Investment Effectively and Benefit Evaluation of Transmission Technology Project Based on DEA

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Abstract. With the advancement of power reform, the profit model of the power grid enterprise will undergo major changes. It is requiring the grid enterprise to control its own costs more precise. As a routine maintenance work to ensure the safe and stable transportation of electric energy, the grid technical transformation project has a great impact on the grid operation cost. Due to the many factors involved in the project, it is generally difficult to estimate the investment efficiency and often based on experience. It is difficult for the power grid enterprise to make a scientific and objective assessment of the investment efficiency of the technical transformation project. Firstly, this paper constructs the evaluation index system of investment efficiency of the grid technical transformation project from input-output perspective, and then the DEA method is chosen. Through the analysis of a case study, it proves the effectiveness of the proposed index system and method, and some advices are also given.

1. Introduction

With the further reform of China's electricity marketization, in the future, the main business of power grid enterprises will change from the theme of conducting electricity purchase and sale transactions to the implementation of electricity transmission and distribution services, and their income will be mainly based on "over-grid fees." The transmission and distribution price of the grid enterprise will be based on the effective assets of the grid, and the government will approve the permitted cost and permitted revenue, and fix the total revenue of the power grid in a cost-plus manner. In this context, it is necessary for power grid enterprises to carry out refined management of their own transmission and distribution assets. Power grid enterprises need to pay more attention to their own transmission service efficiency and efficiency, upgrade and adjust the structure of transmission and distribution assets of the power grid, so as to improve the quality of power supply and strengthen the competitiveness of power grid enterprises in the power market.

Power transmission and transformation project is the basic project of power energy safety transportation. Investment and construction is the basis of power grid transmission and distribution services. As there are many influencing factors of power grid engineering investment, including economic, social, political, and technical factors, it is a more complex issue to evaluate the efficiency and effectiveness of grid engineering investment [1]. The early economic evaluation of grid investment focused on the financial and national economic aspects of grid investment. In terms of evaluation methods, reference was made to relevant methods of investment theory, such as real option theory [2] and value theory [3]. However, some scholars have pointed out that due to the many factors
affecting power grid construction, power grid investment has a strong uncertainty, and a comprehensive evaluation system other than economics needs to be considered [4]. Zhu Xinrong et al. constructed the evaluation system of grid investment benefits from the three aspects of grid investment benefits, costs, and safety [5-6], and proved the feasibility of building an index system based on cases. Some scholars have proceeded from the entire process of power grid construction, screened the corresponding indicators in the construction process in accordance with the power grid construction process to construct a benefit evaluation system for power grid investment projects and have achieved certain results [7-8]. Because grid investment projects are a relatively complex comprehensive evaluation system, in terms of evaluation methods, scientific evaluation methods need to be used to evaluate grid investment projects, such as fuzzy analytic hierarchy process [9], decision tree analysis based on decision theory [10], combining triangular fuzzy number, adjustment factor and Delphi quantified comprehensive evaluation method, etc. [11]. The above studies have confirmed through example policies and analysis that the proposed method can avoid certain subjective evaluation methods, has a certain degree of objectivity and scientificity, and can provide a good guide and reference for power grid investment benefit evaluation. The above studies have achieved certain results in the investment evaluation of power grids, but related studies on the evaluation of investment efficiency and efficiency for technical reform projects of power grid engineering have rarely been seen.

With the further deepening of power reform, power grid enterprises not only need to evaluate the benefits of power grid construction investment, but also need to measure the investment efficiency of technical transformation projects of transmission and transformation projects. The evaluation and analysis of the investment benefit and efficiency of power grid technological transformation projects can further refine the accounting and management of the grid’s transmission and distribution costs, and can strengthen the core business of the grid’s future transmission and distribution power services. This paper takes the technical transformation projects in grid transmission and transformation projects as research objects, and evaluates the investment efficiency and benefits of grid technological transformation projects from the perspective of the input and output of grid investment. On this basis, the DEA model suitable for the investment efficiency and benefit evaluation of power grid technical transformation project is constructed, which provides reference for the cost control of power grid project.

