Evaluation Method of Enterprise Circular Economy Development Level Based on AHP Fuzzy Inference

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Abstract. Circular economy is the key to achieving sustainable development. The development level of circular economy at the enterprise level in China is relatively low, which needs to be improved and improved as soon as possible. A study on the evaluation method of enterprise circular economy development level based on AHP fuzzy inference is proposed to provide a basis for enterprise development. To deeply explore the content of circular economy of enterprises, determine the development mode of circular economy of enterprises, preliminarily select the evaluation indicators for the development level of circular economy, use the regularization transformation scheme to process the evaluation indicators, calculate the correlation coefficient between the evaluation indicators, and on this basis, screen out the principal component indicators, build the evaluation indicator system for the development level of circular economy, and introduce AHP fuzzy inference algorithm to determine the weight value of the evaluation indicators, Fuzzy inference of circular economy development level evaluation results enables accurate evaluation of circular economy development level of enterprises. The experimental results show that the maximum accuracy rate of the evaluation grade of the proposed method for the development level of circular economy is 96%, and the minimum error of the evaluation value is 2%−8%, which fully confirms that the proposed method has a better evaluation effect.

Keywords: Enterprise Economy · Assessment of Economic Development Level · Circular Economy · Ahp Fuzzy Inference · Evaluation Indicators

1 Introduction

China is a developing country, in the process of industrialization, urbanization and rapid economic growth, facing the historic task of improving social productivity, enhancing comprehensive national strength and improving people's living standards [1]. China faces many serious difficulties and problems in the process of development, such as huge population base, relative shortage of per capita resources, low resource utilization rate, serious environmental pollution and ecological damage, low level of production technology and waste of resources caused by extensive economic growth. It will bring enormous

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pressure to the future economic and social development. Therefore, the development of circular economy has special practical significance.

Developed countries have experienced the development of industrialization, combined with the continuous growth of technological level and social demand for environment, they have carried out the practice of circular economy earlier and achieved positive effects, which are shown in the following aspects: First, based on the social level. The United States was the first country to develop circular economy. Since the establishment of the National Environmental Protection Agency in 1970, relevant laws and regulations have been formulated and promulgated, stipulating that 5%−65% of recycled materials must be used for glass containers, 40%−50% of newsprint must be made of recycled materials made of waste paper, and 30% of recycled materials must be used for plastic garbage bags. Japan has the most comprehensive legislation on circular economy among the developed countries, and has a relatively perfect circular social legal security system. Germany is one of the European countries with the highest level of circular economy development. The circular economy has developed into an important industry in Germany thanks to the close cooperation between government, business and citizens. Official statistics show that the German waste recycling industry creates a value of 41 billion euros every year, and the average value of the waste generated by all production industries is about 50%; the second is based on the regional and city levels. The Kalundborg symbiosis system in Denmark is the first typical eco-industrial park in the world. According to reports, the annual environmental protection and economic benefits of the Kalundborg Industrial Park include: saving 45,000 tons of oil, 30,000 tons of coal, and 600,000 m^3 of water, reducing pollution Emission of CO2, 175,000 tons, SO2, 10,200 tons. Reuse of by-products/wastes: 70,000 tons of fly ash, 2,800 tons of sulfur, 200,000 tons of gypsum, 800,000 tons of nitrogen and 600 tons of phosphorus in sludge. Since 1997, Kyushu City of Japan has implemented the ecological city construction plan with the main contents of environmental industry construction, new environmental technology development, waste reduction and realization of a recycling society. It has put forward the concept of an ecological city that "waste generated from one industry is used by other industries, and the overall waste discharge of the region is zero". The city of Heidelberg in central Germany has achieved a virtuous circle of economic growth, social progress, beautiful environment, ecological health, cultural prosperity and developed tourism through years of efforts to build an ecological city. In 1996, it won the first German Prize for Environmentally Friendly City, and in 1997, it won the European Prize for Sustainable Development. Heidelberg people are proud to be called the German City of Environmental Protection; The third is based on the enterprise level. A typical example is the leading chemical manufacturing company, DuPont Chemical Company. In 1994, the waste plastics produced by the company decreased by 25% compared with the end of the 1980s, and the emission of air pollutants also decreased by 70%. In 1997, the company restructured. Its "Carpet Recycling Program," which 80 DuPont retailers across the United States participate in, recycles approximately 10,000 tons of discarded carpet annually [2].

