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Comprehensive Evaluation of Circular Economic Development in North Anhui Province

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Abstract In view of the characteristics of north Anhui Province, an index system was constructed for evaluating the development level of circular economy according to relevant principles. Principal Component Analysis and Analytic Hierarchy Process were adopted to evaluate the circular economic development in north Anhui Province, and corresponding measures were put forward to promote the circular economy in north Anhui Province.

Key words Circular economy; Evaluation system; Principal Component Analysis (PCA); Analytic Hierarchy Process (AHP); North Anhui Province

North Anhui Province includes Huaibei City, Bozhou City, Suzhou City, Bengbu City, Fuyang City and Huainan City with a total area of 39 200 km² and a population of 285.36 million in 2004, which is respectively 28% and 44.2% of the total in Anhui Province.

Since the reform and opening up, economy and society in north Anhui Province have witnessed the great-leap-forward development, and the living standard of local people has been greatly promoted. However, due to the dense population, insufficient talents, underdeveloped sciences and technologies, backward education, slow pace of reform and opening up as well as frequent climatic damages, the economic development in this region has been left far behind by the mean level of Anhui Province.

The enhancement of reform and opening up as well as the promotion of social and economic development in north Anhui Province is important for the full-scale implementation of "Rise of central China" strategies put forward by the central government, and also is significant for the realization of a moderately prosperous society in an all-around way in Anhui Province as scheduled. Being endowed with abundant agricultural, mineral and labor resources as well as a proper foundation of social and economic development, it is critical to correctly evaluate the development status of circular economy in north Anhui Province on the basis of existing conditions and realize the sustainable development.

1 Establishing the evaluation index system

1.1 Establishment principles The following 5 principles should be obeyed in the establishment of such an evaluation system^[1-2].

(1) "3R" principle. Indexes should demonstrate the principle of reducing, reuse and recycling. ZHANG Bo *et al* once established a practical index system by following such a principle and conducted application analysis^[3].

(2) Relevance principle. Indexes should demonstrate the circulation pressure and status of social economy as well as the corresponding conditions of society. In the selection of evaluation indexes, those are able to demonstrate the basic characteristics and norms of circular economy or closely tied with the evaluation of circular economy should be selected.

(3) The combination of systematic indexes and sectional indexes. There should be both indexes to demonstrate the overall development of circular economy and reflect the circular economic development in some critical sections, so as to enable the index system not only to demonstrate the overall situation but also to project the role of critical factors.

(4) The combination of universality and differences. Indexes should play a significant role in characterizing the development level of circular economy in most years within the study region, and also demonstrate their differences.

(5) Availability of data. Because the evaluation object of circular economic development is the circulation degree of economic operation, and the development indexes of circular economy are finally determined by the evaluation indexes, thus the evaluation indexes of different periods should be available, and meanwhile, the availability of data should also be taken into consideration in establishing the evaluation index system.

1.2 Evaluation indexes Combining with the establishment principles, 12 sub-categories of 4 categories are selected according to the regional characteristics of north Anhui Province (Table 1)^[4-5].

(1) Evaluation standard of each index. According to the current situation of north Anhui Province^[6], national conditions, national standards and the mean values of domestic cities with relatively developed economy^[7] as well as the long-term goals of the year 2020 in the eco-construction indexes of Anhui Province and the construction indexes of circular economy, evaluation

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standard of each index can be determined (Table 1).

(2) Weight value determination. Because the significance of each index in the evaluation system of regional circular economy is different from that of another, the weighted processing of each index is necessary in the comprehensive analysis, and

additionally, various methods of determining index weight can be adopted in the practices, such as Delphi Method, Analytic Hierarchy Process, experts investigation and so on. In this study, Analytic Hierarchy Process is selected to determine the weight of each index (Table 2).

Table 1 Evaluation index system and standards of circular economy

Primary index	Secondary index (weight)	Tertiary index (weight)	Standard value
Comprehensive evaluation of circular economic development	Resources consumption (0.227)	Energy consumption per GDP unit(0.539)	≤1.4 t/10 ⁴ yuan of standard coal
		Water consumption per GDP unit(0.297)	≤150 m ³ /10 ⁴ yuan
	Recycling use(0.227)	GDP per unit land area(0.164)	1.42 × 10 ⁴ yuan/hm ²
		Emission ratio of standard industrial wastewater (0.5)	100%
		Comprehensive utilization ratio of industrial solid waste(0.5)	80%
	Social and economic development(0.122)	Ratio of the tertiary industry to the total GDP (0.163)	≥50%
		Technician number per 10 thousand employees (0.232)	–
		Student number in secondary schools and institutions of higher learning per 100 thousand people(0.49)	–
		Urban registered unemployment rate (0.115)	≤5%
	Eco-environmental quality(0.227)	Urban per capita public green land area (0.105)	≥11 m ² /people
		Days with air quality of secondary standards or above (0.258)	300 d
		Ratio of environmental protection investment to the total GDP (0.637)	3.5%

