environment in Beijing, Tianjin and Hebei province from a holistic perspective; Y. J. Geng and S. C. Peng[7] used the comprehensive evaluation model of ecological environment quality to comprehensively evaluate the ecological environment of Huainan coal mine area; Q. Sun and Z. K. Bai [8] applied the minimum damage accumulation model and used remote sensing images to analyse the ecological risk changes brought by mining and reclamation activities. Urbanization is an important growth pole in regional

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TABLE 1: 1-9 MEANINGS OF SCALES

Scale a_{ij}	Meaning	Explanations
1	Equally important	Index A_i and index A_j are equally important
3	Slightly important	Compared with index A_j, index A_i is slightly important based on experience or judgment
5	Obviously important	Compared with index A_j, index A_i is obviously important based on experience or judgment
7	Absolutely important	Compared with index A_j, index A_i feels absolutely important
9	Extremely important	Compared with index A_j, index A_i feels extremely important
2, 4, 6, 8	Median	A scale corresponding to the intermediate state between two judgments
$1/a_{ij}$		If compared with index j, index i gets the judgment value a_{ij}, then $1/a_{ij} = a_{ji}$

development. Currently, many problems have shown in resource consumption, environmental deterioration and industrial restructuring in mining areas. This paper, by taking Xuzhou mining area as the object, studies the eco-environmental governance in the mining area in the process of urbanization, which helps broaden the horizon on the integration of multidisciplinary theories and methods and is also of important theoretical and practical significance to the environmental governance and industrial structure optimization in the mining area and the regional coordinated development of ecological civilization.

2. Research methods

The research method is an important part of comprehensive evaluation. In general, it mainly includes the establishment of weight and fuzzy comprehensive evaluation. In this paper, we mainly use analytic hierarchy process to determine the weight and use fuzzy comprehensive evaluation to evaluate comprehensively.

2.1 WEIGHT DETERMINATION BY THE ANALYTIC HIERARCHY PROCESS

Analytic hierarchy process (AHP) is a multi-objective and multi-criterion system analysis method proposed by T.L.Saaty in 1973. The application of AHP can be done in the following steps:

2.1.1 Construction of the hierarchical structure model

Before applying the analytic hierarchy process, the corresponding evaluation index system should be established. First, the author establishes a clear hierarchical index system, which consists of the target level A: the overall target that the decision problem aims at; the criterion level B: the criteria used to judge whether the method is good or not; and the scheme level C: the specific indices, which constitute the factor set and sub-factor set for the evaluation target. Then the author establishes a hierarchical structure model based on the basic relations in the evaluation index system [9] (Fig.1).

2.1.2 Construction of the judgment matrix

Constructing the judgment matrix is an important step of the analytic hierarchy process. On the whole, it mainly refers to a process where experienced experts compare the relevant sub-index with each index in the last level according to their

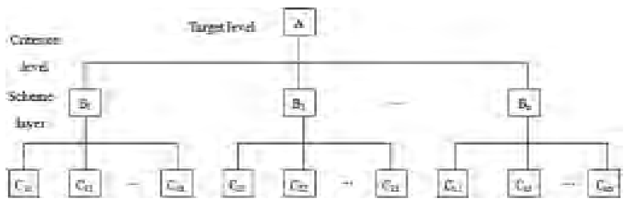

Fig.1 Indicator system hierarchy

own knowledge and experience and make a quantitative scale to determine the importance of each index. The scale method generally adopts the degree of importance 1-9 scale method. Its meaning is shown in Table 1.