Although the development of circular economy in China is relatively slow, it has also made some progress. Since 2000, when China took "developing circular economy and building ecological industrial parks" as an important measure to take a new road to

industrialization and achieve regional sustainable development and "win-win" economic and environmental development, In the development of regional circular economy, it has made theoretical exploration and practical attempt. However, the development level of circular economy at the enterprise level is still relatively low, and it needs to be improved and perfected. The existing methods cannot obtain more accurate evaluation results due to their own shortcomings in the application methods. Therefore, a research on the evaluation method of the development level of enterprise circular economy based on AHP-fuzzy reasoning is proposed.

2 Research on the Evaluation Method of Enterprise Circular Economy Development Level

2.1 In-depth Exploration of the Circular Economy of Enterprises

Circular economy advocates the development of economy on the basis of continuous recycling of materials, and is committed to building a closed economic development model of "resources, production, consumption, and renewable resources". At present, the academic circle has a relatively consistent view on the meaning of circular economy. Regarding the concept of circular economy, although different literatures have different expressions, the academic circles have similar understandings of circular economy, and they all believe that it is an ecological economy and a new closed economic development model. This study believes that the circular economy is a kind of ecological economy, which is different from the traditional linear economy. It is a closed loop flow of material and imitates the ecological economic development model. It advocates a harmonious and unified development model between the economic development of human society and the ecological environment. It imitates the principle of the ecological system, and combines the social and economic systems into a network chain structure with multiple material utilization and recycling, it will form a closed-loop feedback process of "resources products renewable resources" and an efficient ecological socio-economic system with adaptive and self regulating functions that can meet the needs of the ecological cycle and combine with the structure and functions of the ecological environment system.

The connotation of circular economy can be understood from the following different perspectives:

First, circular economy is the conservation and effective use of resources [3]. Circular economy mainly refers to the recycling of resources in all aspects of social production, circulation, consumption and waste generation, and the development of resource recycling and reuse industries. Circular economy requires that economic activities be formed into a closed-loop material circulation and economic development system of "resources-products-waste-resources regeneration";

Second, the core of circular economy is characterized by the closed-loop flow of materials. The traditional economy is a linear economy with one-way flow of "resources, products and pollution emissions". It realizes quantitative economic growth by continuously turning resources into wastes. In the operation of circular economy, the material flow emphasizes a feedback process and advocates an economic development model of harmonious development with the environment. In this feedback process, part of the

waste generated in the production, circulation and consumption process is processed and decomposed into new resources through waste utilization and other technologies to return to the economic operation, and the other part is formed into pollution-free or low pollution substances after environmentally sound treatment and returned to the natural environment for purification by the natural environment;

Third, the essence of circular economy is an ecological economy. Circular economy uses ecological laws rather than mechanistic laws to guide the economic activities of human society, and requires the utilization of natural resources and environmental capacity in accordance with ecological laws to realize the ecological transformation of economic activities. The essence of circular economy development is considered to be to improve ecological efficiency. Ecological economics provides a disciplinary basis for circular economy. When the natural ecology and social economic systems have not yet been able to promote and coordinate with each other, that is, the linear economy has not yet withdrawn from the stage of history, circular economy has become the realization form of ecological economy;

Fourth, developing circular economy is an effective way to solve environmental problems. The essence of environmental problems lies in the unreasonable use of environmental resources. Environmental pollution is actually a waste of resources and energy. In the process of material production, the resources and energy invested either enter into products or into the environment as wastes. The purpose of circular economy is to protect the environment and realize the sustainable development of society, economy and environment. It is a practical model for the international community to promote sustainable development. At the same time, the core of circular economy is to reorganize economic activities into a resource recycling mode of "low exploitation, high utilization and low emission", which is characterized by a closed cycle of materials, so as to maximize the use of resources and energy in the process of economic activities, realize the ecological development of economic activities, reduce resource consumption, eliminate environmental pollution and improve economic quality. Because circular economy is a "win-win" economy with economic and environmental benefits, it will certainly bring high-quality economic growth benefits to mankind while protecting the environment.

