Evaluation on the Developmental Level of Circular Economy in Jiangsu Province

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Abstract Based on the brief description of the developmental status of social economy in Jiangsu Province, the index system including 16 indexes contained in 5 subsystems is established according to the statistics from *Jiangsu Statistical Yearbook*-2009, the practical situation of Jiangsu Province and the connotation of circular economy. The developmental trends of circular economy of 13 prefecture-level cities in Jiangsu Province are comprehensively evaluated by using the improved extreme value treatment, analytic hierarchy process(AHP), comprehensive evaluation of herdsman and comprehensive evaluation model of grey multi-level. The results show that the developmental level of circular economy in Jiangsu Province varies hugely in different areas, the difference of the comprehensive score between the crest value and minimum value is 0.29. In the end, in view of the problems in the development of circular economy, the countermeasures and suggestions on establishing and improving the management of circular economy, the operation and supervision mechanism; accelerating the industrial transformation and intensifying resource saving and comprehensive use of resource.

Key words Jiangsu Province, Circular economy, AHP, Comprehensive evaluation, China

Jiangsu Province, locates in eastern China, is a famous economic province in China. The province covers the area of 102 600 km^2; in the end of 2008, the total number of standing residents was 76 765 000; the local gross domestic products was 3 098.198 billion yuan, 12.7% more than that of the previous year, the aggregate economic volume ranked second in China. Since the reform and opening up, economic society of Jiangsu Province has obtained great achievements. The total economic volume has kept 10%'s high growth for 13 years consecutively. Jiangsu Province, with 5.78% of the total population and 1.1% of the total land in China, creates 10% of the national GDP, which is tantamount to one person makes two contributions. In 2004, *Program of Constructing Jiangsu Circular Economy began* to take into effect. Although the circular economy has obtained great progress, there are still many problems, such as relatively poor basic work, weak awareness of the masses, inadequate technology development and promotion and the great gap between the south and the north. The rapid economic growth stands on the expenses of resources and environment. At the same time, the investment in fixed asserts, application of bank capital and the consumption of main raw materials grow rapidly as well, the features of " extensive economy " is exposed in Jiangsu economic development[1]. So, comprehensively pushing forward circular economy is the inevitable strategy for accelerating the economic development of Jiangsu Province. By using the latest statistics and analytic hierarchy process (AHP), the paper evaluated and analyzed the developmental status of circular economy of Jiangsu Province. The analysis will provide reference for further promoting the circular economy and the sustainable development of circular economy of Jiangsu Province.

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1 Data source, index selection and research method

1.1 Data source The original date come from *Jiangsu Statistical Yearbook* 2009[2] and some other relevant data.

1.2 The establishment of index system In China, circular economy stays at the primary stage and at present the unified index system for evaluating the development level of circular economy has not been formed. Besides, it is hard to collect and quantify some data. Based on the connotation and 3R principle, the paper divides the evaluation index into three levels, the destination level, the standard level and the index level according to the existing research results and the reality of Jiangsu Province. The paper establishes five first-level indices including resource consumption, pollution reduction, recycling use of resource and quality of ecological environment and 16 second-level indices(Table 1), to scientifically and systematically evaluate the development level of circular economy of 13 cities and districts of Jiangsu Province.

1.3 Research method

1.3.1 Improved extreme value handling method. The stability of dimensionless process is very important to handle the data. It refers to the sensibility of standardized results to individual predictive data of index. The lower the sensibility, the stable the process of dimensionless process will be, or *vice verse*. Two reasons trigger the problems of sensibility: the first one is the structure of dimensionless method; the second one is the distribution of indices. Considering the indices many lead to the uneven situation, the dimensionless method is adopted to handle the date. The major steps are as follows:

In the first place, adjusting the value in the exceptional point, that is supposing

$$x_{ij}=\begin{cases}\max(p_j), x_{ij}>\max(p_j)\\ x_{ij}, \min(l_j)\leqslant x_{ij}\leqslant\max(p_j)\\ \min(l_j), x_{ij}<\min(l_j)\end{cases} \quad (1)$$

In the equation, $\max(p_j)$ and $\min(l_j)$ refers to the index value at the ranks of p_j and $l_j(1\leqslant p_j, l_j\leqslant n)$ after ordering the predictive value of x_j as the descending order. Obviously, $\max(p_j)=\min(n-p_j+1)$ and $\min(l_j)=\max(n-l_j+1)$.