The 1-9 scale method is adopted to scale the relative importance of each factor on a pairwise basis. Based on the indices in the middle level, the authors constructed several comparative judgment matrices [10]. Taking the target layer A- the criterion layer B as an example, the construction of the judgment matrix is shown in Table 2:

TABLE 2: OBJECTIVE LAYER A-CRITERION LAYER B JUDGMENT MATRIX

A	B_1	B_2	…	B_n
B_1	a_{11}	a_{12}	…	a_{1n}
B_2	a_{21}	a_{22}	…	a_{2n}
…	…	…	…	…
B_n	a_{n1}	a_{n2}	…	a_{nn}

Note: main diagonal elements $a_{ii} = 1(i = 1,2,…,n)$

2.1.3 Single ordering and consistency test

This process is to obtain each component Wi of the normalized eigenvector (W_1, W_2,…, W_n) corresponding to λmax of the judgment matrix, that is, the single-level ranking weight of each index, or the ranking weight of the relative importance of each relevant factor in the current level with respective to a certain factor in the last level. In order to test the consistency of the judgment matrix, CI (Consistency Index) and CR (Consistency Ratio) also need to be calculated:

$$CI = (\lambda_{max} - n)/(n - 1) \quad ... \quad (1)$$

$$CR = CI/RI \quad ... \quad (2)$$

where RI is Ratio Index, when CR<0.10, i.e., the relative deviation of λ_{max} from n is no greater than 1/10 of the average random consistency index RI, the judgment matrix is considered as having "satisfactory" consistency. If CI = 0,

TABLE 3: AVERAGE RANDOM CONSISTENCY INDEX COMPARISON TABLE

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

the judgment matrix has "complete" consistency; otherwise, it is necessary to adjust the values of the elements in the judgment matrix (Table 3).

2.1.4 Total ordering and consistency test

The general idea is to calculate the relative importance weights of the factors in each level with respect to the overall target level, and then synthesize all the separate weights from top to down to obtain the combined weight of each index with respective to level 1 elements, i.e. the overall targets. For total ordering, consistency test is also required level by level from top to down. If the total ordering passes the consistency test, then the index weights obtained are final.

2.2 COMPREHENSIVE EVALUATION BASED ON THE FUZZY METHOD

Fuzzy mathematics was founded in 1965 by professor LA. Zadeh, an expert on American cybernetics. He is in the process of establishing the fuzzy set theory introduced the concept of membership function to describe the differences in the middle of the transition, and a lot of economic phenomena that exist in the real life are fuzzy and designs an evaluation model and method, the fuzzy comprehensive evaluation method, fuzzy comprehensive evaluation (FCE). In application practice, this method has been continuously evolving with experts and scholars. Fuzzy comprehensive evaluation usually follows the following steps [11]:

2.2.1 Determination of the evaluation factor set

$U = \{u_1, u_2, \ldots, u_n\}$, where U is the hierarchical set, u_i (i = l, 2, …, n) is the evaluation factor, n is the number of single factors in the same level. The i-th factor ui can be further divided into $u_i = \{u_{i1}, u_{i2}, \ldots, u_{ij}, \ldots, u_{im}\}$, where m is the number of evaluation factors in the j-th aspect. This set constitutes the evaluation framework.

2.2.2 Determination of the rating set

$V = \{v_l, v_2, \ldots, v_n\}$, where v_j = (j = l, 2, …, n) is the rating, n is the number of elements, i.e. the number of ratings or review grades. This set defines the range of evaluation options for a certain factor. These options can be quantitative or qualitative scores.

2.2.3 Determination of the membership matrix

If comprehensive evaluation is conducted on n elements, the result will be a matrix of n rows and n columns, which is called the membership matrix R, where $R = (R_1, R_2, \ldots, R_n)$ T = $(r_{ij})n \times n$. Obviously, each row in the matrix is the evaluation result of each single factor, and the entire matrix contains all the information about the evaluation on the factor set U corresponding to the rating set V. For qualitative indices, the membership matrix is determined by the weight statistical method; quantitative indices are divided into efficiency indices and cost indices, and the membership matrix is determined using the membership function method. The membership degree of the index X can be calculated according to the different intervals (defined by the standard values) that the actual value of the index X falls within.