Circular economy should follow the behavioral principle of "reduction, reuse and recycling", which is also called "3R" principle. Each principle is essential for the successful implementation of circular economy. Among them, the principle of reduction belongs to the input method, which aims to reduce the quality of materials entering the production and consumption processes; The principle of reuse belongs to a process approach, which aims to extend the time intensity of products and services; The principle of resource utilization is that the output end method reduces the final disposal volume by turning waste into resources again. The comprehensive use of the "3R" principle is the optimal way of resource utilization [4]. The order of the "3R" principles of circular economy actually reflects the three processes that people have gone through in the second half of the 20th century on the issue of environment and development: First, the idea of pursuing economic growth at the expense of environmental damage was finally adopted. Abandonment, people's thinking is raised from the discharge of waste to the requirement to purify the waste (through the end treatment method); Then, since the essence of environmental pollution is a waste of resources, it is required to further

sublimate from the purification of waste to the utilization of waste (through reuse and recycling); Finally, people realize that the use of waste is still only an auxiliary means, and the highest goal of harmonizing the environment and development should be to achieve a qualitative leap from waste utilization to waste reduction.

The development model of the circular economy of enterprises is shown in Fig. 1.

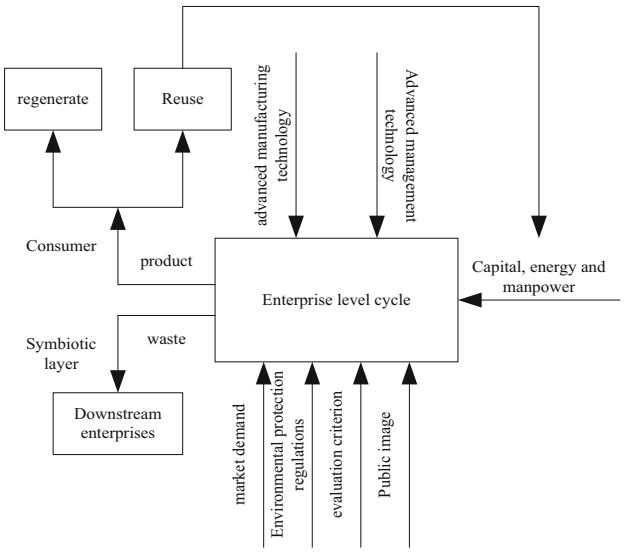

Fig. 1. Schematic diagram of the development model of the circular economy of enterprises

In the development model of enterprise circular economy shown in Fig. 1, it formulates periodic development strategies for enterprises from the four aspects of market demand, environmental protection regulations, evaluation standards and public image, guides enterprises to expand product consumption of downstream enterprises, and saves resources, energy and manpower through the reuse of products, and improves the development ability of enterprises by introducing advanced manufacturing technology and advanced management technology. The above process has completed the in-depth exploration of the development of enterprise's circular economy, and given the development model of enterprise's circular economy, laying a solid foundation for the preliminary selection of subsequent evaluation indicators of the development level of circular economy.

2.2 Primary Selection of Evaluation Indicators for the Development Level of Circular Economy

Based on the above-mentioned research results of circular economy development of enterprises, the primary selection of circular economy development level evaluation indicators is to make adequate preparations for the acquisition of final evaluation results.

Different from the general economic and social evaluation indicators, the circular economy evaluation index has a certain exploratory nature. This is due to the fact that the development of circular economy by enterprises has not started long, and its contents include not only resource extraction, product production, waste utilization and disposal, and urban construction, etc., but also development strategies, planning and design, policy means, scientific and technological support, and methods; both involve economic development. It also involves the field of social consumption; There are both comprehensive issues and single-theme research. Therefore, the selection of circular economy evaluation indicators must give consideration to both the current situation and development, and consider comprehensively from a strategic perspective [5]. In order to establish a feasible enterprise circular economy evaluation index system, the design principles should be clarified first, because these indicators are not simply stacked and randomly combined, but a set of indicators established according to certain principles that can reflect the development of enterprise circular economy. Through the research on the design status of the evaluation indicator system, the indicator design principles can be summarized as follows:

