Effectiveness Evaluation of "Five Chain" Integration of State Grid Corporation of China Based on TOPSIS Method

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Abstract. Under the guidance of the new strategic objectives of the power grid company, it is necessary to inject innovative vitality into personnel training, capital investment, and technological progress in order to achieve the goal of increasing the value of power grid companies. This paper analyzes the coupling relationship of "innovation chain, talent chain, technology chain, capital chain and value chain", and establishes the evaluation index system of "five chain" integration effectiveness. Then, the traditional Analytic Hierarchy Process (AHP) is improved, and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) model is constructed. Finally, three provincial power grid companies are selected for example analysis, and the innovation effectiveness ranking of each company is obtained, which verifies the effectiveness of the model proposed in this paper.

1 Introduction

On March 16, 2020, the Party group of the company established the construction of "international leading energy Internet enterprise with Chinese characteristics" as the strategic goal to lead the company's long-term development. In order to adapt to the requirements of strategic objectives as soon as possible, the company's scientific and technological innovation needs to take "Chinese characteristics, international leading" as the goal pursuit, and optimize the scientific and technological innovation system as the focus, and continuously improve the company's scientific and technological innovation level. Talent, capital and technology have always been the core elements of enterprise innovation [1]. To carry out the research on the evaluation index system of integration effect of "innovation chain, talent chain, technology chain, capital chain and value chain" (hereinafter referred to as "five chains") in the new era [2-3], is a solid foundation and support for promoting the efficient allocation of scientific and technological innovation resources and the optimization and improvement of scientific and technological innovation system [4].

At present, many literatures have carried out a series of studies on enterprise innovation capability by constructing innovation index system and using different evaluation methods [5-6]. Literature [7] constructs the evaluation index system of technological innovation ability of Guangzhou, and makes a longitudinal analysis on the scientific and technological innovation ability of various regions in Guangzhou. Through the research on the theoretical system of the company's "five chain" integration, and the construction and evaluation of the integration evaluation index system, we can effectively grasp the technical methods of the allocation of scientific and technological innovation resources. Based on the "five chain" integration evaluation, we can diagnose the maladjustment of the company's scientific and technological innovation with the new strategic requirements, and put forward the optimization strategy of the scientific and technological innovation system to adapt to the company's strategy.

2 Relationship analysis of "five chain" integration and evaluation index system

In this section, "innovation chain, talent chain, technology chain, capital chain, value chain" of power grid company are deeply considered, and the specific connotation of each chain is clarified. The innovation chain reflects the innovation of the company's basic prospective research and achievements incubation and transformation. Talent chain is a collaborative cooperation of high-quality talents distributed in scientific research and industrial manufacturing. The main performance of the energy chain is the revolution of information technology and environment. The capital chain reflects the whole process of technological innovation and talent management. Value chain is the sum of value created by each link, including not only economic benefits but also social benefits.

On the basis of clarifying the connotation of "five chains", this paper analyzes the integration effect of "five chains", and clarifies the target chain, core chain and auxiliary chain. The "five chains" constitute a closely related whole, forming a multi chain integration structure with the value chain as the goal, the innovation chain as the core, and the talent chain, capital chain and technology chain as the basic elements, which runs

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through all aspects of the company's scientific and technological innovation work. The following table shows the integration index system. Innovation includes two stages: foundation and achievement. The dimensions of talent, capital, technology and value are reflected in different stages, but the emphasis is different. Vertically, it is only for the sake of clarity and intuition in the analysis of indicators, not to "separate" the relationship between these elements, which is also the essence of integration.

Table 1. "five chain" integration index system

Integration of "five chains"	Talent chain	Capital Chain	Technology Chain	Value chain
Foundation	Total training rate	Research Funding Intensity	Cumulative Number of Patents	Number of Provincial Scientific Research Institutions
Achievements	Talent Equivalent Density	Return on Net Assets	Intelligent Level of Power Grid	Cumulative Number of Awards for Major Science and Technology Projects

3 Index weight calculation method

The traditional AHP realizes the quantitative solution of qualitative problems by simulating the decision-making path of human beings. When seeking opinions from many experts, the comparison matrix formed by experts using nine scale method is obviously different, that is, the subjectivity of evaluating the importance degree with 1-9 numbers is too strong. The improved analytic hierarchy process (AHP) uses three scale method to compare the importance of the influencing factors, that is, the importance degree is evaluated by 0, 1 and - 1, only considering the importance or not, not considering the importance degree, so as to enhance the objectivity and comprehensiveness of the comparison matrix. The index comparison matrix is established by 3-scale theory as follows:

$$A=\begin{bmatrix} a_{11}\cdots a_{12}\cdots a_{1n} \\ \vdots \quad \vdots \quad \vdots \\ a_{n1}\cdots a_{n2}\cdots a_{nn} \end{bmatrix}, a_{ij}=\begin{cases} 1, I \text{ is more important than } J \\ 0, I \text{ is as important as } J \\ -1, J \text{ is more important than } I \end{cases} \quad (1)$$