In the second place, the dimensionless of indices; that is $x_{ij}^*=f(x_{ij})$, among which f is the dimensionless function. Supposing $M_j=\max_i\{x_{ij}\}$, $m_j=\min_i\{x_{ij}\}$, as for the positive index, equation (2) is used to standardize; as for negative index, equation (3) is used to standardize.

$$x_{ij}^*=\frac{x_{ij}-m_j}{M_j-m_j} \quad (2)$$

$$x_{ij}^*=\frac{M_j-x_{ij}}{M_j-m_j} \quad (3)$$

In the equation, x_{ij}^* is dimensionless and $x_{ij}^*\in(0,1)$.

Combining the dimensionless handle to extreme value process is the improved extreme value process method.

Table 1 The evaluation index system of developmental level of circular economy in Jiangsu Province

Destination hierarchy	Standard hierarchy		Index hierarchy		Index Weight
	First-level index	Weight	Second-level index	Weight	
Comprehensive development of recycling economy	Resource consumption	0.20	Energy consumption of ten thousand yuan GDP x_1 (ton standard coal/ten thousand yuan)	0.33	0.066
			Water supply of ten thousand yuan GDP x_2 // $\times10^4$ t	0.27	0,054
			GDP of unit land area x_3 // $\times10^8$ yuan/km^2	0.40	0.080
	Pollution reduction	0.21	Volume of waste water discharged by per ten thousand yuan GDP x_4 // $\times10^4$ t	0.39	0.081
			Volume of SO_2 emission of per ten thousand yuan GDP x_5 // $\times10^4$ t	0.30	0.063
			Volume of industrial soot emission of per ten thousand yuan GDP x_6 // $\times10^4$ t	0.31	0.065
	Recycling use of resources	0.18	Attainment rate of industrial waste water discharge x_7 //%	0.30	0.054
			Output of comprehensive use of " three wastes" x_8 $\times10^4$ yuan	0.30	0.054
			Recycling use rate of industrial solid waste x_9 //%	0.40	0.072
	Economic and social development	0.27	The ratio of the tertiary industry to GDP x_{10} //%	0.15	0.040
			Total amount of per capita consumption of urban and township residents x_{11} // $\times10^4$ yuan/people	0.20	0.054
			Professional people and technologists out of every ten thousand people x_{12} //people	0.25	0.067
			Students in colleges and universities out of every ten thousand people x_{13} //people	0.24	0..65
			Registered unemployment people in cities and towns x_{14} //%	0.16	0..43
	Quality of ecological environment	0.14	The area of per capita public green land in cities x_{15} hm^2/ $\times10^4$people	0.56	0.078
			Rate of urban noise that reaching the standard x_{16} //%	0.44	0.062

1.3.2 Analytic hierarchy process. By using the Analytic Hierarchy Process[3] (AHP), the decision maker divides complex problems into various factors and rearranges the factors into order hierarchical structure according to the dominance relationships. Through comparisons, the different weight of different cases can be obtained, and then according to the importance of each factor to rank the overall factors to provide evidence for choosing the best cases.

1.3.3 Fuzzy comprehensive evaluation. The major steps of fuzzy comprehensive evaluation are as follows[4]:

In the first place, determining the steps of weight by using AHP: firstly, establishing the model of analysis of hierarchy process; secondly, constructing judgment matrix on the basis; finally, calculating the relative weight of each index.