2.2.4 Multi-level fuzzy comprehensive evaluation

Suppose that the evaluation model [12] is $S_i = W_i.R_{in}$ (i = 1, 2, ..., n), where S_i is the evaluation set, W_i is the index weight set, R_{in} is the fuzzy relation matrix, and "." is the fuzzy composition operator symbol. In the fuzzy operation using the fuzzy set transformation principle, appropriate fuzzy composition operator should be selected. Usually fuzzy composition operator includes M(□,□), M(·,□), M(□,□) and M(·,□). The maximising "□" and minimising "□" operations of the fuzzy composition operator will both cause judgment information loss to varying extents. Multiplication "·" retains all the information needed in the single-factor evaluation; and the ring sum operation does not impose any restriction on W_i and R_{im}, but only normalises W_i. In this way the fuzzy composition operator M (·,□) can keep all the useful information and take the impacts of various factors into account. For a hierarchical index system, generally the fuzzy comprehensive evaluation is needed on multiple levels. Based on the results of multi-level fuzzy comprehensive evaluation, a score is assigned to each rating in the rating set. At last, the evaluation conclusion is given according to the total score of the comprehensive evaluation and the rating of the evaluation object.

3. Research area and data sources

3.1 RESEARCH AREA OVERVIEW

Xuzhou mining area is located in the northern part of Jiangsu province and at the intersection of Longhai and Jinpu railway. Beijing-Hangzhou Grand Canal also flows through this area. It is located in the bordering areas of four provinces: Jiangsu, Shandong, Henan and Anhui, is the central city in Huaihai Economic Zone, and also one of the four mega-cities in Jiangsu province and one of the core cities in the three metropolitan areas. Besides its strategic location advantage, Xuzhou also has abundant mineral resources. Xuzhou mining area contains more than 30 kinds of minerals such as coal, iron, titanium, limestone, marble and quartz stone. As a large-scale coal mining area with an annual output of over 10 million tonnes of raw coal, it is the only coal producing area and an important energy base in Jiangsu province, and also one of the key coal bases in China. In 2016, the national economy in Xuzhou mining area maintained a steady and sustained growth, and the industrial structure developed towards the middle and high end. The construction of ecological environment progressed steadily and the quality of air and water environment continuously improved. Ecological restoration was carried out successively to 180,000 mu of collapsed coal mine, 34,000 mu of deserted industrial and mining area and 43 quarries. New afforestation land reached 655,000mu, forest coverage rate was up to 30.3%, and the green coverage rate of the built-up area was up to 43.7%. The energy conservation and emission reduction result was remarkable, outdated production facilities were closed down in strict accordance with the national policy on excess capacity, high energy consumption and high pollution projects were strictly controlled and key energy-consuming enterprises continued to improve their energy efficiency. In 2016, energy consumption per unit GDP throughout the city fell by 5.9%, exceeding the target set by the province. However, the resources and energy consumption in the mining area was still large, the air, surface water and groundwater quality needed to be further improved, and bottlenecks still existed in the ecological environment, which all affected the coordinated and sustainable development of economy, society and ecology in the mining area.

3.2 Data sources

The data used in the research are mainly obtained from Xuzhou Environment Quality Bulletin (2010-2016), Xuzhou Government Work Report (2007-2017), Xuzhou Statistical Yearbook (2000-2017), Xuzhou National Economy and Social Development Statistical Bulletin (2006-2016), Xuzhou Bureau of Statistics (http://tjj.xz.gov.cn/), Xuzhou Environmental Protection Bureau (http://www.xzhb.gov.cn/), Xuzhou Twelfth Five-Year Plan for National Economy and Social Development, Xuzhou Thirteenth Five-Year Plan for National Economy and Social Development and Xuzhou People's Government (http://tjj.xz.gov.cn/), etc.