The optimal transfer matrix and comprehensive judgment matrix are established as follows:

$$R=\begin{bmatrix} r_{11}\cdots r_{12}\cdots r_{1j} \\ \vdots \quad \vdots \quad \vdots \\ r_{i1}\cdots r_{i2}\cdots r_{ij} \end{bmatrix}, r_{ij}=\frac{1}{n}\sum_{n=1}^{n}(a_{in}+a_{nj}) \quad (2)$$

$$P=\begin{bmatrix} p_{11}\cdots p_{12}\cdots p_{1n} \\ \vdots \quad \vdots \quad \vdots \\ p_{n1}\cdots p_{n2}\cdots p_{nn} \end{bmatrix}, p_{in}=e^{r_{in}} \quad (3)$$

The product square root is used to calculate the weight.

$$w=(w_1,w_2,\cdots,w_n), w_i=\left(\Pi d_{in}\right)^{1/n}/\sum_{n=1}^{n}\left(\Pi d_{in}\right)^{1/n} \quad (4)$$

4 Order Preference by Similarity to Ideal Solution

Because the objective data of the same type of distribution network equipment have strong comparability, TOPSIS method is selected to evaluate the comprehensive benefits of equipment level assets. The principle of this method is as follows: if a certain index of the scheme is closer to the maximum value of the index in all schemes, and it is further away from the minimum value of the index, the higher the score of the index is. The comprehensive score is obtained by multiplying the score of each index of the scheme by the weight, and the comprehensive score is used to compare the advantages and disadvantages of the scheme. The specific steps are as follows:

(1) According to the data of the evaluation index, the original matrix P_{mn} is obtained, and then the maximum value minus the very small index is used to realize the forward conversation. Finally, the change matrix P'_{mn} is obtained by normalization.

$$P_{ij}'=\frac{P_{ij}}{\sqrt{\sum_{i=1}^{m}P_{ij}^{2}}} \quad (5)$$

(2) Because of the different importance ω_j of each evaluation index, the weight of each index should be considered, and the normalized data should be weighted to form a weighted normalized matrix.

$$V=\left(\omega_j P_{ij}\right)_{mn} \quad (6)$$

$$V=\left(v_{ij}\right)_{mn}=\begin{bmatrix} \omega_1 P_{11} & \omega_1 P_{21} & \ldots & \omega_1 P_{m1} \\ \omega_2 P_{12} & \omega_2 P_{22} & \ldots & \omega_2 P_{m2} \\ \ldots & \ldots & \ldots & \ldots \\ \omega_n P_{1n} & \omega_n P_{2n} & \ldots & \omega_n P_{mn} \end{bmatrix} \quad (7)$$

(3) Define positive ideal scheme V^+ and negative ideal scheme V^-

$$V^+=\left\{v_1^+,\ldots,v_n^+\right\}=\left\{\begin{matrix} \left(\max_i v_{ij}\,\middle|\, j\in J_1\right), \\ \left(\min_i v_{ij}\,\middle|\, j\in J_2\right) \end{matrix}\right\} i=1,2,\ldots,m \quad (8)$$

$$V^-=\left\{v_1^-,\ldots,v_n^-\right\}=\left\{\begin{matrix} \left(\min_i v_{ij}\,\middle|\, j\in J_1\right), \\ \left(\max_i v_{ij}\,\middle|\, j\in J_2\right) \end{matrix}\right\} i=1,2,\ldots,m \quad (9)$$

Wherein, J_1 is the set of benefit index, J_2 is the set of cost index.

(4) Calculating Euclidean distance

Let the distance from the scheme $i(i=1,2,...,n)$ to the positive ideal scheme is S_i^+ and the distance to the negative ideal scheme S_i^- is S_i^-, then

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^+\right)^2} \tag{10}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^-\right)^2} \tag{11}$$

(5) Calculation of relative closeness

$$e_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{12}$$

The TOPSIS evaluation value of each scheme is calculated by the above formula, and the evaluation objects are sorted and optimized according to the evaluation value.