Table 2 Evaluation results of Analytic Hierarchy Process

	Weight	Huaibei City	Bozhou City	Fuyang City	Bengbu City	Huainan City	Suzhou City
Resources consumption	0.227	0.339	0.014	0.316	0.275	0.703	0.214
Recycling utilization	0.227	1	0.312	0.751	0.079	0.503	0.598
Social and economic development	0.122	0.718	0.415	0.036	0.549	0.577	0.204
Quality of ecological environment	0.423	0.409	0.392	0.231	0.288	0.169	0.302
Level evaluation of circular economy		0.564	0.317	0.397	0.269	0.415	0.337
Order		1	5	3	6	2	4

2 Evaluating the development level of circular economy based on Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a way of analyzing and evaluating the multi-targeting and multi-criteria system through combining qualitative and quantitative methods, which adopts the numeric scale (the quantitative scale of relative importance between two factors) to express and process the subjective judgment of people in numbers. In this study, the 9-scale AHP is selected to evaluate the development level of circular economy in north Anhui Province^[8].

2.1 Standardization of data The following formula can be adopted for the standardization of data, in that case, all data will be in a range of 0–1 and convenient to be compared directly.

As for effect indexes;

$$x'_{ij} = \frac{x_{ij} - \min_{1 \leq j \leq m} \{x_{ij}\}}{\max_{1 \leq j \leq m} \{x_{ij}\} - \min_{1 \leq j \leq m} \{x_{ij}\}}$$

As for cost indexes:

$$x'_{ij} = \frac{\max_{1 \leq j \leq m} \{x_{ij}\} - x_{ij}}{\max_{1 \leq j \leq m} \{x_{ij}\} - \min_{1 \leq j \leq m} \{x_{ij}\}}$$

Where $\max_{1 \leq j \leq m} \{x_{ij}\}$ and $\min_{1 \leq j \leq m} \{x_{ij}\}$ respectively indicates the maximum and minimum value of each sample in the i^{th} evaluation index, and then the standardized data matrix can be obtained; and x'_{ij} indicates the standardized value of the i^{th} evaluation index in the j^{th} year, $x'_{ij} \in [0, 1]$.

2.2 Evaluation standards The standards of evaluating the development level of circular economy are as follows^[9]: as the comprehensive evaluation value < 0.3, the development level is in the preparatory stage, 0.3–0.6 indicates the primary stage, 0.6–0.8 indicates the intermediate stage and > 0.8 indicates the mature stage.

2.3 Evaluation results Matlab7.0 is adopted for the calculation, and the development level of circular economy in north Anhui Province can be obtained as below based on AHP (Table 2), which demonstrates that Huaibei City ranks the first in

the evaluation results and is followed by Huainan City, Fuyang City, Suzhou City, Bozhou City and Bengbu City.

3 Evaluating the development level of circular economy based on Principal Component Analysis

3.1 Evaluation procedures ① Suppose there is n samples, and P indexes of each sample will be observed to write the original data into matrixes. ② Original data should be standardized as it is done in AHP. ③ Correlation coefficient matrixes of index data should be obtained. ④ Eigenvectors and eigenvalues of relevant matrixes should be obtained, and the principal components should be determined. ⑤ The contribution rate of variance and the quantity of principal component should be obtained. Generally speaking, the quantity of princi-

pal component is equal to that of original index, and if there are plenty of original indexes, it is rather complicate to do comprehensive evaluation, thus Principal Component Analysis is to select the least component (suppose it is k , and $k < P$), meanwhile, the lost information should be as less as possible. The value of k is determined by the accumulated variance contribution rate $\geq 85\%$. ⑥ These k principal components should be evaluated comprehensively. The linearity of each principal component should be obtained first to carry out the comprehensive evaluation of k principal components.

3.2 Evaluation results Matlab7.0 is applied to analyze all data, and it can be known that only 6 eigenvalues of data among all obtained ones is larger than 0, thus only such 6 data will be analyzed in this study (Table 3, 4).

Table 3 Eigenvalues and variance contribution rates of Principal Component Analysis evaluation

Circular indexes	X_1	X_2	X_3	X_4	X_5	X_6
Eigenvalue	0.015	0.109 3	0.247	0.129	0.262	0.722
Variance contribution rate//%	1	7.4	16.6	8.7	17.7	48.7
Accumulative variance contribution rate//%	100	99.1	83	91.7	66.4	48.7

Table 4 Final results of Principal Component Analysis

Indexes	Huaibei	Bozhou	Fuyang	Bengbu	Huainan	Suzhou
Level evaluation of circular economy	0.479	0.284	0.356	0.231	0.412	0.311
Order	1	5	3	6	2	4

4 Analysis of the results obtained by two evaluation methods

It can be known from Table 5 that the results of two evaluation methods are similar and basically comply with the actual

conditions, 6 cities in north Anhui Province are still in the preparatory or primary stage of circular economy, thus resources advantages in this region should be fully utilized to greatly promote the circular economy.