4. Empirical analysis

In order to further illustrate the key factors of ecological environment governance benefits in the mining area in the process of urbanization, this part will be in Xuzhou mining area as a whole, evaluate the comprehensive benefit of the mining area on ecological environment governance on the basis of constructing evaluation index system.

4.1 Construction of the index system

By using the evaluation index system, the quantitative analysis is carried out, and the problems existing in it are found, so as to determine the direction and path of future development. Based on the connotation, basic theory and basic principle on comprehensive benefit of the mining area ecological environment governance in the process of urbanization, to construct the evaluation index system, and combining the Xuzhou mining area ecological environment comprehensive governance of the actual situation of urbanization, the index system is designed to give class structure, divided into the target layer, criterion layer and layer scheme [13].

4.1.1 Target level

Target level A is a high-level summary of the comprehensive efficiency evaluation index system for ecological environment governance in the process of urbanization, used to reflect the overall level of comprehensive governance efficiency. It is the aggregation result of the criterion and index levels.

4.1.2 Criterion level

The criterion level reflects the comprehensive efficiency of ecological environment governance in the mining area in the process of urbanization from different aspects, and includes economic efficiency (B_1), ecological efficiency (B_2) and social efficiency (B_3).

4.1.3 Scheme level

The scheme level is composed of multiple indices selected under the criterion level [14]. This research mainly takes the situation of Xuzhou mining area in 2016 as an example, and selects 17 indices to reflect the comprehensive efficiency of the ecological environment governance in the mining area in the process of urbanization. The framework and description of the evaluation index system are shown in Table 4.

4.2 Grading of the evaluation indices

Evaluation index system is determined, it is necessary to define the specific grade of each index evaluation standard, the concrete index is converted into a comprehensive benefit evaluation to determine the mining area ecological environment governance level, and then find out the key factors influencing the comprehensive benefits, and then puts forward the corresponding implementation way.

In the process of determining the standard values for index evaluation, this research refers to relevant researches, comprehensively employs the standard method, reference method and expert opinion method, consults some of the international, national and industrial standards and codes currently in force, including China Statistical Monitoring Index System for Building Well-off Society in an All-Round Way by National Bureau of Statistics, Ambient Air Quality Standards (GB3095-2012) and Evaluation Standard for Urban Landscaping and Greening (GB/T50563-2010) by the Ministry of Housing and Urban-Rural Development and General Administration of Quality Supervision, Inspection and Quarantine, and takes into account the existing theoretical research results on ecological environment governance in mining areas and actual comprehensive efficiency evaluation effects. Finally, this research divides the evaluation indices into five ratings and the rating set is $V = \{V_1, V_2, V_3, V_4, V_5\}$, i.e. {excellent, good, medium, poor and very poor}. See Table 5 for specific levels.

4.3 Determination of index weights

4.3.1 Construction of the judgment matrix and single ordering

In order to establish a quantitative AHP judgment matrix

TABLE 4: EVALUATION INDEX SYSTEM AND DESCRIPTIONS

Target level	Criterion level	Scheme level	Unit	Actual value 2016
Comprehensive efficiencies on ecological environment governance of mining areas in the process of urbanization (A)	Economic efficiency (B1)	Per capita GDP (C_{11})	Yuan	66845
		Proportion of the added value of the service industry in GDP(C_{12})	%	47.4
		Contribution rate of scientific and technological progress (C_{13})	%	57
		Proportion of environmental protection investment in GDP (C_{14})	%	2.65
		Urban per capita disposable income (C_{15})	Yuan	28421
	Ecological efficiency (B2)	Proportion of the days with good ambient air quality (C_{21})	%	65
		Water qualification rate of centralized drinking water source area (C_{22})	%	100
		Land reclamation rate of mining area (C_{23})	%	93
		Urban sewage treatment rate (C_{24})	%	90
		Harmless treatment rate of urban domestic waste (C_{25})	%	95
		Night-time noise qualification rate of functional area (C_{26})	%	80
		Green coverage rate of built-up area (C_{27})	%	43.3%
	Social efficiency (B3)	Registered urban unemployment rate (C_{31})	%	1.85
		Urbanization rate (C_{32})	%	62.4
		Life expectancy of urban residents (C_{33})	Age	82.22
		Engel coefficient (C_{34})	%	30.5
		Per capita housing area of urban residents (C_{35})	m^2	38.6