In the second place, establishing the judgment matrix of fuzzy comprehensive evaluation. Supposing the collection of factors or indices is $U=\{u_1,u_2,\cdots,u_n\}$; the factor evaluation collection is $V=\{v_1,v_2,\cdots,v_m\}$; evaluation $v_j(j=1,2,\cdots,m)$ refers to the evaluation grades given by each factor or index and the fuzzy sub-collection of the fuzzy evaluation grade v of each index. Supposing the fuzzy evaluation vector quantity of the i factor is $R_i=\{r_{i1},r_{i2},\cdots,r_{im}\}$ $(i=1,2,\cdots,n)$, among which, r_{ij} represents the degree of membership of the i factor to the j evaluation. n fuzzy vector quantity $(R_1,R_2,\cdots,R_n)$ composes the fuzzy relations from U to V, and then the fuzzy comprehensive evaluation matrix is:

$$R_i=(R_1,R_2,\cdots,R_n)=(r_{ij})_{nm}$$

In the third place, analyzing single factor u_i. The cub-collection U of factor collection U can be expressed by fuzzy vector variable $A_i=\{a_{i1},a_{i2},\cdots,a_{im}\}$. The degree of membership $a_{ik}(k=1,2,\cdots,m)$ represents the weight of each factor in single factor evaluation. Each weight can be represented by w_{ik}.

As for the given A_i and B_i, the evaluation vector variable of single factor can be obtained $B_i = A_i \cdot R_i = (b_{i1}, b_{i2}, \cdots, b_{im})$, $i = 1, 2, \cdots, k$.

In the fourth place, the comprehensive evaluation of factor. Supposing the vector variable of the weight of each sub collection is $A = (a_1, a_2, \cdots, a_k)$, and then comprehensive evaluation matrix is

$R = (B_1, B_2, \cdots, B_k)^T = (b_{ij})_{k \times m}$

Therefore, the comprehensive evaluation vector variable is $B = AR = (b_1, b_2, \cdots, b_m)$.

In the fifth place, calculating the comprehensive evaluation value E. Each evaluation grade in the evaluation collection should be given certain score. Supposing the evaluation collection after being given scores is $H = (h_1, h_2, \cdots, h_m)$, then the comprehensive evaluation score is $E = BH^T$. According to grades of different division, the grade of the subjects that will be evaluated can be known.

1.3.4 Grey multi-level comprehensive evaluation model[5-7]. Degree of correlation refers to the association among multiple factors in a system. Using grey multi-level comprehensive evaluation model is to apply the correlation analysis to analyze the system with hierarchical structure to establish mathematic model, that is to say, judging the degree of association according to the similar degree of curve. The steps are as follows. In the first place, the target sequence and comparable sequence should be determined and the correlation coefficient among them should be worked out. By combining the relative important weight, the correlation degree of each comparative sequence and target sequence can be calculated layer by layer. The big correlation degree shows the relatively consistent change of the two sequences; or vice versa. The processes for establishing grey multi-level comprehensive evaluation model are as follows. After standardizing the indices of the given original evaluation matrix, single layer correlation coefficient of each system and best score can be worked out. Due to the different importance of each index, the single layer correlation degree equal to the multiplied summation of weight and correlation coefficient. And then according o the principle that the lower correlation degree composes the upper correlation degree, the upper correlation degree can be figured out.

2 Results and analysis

2.1 Data processing By using the Z-score standardization method to conduct the dimensionless processing on original data, the data matrix (Table 2) of the developmental level of recycling economy in 13 cities and districts in Jiangsu Province can be obtained. The matrix is $A = (x_{ij})$, $i = 1, 2, \cdots, 13$; $j = 1, 2, \cdots, 16$; x_{ij} represents the value of the i evaluation subjects in the j index.

Table 2 Data matrix of the developmental level of circular economy in 13 cities and districts of Jiangsu Province in 2008