Table 5 Comparisons among the results of two evaluation methods

	Huaibei	Bozhou	Fuyang	Bengbu	Huainan	Suzhou
Analytic Hierarchy Process	1	5	3	6	2	4
Development level	Primary stage	Primary stage	Primary stage	Preparatory stage	Primary stage	Primary stage
Principal Component Analysis	1	5	3	6	2	4
Development level	Primary stage	Preparatory stage	Primary stage	Preparatory stage	Primary stage	Primary stage

5 Countermeasures for developing circular economy in north Anhui Province

5.1 Developing circular agriculture The agricultural development in this region has a solid foundation, thus circular agriculture should be advocated and agricultural leading enterprises should be cultured with great efforts. And the following measures can be adopted to develop agriculture, such as enhancing the planning and instruction, technological innovation, issuing relevant technical standards, improving the policy assurance system, constructing the demonstration projects of circular economy and so on.

5.2 Constructing circular industry The industrial development in this region is relatively underdeveloped, thus the circular industry should be attached more importance, clean production and recycling use of sewage disposal of enterprises should be enhanced; raw materials and energy resources should be

saved, poisonous raw materials should be eliminated, the volume and toxicity of emissions should be reduced to the least before all emissions and wastes leaving the production process; the influence of a product from its raw material selection to final processing on human beings and environment should be eliminated through clean production.

5.3 Promoting circular tourism industry Farm tourism is a kind of new eco-tourism based on agriculture and rural areas, which is a part with the most development potential in the promising tourism industry. Farm tourism will enjoy a broad market in the near future, thus circular tourism industry should be promoted greatly in north Anhui Province due to the excellent tourism resources it owns.

5.4 Constructing a circular-pattern society Through the coupling of characteristic industries, the exchange of resources and energy in north Anhui Province, the internal cycling of industry, agriculture and the tertiary industry should be developed

into the integration of 3 industries, thus a circular economic system of the whole society can be realized and resources can be utilized to the largest extent to fully demonstrate the circular economic thoughts in the planning and construction of society. The construction of green communities and schools should be enhanced to promote the construction of a circular-pattern society.

5.5 Enhancing the support and guarantee construction for the circular economy The construction of technical support system for the circular economy should be upheld and cultured; the construction of economic support system should be promoted, and a development foundation for the circular economy should be established to ensure special funds for special use; the guarantee construction at the government level should be implemented, conservation-minded government departments should be established, policies should be made to guarantee the smooth implementation of circular economy; eco-compensation mechanism and green GDP assessment system should be studied; the uniform control over the construction of circular economy should be enhanced. Through greatly promoting the support and guarantee construction, circular economy in north Anhui Province will be developed faster and better.

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皖北地区循环经济发展水平综合评价

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摘要 针对皖北地区人口稠密、科技薄弱、人才缺乏、教育落后气候灾害频繁等特点, 依据“3R”原则、相关性原则、系统性指标和部门性指标相结合原则、普遍性与差异性相结合原则、数据可得性原则, 结合国家国情, 参照国家标准, 比照地域国内循环经济水平较高城市的平均值, 结合安徽省生态建设指标中的 2020 年远期指标、循环经济建设指标等, 构建了 1 个一级指标、4 个二级指标、12 个三级指标。运用层次分析法评价循环经济发展水平, 对数据进行标准化, 确立了循环经济发展水平评价标准 (即综合评估值 $Y < 0.3$ 为准备阶段, Y 在 $0.3 \sim 0.6$ 为初级阶段, Y 在 $0.6 \sim 0.8$ 为中期阶段, $Y > 0.8$ 为成熟阶段), 在综合排序中, 淮北第 1 名, 淮南市、阜阳市、宿州市、亳州市、蚌埠市以此类推。运用主成分分析法评价循环经济发展水平, 构造相关系数矩阵, 确定主成分个数, 对其进行综合评价, 运用 Matlab7.0 对所有数据进行分析发现只有 6 个数据的特征值大于 0。经对层次分析法和主成分分析法 2 种方法的评价结果分析发现, 结果相同, 基本和实际相符, 皖北地区 6 市正处于循环经济发展的准备和初级阶段, 需充分利用资源优势, 大力发展循环经济。最后, 提出发展循环型农业、建设循环型工业、发展循环型旅游业、建设循环型社会、加强循环经济建设的支持与保障建设的建议。

关键词 循环经济; 评价体系; 主成分分析法; 层次分析法; 皖北地区