and weight distribution, etc., this study using the method of expert consultation, on the mining area ecological environment governance evaluation index system of comprehensive efficiency of the factors important degree of pairwise comparison. At the same time, using Table 1, 1-9 scaling method, we can draw A-B_i, B_i-C_{ij} judgment matrix, the judgment matrix is calculated by applying Matlab software and the maximum characteristic value of λ_{max} and their corresponding normalized eigenvector, and verify the consistency of judgement matrix, determine the weight coefficient, etc., the results are shown in Tables 6-9:

(1) Determination of Level 1 index weights

Firstly, the row indices in criterion level B are compared to the corresponding column indices and scaled by the 1-9 scale method so as to construct the target level A-criterion level B judgment matrix. The maximum eigenvalue, corresponding normalized eigenvector W, the consistency index CI value, and the average random consistency index RI value of A-B_i judgment matrix is calculated by Matlab software. The results are shown in Table 6.

(2) Determination of Level 2 index weights

Level 2 index weights are determined by the same method and through the same process as Level 1 index weights. The weight of the secondary index (Tables 7-9) is determined by the importance of the secondary index

TABLE 5. EVALUATION INDEX LEVEL SPECIFICATION

	V_1	V_2	V_3	V_4	V_5
C_{11}	100000	80000	57000	31400	20000
C_{12}	60	55	50	45	40
C_{13}	75	65	55	45	35
C_{14}	5	3	2	1.5	1
C_{15}	40000	25000	18000	13000	10000
C_{21}	100	95	90	85	80
C_{22}	100	99	98	97	96
C_{23}	100	98	95	92	90
C_{24}	100	90	85	75	65
C_{25}	100	98	95	90	85
C_{26}	100	95	85	75	70
C_{27}	60	50	40	30	20
C_{31}	0	3	6	8	10
C_{32}	80	70	60	50	40
C_{33}	90	80	75	70	65
C_{34}	30	35	40	45	50
C_{35}	50	45	40	35	30

TABLE 6: A-B_i JUDGMENT MATRIX AND WEIGHT (I = 1, 2, 3)

A	B_1	B_2	B_3	W_i
B_1	1	1/2	1	0.2500
B_2		1	2	0.5000
B_3			1	0.2500

λ_{max} = 3; C.I. = 0; R.I. = 0.58; C.R. = 0

TABLE 7: B_1-C_{1i} JUDGMENT MATRIX AND WEIGHT (I = 1, 2, 3, 4, 5)

B_1	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	W_{1i}
C_{11}	1	3	3	2	2	0.3683
C_{12}		1	1	1/2	1/2	0.1094
C_{13}			1	1/2	1/2	0.1094
C_{14}				1	1	0.2064
C_{15}					1	0.2064

λ_{max} = 5.0133; C.I.= 0.0033; R.I.= 1.1200; C.R.= 0.0030

TABLE 8: B_2-C_{2i} JUDGMENT MATRIX AND WEIGHT (I = 1, 2, 3, 4, 5, 6)

B_2	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	W_{2i}
C_{21}	1	1	1	3	2	2	3	0.2125
C_{22}		1	1	3	2	2	3	0.2125
C_{23}			1	3	2	2	3	0.2125
C_{24}				1	1/2	1/2	1	0.0655
C_{25}					1	1	2	0.1158
C_{26}						1	2	0.1158
C_{27}							1	0.0655

λ_{max} = 7.0203; C.I. = 0.0034; R.I. = 1.3200; C.R. = 0.0026

TABLE 9: B_3-C_{3i} JUDGMENT MATRIX AND WEIGHT (I = 1, 2, 3, 4, 5)