Cities	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
Nanjing	1.253	42 154	0.498 9	40 400	42 230	3 610	95.1	20 500
Wuxi	0.848	13 293	0.805 9	45 311	3 610	1 410	97.4	9 170
Xuzhou	1.304	1 868	0.149 2	9 359	2 590	760	98.0	21 260
Changzhou	0.992	16 049	0.429 0	31 961	3760	2 230	98.8	26 980
Suzhou	0.963	15 811	0.671 6	67 504	6 460	1 270	99.5	71 240
Nantong	0.774	3 949	0.264 0	15 686	4 070	2 460	99.4	6 870
Lianyun gang	0.881	3 527	0.082 4	3 344	3 020	1 000	98.1	2 650
Huaian	1.033	2 000	0.076 0	7 568	3 470	1 280	100.0	5 020
Yancheng	0.763	1 189	0.080 8	9 319	770	280	96.4	6 750
Yangzhou	0.794	3 772	0.197 8	9 069	6 590	530	99.3	2 600
Zhenjiang	0.946	6 779	0.313 7	9 778	9 230	1 420	92.0	4 740
Taizhou	1.160	1 570	0.207 3	15 568	130	90	96.3	3 500
Suqian	0.800	867	0.063 4	4 449	890	210	93.4	1 830
Cities	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}
Nanjing	91.1	48.4	1.327 8	67.03	17.40	3.26	11.347 5	69.4
Wuxi	98.9	40.1	1.225 7	41.86	0.97	3.28	11.927 8	69.1
Xuzhou	99.1	36.0	0.980 9	26.59	3.24	2.80	8.566 1	68.3
Changzhou	98.3	37.0	1.378 9	26.50	1.92	3.21	6.181 0	69.0
Suzhou	97.9	34.6	1.395 9	55.82	3.97	2.78	13.998 6	69.1
Nantong	98.7	35.1	1.018 8	27.81	1.23	3.04	8.596 0	68.4
Lianyungang	91.3	36.2	0.835 7	17.09	0.29	3.05	9.628 3	68.0
Huaian	99.8	34.8	0.821 3	12.43	0.81	3.04	3.366 8	68.1
Yancheng	93.9	34.1	0.845 4	21.17	0.70	2.47	4.317 7	69.3
Yangzhou	81.9	35.3	0.969 6	20.30	1.58	3.01	10.740 3	68.9
Zhenjiang	95.5	36.4	1.200 8	13.36	2.77	2.78	11.865 4	68.0
Taizhou	99.4	33.2	0.902 1	17.39	0.10	3.08	7.289 6	68.4
Suqian	100.0	32.0	0.581 0	12.68	0.08	3.50	2.679 8	65.1

2.2 The determination of weight The equation (4) is used to determine the weight

$$w_j = \sigma_j^2 / \sum_{j=1}^{m} \sigma_j^2 \quad (4)$$

In the equation, $\bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}$ and $\sigma_j^2 = \frac{1}{n-1}\sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2$.

After calculating, the weight of first and second level indices are listed on Table 1. And then multiplying the weight of the first level indices by the relevant lower level indices, the weight of $x_1 : x_{16}$ can be obtained. The results can be seen on the last line of Table 1.

2.3 Calculating results and evaluation analysis By using the linear weighting method and equation (5), the comprehensive index of developmental level of circular economy in 13 cities and districts in Jiangsu Province can be figured out:

$$y_i = \sum_{j=1}^{16} w_j x_{ij} \ (i = 1, 2, \cdots, 13) \quad (5)$$

The results are listed on Table 3. According to the descending order of comprehensive index, the ranks of the 13 cities are Suzhou, Wuxi, Taizhou, Nantong, Xuzhou, Changzhou, Yancheng, Yangzhou, Zhenjiang, Lianyungang, Nanjing, Huaian, Suqian. If following the 0.05 interpacket gap, the developmental level of circular economy in 13 cities and districts in Jiangsu Province can be classified into the following five categories by descending order.

Table 3 The comprehensive index of the developmental level of circular economy in 13 prefecture-level cities in Jiangsu Province

Cities	Comprehensive index	Cities	Comprehensive index
Nanjing	0.140 6	Huaian	0.112 0
Wuxi	0.270 1	Yancheng	0.178 2
Xuzhou	0.180 7	Yangzhou	0.168 6
Changzhou	0.179 9	Zhenjiang	0.162 2
Suzhou	0.328 5	Taizhou	0.231 8
Nantong	0.196 0	Suqian	0.038 5
Lianyungang	0.141 4		

Suzhou is in the first category, with its prominent higher comprehensive index than other cities and it has strongest developmental momentum in the five categories of recycling economy development. The following reasons are accountable for the advantages of Suzhou Province. In the first place, Suzhou has favorable economic and social basis. There is advanced equipments for developing recycling economy. Although it needs large input, the energy consumption can be reduced. In the second place, Suzhou endeavors to develop service industry and high-tech industry, which allows it to make full use of resources. in the third place, the " Green Lung" project and green construction in Suzou city has achieved fruitful results, and the per capita area of public green land ranks top in Jiangsu Province.

