

Fuzzy Competitiveness Evaluation Method of Electricity Retailers Based on Analytic Hierarchy Process

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Abstract. With the development of the reform of electricity sale market, electricity retailers face fiercer and fiercer competition, and the importance of the electricity retailers' competitiveness evaluation is becoming increasingly prominent. According to the developing environment of power sales market in China, this paper proposes a new method to evaluate electricity retailers, which tap the core influence factors and construct the comprehensive index system evaluation model based on analytic hierarchy process and fuzzy theory. The evaluation method can not only grasp the macroscopical trend of the electricity retailers' development, but also reflect the microcosmic state of the various components of the electricity retailers' competitiveness. The validity and operability of the method are verified when it applies to the competitiveness evaluation of four typical electricity retailers.

1. Introduction

With the reform of the electricity market, electricity sale side has been liberalized in many countries, and China is also included. With the promotion of marketization reform, different forms of the electric sale companies are emerging and the number of electricity retailers is on the rise. The electricity retailers are bound to face more and fiercer competition and challenges. Therefore, how to evaluate the competitiveness of the electricity retailers has become a question that must be considered by the decision-makers and the participants of the market. However, a scientific and reasonable evaluation method of competitiveness can identify retailers' own position in the future and enhance their competitiveness to provide them reference.

At present, researchers have carried out some work on the competitiveness evaluation of power companies. Reference [3] evaluated the development of Dutch energy retail market based on several indicators such as pricing strategy and dynamic efficiency. Reference [4] evaluated the sector efficiency of the US vertically integrated power company using WSBM model and revealed that the power generation sector has the greatest impact on the total cost of the power company. Although the reform of electricity sale side is relatively mature in many countries, the research of the evaluation of the competitiveness of electricity sales companies is still rare. The research on the electricity sale side mainly focuses on the competition theory and competition model of the electricity sale market [5], electricity business decision-making and risk management [6], and analyzing the main factors influencing electricity bidding strategies [7].



Because various factors affect the competitiveness of electricity retailers, and there are correlation and coupling between the factors, how to choose the method to evaluate the competitiveness of electricity retailers is very important. Analytic hierarchy process (AHP) is a multi-objective decision analysis method [8]. This method can make complex problems hierarchical, and can comprehensively deal with qualitative and quantitative factors, which is suitable and flexible for decision-making with many criteria and indicators not easily quantified problems. Based on this background, this paper establishes a multi-level comprehensive evaluation index system for the competitiveness of electricity retailers, and proposes a fuzzy evaluation method for the competitiveness of the sales companies based on AHP. It not only combines the subjectivity of experts' qualitative analysis with the objectivity of data quantitative processing, but also improves the validity and reliability of the evaluation.

2. Fuzzy Competitiveness Evaluation Method of Electricity Retailers Based on AHP

2.1. Competitiveness Evaluation Index System of Electricity Retailers

This paper analyzes and summarizes the key factors affecting the competitiveness of electricity retailers, and establishes a multi-hierarchy index system according to the key factors' affiliation. The index system includes target hierarchy A , criterion hierarchy B and base hierarchy C , as is shown in TABLE 1.

Table 1. The evaluation index system for the competitiveness of electricity retailers

Target Index	Criterion Indexes	Basic Indexes
Competitiveness of Electricity Retailers: A	Technological competitiveness: B_1	Informatization level: C_1
		Integrated energy efficiency management: C_2
	Organizational competitiveness: B_2	Enterprise Scale: C_3
		Support degree from government: C_4
		Brand image: C_5
		Human resources: C_6
	Service competitiveness: B_3	Customer service level: C_7
		Value-added services: C_8
	Marketing competitiveness: B_4	Sale price strategy: C_9
		Promotion ability: C_{10}
		Capacity of potential development: C_{11}
	Benefit competitiveness: B_5	Bargain power of purchasing electricity: C_{12}
		Benefit of operating cost: C_{13}
		Capacity of assets operating: C_{14}

Note: the definition of the indexes is shown in the next part.

2.2. Constructing Judgment Matrixes

As different factors have different impact on competitiveness, we should determine the weight of every index by constructing judgment matrixes. Suppose the upper index B_k has a dominant relationship with the next index C_{ki} , C_{kj} , then we can establish the judgment matrix, marked as matrix C , shown in TABLE 2. Data c_{ij} reflects the relative importance of index C_{ki} to C_{kj} . The determination of c_{ij} requires the experts to evaluate the importance of the indexes, and the scoring is based on the 9 standard degree method [9], shown in TABLE 3. In addition, $c_{ij} \cdot c_{ji} = 1$.