2. Research method

2.1. Thoughts on Evaluation of Power Grid Technical Transformation Projects

The technical transformation project of the power grid is the basic work to ensure the safe transmission of electricity. In addition to electricity as a commodity attribute, it also has the social service attribute of protecting the national economy and people’s livelihood. When evaluating the efficiency and effectiveness of the technological transformation of the power grid, in addition to considering the economic impact of the technological transformation project, the social attributes of the technological transformation project must also be considered. In addition, technical transformation projects are projects that are carried out after the construction of transmission and transformation projects, so they are often carried out on the basis that transmission and transformation lines have been completed and operated. According to the characteristics of technological transformation projects, the reasons for technological transformation of power grid projects generally include policy factors, safety factors, standard changes, equipment status, and equipment life. Therefore, when evaluating the investment benefits of power grid projects, it is necessary to take into account the economic benefits of the power grid, fully combine the characteristics of the grid technical transformation project, and screen the input-output measurement indicators of the grid technological transformation project, combine the characteristics of data availability and evaluation methods, scientifically comb and effectively screen the indicators, and strive to build a scientific and systematic evaluation index system, which can provide reference for the evaluation, analysis and comparative study of the benefit and efficiency of the power grid technical transformation project, so as to ensure the scientificity of the evaluation conclusion and provide support for the practical application.
2.2. Selection of Evaluation Indexes for Power Grid Technical Transformation Projects

According to the evaluation ideas and characteristics of power grid technical transformation projects, and with reference to the relevant research on the investment benefit evaluation of power grid transmission and transformation projects, the evaluation of the efficiency of power grid technological transformation projects can be summarized as an input-output efficiency evaluation problem. When selecting the evaluation indicators, the comprehensive evaluation index systems of input indicators and output indicators need to be screened separately in accordance with the characteristics of the technical transformation project of the power grid. The screening process is as follows:

2.2.1. Selection of input indicators
The input of power grid technical transformation projects can be attributed to the three types of resources: human, financial, and material resources. Among them, the manual input can be obtained by counting the number of people who have invested in the technical transformation projects. The financial input can be measured by capital investment, that is, the labor cost, mechanical cost and material cost involved in power grid technical transformation are added up. According to the relevant composition, the cost includes the builder The project cost, installation engineering cost, equipment purchase cost and other costs excluding land acquisition cost are invested by the technical transformation project. Material input refers to the material resources invested in the technical transformation of the power grid, including replacement of power transmission and transformation equipment, related parts, and related facilities' reconstruction materials. Generally, it is not convenient to measure the material input directly. Therefore, it can be measured by the cost of purchasing equipment. Since the equipment purchase cost is included in the investment calculation of power grid projects, the equipment input and capital investment can be combined, and the investment cost of power grid technical transformation can be used for unified measurement.

2.2.2. Selection of output indicators
Due to the special attributes of power products, electricity has both economic and social output. In addition, the purpose of grid technology transformation projects is to ensure the safe and stable operation of the grid and improve the service quality of transmission and transformation. It also implies the output that guarantees the security of the power grid. In summary, the screening indicators for these three output categories are as follows:

- **Economic benefit output indicators.** Since the power grid technical transformation projects are all constructed on the existing power transmission and transformation projects, it is difficult to separate the economic benefits of technological transformation projects from the economic benefits of transmission and transformation projects, and it is difficult to directly measure them separately. The main purpose of the grid technical transformation project is to ensure the safe operation of transmission and transformation lines. Therefore, the sales of electricity in the power supply area of the technological transformation project is selected as an indirect measure of the efficiency of the technological transformation project. In addition, power grid technology transformation projects often update related lines and equipment, thereby reducing the line loss of transmission and transformation lines, which will also bring certain benefits. Therefore, the change of the line loss rate is selected as a measure of the economic benefits of the technical transformation project of the power grid.

- **Social benefit output indicators.** The power grid is a carrier for ensuring economic production and energy transmission by users, and has certain social attributes. The main purpose of the grid technical transformation project is to guarantee the power consumption of users. Therefore, the social benefit output indicators of the grid technological transformation project can be measured by the number of power users in the district where the technological transformation project is located. When the number of users is difficult to obtain, this indicator can be replaced by the number of people in the area where the technological transformation project is located.

- **Safety output indicators.** Grid technical transformation projects are sometimes generated when the grid power supply voltage or power supply reliability value warning occurs and cannot be resolved through overhaul. At this time, the output of the grid technical transformation project can be measured by the grid voltage or reliability. In addition, the technological transformation project will update the relevant equipment assets of the power grid, which can increase the average life of the safe use period of the power grid equipment. However, this output indicator is difficult to measure and quantify. Therefore,
the difference between the asset value of the power grid at the end of the year and the asset value of the grid at the beginning of the year can be used to indirectly measure the value added of the newly constructed transmission and transformation projects.

In summary, Table 1 shows the index system for the evaluation of the efficiency and effectiveness of power grid technological transformation projects.