Wuxi and Taizhou belong to the second category, with their relatively strong developmental level of circular economy, but they still have difference with Suzhou. Wuxi ranks second only to Suzhou is on account of its strong economic power. Wuxi boasts numerous private-owned enterprises, in the whole city, 1.89 million people participate in the activities of private economy, and the private economy has achieved the added value of 309.988 billion yua, 62.1% of the total volume of economy. The vitality of private economy has pushed forward the development of economic construction. Different from Wuxi, Taizhou has many foreign-funded enterprises. Owning to the favorable domestic and foreign economic environment in recent years, Taizhou economy has had rapid development. Besides, Taizhou has developed wide wet land, after this year, Taizhou will build many ecological gardens. The ecological tourism has been the key project in Taizhou for a long time, which has created a new economic growth point.

Nantong, Xuzhou, Changzhou and Yancheng belong to the third category. The comprehensive index of their circular economy is among 0.178 2 and 0.196 0, which belongs to the medium level of recycling economic development. Nantong, with relatively good population and environment, is one of the 14 coastal cities that was listed by Chinese central government as the opening city. But with the increasingly improved economy, the environmental problems and recycling economic developmental problems are exposed. That is one of the reasons that Nantong has the highest industrial soot emission of every ten thousand yuan' industrial output. Xuzhou is the biggest city in north Jiangsu Province, as well as one of the core city of three metropolitan circle and four distinctive cities. Xuzhou is a major city for producing coal in China and an important base for producing electricity in east China, but its has lower level of energy consumption. Changzhou has ever been honored as " The 50 Cities in China with Strong Comprehensive Strength" and its economic power ranks top in Jiangsu Province. The disposable income of urban residents in Xuzhou has broken through 20 000 yuan and the total volume of per capita consumption of urban and township residents had high level. But Xuzhou has few colleges and universities, so the quality of people leads to the high registered unemployment rate. in terms of energy consumption, the industrial soot emission of every ten thousand yuan industrial output stays at the lower level. Yancheng , the largest city in Jiangsu Province, boasts rich sea and mudflat resources and abundant oil and natural gas. In terms of energy consumption, the consumption of every ten thousand yuan GDP stays at the lowest level comparing with other cities, which indicates that the extensive economic growth has not been changed completely. Besides, the small number of private-owned enterprises and township enterprises lead to the highest registered unemployment rate of Yancheng City in Jiangsu Province.

Nanjing, Lianyungang, Zhenjiang and Yangzhou belong to the fourth category. The developmental index of the four cities is among 0.140 6 and 0.168 6. Their developmental levels of circular economy stay at the medium or lower level. Nanjing is an important production base of comprehensive industries in China, but its index of water supply of ten thousand yuan GDP, Volume of SO_2 emission of per ten thousand yuan GDP and Volume of industrial soot emission of per ten thousand yuan GDP is low, which greatly affected the comprehensive score. Lianyungang is the east bridgehead of new Eurasia continental bridge. Nanjing owns wide and stable economic hinterland and its pharmaceutical industry takes leading role in the peer industries with its advantages of " strong, big and new" , but at the same time, its waste water emission of ten thousand yuan GDP lays at the lowest level. Zhenjiang City locates in the intersection of the Yangtze River and the Great Canal from Beijing to Hangzhou. The city has formed the four pillar industries covering chemical industry, paper making, building materials and aluminium industry. In terms of recycling use of resources, the Rate of industrial waste water emission that reaching the standard lays at the lowest level of the whole province, which is closely related to the pollution of its pillar industries. Yangzhou is one of the cities that opened foreign trade and international exchange city in China. Petrochemical industry, automobiles and boats and mechanical and electrical equipment are the three pillar industries of Yangzhou. But in the recycling use rate of industrial solid waste, Yangzhou is the last one of the whole province.