B_3	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	W_{3i}
C_{31}	1	1/2	1	2	3	0.2147
C_{32}		1	2	3	4	0.3751
C_{33}			1	2	3	0.2147
C_{34}				1	2	0.1215
C_{35}					1	0.0741

λ_{max} = 5.0331; C.I.= 0.0083; R.I.= 1.1200; C.R.= 0.0074

TABLE 10: TOTAL ORDER OF EACH HIERARCHY EVALUATION INDEX SYSTEM

A	B	Weight	Order	C	Weight	Order
A	B_1	0.2500	2	C_{11}	0.0921	5
				C_{12}	0.0274	15
				C_{13}	0.0274	15
				C_{14}	0.0516	10
				C_{15}	0.0516	10
	B_2	0.5000	1	C_{21}	0.1062	1
				C_{22}	0.1062	1
				C_{23}	0.1062	1
				C_{24}	0.0328	12
				C_{25}	0.0579	6
				C_{26}	0.0579	6
				C_{27}	0.0328	12
	B_3	0.2500	2	C_{31}	0.0537	8
				C_{32}	0.0938	4
				C_{33}	0.0537	8
				C_{34}	0.0304	14
				C_{35}	0.0185	17

(scheme layer C) relative to the primary index (criterion layer B).

The consistency of the judgment matrix can be determined based on the value of the random consistency ratio CR, for which, there is CR = CI/RI. If $CI = 0$, the judgment matrix has "complete" consistency; if $CI \neq 0$, and CR<0.1, the judgment matrix has "satisfactory" consistency and the evaluation result is reliable; otherwise, the judgment matrix needs to be adjusted. From the above, it can be concluded that, if CI = 0 or CR<0.1, i.e. the judgment matrix has "complete" or "satisfactory" consistency, such matrix passes the consistency test.

4.3.2 Total ordering

Single ordering is the weight ranking in each level with respect to the last level; and total ordering is the weight ranking with respect to the target level. Criterion layer are calculated by Matlab software layer relative to the target weights of A and B sorts, according to the judgment matrix A-B, B_1-C, B_2-C, B_3-C level single sorting and weight assignment as A result, the solution layer C and weights of each index relative to the target layer of A sort, the results are shown in Table 10.

4.4 DETERMINATION OF THE MEMBERSHIP MATRIX

For a qualitative index, the membership degree is determined by the weight statistical method; for a quantitative index, the membership degree is calculated using the membership function. The membership degree of index X can be calculated according to the different intervals (defined by the standard values) that the actual value of the index X falls within. When X falls in the interval (V_n, 0), which is $X<V_n$, $r_n = 1$, $r_1 = r_2 = \ldots = r_{n-1} = 0$; when $V_{J+1}<X<V_j$, $r_{j+1} = (V_J-X)/(V_J-V_{j+1})$, $r_j = 1-r_{j+1}$, $j = 1,2\ldots n-1$; when $X>V_1$, $r_1 = 1$, $r_2 = r_3 = \ldots = r_n = 0$.

According to the above analysis, according to the method and steps of the quantitative indicators are calculated respectively membership degree, and the 2016 mining area ecological environment governance in urbanization comprehensive benefit evaluation index membership degree matrix values (Table 11).

4.5 MULTI-LEVEL FUZZY EVALUATION

In this study, the authors use the fuzzy operator $M(\cdot,\oplus)$, which first performs the multiplication operation ($W_i \cdot R_{in}$), and then performs the ring-sum operation [15]. Based on the above weighting results and index membership values, the authors carry out the multi-level fuzzy comprehensive evaluation using the comprehensive efficiency evaluation index system for ecological environment governance in the mining area in the process of urbanization with the help of Matlab. Because the evaluation index system in this study has the target layer A, the criterion layer B, and the scheme layer C, therefore, it is important to carry out the first class fuzzy comprehensive evaluation and second-level fuzzy comprehensive evaluation [16].