**Table 1. Evaluating the efficiency of power grid technological transformation projects Index System**

| Indicator description                  | Specific indicators                         |
|----------------------------------------|--------------------------------------------|
| Input indicator                        | Investment in technological transformation projects I₁ |
|                                        | Number of inputs I₂                        |
|                                        | Electricity sales O₁                       |
|                                        | Line loss rate O₂                          |
| Output indicator                       | Power supply population O₃                 |
|                                        | New grid assets in technological transformation O₄ |
|                                        | Grid reliability O₅                        |

2.3. **Selection of DEA evaluation method**

It can be seen from the evaluation index system of investment efficiency of power grid technology transformation projects that the essence of the efficiency evaluation of power grid technological transformation projects is the comparative evaluation of the investment in the power grid and the evaluation of the post-investment efficiency. It is appropriate to select an input-output related evaluation model for evaluation. The DEA evaluation model is an evaluation model based on a combination of economics, management science, and operations research. It combines the input and output indicators in economic production to build a production frontier curve, thereby evaluating the input-output efficiency in economic production. Among them, the input unit is also called DMU (Decision Making Unit). Based on the positional relationship between the DMU and the production curve, it determines whether the input elements of production have relative efficiency, thereby evaluating the effectiveness of production.

DEA method is a non-parametric statistical evaluation method with economic background. When using DEA to evaluate DMU, a lot of management information related to benefits and efficiency can be obtained in advance. Therefore, once this method was introduced, it was frequently used by scholars in the evaluation of the efficiency of input and output, and improvements were made to produce many classic evaluation models, such as C²R model, BC² model, C²GS² model, FG model, etc. The more classic ones are the C²R model and the BC² model, both of which are used to measure technical efficiency and pure technical efficiency, respectively. The BC² model is based on the C²R and a data limit is added to perform the corresponding transformation. Among them, the C²R model uses the linear programming theory in operations research when estimating the production frontier. When considering the production scale, it is assumed that the fixed production scale and the scale return are increasing or decreasing, so as to measure the scale efficiency. BC² measures the production efficiency affected by management or technology. According to the characteristics, models, and theories of the above-mentioned DEA method, combined with the purpose of evaluating the efficiency and benefits of power grid technical transformation projects, this paper selects an improved BC² model based on the C²R model to evaluate the efficiency benefits of power grid technological transformation projects.
2.4. Construction of DEA Evaluation Model

According to the index system for the evaluation of the efficiency of power grid technological transformation projects, the input index is regarded as a DMU. The basic model is as follows: Assume that there are s decision units, namely \( DMU_k (k = 1, 2, \ldots, s) \). Each \( DMU \) has \( m \) types of inputs and \( n \) types of outputs. The input and output vectors are expressed as:

\[
X_k = (x_{1k}, x_{2k}, x_{3k}, \ldots, x_{mk}), \quad Y_k = (y_{1k}, y_{2k}, y_{3k}, \ldots, y_{nk})
\]

The typical C2R model can be expressed as follows:

\[
\begin{align*}
\min \theta \\
\text{s.t.} \sum_{k=1}^s x_k \lambda_k + s^- = \theta x_0 \\
\sum_{k=1}^s y_k \lambda_k - s^+ = \theta y_0 \\
\lambda_k \geq 0 (j = 1, 2, \ldots, s) \\
s^+ \geq 0, s^- \geq 0
\end{align*}
\]

(1)

Among them, \( \theta \) represents the validity of the input configuration of the decision-making unit of the grid technological transformation project. According to the principle of DEA, the closer the value of \( \theta \) is to 1, the more effective it is. \( \lambda_k \) is the combined weight of the \( k \)-th decision unit. \( S^- \) is a non-negative deviation variable introduced by \( n \) kinds of outputs, and \( S^+ \) is a non-negative deviation variable introduced by \( m \) kinds of inputs, recorded as \( S^+ = (s_1^+, s_2^+, \ldots, s_n^+) \), \( S^- = (s_1^-, s_2^-, \ldots, s_m^-) \). Under the assumption of variable returns to scale, \( BC^2 \) model can be obtained by adding a new benefit to scale condition.

\[
\begin{align*}
\min \theta \\
\text{s.t.} \sum_{k=1}^s x_k \lambda_k + s^- = \theta x_0 \\
\sum_{k=1}^s y_k \lambda_k - s^+ = \theta y_0 \\
\frac{1}{\theta^s} \sum_{k=1}^s \lambda_k = 1 \\
\lambda_k \geq 0 (k = 1, 2, \ldots, s) \\
s^+ \geq 0, s^- \geq 0
\end{align*}
\]

(2)