First, the principle of scientificity and practicality

The index system should fully reflect and embody the connotation of circular economy, systematically and accurately understand and grasp the essence of circular economy from a scientific perspective; it should be able to reflect the main features of things, have a reasonable hierarchical structure, data sources should be accurate, and processing should be done accurately. The method must be scientific, the specific indicators can reflect the realization of the main objectives of the circular economy, the coverage of the indicator system must be broad, and it can objectively and comprehensively reflect social progress, economic development, comprehensive utilization and protection of resources, and environmental quality. The purpose should be clear and the definition should be accurate, and the content of the indicators should be concise and easy to understand, but not ambiguous or ambiguous, because many high-level indicator values in the indicator system are obtained by processing and calculating a large number of basic indicator values. If the meanings of the selected basic-level indicators are ambiguous, it is difficult to unify their calculation formulas or operation methods. In addition, the calculation method used must also be scientific and standardized, so as to ensure the authenticity of the evaluation results;

Second, systematic and hierarchical principles

The development of enterprise circular economy is a systematic project, and its evaluation index system must be able to comprehensively reflect all aspects of the development of circular economy, with the characteristics of high level, wide coverage and strong systematicness. The enterprise circular economy evaluation index system is a complex system, which can be decomposed into several subsystems. Therefore, different indicators should be used at different levels, so as to facilitate the enterprise decision-makers to regulate the economic development at different levels, effectively allocate resources, and maximize the optimization of the environment;

The third is the principle of dynamics and stability

The content of the indicators in the indicator system should remain relatively stable within a certain period of time, so that the development process of the circular economy

of enterprises can be compared and analyzed and its development trend can be predicted, but it is impossible for the indicator system to remain unchanged. It has changed according to the situation [6]. The construction of circular economy is a process of continuous improvement, so the dynamic changes of the system should be fully considered when designing the index system, and it should be able to comprehensively reflect the current situation and development trend of construction, so as to facilitate prediction and management. Coordinated development among economy, resources and environment, therefore, requires close internal connection between indicators, so as to better evaluate the development level of circular economy of enterprises.

According to the above principles, the evaluation indicators for the development level of circular economy were selected as the primary selection, as shown in Table 1.

Table 1. The primary selection of indicators for the evaluation of the development level of circular economy

First-level indicator	Secondary indicators	Three-level indicator
Circular economy development level evaluation index	Economic Indicators	Corporate profit growth rate, corporate total output value, corporate labor productivity, total investment, sales revenue, et al
	Social indicators	Urban gasification rate, green space area, tap water penetration rate, public satisfaction with the environment, et al
	Environmental indicators	Air quality compliance rate, water quality compliance rate, waste generation, noise compliance area coverage, comprehensive utilization rate of three wastes, et al
	Resource metrics	Energy inventory, energy consumption, garbage disposal rate, water reuse rate, et al

As shown in Table 1, due to the large number of Level III indicators, it is impossible to display them all.

The above process has completed the preliminary selection of the evaluation indicators for the development level of circular economy, providing a basis for the screening and processing of the follow-up evaluation indicators.

2.3 Screening and Processing of Evaluation Indicators

Based on the above-mentioned preliminary selection results of the evaluation indicators of the development level of circular economy, a normalized conversion scheme is used to process the evaluation indicators, and the correlation coefficient between the evaluation indicators is calculated. System [7].

The original evaluation index data has different dimensions and obvious differences in the order of magnitude between indicators. Before calculating the correlation coefficient, it is necessary to uniformly specify the scalar dimension and narrow the quantity level difference between indicators. At present, the most widely used data conversion scheme is the regularization conversion scheme, so the normalized processing result of the original evaluation index is

$$y_i = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \tag{1}$$

In formula (1), x_i and y_i respectively represent the evaluation index data before and after normalization conversion; $x_{\min}$ and $x_{\max}$ respectively represent the minimum and maximum value of the original evaluation index data.

Based on the processed evaluation index data, the evaluation index screening procedure is formulated, as shown in Fig. 2.

