Research and Application of Post Evaluation Method for Power Grid Technology Projects

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Abstract. With the development of refined power grid investment, power grid companies pay more attention to investment benefits and effects while taking into account reliability. However, in the practice of project evaluation, there are problems of "emphasis on results and neglect of transformation", "emphasis on long-term and neglect on short-term", poor objectivity and low accuracy of economic benefit evaluation. According to the characteristics of science and technology projects, the concept, scope and time scale of the post-evaluation of power grid science and technology projects are defined. On the basis of the existing State Grid Corporation’s project post-evaluation, an evaluation index and a mid- and long-term evaluation system were established to comprehensively evaluate the investment benefits of scientific and technological projects and improve the evaluation mechanism of current evaluation indicators. This paper also digs out the guiding indicators of evaluation, and takes the economic benefits of result transformation as an important evaluation indicator to guide project implementers to improve project quality during project implementation, thereby improving the efficiency and benefits of scientific research project investment.

Keywords: Post evaluation of technology projects, Post-evaluation index system, Analytic hierarchy process.

1. Introduction
At present, power grid companies are facing the problem of transforming from a “high investment and asset-heavy” to a “digital ecology” and need to reduce investment and optimize cost management. In terms of investment in scientific research projects, how to comprehensively evaluate the investment benefits of scientific and technological projects to provide reference for precise scientific and technological investment decisions of power grid companies is a problem that needs to be resolved.

State Grid Corporation has carried out the post-project evaluation work and designed 4 indicators of economic and technological value, comprehensive benefits, talent training, and technology management [1] [2]. The principles and content of post-evaluation of the project are clarified to provide reference for the implementation of post-evaluation [3]. Literature [4] divides 4 types of results of enterprise science and technology project evaluation from the two dimensions of attribute and management of scientific and technological achievements, and proposes post-evaluation indicators under different conditions. In order to overcome the limitations of subjective weighting, literature [5] combines a variety of methods...
to determine the evaluation index weight and obtains a large sample by stochastic simulation to obtain the oriented evaluation index, but this method extracts evaluation index based on a specific case, limited by the industry and different project categories, so the algorithm lacks a certain generalization ability. Literature [6] puts forward the evaluation method of the item group by focusing on one type of project. Compared with the evaluation method of a single item, there is no significant difference in the evaluation index. At the same time, the current post-evaluation work lacks certain operability in terms of economic and technical value and comprehensive benefits limited by the data that can be collected by the project. And the evaluation data mainly comes from the project acceptance data and the self-evaluation certificate of the project implementation unit. The economic benefit evaluation after the implementation of the project has poor objectivity and accuracy.

At present, the power grid companies focus on the post-evaluation of science and technology projects mainly for the projects from 1 to 3 after acceptance. This evaluation cycle has a certain effect on the evaluation of projects with large short-term benefits and can reflect the effect of project implementation. However, some technology projects such as patent achievements are difficult to be successfully transformed in a short period of time, the investment recovery period is long, and the short-term benefits are not significant. Therefore, a simple annual or 3-year evaluation cycle cannot reflect the investment benefits of such projects, and it is easy to cause the investment in power grid technology projects to tend to short-term benefits projects, while ignoring long-term high-yield projects, affecting the sustainable development of the power grid.

In order to solve the above problems and combine the characteristics of science and technology projects, this article first defines the concept, scope and time scale of the post evaluation of power grid science and technology projects, with the goal of improving the quality of science and technology projects and the value of scientific research results, establish evaluation indicators and a mid- and long-term evaluation system to comprehensively evaluate the investment benefits of scientific and technological projects and guide the project in the implementation guided by evaluation indicators, improve project quality and management level based on the existing post-evaluation of the State Grid Corporation's project. Based on the comprehensive evaluation of the scientific and technological projects undertaken by Qingdao Power Supply Company, this paper summarize the problems that occurred during the completion of the scientific and technological projects, form the evaluation results, and summarize management suggestions to provide reference for the power grid company's scientific and technological investment decisions.