If \( \frac{1}{\theta^s} \sum_{k=1}^s \lambda_k = 1 \), the return on scale of the \( DMU_k \) remains unchanged, indicating that the \( DMU_k \) has reached the optimal return on scale at this time; If \( \frac{1}{\theta^s} \sum_{k=1}^s \lambda_k \geq 1 \), \( DMU_k \) scale returns diminish, indicating that increasing input will not bring more legal output, but will reduce efficiency; If \( \frac{1}{\theta^s} \sum_{k=1}^s \lambda_k \leq 1 \), \( DMU \) scale returns increase, indicating that an increase in input will bring higher output and higher efficiency. According to formula (2), the pure technical efficiency of \( DMU_k \) under variable returns to scale can be calculated, which reflects the input and output level of the DMU of the enterprises’ technology resource allocation. Under the same conditions, the higher the pure technology efficiency, the better the scale efficiency, and the higher the efficiency of technology resource allocation. At the same time, the combination of formula (1) and formula (2) can be used to obtain the redundant input \( S^+ \) and insufficient output \( S^- \) of resource allocation.
3. Empirical analysis

According to the above, the establishment of the index model of the benefit and efficiency evaluation system of the technical reform project of the power grid, and the basic principles of the DEA evaluation model. Data collection was carried out for the regional power grid technical transformation projects. A total of 5 years from 2013 to 2017 were collected for the technical transformation project related data. After the collection, the data was normalized. The relevant data table is shown in Table 2.

| Year     | 2013 | 2014 | 2015 | 2016 | 2017 |
|----------|------|------|------|------|------|
| Investment | 0.375 | 0.589 | 1.000 | 0.860 | 0.576 |
| Number of inputs | 0.792 | 0.799 | 0.893 | 0.943 | 1.000 |
| Electricity sales | 0.992 | 1.000 | 0.914 | 0.922 | 0.959 |
| Line loss rate | 1.000 | 0.951 | 0.915 | 0.939 | 0.939 |
| Population | 0.975 | 1.000 | 0.971 | 0.985 | 0.990 |
| New grid assets in technological transformation | 0.857 | 1.000 | 0.346 | 0.674 | 0.445 |
| Grid reliability | 1.000 | 1.000 | 0.992 | 0.9992 | 1.000 |

According to the above DEA principle, use MATLAB to program and calculate the above data. The calculation results are shown in Table 3:

| Year     | 2013 | 2014 | 2015 | 2016 | 2017 |
|----------|------|------|------|------|------|
| $\lambda_1$ | 0.996 | 0.617 | 0.618 |      |      |
| $\lambda_2$ | 0.383 | 0.382 |      |      |      |
| $\theta$   | 0.416 | 0.584 | 0.869 |      |      |

The following conclusions can be drawn from the results:

1. In 2013 and 2014, the input-output efficiency benefit of the grid's technical transformation projects in the region was 1, indicating that DEA is effective. The input and output in the past two years are on the production frontier, and the returns to scale are unchanged.

2. In 2015 and 2016, the input-output efficiency value of the grid's technical transformation projects in the region was around 0.5, of which the investment efficiency in 2015 was 0.416, and the investment efficiency benefit value was the lowest in years. Over the past two years, the situation of excessive capital investment was serious, and nearly half of the two-year capital investment was redundant. Among them, scale returns decreased in 2015, and scale returns increased in 2016.

3. In 2017, the input-output efficiency value of the regional power grid technology transformation project reached 0.869, which has improved compared with 2015 and 2016, and the returns to scale have increased.

From the perspective of the entire DEA analysis, funding has the largest impact on the technical transformation project investment in power grids, and manual investment has the second largest impact. The input and output of the power grid technical transformation projects in the region have been in redundant since 2015. Further analysis should be made in combination with the situation, and a stricter control mechanism should be established to carry out the cost budget control management system of technological transformation projects, so as to minimize the waste in investment. The example proves that the DEA model can evaluate the investment efficiency and effectiveness in the evaluation of power grid technology transformation projects, and can provide certain guidance for the grid technology transformation project investment. The model can meet the needs of practical work, which shows the effectiveness of the model.
4. Conclusion

In this paper, the evaluation of the investment efficiency of power grid technology transformation projects is studied. Based on the characteristics of grid technology transformation projects, an evaluation index system is constructed from the perspective of input and output. In the input index, select the investment amount and manual input to measure the input of the grid technical transformation project; Among the output indicators, comprehensive output grid core business, social service attributes, and safe and stable operation are given corresponding output indicators, and a DEA evaluation method is selected for evaluation. In the output index, the core business of power transmission and distribution, social service attribute and safe and stable operation of the integrated power grid are given, and DEA evaluation method is selected for evaluation. Finally, combined with relevant actual data, the index system and evaluation method proposed in this paper are verified by examples. The evaluation results show that the index system and method proposed in this paper can meet the needs of efficiency evaluation of power grid technical transformation project, and can provide reference for power grid technical transformation project management.

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