After constructing the judgment matrixes, the weight of indexes can be calculated by formula (1).

$$w_{ki} = \left(\prod_{j=1}^m c_{ij} \right)^{\frac{1}{m}} / \sum_{i=1}^m \left(\prod_{j=1}^m c_{ij} \right)^{\frac{1}{m}} \quad (1)$$

Where w_{ki} is the weight of index C_{ki} affiliated to criterion index B_k , and m is the number of the indexes affiliated to B_k .

Table 2. The judgment matrix C based on the criterion B_k

B_k-C	C_i	C_j
C_i	1	c_{ij}
C_j	c_{ji}	1

Table 3. The 9 standard degree method

a_{ij}	The degree of importance	a_{ij}	The degree of importance
1	equally important	7	very important
3	weakly important	9	extremely important
5	obviously important	2, 4, 6, 8	between two adjacent important degrees

2.3. Checking consistency

In practice, because the comparison between the indexes has strong subjectivity and fuzziness, which may lead to wrong evaluation results, checking the consistency of the judgment matrixes is necessary, and we should calculate the value of the random consistency ratio CR . And the research experience shows that, it is considered that the judgment matrix has satisfactory consistency and the calculation results are scientific when $CR < 0.1$.

$$CR = (\lambda_{\max} - n) / [(n-1) \cdot RI] \quad (2)$$

Where λ_{\max} is the largest eigenvalue of judgment matrix C , n is the order of the matrix, RI is the average value of random consistency index. The value of RI of 1-6 order judgment matrix can be referred in [10].

2.4. Fuzzy comprehensive evaluation

According to membership theory, fuzzy comprehensive evaluation method is based on fuzzy mathematics and can quantitatively assess the qualitative indexes whose boundary is not clear through fuzzy relation synthesis. As many indexes are qualitative and cannot be quantified, this paper adopts fuzzy evaluation method to evaluate the competitiveness of electricity retailers, making the evaluation results more scientific and reasonable.

The assessment of qualitative index is divided into five grades: excellent, good, middle, poor, inferior, and the corresponding evaluation score is $V = [90, 70, 50, 30, 10]$. Suppose the number of the indexes is s , then we can get the fuzzy relational matrix R after the fuzzy evaluation of each basic index, where the i th line reflects the degree of membership of the subset of the i th evaluation object.

$$R = (r_{ij})_{s \times 5} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ L & L & L & L & L \\ r_{s1} & r_{s2} & r_{s3} & r_{s4} & r_{s5} \end{bmatrix} \quad (3)$$

Suppose W is the index weight vector calculated by AHP, and we can get the competitiveness fuzzy relation matrix B by compositionally operating W and R . Finally, the assessment score S can be

obtained. Then the competitiveness of each electricity retailers can be compared and ranked according to the competitive assessment score.

$$B = W \cdot R \quad (4)$$

$$S = B \cdot V^T \quad (5)$$

3. Definition of the Indexes

The meanings of the basic indexes are described below. It is necessary to explain that, in order to better quantify the basic hierarchy indexes, some basic indexes also have subordinated fourth hierarchy indexes, the weights of which can also be obtained by AHP.

■ *Technological Competitiveness*

- **Informatization level:** electricity retailers should provide Internet service platforms for users to buy and sell electricity and improve user experience. At the same time, electricity retailers are supposed to popularize the use of smart meters, so that they can obtain more accurate user data, analyze the electricity market quotation and do a good job in load forecasting, which can help the electricity retailers avoid assessment punishment, realize scientific risk management and do precision marketing for users.

- **Integrated energy efficiency management:** electricity retailers had better be able to integrate all kind of energy technologies together, and accurately grasp the power technology and improve the efficiency management of users. According to users' electrical habits, the electricity retailers can provide energy saving technology consultation, and their business of selling electricity can be bundled with other energy sources such as gas, water and heating supply business. Offering users the optimal and comprehensive energy project through economic analysis, the users are convenient and can actively participate in demand response, which effectively enhance the users' viscosity and reduce the difficulty of marketing and operational risk.

■ *Organizational Competitiveness*

- **Enterprise scale:** it is one of the external manifestations of competitiveness, we measure the capital scale by the total assets and measure the market scale by the market share. Generally speaking, the larger the scale, the lower the cost of operating and selling, the better the ability to resist risk. Enterprise scale' score can be obtained by formula (6).

$$S_{sl} = w_a \cdot S_a + w_{ms} \cdot S_{ms} \quad (6)$$

Where S_{sl} , S_a and S_{ms} represent the scores of enterprise scale level, the total assets and market share. w_a , w_{ms} are the weights of the total assets and market share, in addition, $w_a, w_{ms} \in [0, 1]$, $w_a + w_{ms} = 1$.

- **Support degree from government:** electric power industry is a basic industry of the national economy, which has important economic, political and strategic significance. The policies and measures from government will have great impact on electricity retailers. Electricity retailers encouraged by the government's policy will have a certain advantage.