5 Case analysis

Taking different provinces as boundary conditions, three provincial power grid companies are selected to investigate the status quo of innovation achievements, personnel management, capital investment, technological development and value-added of provincial companies, and sort out or obtain various index data. The following table shows the data of relevant indicators of Companies in A, B and C provinces.

Table 2. Index data of companies in three provinces

Index	A	B	C
Total training rate	93.1%	94.5%	95.8%
Talent Equivalent Density	1.02	1.05	1.04
Research Funding Intensity	0.98%	0.99%	1.01%
Return on Net Assets	2.38%	2.36%	2.34%
Cumulative Number of Patents	108	105	107
Intelligent Level of Power Grid	1	1	2
Number of Provincial Scientific Research Institutions	1	3	2
Cumulative Number of Awards for Major Science and Technology Projects	88.2%	87.7%	88.5%

By means of capital collection research and consulting power companies, the evaluation index data of "five chain" integration effect of three different provinces grid companies are obtained to evaluate the collaborative innovation ability of different regions. Experts from power grid companies, distribution network planning, scientific research institutes and other units are invited to determine the judgment matrix representing the importance of indicators based on their senior experience.

Table 3. Judgment matrix

A	B1	B2	B3	B4	B5	B6	B7	B8
B1	0	0	-1	1	1	-1	-1	0
B2	0	0	-1	1	1	-1	-1	0
B3	1	1	0	1	1	0	1	1
B4	-1	-1	-1	0	1	-1	-1	0
B5	-1	-1	-1	-1	0	-1	-1	-1
B6	1	1	0	1	1	0	1	1
B7	1	1	-1	1	1	-1	0	1
B8	0	0	-1	0	1	-1	-1	0

According to the judgment matrix in Table 3, the weight of 8 indexes is w = (0.109, 0.109, 0.188, 0.087, 0.069, 0.188, 0.149, 0.101). In order to highlight the advantages of the improved AHP, the traditional AHP and the improved index weight results are compared. Using the traditional 9-scale AHP, the weight of some indexes is too large due to the setting of the importance degree. For example, C3 index weight is 0.219, C6 index is 0.214, although these indicators are important, the sum weight of the two accounts for nearly 0.5, which is obviously inconsistent with the actual situation. After using the improved AHP, the weights of C3 and C6 indicators are both 0.188, which are still the most important indicators, but the weight proportion is appropriate, which is consistent with the actual innovation situation of the company.

Use the formula to calculate the distance between the "five chain" integration effect index of the three provincial power grid companies and the positive ideal scheme and the negative ideal scheme, and draw Figure 1 according to the calculation results in the table below.

Table 4. Evaluation of distance and solution

Provincial Power Grid Corporation	S_i^+	S_i^-	e_i	Sort
A	0.393	0.239	0.378	Third
B	0.331	0.318	0.490	Second
C	0.215	0.303	0.586	First

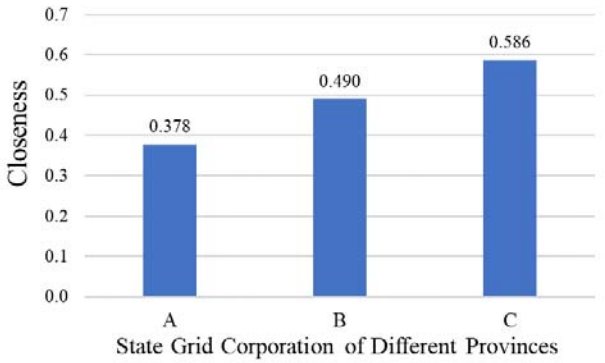

Figure 1. Ranking of integration innovation achievements

It can be seen from the above table that the "five chain" integration innovation effect of provincial power grid company C is the best, followed by provincial power grid company B, and the worst is provincial power grid company A. The power grid company of A province needs to strengthen the training of human resources, design reasonable training and training mechanism, strengthen the investment of scientific research funds, build and improve the feasibility research institutions, and inject innovative vitality into the realization of the strategic objectives of State Grid Corporation of China.

6 Conclusion

Based on the relationship of "innovation chain, talent chain, technology chain, capital chain and value chain" of power grid company, this paper constructs the evaluation index system of "five chain" integration effect. Using the improved AHP method to calculate the weight can overcome the shortcomings of the traditional AHP method which is too subjective, and the experimental results are more in line with the reality. Using TOPSIS method to evaluate, the ranking results of innovation ability of three provincial companies are obtained, among which the innovation ability of a province company is the worst. It is necessary to strengthen the investment of scientific research funds, improve the construction of scientific research facilities and cultivate high-quality scientific research personnel.

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