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The Comprehensive Evaluation Model of Fuzzy Mathematics Based on Third Class Cities' Low Carbon Economy

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Large amounts of carbon dioxide emission are the main cause of climate warming, socarbon emission abatement is urgent for the cities. In this paper, the low carbon economy of third class cities is regarded as the research object, and evaluation is regarded as the breakthrough point. The evaluation index system of third class cities' low carbon economy is established. Using AHP to determine the index weight, the fuzzy evaluation model of third class cities' low carbon economy is constructed. This model is used to evaluate the low carbon economy of Weifang, and the result is general, which is consistent with the actual situation. The model is feasible.

1. Introduction

Low carbon economy researches abroad started earlier. In 1987, the study of environmental indexes was carried out in the Netherlands. In 1994, a set of environmental indexes was released in Canada. In 2001, the environmental indexes were launched in the United States(Wang, 2000). While the domestic study of urban low carbon economy is still in the exploratory stage. And its evaluation research is even less. In this paper, on the basis of establishing the evaluation index system of the third class cities' low carbon economy, using the fuzzy comprehensive evaluation method, the third class cities' low carbon economy is evaluated. This method is novel and unique, scientific and reasonable which is feasible(Zhang, 2016).

2. The establishment of evaluation index system of third class cities' low carbon economy

Through the fieldwork to third class city, Weifang, the 5 first-level indexes and 19 second-level indexes of third class cities' low carbon economy evaluation index system could be determined. The detailed indexes are shown in table 1.

Table 1: The evaluation index system of third class cities' low carbon economy

	first-level evaluation indexes	second-level evaluation indexes
The evaluation index system of third class cities' low carbon economy P	Economic factors A	Resident income A1; Low carbon industry output value A 2. GDP per capita A 3; Financial input A 4;
	Environmental factors B	Nature reserve area ratio B1; coverage of green land B2; green area per capita B3. Environmental protection investment ratio B4.
	Social factors C	Low carbon popularity C 1; urbanization ratio C 2; car number per capita C 3; housing area per capita C4
	Technical factors D	Acquisition and preservation ratio of greenhouse gas D1; low carbon material ratio D2; utilization ratio of the three wastes D3; garbage disposal D4.
	energy emission factors E	CO2 per GDP E1; SO2 per GDP E2; energy consumption per GDP E3;

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3. The introduction of fuzzy mathematics comprehensive evaluation method

Fuzzy mathematics comprehensive evaluation method is one of the most common methods used in fuzzy decision problems.

(1)Determine the evaluation index factor set P={$p_1,p_2,\ldots p_n$} , and there are n indexes of the object.

(2)Determine the grade evaluation set V={$v_1,v_2,\ldots v_m$} , and m is the grade number of the evaluation.

(3)Determine the fuzzy evaluation matrix $R=(r_{ij})_{n\times m}$, the basic method is as follows:
First of all, make a grade evaluation $f(p)$(i=1,2,…,n)to all index factors p, we could get a fuzzy mapping f from P to V, namely $f: P\rightarrow F(P), p_i\rightarrow f(p_i)=(r_{i1},r_{i2},\ldots r_{im})\in F(V)$
Then, from the fuzzy mapping f, the fuzzy relation $R_f\in F(p\times V)$ could be induced, namely $R_f(p_i,v_i)=f(P_l)(v_l)=R_{ij}$ and i=1,2,…,n; j=1,2,…,m.
The fuzzy evaluation matrix could be determined as $R=(r_{ij})_{n\times m}$.
(4)AHP method is used to determine the weights of evaluation indexes at all levels (Han, 2005)
AHP is one of the most common methods that determine the weight. It is an effective method that transforms non-quantitative problems into quantitative problems, by comparing the importance of two indexes to determine the comparison matrix so as to make a decision. The specific process is as follows:
First of all, according to the evaluation index system, the hierarchical structure diagram of the system is established.
Secondly, carry on the multiple comparisons to all the evaluation indexes at the same level, construct comparison matrix by using 1-9 scale value (The specific is shown in table 2.)

Table 2: 1-9 scale value

scale a_{ij}	1	2	3	4	5	6	7	8	9
Comparison between index i and index j	The same		A bit strong		strong		Obviously strong		Absolute strong

Thirdly,the determination of the weights of each evaluation index. The geometric average method is used to calculate the weight vector of each evaluation index. The specific process is divided into three steps:
Carry on the product to the elements in each line of the comparison matrix, we could get vector α; Carry on square root to vector α n times, we could get vector β ; Carry on normalization processing to vector β, we could get index weight vector γ.
Fourth, carry on the consistency check. The process of consistency check is divided into three steps:

Calculate consistency index: CI=(λ_{max}-n)/(n-1) , and $\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{\sum_{j=1}^{n} a_{ij}r_j}{r_i}$ is the maximum eigenvalue.