- **Brand image:** Good brand image can help electricity retailers expand products lines, occupy more market share and enhance the competitiveness. Rating the brand image is mainly based on public familiarity and customer satisfaction, which can be obtained through questionnaire survey. The brand image score can be calculated from formula (7).

$$S_b = w_{fa} \cdot S_{fa} + w_{sat} \cdot S_{sat} \quad (7)$$

Where S_b , S_{fa} , S_{sat} are the score of brand image, public familiarity and customer satisfaction. w_{fa} , w_{sat} are the weights of public familiarity and customer satisfaction, in addition, $w_{fa}, w_{sat} \in (0,1)$, $w_{fa} + w_{sat} = 1$.

- **Human resources:** Talent is an important soft power, and the electricity retailers should own talents who know the policies and rules of the electricity market well, grasp the power supply and demand trends, be good at market analysis and risk control, be skilled in package design and do well in quoted price and decision-making and so on. Human resources is mainly evaluated from the proportion of market professionals and the proportion of technical professionals.

$$S_{hr} = w_{mt} \cdot S_{mt} + w_{tt} \cdot S_{tt} \quad (8)$$

Where S_{hr} , S_{mt} , S_{tt} are the scores of human resources, the proportion of market professionals and the proportion of technical professionals. w_{mt} , w_{tt} are the weights of the proportion of market professionals and the proportion of technical professional, in addition, $w_{mt}, w_{tt} \in [0,1]$, $w_{mt} + w_{tt} = 1$.

■ *Service Competitiveness*

- **Customer service level:** it is mainly measured from the service speed, service convenience, staff service quality and hardware service facilities. When the price is gradually determined by the market, good and thoughtful service becomes the key to increase the quantity of sold electricity of retailers.

- **Value-added services:** valued-added service ability is mainly measured by energy property, energy financial service and energy internet service and so on. The key competitiveness of electricity retailers will be value-added service in the future. Only the electricity retailers have deep excavation of user demand, professional service and creative added value can they have a place in the future market and develop sustainably.

■ *Marketing Competitiveness*

- **Sale price strategy:** it is mainly measured from aspects such as the average electricity price, the diversity and rationality of the electricity package. According to different users' preference, the electricity retailers can make various kinds of electricity package, such as time-of-use electricity price package, green energy packages and so on, so that they can meet different market demand and make products be better to adapt to market development.

- **Promotion ability:** it is an ability of the electricity retailers to attract new users and retaining old users in some ways, such as price discount through electricity deposited and holiday activities. Promotion ability is mainly evaluated through the promotion of business.

- **Capacity of potential development:** Electricity should grasp the social electricity consumption and the development trend of the sale market. The capacity of potential development is mainly measured by the forecast of the growth rate of the quantity of sold electricity, the profit and market share. The score of potential development ability is calculated as follows.

$$S_d = w_{ef} \cdot S_{ef} + w_{msf} \cdot S_{msf} + w_{pf} \cdot S_{pf} \quad (9)$$

where S_d , S_{ef} , S_{msf} , S_{pf} are the scores of the capacity of potential development, quantity of sold electricity growth rate, market share growth rate and profit growth rate, and w_{ef} , w_{msf} , w_{pf} are the corresponding weights of the 3 factors, in addition, $w_{ef}, w_{msf}, w_{pf} \in [0,1]$, $w_{ef} + w_{msf} + w_{pf} = 1$.

■ *Benefit Competitiveness*

- **Bargain power of purchasing electricity:** it means the electricity retailers' ability to get advantageous purchasing price from power Generation Company. It is mainly measured by the average price of purchasing electricity. The stronger the bargain power of the retailers, the lower the purchasing price will be and the more competitive bidding space will be, and then the retailers will be more likely to acquire users and have the advantage of survival and development.

• **Benefit of operating cost:** the operating costs includes basic infrastructure (platform construction, etc.), electricity purchase cost, management cost and marketing costs, financial cost, etc. It mainly measured by the cost efficiency. The higher the cost profit rate, the stronger the retailers' sustainable development ability.

• **Capacity of assets operating:** it mainly reflects the ability of electricity retailers to utilize all kind of resources, including the integration of resources, cooperation with outside firms' merger and reorganization. It is mainly measured by the total assets turnover ratio, and the higher the total assets turnover rate, the better the capacity of assets operating.

4. Case Analysis

In this part, we will assess 4 types electricity retailers in a certain electricity sale market in detail based on the evaluation method proposed in this paper. The competitiveness evaluation process is as follows.

4.1. Calculate the weights of indexes

We take the judgment matrix constructed by the competitiveness of the electricity retailers as an example, shown in TABLE 4. And after calculating, we can know that $\lambda_{max}=5$, $CR=0<0.1$, which satisfies the consistency requirement. In the same way, other judgment matrixes can also be constructed, and the weights of indexes are shown in TABLE 5.