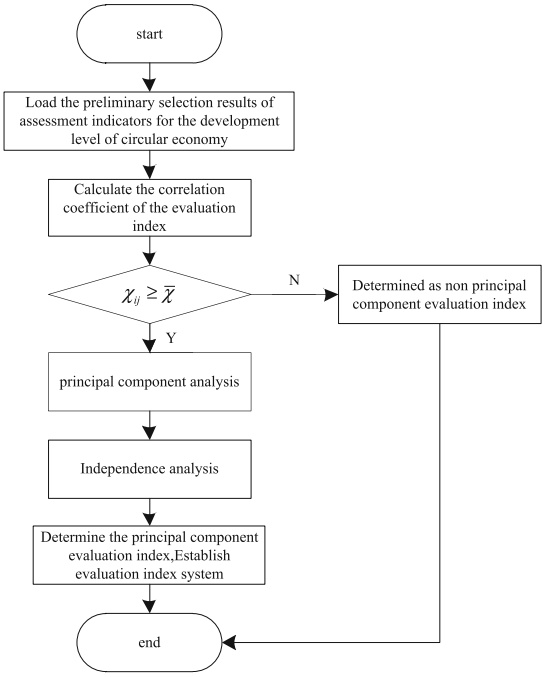

Fig. 2. Schematic diagram of the evaluation index screening procedure

As shown in Fig. 2, the calculation of the correlation coefficient of the evaluation index is very important, and the expression is

$$\chi_{ij} = \frac{\sum (y_i - \overline{y})\left(y_j - \overline{y}\right)}{\sqrt{\sum (y_i - \overline{y})^2 \sum \left(y_j - \overline{y}\right)^2}} \tag{2}$$

In formula (2), χ_{ij} represents the correlation coefficient between evaluation indicators y_i and y_j, and the value range is $[-1, 1]$. The larger the absolute value of χ_{ij}, the greater the correlation; conversely, the smaller the absolute value of χ_{ij}, the smaller the correlation; $\overline{y}$ represents the average value of the evaluation indicators.

Based on the calculation result χ_{ij} of formula (2), formulate the principle component index screening rule, which is expressed as

$$\begin{cases} \chi_{ij} \geq \overline{\chi} & \textit{Principal component index} \\ \chi_{ij} < \overline{\chi} & \textit{Non principal component index} \end{cases} \tag{3}$$

In Eq. (3), $\overline{\chi}$ represents the average value of the overall correlation coefficient.

In addition, in the principal component indicators, identify the true and false correlation, combine indicators with a true correlation coefficient of more than 0.95 according to the consolidation method, and select independent indicators to describe the development level of the circular economy [8]. The calculation formula of evaluation index independence analysis factor is

$$\alpha_i = \frac{\psi_i \times \operatorname{sgn}(y_i)}{\beta^* \cdot \delta_0} \tag{4}$$

In formula (4), α_i represents the independent analysis factor corresponding to the evaluation index y_i; ψ_i represents the independence value of the evaluation index y_i; $\operatorname{sgn}(\cdot)$ represents the value function; β^* represents the independent analysis factor calculation assistance parameter, the value range is $[0, 1]$; δ_0 represents the standard value of independence.

Based on the calculation result α_i of formula (4), the independence judgment rule is formulated, which is expressed as

$$\begin{cases} \alpha_i \geq \zeta' & \textit{Independent} \\ \alpha_i < \zeta' & \textit{Dependent} \end{cases} \tag{5}$$

In formula (5), ζ' represents the threshold value for determining the independence of the evaluation index, which needs to be set according to the actual situation.

According to the above rules, the processing and screening of evaluation indicators were completed, and the final evaluation indicator system of circular economy development level was obtained, as shown in Table 2.

The above process completes the processing and screening of evaluation indicators, and obtains the final evaluation index system for the development level of circular economy, which lays a solid foundation for the realization of the subsequent evaluation of the development level of circular economy.

Table 2. Evaluation index system of circular economy development level

First-level indicator	Secondary indicators	Three-level indicator
Circular economy development level evaluation index	Economic Indicators	Total enterprise output value
		Corporate profit growth rate
		Enterprise labor productivity
	Social indicators	Urban gasification rate
		Public satisfaction with the environment
	Environmental indicators	Air quality compliance rate
		Water quality compliance rate
		Waste generation
		Comprehensive utilization rate of three wastes
	Resource metrics	Energy inventory
		Energy consumption
		Harmless treatment rate of garbage
		Water reuse rate
		Energy recycling rate

2.4 Realization of Circular Economy Development Level Evaluation

Based on the evaluation index system of circular economy development level determined above, AHP fuzzy inference algorithm is introduced to determine the weight value of the evaluation index, and the evaluation results of circular economy development level are fuzzy inference, so as to realize the accurate evaluation of circular economy development level of enterprises.