According to the number n of evaluation indexes, the random consistency index RI could be determined. The specific values are shown in table 3;

Table 3: the random consistency index

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54

Calculate the consistency ratio $CR=CI/RI$, when CR<0.10, the consistency check could pass. Finally, according to the weight of each evaluation index and the evaluation matrix, using the matrix multiplication, the comprehensive evaluation vector $w=\gamma^T R$ could then be obtained.

4. The fuzzy evaluation model of third class cities' low carbon economy

(1)According to table 1, the evaluation index factor set P={$p_1,p_2,\ldots p_{19}$}could be determined, and the evaluated object has 19 evaluation indexes (Liang and Cao.2007).

(2)Determine grade evaluation set V={$v_1,v_2,\ldots v_5$} , the evaluation results of third class cities' low carbon economy are divided into five levels: excellent, good, general, poor, very poor. The specific classification is shown in table 4.

Table 4: The second-level evaluation index classification of third class cities' low carbon economy

The second-level evaluation index	evaluation grade				
Resident income A1；	Very high	high	general	low	Very low
Low carbon industry output value A2；	Very high	high	general	low	Very low
GDP per capita A3；	Very high	high	general	low	Very low
Financial input A4；	Very high	high	general	low	Very low
Nature reserve area ratio B1；	very large	large	general	small	very small
coverage of green land B2；	very large	large	general	small	very small
green area per capita B3；	very large	large	general	small	very small
Environmental protection investment ratio B4；	very large	large	general	small	very small
Low carbon popularity C1；	very large	large	general	small	very small
urbanization ratio C2；	very large	large	general	small	very small
car number per capita C3；	Very few	few	general	many	A lot
housing area per capita C4	very large	large	general	small	very small
acquisition and preservation ratio of greenhouse gas D1;	very large	large	general	small	very small
low carbon material ratio D2；	very large	large	general	small	very small
utilization ratio of the three wastes D3；	very large	large	general	small	very small
garbage disposal D4；	Very good	good	general	poor	very poor
CO2 per GDP E1；	little	A little	general	much	A lot
SO2 per GDP E2；	little	A little	general	much	A lot
energy consumption per GDP E3；	very small	small	general	large	very large

(3)Determine the fuzzy evaluation matrix$R=(r_{ij})_{n\times m}$.
Using the expert judgment method, the second-level indexes of third class cities' low carbon economy are evaluated. Here we choose 10 experts to evaluate. And we could get that:

$$R_A=\begin{bmatrix} r_{11}^{(A)} & r_{12}^{(A)} & \cdots & r_{15}^{(A)} \\ \cdots & & \cdots & \cdots \\ r_{41}^{(A)} & r_{42}^{(A)} & \cdots & r_{45}^{(A)} \end{bmatrix}$$ and r_{ij}=The expert number of level J/10.

Similarly to the following conclusions: R_B, R_C, R_D, R_E
(4)Determine the weights of evaluation indexes at all levels.
First, select 10 experts to score, and get the average value. Confirm the influence of each index so as to determine the comparison matrixes: A, B, C, D, E, P.
Second, calculate the weight vector of each index, the five weight vectors could be obtained as follows: γ_A, γ_B , γ_C , γ_D , γ_E , γ_R.
Finally, carry on the consistency check.
(5)According to the corresponding weight of each second-level evaluation index, the fuzzy evaluation matrixes of 5 first-level evaluation indexes could be calculated as follows: $R_p=(\gamma_A^T R_A\ \gamma_B^T R_B\ \gamma_C^T R_C\ \gamma_D^T R_D\ \gamma_E^T R_E)^T$.
According to the weights of the first-level evaluation indexes, the level evaluation vector of third class cities' low carbon economy could be obtained as follows:$w=\gamma_p^T R_p$.
Based on the maximum principle, the biggest component among $w$is the level of third class cities' low carbon economy.

5. The empirical analysis of third class cities' low carbon economy evaluation

Table 5: The comparison matrix and the test results of first-level evaluation indexes aiming to the target layer

Target layer	the evaluation index system of third class cities' low carbon economy P						The largest eigenvalue	The consistency ratio
First-level evaluation indexes	Economic factors A	Environmental factors B	Social factors C	Technical factors D	energy emission factors E	weight		
Economic factors A	1	1/5	1/3	1/2	1/7	0.0506	5.1457	0.0325
Environmental factors B	5	1	3	2	1/3	0.2339		
Social factors C	3	1/3	1	2	1/4	0.1285		
Technical factors D	2	1/2	1/2	1	1/5	0.0931		
energy emission factors E	7	3	4	5	1	0.4939		

Table 6: The comparison matrix and the test results of second-level evaluation indexes aiming at first-level evaluation indexes' economic factors A

first-level evaluation indexes	economic factors A					The largest eigenvalue	The consistency ratio
second-level evaluation indexes	Resident income A1	Low carbon industry output value A 2	GDP per capita A 3	Financial input A 4	weight		
Resident income A1	1	1/5	1/2	1	0.1154	4.2507	0.0939
Low carbon industry output value A 2	5	1	5	2	0.5455		
GDP per capita A 3	2	1/5	1	2	0.1940		
Financial input A 4	1	1/2	1/2	1	0.1451		