Table 4. The judgment matrix based on the criterion of competitiveness of the electricity retailers

$A-B$	B_1	B_2	B_3	B_4	B_5	W
B_1	1	1	1/2	1/2	1/2	0.125
B_2	1	1	1/2	1/2	1/2	0.125
B_3	2	2	1	1	1	0.250
B_4	2	2	1	1	1	0.250
B_5	2	2	1	1	1	0.250

Table 5. The weights of the competitiveness indexes

Target Index	A_1													
Criterion Indexes	B_1		B_2				B_3		B_4			B_5		
Weight	0.125		0.125				0.250		0.250			0.250		
Basic Indexes	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
Weight	0.750	0.250	0.467	0.095	0.160	0.278	0.500	0.500	0.606	0.184	0.210	0.600	0.200	0.200

4.2. Competitiveness evaluation of typical electricity retailers

The weights of the indexes are applied to the following 4 typical electricity retailers: 1) electricity retailer 1 is set up by local grid company; 2) electricity retailer 2 is set up by large-scale power generation group, which combine power generation and sale; 3) electricity retailer 3 is a micro grid sales company, which owns distributed generation; 4) electricity retailer 4 is an independent sale company without electricity generation and grid.

8 experts were invited to evaluate the 4 typical electricity retailers. Firstly, take retailer 1 as an example. In terms of technical competitiveness, experts determine the membership degree of the technical indexes to the evaluation grades according to the actual situation of the retailer and experts' experience, and the results are shown in TABLE 6.

According to formula (4), the evaluation result of the technological competitiveness indexes of retailer 1 is $B = (0.281, 0.428, 0.219, 0.031, 0.031)$. And we can get the evaluation results of other criterion indexes of retailer 1 in the same way, shown in Table 8. Furthermore, the fuzzy comprehensive evaluation result and the competitiveness score of retailer 1 can be calculated by

formula (4) and (5), shown in TABLE 7 and TABLE 8. In the same way, the evaluation results of other 3 retailers are shown in TABLE 8.

The comprehensive competitiveness score of retailer 1 is the highest, owing to its strong market resources, high-quality brand and excellent talent resources when it was still a local monopolistic electricity sale company. Such company generally develop in a balanced way.

Table 6. The technical index membership degree of retailer 1 to the evaluation grade

B_1-C	Excellent	Good	Middle	Poor	Inferior
C_1	0.375	0.5	0.125	0	0
C_2	0	0.25	0.5	0.125	0.125

Table 7. Evaluation results of the first kind of retailer 1

	Excellent	Good	Middle	Poor	Inferior
B_1	0.281	0.428	0.219	0.031	0.031
B_2	0.604	0.246	0.079	0.048	0.024
B_3	0.500	0.313	0.188	0.000	0.000
B_4	0.125	0.421	0.250	0.204	0.000
B_5	0.250	0.225	0.250	0.175	0.100

Table 8. The comprehensive evaluation results of 4 typical electricity retailers

	Excellent	Good	Middle	Poor	Inferior	Score
Retailer 1	0.329	0.325	0.209	0.105	0.032	66.3
Retailer 2	0.330	0.243	0.217	0.150	0.060	62.7
Retailer 3	0.312	0.270	0.276	0.104	0.038	64.3
Retailer 4	0.310	0.269	0.198	0.134	0.089	61.5

The scores of retailer 2 and retailer 3 are in the middle. They both have the advantage of owing generate resources, which can help them quickly occupy the market making use of their strongly bidding ability. Retailer 2 has the advantage that it can integrate power generation, distribution power grid and electricity sale, so that when the power grid breaks down, the micro grid can be operated in isolation. Thus, the competitiveness score of retailer 2 is slightly higher than retailer 3 as retailer 2 can provide higher security and stronger ability to supply continuous electricity.

The competitiveness score of retailer 4 is the lowest, but it has a great potential for development. Despite retailer 4 is just like a middleman and it occupy the least resources and the company scale is also the lowest, its decision strategy is the most flexible. The innovation of the business model of the market in the future will be mainly from the companies like retailer 4. Besides, the value-added service will become the decisive point of this kind of company.

5. Conclusion

This paper studies the problem of the competitiveness evaluation of electricity retailers. We establish the evaluation index system by comprehensively analyzing the influence of quantitative and qualitative factors, and propose a method to assess the competitiveness of electricity retailers based on AHP and fuzzy evaluation method. This method not only can combine the subjective judgment and objective calculation during the evaluating process, but also is comprehensive and easy to operate, which lays a good foundation for decision-making for the improvement of the competitiveness and provides scientific guidance for the development of China's electric power retail market.

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