Analytic Hierarchy Process (AHP) is a multi-objective and multi-criteria decision-making method proposed in the 1970s by American operations researcher Satty, a professor at the University of Pittsburgh. It is an effective method to transform semi-qualitative and semi-quantitative problems into quantitative calculations [9]. It can express and process people's subjective judgments in quantitative form. When people make decisions in social, economic and scientific management, they are often faced with a complex system composed of many interrelated and mutually restrictive factors. It is impossible to make decisions on many factors at once. AHP can help. By comparing two factors, we reduce the difficulty and uncertainty of comparing several factors together, and also reduce the influence of subjective factors. AHP is applicable to the decision-making analysis of complex problems with multiple criteria and objectives, quantifying the decision-making thinking process of decision-makers on complex systems, and providing a basis for selecting the optimal decision. In order to establish a relatively stable indicator weight system, this study uses the analytic hierarchy process (AHP) to determine the indicator

weight of enterprise circular economy development level evaluation based on expert survey. The specific steps are as follows:

Step 1: Build a hierarchical hierarchy model

When AHP researches a problem, it should be divided into several levels according to the causal relationship of each factor in the problem. This research is divided into four levels according to the causal relationship of the evaluation index;

Step 2: Construct judgment matrix

The judgment matrix can be formed by judging and comparing the relative importance of each evaluation indicator in a certain level, that is, for a certain evaluation indicator in the upper level, comparing the related evaluation indicators in this level in pairs, and quantifying the comparison results according to a certain scale. The judgment matrix is the basis of AHP, and the value of its evaluation index reflects people's estimation of the relative importance of each evaluation index.The evaluation index of the judgment matrix generally adopts the scaling method of 1−9 and its reciprocal. The rule is: when two evaluation indexes have the same importance, the scale is 1; when evaluation index y_i is slightly more important than evaluation index y_j, the scale is 3; when the evaluation index y_i is significantly more important than the evaluation index y_j, the scale is 5; When the evaluation index y_i is more important than the evaluation index y_j, the scale is 7; When the evaluation index y_i is extremely important than the evaluation index y_j, the scale is 9; the intermediate value scale of adjacent judgment is 2, 4, 6, and 8.

By comparing and assigning each evaluation indicator at this level one by one, a judgment matrix composed of a judgment system can be obtained, which is expressed as

$$\gamma_{n\times n} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & a_{ij} & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{6}$$

In formula (6), $\gamma_{n\times n}$ represents the evaluation index weight judgment matrix; a_{ij} represents the scale value of the j evaluation index of the i layer.

Step 3: Hierarchical weights and their consistency check

According to the judgment matrix $\gamma_{n\times n}$, solve the relative weight problem of index subsystems or index items at each level, which is mathematically the problem of calculating the maximum eigenvalue of the judgment matrix and its corresponding eigenvector. Take judgment matrix $\gamma_{n\times n}$ as an example, namely:

$$\gamma_{n\times n}\vartheta = 0 \tag{7}$$

In formula (7), ϑ represents the feature vector.

By normalizing the maximum eigenvectors corresponding to ϑ and ϑ_{amx} in formula (7), the weight set of the level evaluation index can be obtained, denoted as $\omega_i (i = 1, 2, \cdots, n)$.

In the application process of AHP, consistency test is very important. The calculation formula is

$$\mu = \frac{-1}{n-1} \sum \frac{\vartheta_{amx} - n}{n-1} \tag{8}$$

In formula (8), μ represents the consistency test result.

The higher the consistency of the judgment matrix, the smaller the μ value. When $\mu = 0$, the judgment matrix is completely consistent. However, in the process of establishing the judgment matrix, the inconsistency of thinking judgment is only one of the reasons that affect the consistency of the judgment matrix. The use of the 1–9 scale as the result of the comparison of the two factors is also the reason for the deviation of the judgment matrix from the consistency. It is clearly not appropriate to set an acceptable standard of inconsistency based solely on the μ value. In order to obtain a critical value of consistency check applicable to different order judgment matrices, the influence of matrix order must be eliminated. In the AHP method, the consistency ratio is used to solve this problem. Due to the limitation of space, it will not be described in detail.

Step 4: Calculation of combination weight of each level

According to the above, the overall level of circular economy development of enterprises is a comprehensive score, which is obtained by multiplying the score of each specific indicator item by the corresponding combination weight and then adding [10]. The weight value obtained from each judgment matrix is only the separation weight value of the indicator subsystem at each level relative to the upper level. Therefore, the separation weight value should be combined as the combined weight value of specific indicators to the target layer, which is recorded as $\omega_i'(i = 1, 2, \cdots, n)$.