TABLE 11: MEMBERSHIP DEGREE OF INDEX

	V_1	V_2	V_3	V_4	V_5
C_{11}	0.0000	0.4280	0.5720	0.0000	0.0000
C_{12}	0.0000	0.0000	0.4800	0.5200	0.0000
C_{13}	0.0000	0.2000	0.8000	0.0000	0.0000
C_{14}	0.0000	0.6500	0.3500	0.0000	0.0000
C_{15}	0.2281	0.7719	0.0000	0.0000	0.0000
C_{21}	0.0000	0.0000	0.0000	0.0000	1.0000
C_{22}	1.0000	0.0000	0.0000	0.0000	0.0000
C_{23}	0.0000	0.0000	0.3333	0.6667	0.0000
C_{24}	0.0000	1.0000	0.0000	0.0000	0.0000
C_{25}	0.0000	0.0000	1.0000	0.0000	0.0000
C_{26}	0.0000	0.0000	0.5000	0.5000	0.0000
C_{27}	0.0000	0.3300	0.6700	0.0000	0.0000
C_{31}	0.3833	0.6167	0.0000	0.0000	0.0000
C_{32}	0.0000	0.2400	0.7600	0.0000	0.0000
C_{33}	0.2220	0.7780	0.0000	0.0000	0.0000
C_{34}	0.9000	0.1000	0.0000	0.0000	0.0000
C_{35}	0.0000	0.0000	0.7200	0.2800	0.0000

4.5.1 Level 1 fuzzy comprehensive evaluation

Level 1 fuzzy comprehensive evaluation, that is, the single-factor fuzzy comprehensive evaluation, is the fuzzy operation result of the weights of m factors in the scheme level C with respect to the n-th factor in the criterion level and the membership matrix of the corresponding factors in the scheme level C under the action of the fuzzy operator $M(\cdot,\oplus)$. Let $B_i = W_{Cn}.R_{mi}$ (i = 1, 2, 3), where B_i is the fuzzy evaluation of the n-th factor in the criterion level B, $W_{Cn} = (w_{Cn1}, w_{Cn2}, \ldots, w_{Cnm})$ is the weights of the m factors in level C with respect to the n-th factor in level B, R_{mi} is the membership matrix corresponding to the m factors in level C, and "." is the fuzzy composition operator. In accordance with this method, the layer C factors corresponding to other factors of layer B can be determined by a fuzzy comprehensive judgment (Table 12).

TABLE 12: LEVEL 1 FUZZY COMPREHENSIVE EVALUATION

	V_1	V_2	V_3	V_4	V_5
B_1	0.0471	0.4730	0.4230	0.0569	0.0000
B_2	0.2125	0.0872	0.2884	0.1995	0.2125
B_3	0.2393	0.4016	0.3384	0.0207	0.0000

4.5.2 Level 2 fuzzy comprehensive evaluation

Level 2 fuzzy comprehensive judgment matrix can be obtained by aggregating the relative importance weight of the criterion level B with respect to the target level A and the Level 1 comprehensive evaluation result. Let $A_i = W_{Bk}.B$ (i = 1, 2, 3), where A_i is the fuzzy evaluation of a factor in the target level, W_{Bk} is the weight of the k factors in level B with respect to the factor in level *A*, *B* is the Level 1 fuzzy comprehensive evaluation result, and "." is the fuzzy composition operator. According to the calculation procedure of fuzzy comprehensive evaluation, the secondary fuzzy comprehensive evaluation matrix (Table 13) can be calculated separately from the Matlab software.