2. Definition and Analysis Process of Post-Evaluation
The post-evaluation of a science and technology project refers to the project that has been accepted, objectively analyzes and summarizes the effectiveness and economic benefits of the project after implementation, finds out the reasons for the success or failure of the project through analysis and evaluation, summarizes experience and lessons, and provides timely and effective information feedback to provide reference for future investment and construction of similar projects. The goal of post-evaluation is to guide the project to be guided by evaluation indicators in the implementation process by establishing evaluation standards, thereby improving the quality of scientific and technological projects and enhancing the value of scientific research results. The goal of post-evaluation is to guide the project to be guided by evaluation indicators in the implementation process by establishing evaluation standards, thereby improving the quality of scientific and technological projects and enhancing the value of scientific research results. The object of post-evaluation of science and technology projects is for projects that have passed acceptance or appraisal. The time scale of the evaluation has been changed from the items 1 to 3 after the original approval to continuous and periodic evaluation, and short-term and medium-long-term evaluation index models are established. The longest evaluation time scale for the same project is 10 years.

The basic process of project evaluation includes: 1) collection of information; 2) constructing an index system through the analysis of target data characteristics; 3) establishing an index system based
on intelligent analysis methods and manual experience; 4) making project evaluation based on sample data and making predictions and judgments based on the evaluation results to form investment decisions.

Fig. 1 The basic steps of post-evaluation

The post-project evaluation result is one of the key indicators that support the investment decision of science and technology projects. The economic benefits of the project are determined through the post-evaluation results, so as to assist the on-site personnel to determine whether to increase investment in the project.

3. Evaluation Index and Method of post-Evaluation

3.1. Evaluation Index

The current power grid technology projects are divided into key technology research and application categories and basic forward-looking, decision support or soft science categories. Regardless of the type of scientific and technological project, the evaluation of the results should focus on the application benefits of the technical results. The post-evaluation indicators designed by State Grid include four indicators: economic and technological value, comprehensive benefits, talent training, and technology management, talent training and technology management focus more on project management, and the current indicators meet the actual needs of the site, so this paper won’t discuss too much. This paper focuses on discussing the economic and technological value and comprehensive benefits of scientific and technological projects, including the carrier form of technological achievements of scientific and technological projects, and the direct income from the transformation of achievements such as patent authorization or transfer, finalize the first-level indicators of benefit post-evaluation, post-impact evaluation, and sustainability post-evaluation indicators and corresponding second-level indicators and several third-level indicators.

Table 1. Evaluation Index

| The first-level goal          | The second-level goal         | The evaluation indicators                                      |
|------------------------------|-------------------------------|----------------------------------------------------------------|
| benefit post-evaluation      | Economic evaluation           | Benefit generation                                              |
|                              |                               | Achievement transformation                                      |
|                              |                               | Return on investment                                            |
| post-impact evaluation       | Environmental impact          | Energy conservation                                             |
|                              | Technology Direct Output      | Papers and Monographs                                          |
|                              |                               | Technical standards                                             |
|                              |                               | Inventions and other intellectual property rights              |
|                              |                               | Awards                                                          |
| sustainability post-evaluation | Project sustainability    | Academic citations                                              |

Post-benefit evaluation is a comprehensive evaluation of whether a technology or product formed by a scientific and technological project has increased the company’s economic income, improved the company’s management efficiency, and reduced the company’s operating costs. Among them, the increase in economic income includes the direct benefits of conversion of results. The main methods of achievement transformation include ① Self-investment and implementation of transformation; ② Transfer of scientific and technological achievements to others; ③ Permit others to use scientific and technological achievements; ④ Use scientific and technological achievements as a condition for
cooperation to implement transformation with others; ⑤ Use the scientific and technological achievements as the investment, convert the shares or the proportion of capital, etc. The return on investment is the annual income/total investment.

The post-impact evaluation focuses on the degree of impact of scientific and technological projects on the progress of social sciences. The results carriers are papers and monographs, patents, technical standards and other intellectual property rights, and awards for scientific and technological achievements.

Academic citations mainly refer to the number of citations in the paper.

3.2. Evaluation Method

Using the improved Analytic Hierarchy Process (AHP) and the Entropy Weight Method [7] to determine the subjective and objective weights of the evaluation indicators of science and technology projects, and then determine the comprehensive weights $W_1$~$W_8$, and getting the score of science and technology projects by weighted average.

Step 1: Use improved AHP to determine the subjective weight of evaluation indicator $W_{j,1}$.

Step 2: Use the entropy weight method to determine the objective weight of each indicator $W_{j,2}$.

Step 3: Combine the subjective and objective weights to find the comprehensive weight of each indicator $W_{j}^*$. 

Step 4: Obtain the comprehensive evaluation index $P(t)$ of science and technology projects through weighted average, and reflect and evaluate the level of science and technology projects through the size of the comprehensive evaluation index $P(t)$.