Table 7: The comparison matrix and the test results of second-level evaluation indexes aiming at first-level evaluation indexes' environmental factors B

first-level evaluation indexes	Environmental factorsB					The largest eigenvalue	The consistency ratio
second-level evaluation indexes	Nature reserve area ratio B1	coverage of green land B2	green area per capita B3	Environmental protection investment ratio B4	weight		
Nature reserve area ratio B1	1	1/3	1/4	1/2	0.0931	4.0873	0.0327
coverage of green land B2	3	1	1/3	2	0.2452		
green area per capita B3	4	3	1	3	0.5050		
Environmental protection investment ratio B4	2	1/2	1/3	1	0.1567		

Table 8: The comparison matrix and the test results of second-level evaluation indexes aiming at first-level evaluation indexes' social factors C

first-level evaluation indexes	social factors C					The largest eigenvalue	The consistency ratio
second-level evaluation indexes	Low carbon popularity C1	urbanization ratio C2	car number per capita C3	housing area per capita C4	weight		
Low carbon popularity C 1	1	7	5	9	0.6489	4.2313	0.0866
urbanization ratio C 2	1/7	1	1/4	3	0.0881		
car number per capita C 3	1/5	4	1	5	0.2178		
housing area per capita C4	1/9	1/3	1/5	1	0.0452		

Table 9: The comparison matrix and the test results of second-level evaluation indexes aiming at first-level evaluation indexes' technical factors

first-level evaluation indexes	technical factors D					The largest eigenvalue	The consistency ratio
second-level evaluation indexes	acquisition and preservation ratio of greenhouse gas D1	low carbon material ratio D2	utilization ratio of the three wastes D3	garbage disposal D4	weight		
acquisition and preservation ratio of greenhouse gas D1	1	1/4	1/3	5	0.1445	4.2323	0.0870
low carbon material ratio D2	4	1	1/2	9	0.3705		
utilization ratio of the three wastes D3	3	2	1	6	0.4406		
garbage disposal D4	1/5	1/9	1/6	1	0.0444		

Table 10: The comparison matrix and the test results of second-level evaluation indexes aiming at first-level evaluation indexes' energy emission factors E

first-level evaluation indexes	energy emission factors E				The largest eigenvalue	The consistency ratio
second-level evaluation indexes	CO2 per GDP E1	SO2 per GDP E2 E2	energy consumption per GDP E3	weight		
CO2 per GDP E1	1	4	3	0.6250	3.0183	0.0176
SO2 per GDP E2E2	1/4	1	1/2	0.1365		
energy consumption per GDP E3	1/3	2	1	0.2385		

Table 11: The level evaluation results of Weifang low-carbon economy's second-level evaluation indexes

second-level evaluation indexes	evaluation level				
Resident income A1；	0	2	6	2	0
Low carbon industry output value A 2；	1	2	4	2	1
GDP per capita A 3；	1	3	3	2	1
Financial input A 4；	0	2	4	3	1
Nature reserve area ratio B1；	0	2	5	2	1
coverage of green land B2；	0	1	7	1	1
green area per capita B3；	2	4	4	0	0
Environmental protection investment ratio B4；	5	3	2	0	0
Low carbon popularity C 1；	3	5	1	1	0
urbanization ratio C 2；	1	3	5	1	0
car number per capita C 3；	4	3	3	0	0
housing area per capita C4	1	2	4	3	0
acquisition and preservation ratio of greenhouse gas D1；	0	2	6	1	1
low carbon material ratio D2；	4	5	1	0	0
utilization ratio of the three wastes D3；	2	4	3	1	0
garbage disposal D4；	1	3	5	1	0
CO2 per GDP E1E1；	2	3	4	1	0
SO2 per GDP E2；	1	3	6	0	0
energy consumption per GDP E3；	3	2	4	1	0

(1)The weight solution interviewing the experts of Weifang low carbon economy research, according to its results, the comparison matrixes could be determined. The calculation results are shown in table 5 to table 10.
(2)The evaluation research of Weifang low-carbon economy
First of all, ten experts carry on the fuzzy evaluation to the 19 second-level evaluation indexes of Weifang low-carbon economy. The results are shown in table 11:
Secondusing procedure MATLB(attachment), the evaluation vector of Weifang low carbon economy is calculated as follows: w=(0.2098,0.3081,0.3877,0.0807,0.0137), Based on the maximum principle we could get that the evaluation level of Weifang low carbon economy is general.

6. Conclusion

It is feasible to use the fuzzy mathematics to evaluate the third class cities' low carbon economy. From the application we could get that the 5 first-level indexes of third class cities' low carbon economy don't coordinate well, especially the environmental aspect. Here I suggest that the government of third class cities strengthens its management coordination through administrative, marketing and technical means, changes the energy structure, reduces carbon emissions and improves the use of renewable resources.

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