Huaian and Suqian belong to the fifth category, which have the worst developmental level of recycling economy of the whole province. The high education of Huaian City is weak and there are only two universities in the city. So the professional

people and technologists out of every ten thousand people stay at the low level. the index of economic development, resource reduction, cultural and developmental level and ecological environment of Suqian lays at the disadvantaged stage. The eight indices all rank last and the other indices are not so high, which lead to the great difference with the overall indices of other areas.

3 Conclusions

Jiangsu is strong province of China in economy and population, but a small province in resources. The statistics show that Jiangsu has the densest population but smallest mineral resources and environmental capacity. At present, Jiangsu has entered the middle age of heavy and chemical industries, but the resource and environment become the "choke point" for its economic development, which are the largest challenge confronted by Jiangsu Province. However, insisting on scientific development view and laying tress on developing recycling economy are the crucial way for solving the difficulties of resources and environment. In view of the problems mentioned above, the following developing strategies and suggestions are put forward.

Firstly, the government should construct and perfect the management, operation and supervision of recycling economy. Secondly, industrial transformation should be accelerated and the industrial structure adjustment should be positively pushed forward to form the industrial system that can meet the demands of recycling economy. Thirdly, energy saving and comprehensive use of resources should be intensified to improve the efficiency of energy use and promote the energy saving, land saving and material saving; positively improve the deep processing of mineral resources and enhance the added value of products and then realize the optimization and upgrade of mineral industry. Fourthly, the research and development of recycling economy should be intensified. Fifthly, the government should construct ecological cities and countryside; give priority to the development of urban public transportation; guarantee the priority of public transportation; promote the construction of urban transportation equipments; positively push forward the construction of metro or light train; advocate the use of energy-saving and environment-friendly vehicles. Besides, the design and the building materials of civil architecture should fully consider the needs of energy saving and heat preservation.

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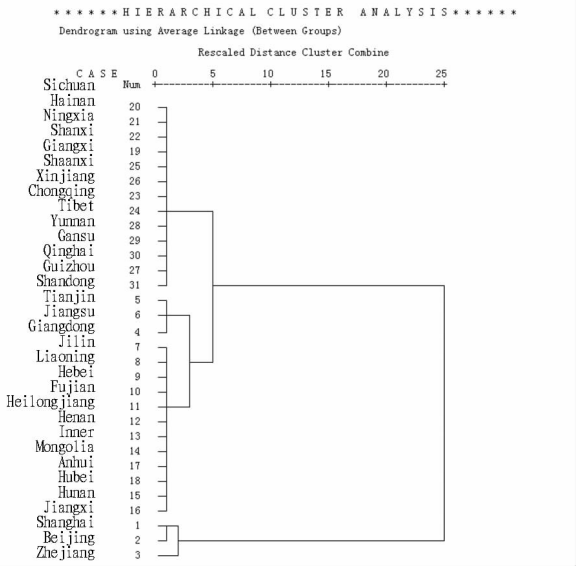

Fig. 4 The cluster dendrogram of rural development level in 31 provinces and regions in China

According to Fig. 4, rural development levels of different provinces and regions in China can be divided into four categories. The first category is Shanghai, Beijing and Zhejiang, which have the highest comprehensive scores *F* of rural development level, and are far greater than the comprehensive scores *F* of other provinces and regions. Due to the developed economy and superior geographical position, the rural development level of the first category is relatively high. The second category includes Jiangsu, Shandong and Tianjin, which take the 4th to 6th places. The third category is Guangdong, Jilin, Liaoning, Hebei, Fujian, Heilongjiang, Henan, Inner Mongolia, Anhui, Hubei, Hunan and Jiangxi, which rank the 7th – 18th. And the fourth category includes Sichuan, Hainan, Ningxia, Shanxi, Guangxi, Shanxi, Xinjiang, Chongqing, Tibet, Yunnan, Gansu, Qinghai and Guizhou, taking the 19th – 31st places. These provinces and regions are mostly located in western China where people of an ethnic minority with a smaller population live in concentrated communities. Due to the backward economy. And rural development level of this category is relatively low.

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