1) Subjective weight calculation model

Traditional AHP needs to check the consistency of the judgment matrix. If the consistency check fails, the judgment matrix needs to be reconstructed. Improved AHP adopts a new construction method of judgment matrix to simplify the calculation process and improve the accuracy of evaluation. That is: suppose that according to the scale expansion method, the importance of n indicators is ranked as $x_1 \geq x_2 \geq \ldots \geq x_n$, compare $x_i$ and $x_{i+1}$, and record the corresponding scale value as $t_i$, and then calculate the values of other elements in the judgment matrix according to the transitivity of the importance of the index, and finally get the judgment matrix.

   a) Construction of the judgment matrix

   The judgment matrix indicates that the relative importance of each factor at this level is compared with a factor at the upper level, and its value assignment is completed by consulting relevant materials and expert opinions. The 1-9 scale method is used to quantify the significance of each evaluation factor and construct a judgment matrix. Determine the weight order of each factor by calculating the eigenvector of the judgment matrix, that is, the index weight coefficient of the matrix. The specific steps include:

   - Calculate the product of each element of each row of the judgment matrix:

     $$ m_i = \prod_{j=1}^{n} a_{ij} i = 1, 2, \ldots, n $$  \hspace{1cm} (1)

   - Find the nth root:

     $$ \sigma_i = \sqrt[n]{m_i} \hspace{1cm} (i = 1, 2, \ldots, n) $$  \hspace{1cm} (2)

   - Normalize the vector $\sigma = \left( \sigma_1, \sigma_2, \ldots, \sigma_n \right)^T$ to be the required feature vector or index weight coefficient:
\[ \omega_i = \frac{\alpha_i}{\sum_{j=1}^{n} \alpha_j} \quad i = 1, 2, \ldots, n \]  

(3)

b) Total ranking

Calculate the composite weight of each layer factor to the overall goal of the system, and perform a total ranking to determine the relative importance of all the factors of the bottom layer C to the overall goal of the system. This process must be carried out layer by layer from the target layer to the indicator layer. Specific calculations are shown in Table 2.

| Table 2. Total ranking |
|------------------------|
| Layer C | Layer B | The total ranking value of layer C to layer A |
|---------|---------|-----------------------------------------------|
| C1      | \( C_{11}, C_{12}, \ldots, C_{1n} \) | \( \sum b_i C_{iu} \) |
| C2      | \( C_{21}, C_{22}, \ldots, C_{2n} \) | \( \sum b_i C_{u2l} \) |
| \vdots  | \vdots  | \vdots                                      |
| Cm      | \( C_{m1}, C_{m2}, \ldots, C_{mn} \) | \( \sum b_i C_{um} \) |

In the table, \( b_1, b_2, \ldots, b_n \) is the index weight coefficient of layer B to layer A, and \( C_{11}, C_{12}, \ldots, C_{mn} \) is the index weight coefficient of layer C to layer B. After the overall ranking of levels is determined and the consistency test is passed, the relative importance of each index can be determined.

2) Objective weight calculation model

- For n scientific and technological projects and m evaluation indicators, the original matrix is formed as follows:

\[
X = \begin{bmatrix}
    x_{11} & \cdots & x_{1n} \\
    \vdots & \ddots & \vdots \\
    x_{n1} & \cdots & x_{nn}
\end{bmatrix}
\]

- Normalize the elements in the matrix to get \( X' = (x'_{ij})_{n \times m} \), \( x'_{ij} \) is the normalized value of the j-th index of the i-th science and technology project (i=1, 2,...,n; j=1, 2,...,m)

- Calculate the proportion of the j-th index value of the i-th sample, and its proportion matrix \( f_{ij} \) is:

\[
f_{ij} = \frac{x'_{ij}}{\sum_{j=1}^{m} x'_{ij}}
\]

(4)

So the information entropy of the index value is:

\[
H_j = -k \sum_{i=1}^{n} f_{ij} \ln f_{ij} \quad (j = 1, 2, \ldots, m)
\]

(5)

Where \( k = 1/\ln m \)

The entropy weight or weight of the j-th index value is defined as:

\[
W_{j,2} = \frac{1 - H_j}{m - \sum_{j=1}^{m} H_j}
\]

(6)

3) Calculation of evaluation results
The integrated method is used to calculate the comprehensive weight of each indicator, that is

\[ W_j = \frac{W_{j,1}W_{j,2}}{\sum_{j=1}^{k} W_{j,1}W_{j,2}} \]  \hspace{1cm} (7)

Get the comprehensive evaluation index \( P(t) \) by weighted average, that is,

\[ P(t) = \sum_{j=1}^{k} y_j \cdot W_j \cdot 100 \]  \hspace{1cm} (8)

In the formula, \( P(t) \) is the evaluation result; \( W_j \) is the comprehensive weight of the \( j \)-th index; \( y_j \) is the normalized value of the \( j \)-th index.

