Selection of Excellent Digital Demonstration Units Based on Entropy Weight TOPSIS Method

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Abstract. In 2023, in order to accelerate the digital transformation of enterprises, A Provincial Power Company selected 12 units (3 city level units, 4 county-level units, and 5 power supply station level units) to carry out digital demonstration work. At the end of the year, 3 excellent units (1 each at the city and county level) were selected through the entropy weight TOPSIS method, forming a batch of digital transformation models.

Keywords: Digital demonstration; Entropy Weight TOPSIS Method; Excellent unit

1 INTRODUCTION

At present, foreign power companies have not carried out digital demonstration work, but there is relevant research on digital transformation. Ijeoma Onyeji Nwogu et al. explored the application cases of IoT, cloud technology, big data and other technologies as key elements in power infrastructure planning, power sector business, and power field[1]. Gibadullin et al. affirmed the important role of digital technology in engineering solutions for the power industry [2]. Candelo and Elena summarize continuous observation, network scale, and cloud computing technology as three forces of digital transformation[3].

Domestic power companies launched digital demonstration work in 2022, and after two years of construction, they have achieved fruitful results, accelerating the speed of digital transformation for enterprises. Zheng Xi et al. proposed the construction of a "one type, two modernizations" (service-oriented, intensive, digital) enterprise operation and control model[4]. Cai Yunan and others suggest strengthening data analysis applications, strengthening management mechanism construction, and enhancing data perception capabilities[5]. GongLi huiqian proposed that China's power grid enterprises are generally in an immersion period, while a few regional enterprises are in a mature

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or progressive stage[6]. Tang Yuezhong conducted research on power grid security and new energy access[7]. Liu Qi explores the path of digital transformation in power grid production and operation[8]. Sun Yiqing analyzed five aspects of digital energy ecology[9]. Huang Jiancheng and others studied the digital transformation path of power design enterprises[10].

This article takes 12 demonstration units (3 city level units, 4 county-level units, and 5 power supply station level units) of A Province Power Company as the research objects. Firstly, the evaluation indicators are determined through the Delphi method. Secondly, the entropy weight method is applied to determine the weights of various indicators. Thirdly, the TOPSIS method is used to conduct comprehensive evaluation, and 3 excellent digital demonstration units (1 each at the city and county level) are selected. A batch of digital transformation models are selected to provide reference and reference for other units to accelerate digital transformation.

2 RELATED WORK

To select a group of excellent digital demonstration units, this article first uses the Delphi method to determine evaluation indicators, secondly uses the entropy weight method to determine the weights of various indicators, and thirdly uses the TOPSIS method to conduct comprehensive evaluation, making the evaluation results more accurate. The advantages of various methods are as follows.

By using the Delphi method to determine evaluation indicators, various demonstration units can actively participate, making the evaluation indicators more closely aligned with actual work. The entropy weight method is used to determine the weights of various indicators, making the weights more objective and avoiding biases caused by subjective weighting. By using the TOPSIS method for comprehensive evaluation, the original data information can be fully utilized to truly reflect the level of differences among demonstration units.

3 METHOD

3.1 Delphi method

The Delphi method, also known as the expert survey method, was founded and implemented by the Rand Corporation in 1946. Essentially, it is a feedback anonymous inquiry method. The general process is to obtain the opinions of experts on the problems to be predicted, organize, summarize, and statistically analyze them, then anonymously provide feedback to various experts, solicit opinions again, concentrate, and provide feedback until a consensus is reached. This method is a specialized prediction organization composed of enterprises, including several experts and enterprise prediction organizers. According to the prescribed procedures, experts are consulted back-to-back for their opinions or judgments on the future market, and then the prediction is made.

3.2 Entropy weighting method

According to the basic principles of information theory, information is a measure of the degree of order in a system, while entropy is a measure of the degree of disorder in a system; According to the definition of information entropy, for a certain indicator, the entropy value can be used to determine the degree of dispersion of the indicator. The smaller the information entropy value, the greater the degree of dispersion of the indicator, and the greater the impact (i.e. weight) of the indicator on the comprehensive evaluation. If the values of a certain indicator are all equal, the indicator will not play a role in the comprehensive evaluation. Therefore, information entropy can be used as a tool to calculate the weights of each indicator, providing a basis for comprehensive evaluation of multiple indicators. The calculation steps are shown in the left section of Figure 1. The relevant formula is as follows.

(1) Building the original data matrix. Assuming there are M evaluation objects, each corresponding to N evaluation indicators, establish the original data matrix $A=(a_{ij})_{m\times n}$, where a_{ij} represents the value of the jth indicator under the i-th evaluation object.