Based on the above-determined evaluation index weight values, the fuzzy inference algorithm is applied to formulate the evaluation process of the development level of the circular economy of enterprises, as follows:

Step 1: Determine the factor universe of the evaluation object: $Y = \{y_1, y_2, \cdots, y_n\}$, that is, n evaluation indicators;

Step 2: Determine the comment grade: $\Gamma = \{\Gamma_1, \Gamma_2, \cdots, \Gamma_m\}$, that is, the grade set. Generally, the number of comment grades m is an integer in [3, 7]. If m is too large, it is difficult to describe in language and judge the grade attribution; If m is too small, it does not meet the quality requirements of fuzzy comprehensive evaluation. There are many cases where m is an odd number, because there can be an intermediate grade, which is convenient to judge the grade of the thing to be evaluated;

Step 3: Carry out single factor evaluation and establish fuzzy relationship matrix $\tilde{\xi}$. That is to quantify the evaluated things one by one from each factor y_i, determine the membership degree $\left(\tilde{\xi}|y_i\right)$ of the evaluated things to each grade subset from a single factor, and then obtain the fuzzy relationship matrix, the expression is:

$$\tilde{\xi} = \Psi_o \times \begin{pmatrix} \tilde{\xi}|y_1 \\ \tilde{\xi}|y_2 \\ \vdots \\ \tilde{\xi}|y_n \end{pmatrix} = \begin{pmatrix} \xi_{11} & \cdots & \xi_{1m} \\ \vdots & \ddots & \vdots \\ \xi_{n1} & \cdots & \xi_{nm} \end{pmatrix} \tag{9}$$

In formula (9), Ψ_o represents the calculation factor of membership degree; ξ_{ij} represents the degree of membership of the evaluated object to the fuzzy subset of grade Γ_j from the perspective of index y_i.

Step 4: Determine the fuzzy weight vector $W = (\omega_1, \omega_2, \cdots, \omega_n)$ of the evaluation index;

Step 5: Synthesize W and $\tilde{\xi}$ of the thing to be evaluated by using a suitable synthesis operator to obtain the fuzzy comprehensive evaluation result vector $\widehat{\sigma} = (\sigma_1, \sigma_2, \cdots, \Gamma_m)$ of the thing to be evaluated. σ_j represents the degree of membership of the evaluated object to grade Γ_j as a whole;

Step 6: Analyze the result vector of fuzzy comprehensive evaluation;

Step 7: For multi-level hierarchical structure, go through the above steps 1–5 from bottom to top, and you can get the final evaluation results of the enterprise's circular economy development level.

According to the above steps, the assessment of the development level of enterprise circular economy can be realized, providing effective support for the development of enterprise circular economy.

The assessment process of circular economy development level is shown in Fig. 3.

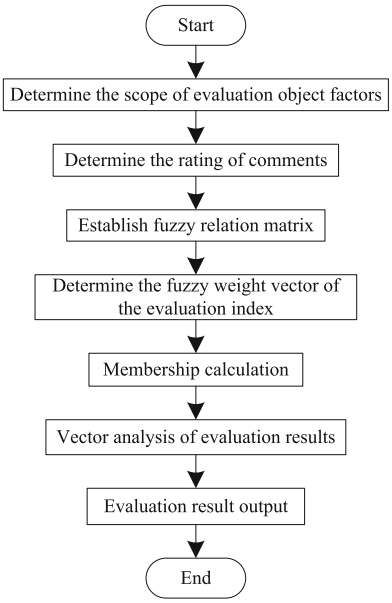

Fig. 3. Assessment process of circular economy development level

3 Experiment and Result Analysis

3.1 Experiment Preparation Stage

In order to verify the effectiveness and feasibility of the proposed method, sufficient experimental preparation is required. According to the evaluation of the experimental needs of the enterprise's circular economy development level, the content of the experimental preparation stage is determined as follows: the determination of the optimal value of the experimental parameters and the formulation of the level of circular economy development level.

Among them, parameters β^* and Ψ_o quoted in the proposed method indirectly determine the evaluation effect of circular economy development level. Therefore, it is necessary to determine the optimal values of parameters β^* and Ψ_o before the experiment.