4. Applications

4.1. Project overview

Take the science and technology project Research on Distributed Resource Interaction Mechanism and Cooperative Scheduling Theory as an example. The project was established in 2011 with a project investment of 950,000 yuan. A set of collaborative scheduling system was completed through the implementation of the project. In 2012, the project acceptance and achievement appraisal were completed. In 2012, it won the first prize of Shandong Electric Power Technology Progress Award. The project was continued to invest in 2014, and won the second prize of Shandong Electric Power Science and Technology Progress Award in 2015, and formed the Grid Intermittent Power Supply and Electric Vehicle Charging Cooperative Dispatching Technical Guidelines, and 5 invention patents have been authorized. This paper evaluates the project separately from two time nodes. The first time node is one year after the implementation of the project, and the second time node is 2019. Because the project has the function of wind power-energy storage-small thermal power coordinated dispatch, the application objects are Xuejiadao charging station and the whole grid wind power, the function of energy storage battery discharge is not realized in actual operation. Therefore, the length of time and the amount of charging power are collected that the Xuejiadao charging station participated in the coordinated dispatch from 2012 to 2019 are the economic benefit after the project is implemented.

4.2. Calculation and evaluation of project indicators

Each year, Xuejiadao Charging and Swap Station as energy storage participates in coordinated scheduling of 270 MWh of charging power, according to the principle of system implementation, this part of the charging power comes from wind power, which increases the grid power of wind power, according to the commercial electricity consumption of 1 yuan/kWh, the new electricity revenue will be 270,000 yuan, and the reduction of standard coal consumption will be

\[ 270 \times 350 \times \frac{1}{1000} = 94.5 \text{ t} \]

According to the research content of part Evaluation Method, the indicators of each part can be determined as shown in Table III.

| Index weights         | Secondary indicators | Evaluation index            | Weights |
|-----------------------|----------------------|------------------------------|---------|
| Economic evaluation   | 0.5176               | Benefits                     | 0.35    |
|                       |                      | Achievement transformation   | 0.35    |
|                       |                      | Return on investment         | 0.3     |
| Technology impact     | 0.2942               | Papers and Monographs        | 0.0675  |
|                       |                      | Technical Standards          | 0.1509  |
|                       |                      | Inventions and other intellectual property rights | 0.3908 |
|                       |                      | Awards                       | 0.3908  |
| Environmental impact  | 0.127                | Energy conservation          | 1       |
| Project sustainability | 0.0612               | Academic citations           | 1       |

Table 3. Weight table
According to the comprehensive weight, after normalizing the data of each indicator, the weighted sum is multiplied by 100, and the result of the comprehensive evaluation of terminal quality is calculated. The project scored 88.9% in the 2013 evaluation.

Further additional investment was made in the project in 2014, and formed 1 technical guide, 3 authorized invention patents, and 1 second prize for scientific and technological progress. On the basis of the previous project, some photovoltaic scheduling functions have been added. With the large-scale grid connection of photovoltaic and the promotion of electric vehicles, the electricity consumed through photovoltaic-electric vehicle coordinated dispatch has reached 400MWh each year, and the additional electricity revenue will be 400,000yuan.

5. Conclusion
Based on the actual situation of Qingdao Power Supply Company’s scientific and technological project research and development, the concept, scope and time scale of the post-evaluation of power grid science and technology projects are defined. On the basis of the existing State Grid Corporation’s project post-evaluation, an evaluation index and a mid- and long-term evaluation system were established to comprehensively evaluate the investment benefits of scientific and technological projects and improve the evaluation mechanism of current evaluation indicators. This paper also digs out the guiding indicators of evaluation, and takes the economic benefits of result transformation as an important evaluation indicator to guide project implementers to improve project quality during project implementation, thereby improving the efficiency and benefits of scientific research project investment.

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