TABLE 13: LEVEL 2 FUZZY COMPREHENSIVE JUDGMENT EVALUATION

	V_1	V_2	V_3	V_4	V_5
A	0.1778	0.2622	0.3345	0.1192	0.1062

4.6 RESULTS DISCUSSION

According to the result of the fuzzy comprehensive evaluation of the second-level fuzzy comprehensive evaluation, this paper draws the fuzzy comprehensive evaluation bar chart for 2016 in Xuzhou mining area, as shown in Fig.2. It shows: with the accelerating process of urbanization, the ecological environment governance in the mining area has been given more attention to. In 2016, V_1 was 0.1778, and V_2 was 0.2622, with an excellent and good ratio being up to 44%, and V_3 was 0.3345, showing that the overall situation was good, and the overall efficiency was gradually improving.

Based on the results of level 2 fuzzy comprehensive evaluation, the author assigns a score to each rating in the rating set. In this study, the hundred-mark system is used to quantify the rating set $V = \{V_1, V_2, V_3, V_4, V_5\}$={excellent, good, fair, poor, very poor}into P = [95, 85, 75, 65, 55], where 95 or more is "excellent", 85 "good", 75 "fair", 65 "poor", and 55 "very poor". A is the Level 2 fuzzy evaluation result, A_i is the value of the rating corresponding to the fuzzy evaluation result of the factor in the target level, and $A = A_i$ (i = 1, 2, 3, 4, 5), so the target level A, i.e. the total score is $Z = A \cdot PT$. By using Matlab, the authors calculate the total score of the comprehensive efficiency of ecological environment governance in the mining area in the process of urbanization in 2016 is 77.8545, which is between 75-85, i.e. "medium", with a trend towards "good". It shows that the comprehensive efficiency of ecological environment governance in the mining area achieved some progress. In particular, C_{22} reached 100%; the actual C_{11} and C_{15} values were higher over previous

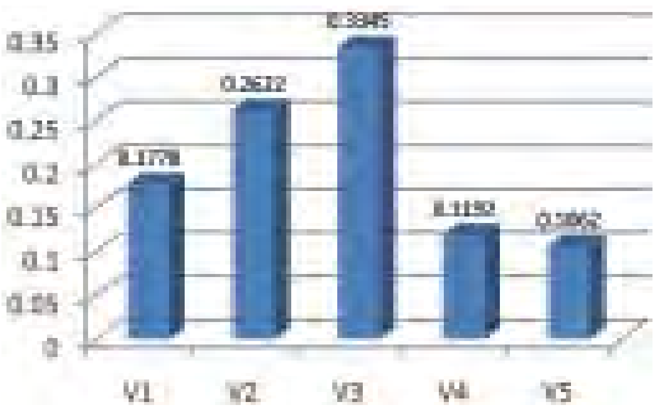

Fig.2 Level 2 fuzzy comprehensive evaluation

years; and C_{32} was improved to some extent, which resulted in an increase in the total score; but on the other hand, C_{21} took the largest weight, but the actual value of AQI was 65%, which was not much desired; and C_{14} was also relatively low, which affected the overall evaluation score. On the whole, the ecological environment governance in the mining area still needs more effective measures to further improve the comprehensive efficiency.

5. Conclusions

Through the above analysis, it is concluded that Xuzhou mining area should make persistent efforts in the ecological environment governance in the mining area, try to turn its ecological advantage into economic advantage and let the development of the green industry lead the way for economic transformation and upgrading. These efforts involve deepening the ecological civilization system reform in Xuzhou mining area, improving the institutional mechanisms for land development, natural resources conservation and utilization and ecological environment protection and improving the property rights system and use governance system for natural resources to help form a new pattern of modernization with harmony between human and nature. Xuzhou mining area also needs to find a special development path, carry out top-level design for the mining area according to local conditions and break down barriers in the ecological environment governance, so as to enhance economic growth and sustainable social development, and at the same time, cultivate new economic growth points so that the vision of ecological civilization construction will become a realistic and achievable goal. In summary, it should promote the coordinated development of the ecological civilization and the economy in the mining area and further integrate urbanization with ecology, economy and society.

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