(2) Standardize the original matrix data. In performance evaluation, evaluation indicators are generally divided into two categories, namely benefit indicators and cost indicators. Corresponding data standardization processing should be carried out for different indicators to obtain a standardized matrix $B=(b_{ij})_{m\times n}$, Among them:

For positive indicators (benefit indicators): $b_{ij}=\frac{a_{ij}-a_j^{\min}}{a_j^{\max}-a_j^{\min}}$

For negative indicators (cost based indicators): $b_{ij}=\frac{a_j^{\max}-a_{ij}}{a_j^{\max}-a_j^{\min}}$

(3) Calculate the contribution of the i-th unit under the j-th indicator using the entropy weight method.

$$p_{ij}=\frac{b_{ij}}{\sum_{i=1}^{n}b_{ij}}$$

(4) Calculate the entropy value of the index under the entropy weight method.

$$e_j=-\frac{1}{\ln n}\sum_{i=1}^{n}p_{ij}\ln p_{ij}$$

(5) Calculate the coefficient of difference using the entropy weight method.

$$g_j=1-e_j$$

(6) Determine the weight w_j of evaluation indicators under the entropy weight method.

$$\omega_j = \frac{g_j}{\sum_{j=1}^{m} g_j}$$

3.3 TOPSIS method

TOPSIS method is a commonly used comprehensive evaluation method that can fully utilize the information of raw data and accurately reflect the differences between evaluation schemes. The basic process is to use the cosine method to find the optimal and worst solutions among the limited solutions based on the normalized raw data matrix. Then, the distance between each evaluation object and the optimal and worst solutions is calculated separately, and the relative closeness between each evaluation object and the optimal solution is obtained, which serves as the basis for evaluating the quality. The calculation steps are shown in the right-hand section of Figure 1.

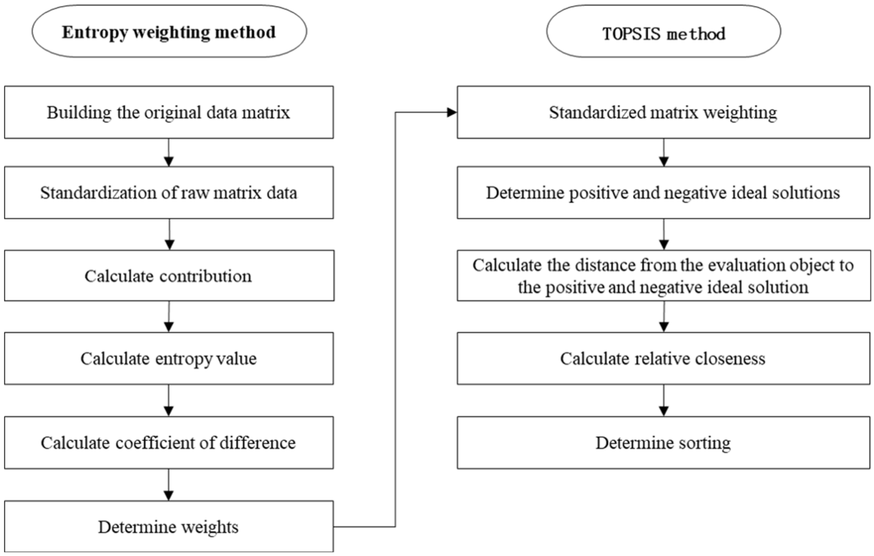

Fig. 1. Calculation steps of entropy weight TOPSIS method

The relevant formula is as follows.

(1) Weighting the indicators in the standardized matrix to form a weighted matrix.

$$c_{ij} = b_{ij} \times \omega_j$$

(2) Determine the positive ideal solution C^+ and the negative ideal solution C^-.

$$C^{+} = [C_1^{+}, C_2^{+}, ..., C_n^{+}]; \quad C^{-} = [C_1^{-}, C_2^{-}, ..., C_n^{-}];$$

(3) Calculate the distance between each object to be evaluated and its positive and negative ideal solutions. The distance from the evaluation object a_i to the positive ideal solution:

$$d_i^{*} = \sqrt{\sum_{j=1}^{n} (c_{ij} - c_j^{+})^2}, i = 1, 2, ..., m$$

The distance from the evaluation object a_i to the negative ideal solution:

$$d_i^{0} = \sqrt{\sum_{j=1}^{n} (c_{ij} - c_j^{-})^2}, i = 1, 2, ..., m$$

(4) Calculate the relative closeness (evaluation reference value) of each object to be evaluated.

$$f_i = \frac{d_i^0}{d_i^0 + d_i^*}, i = 1, 2, ..., m$$

Arrange fi from small to large to obtain the priority order of each evaluation object.