The relationship between parameter β^* obtained through testing and independence analysis precision is shown in Fig. 4.

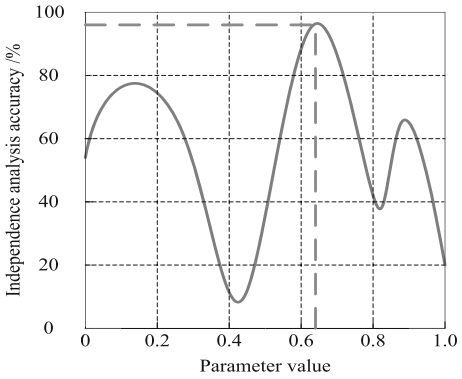

Fig. 4. Schematic diagram of the relationship between parameter β^* and the accuracy of independent analysis

As shown in Fig. 3, when the value of parameter β^* is 0.62, the independent analysis accuracy reaches the maximum value of 96%, so the optimal value of parameter β^* is determined to be 0.62.

Figure 5 shows the relationship between the parameter Ψ_o obtained through the test and the determination accuracy of the fuzzy relationship.

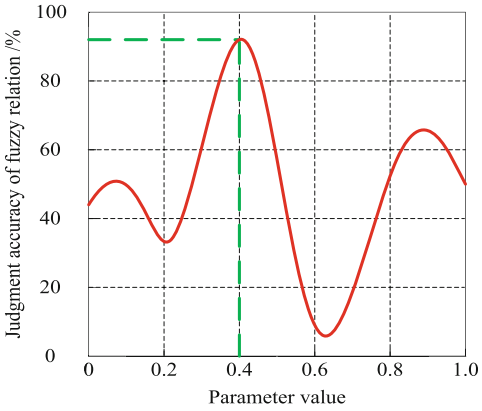

Fig. 5. Schematic diagram of the relationship between parameter Ψ_o and the determination accuracy of fuzzy relationship

As shown in Fig. 5, when the value of parameter Ψ_o is 0.40, the judgment accuracy of fuzzy relationship reaches 92% of the maximum value, so the optimal value of parameter Ψ_o is determined to be 0.40.

The results of the development level of circular economy are shown in Table 3.

Table 3. Circular economy development level grading table

Grade	The level of development	Evaluation value
1	Developed stage	8.0−10.0
2	More developed stage	5.1−7.9
3	Middle stage of development	3.6−5.0
4	Primary Stage	1.1−3.5
5	Not developed	0.0−1.0

The above process completed the task of experiment preparation and provided convenience for subsequent experiments.

3.2 Analysis of Experimental Results

The accuracy rate of the evaluation grade of the development level of circular economy and the error of the evaluation value are shown in Table 4.

Table 4. Evaluation results of circular economy development level

Number of tests	Accuracy of evaluation grade/%	Evaluate numerical error/%
1	92	6
2	84	4
3	64	7
4	80	5
5	85	8
6	80	3
7	82	2
8	70	5
9	96	2
10	77	4

As shown in Table 4, in many evaluation experiments, the method in this paper has achieved good experimental results. The accuracy rate of the evaluation grade of the development level of circular economy obtained by applying the proposed method is 64%−96%, and the error range of the evaluation value is 2%−8%. The accuracy of the evaluation grade of the method in this paper is high, and the error of the evaluation data is low. Therefore, it shows that the method in this paper can meet the needs of the evaluation of the development level of circular economy, and fully proves the effectiveness and feasibility of the proposed method.

4 Conclusion

The construction of enterprises based on the theory of circular economy needs to recycle the existing operation mode in enterprises. Therefore, the evaluation method of the development level of enterprise circular economy based on AHP-fuzzy reasoning is proposed. This study takes the development of enterprises' circular economy as the research object, analyzes the current situation of domestic enterprises' circular economy development and the problems in its development process, and analyzes and evaluates the development level of enterprises' circular economy by constructing the evaluation index system of enterprises' circular economy and establishing the evaluation model. The experimental results show that the proposed evaluation method can improve the evaluation accuracy of the development level of the enterprise's circular economy and reduce the error of the evaluation value. In the future research work, we should further improve the evaluation accuracy to ensure the evaluation quality of economic cycle development and promote the steady development of enterprise economy.

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