4 EXPERIMENTS

4.1 Building the original matrix

By combining the evaluation indicators determined by the Delphi method with the indicator values of each demonstration unit, the original matrix is obtained as shown below table 1 to 5.

Table 1. Original Matrix of Municipal Demonstration Units

Number	Index	Demonstration Unit 1	Demonstration Unit 2	Demonstration Unit 3
1	Distribution network automation coverage rate (%)	72	70	67
2	Distribution network data accuracy (%)	95	94	86
3	Mobile homework application rate (%)	46	43	36
4	Overload rate of distribution network lines (%)	12	21	21

5	Defect rate of distribution network equipment (%)	6	13	19
6	Comprehensive line loss rate (%)	2	3	2

Table 2. Original Matrix of County Demonstration Units

Number	Index	Demonstration Unit 4	Demonstration Unit 5	Demonstration Unit 6	Demonstration Unit 7
1	Distribution network automation coverage rate (%)	59	54	67	54
2	Distribution network data accuracy (%)	93	92	95	90
3	Mobile homework application rate (%)	22	22	25	22
4	Overload rate of distribution network lines (%)	39	21	28	22
5	Defect rate of distribution network equipment (%)	12	26	30	19
6	Comprehensive line loss rate (%)	3	5	5	3

Table 3. Original Matrix of Demonstration Units at the Institute Level

Number	Index	Demonstration Unit 8	Demonstration Unit 9	Demonstration Unit 10	Demonstration Unit 11	Demonstration Unit 12
1	Distribution network automation coverage rate (%)	42	31	48	48	45
2	Distribution network data accuracy (%)	86	78	80	78	79
3	Mobile homework application rate (%)	30	10	27	17	24
4	Overload rate of distribution network lines (%)	43	43	33	32	41
5	Defect rate of distribution network equipment (%)	15	25	23	14	24
6	Comprehensive line loss rate (%)	6	7	5	4	7

4.2 Determine indicator weights

According to the steps of standardizing the original matrix data, calculating contribution, entropy, coefficient of difference, and determining weights, the weights of various indicators at the city and county levels are obtained as follows.

Table 4. Weights of City and County Level Indicators

Number	Index	City level weight	County level weight	Level weight
1	Distribution network automation coverage rate (%)	0.1625	0.247	0.0775
2	Distribution network data accuracy (%)	0.1515	0.1108	0.2767
3	Mobile homework application rate (%)	0.2077	0.0894	0.139
4	Overload rate of distribution network lines (%)	0.1508	0.2029	0.1337
5	Defect rate of distribution network equipment (%)	0.1766	0.1347	0.1784
6	Comprehensive line loss rate (%)	0.1508	0.2153	0.1947

4.3 Selection of Excellent Units

Using the TOPSIS method, following the steps of "standardizing matrix weighting, determining positive and negative ideal solutions, calculating the distance from the evaluation object to positive and negative ideal solutions, calculating relative closeness, and determining ranking," the results of the excellent unit selection are shown below.

Table 5. Results of Excellent Unit Selection

Number	Unit level	Unit Name	Relative closeness	Rank	Remarks
1	City level	Demonstration Unit 1	0.5214	1	Excellent unit
2		Demonstration Unit 2	0.4757	3	
3		Demonstration Unit 3	0.5203	2	
4	county level	Demonstration Unit 4	0.6504	1	Excellent unit
5		Demonstration Unit 5	0.135	4	
6		Demonstration Unit 6	0.5505	2	
7		Demonstration Unit 7	0.3432	3	
8	Institute level	Demonstration Unit 8	0.7042	1	Excellent unit
9		Demonstration Unit 9	0.2521	4	
10		Demonstration Unit 10	0.3233	3	
11		Demonstration Unit 11	0.3958	2	
12		Demonstration Unit 12	0.1951	5	

5 CONCLUSION

This article focuses on 12 demonstration units of A Province Power Company. Firstly, the evaluation indicators were determined using the Delphi method, secondly, the indicator weights were determined using the entropy weight method, and thirdly, three excellent demonstration units were selected using the TOPSIS method, namely Demonstration Unit 1 (city level), Demonstration Unit 4 (county level), and Demonstration Unit 8 (institute level), providing reference for other units to accelerate digital transformation.

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