Research on the Construction and Application of Post-Evaluation Index System of Technology Development Projects Based on Cloud Model

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Abstract: Science and technology is a key factor in promoting productivity development and national economic construction. This paper takes the benefits and impacts produced by science and technology projects for a period of time after their completion as the research object, studies the methods and index systems of post-evaluation of science and technology projects, designs evaluation indexes for technology development-oriented science and technology projects, uses hierarchical analysis to determine index weights, and then uses the cloud model comprehensive evaluation method to construct science and technology projects The cloud model of comprehensive evaluation is then used to construct the cloud model of science and technology projects, and then the post-evaluation is applied to the specific science and technology projects, and the comprehensive evaluation results are obtained to prove the credibility of this method. Finally, recommendations are made at the level of science and technology management departments at the national level and at the level of project undertaking units to finally achieve the improvement of the comprehensive benefits of future science and technology projects.

Keywords: Science and technology project, Post-evaluation, Cloud model

1 Introduction

As the number of government-funded research projects continues to increase and funding expands, the government's and people's interest in research projects has shifted to a series of sustainable impacts such as economic and social benefits to society after the completion of science and technology projects. 2021 The General Office of the State Council promulgated the "On Improving the Evaluation Mechanism of Scientific and Technological Achievements Guiding Opinions", in which it is clearly stated that the post-evaluation system of science and technology plan results should be established urgently to accelerate the common development of social economy and science and technology, and to promote better application of science and technology results and better transformation into production power. Therefore it is very necessary to do a good job in post-evaluation research of science and technology projects, form

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a set of standard post-evaluation system, and feed back to science and technology management departments through post-evaluation results, so that they can follow up and adjust the planning of science and technology projects, which can not only improve the ability and decision-making level of research management departments in managing projects, but also improve the comprehensive benefits of science and technology projects.

2 Status of research on post-evaluation of science and technology projects

2.1 Foreign research status

The United States was the first to start post-project evaluation and set up an evaluation agency specializing in evaluating scientific research projects, which gave a good lead to other countries [1]. Glenn J. pointed out that with the continuous development of science and technology, science and technology projects will gradually be expanded to an international scale, and the capacity of each country in science and technology project management should be gradually strengthened, and suggested that international science and technology organizations or science and technology funds should be established, etc [2].[4] Kostoff R.N. , Block J.A. used various econometric methods to compare the input-output efficiency of different science and technology projects held in different scientific research institutions [4].

2.2 Domestic research status

Domestic scholars have also achieved some results on the evaluation of science and technology projects.

On the division of the evaluation index system, Zhang Li and Meng Yuezhi constructed a post-evaluation system of three primary indicators as well as ten secondary indicators from the characteristics of enterprise science and technology projects, and tested the specific application of the system [6]. Gao Shanb et al. constructed an evaluation index system from four perspectives and applied it to specific projects, using hierarchical analysis for post-evaluation of pipeline application research projects [3]. In discussing the evaluation system of China's science and technology projects, Li Lai'er proposes to draw on the excellent experience of foreign countries, adopt strict review procedures for project evaluation experts, and improve the construction of third-party evaluation agencies to guarantee the independence of evaluation [5].

Through the above methodological research on science and technology projects at home and abroad, it is found that the vast majority of post-evaluations use a simple scoring and weighted average method to determine the project score. However, the complexity and diversity of science and technology projects, more qualitative analysis process, ambiguity and randomness exist, and only fixed values as evaluation results ignore the ambiguity of the project. Therefore, this paper introduces cloud model, which can solve the problem of fuzziness and randomness at the same time.

3 Construction of post-evaluation index system for technology development projects

3.1 Design of the indicator system

Technology development projects are mainly designed to solve difficult scientific and technological problems that arise in the process of socio-economic development, and it looks at bringing scientific and technological achievements to the market and operating them to form a market-oriented and industrialized mechanism, in order to make scientific and technological achievements better serve public life and economic and social environmental development. The evaluation focuses on the transformation of scientific and technological achievements, the formation of patents, and the positive impact to the economy and society. Based on the above focus, this paper designs an index system containing five first-level indicators and thirteen second-level indicators, and the specific content of the indicators and the explanation of the indicators are shown in Table 1.

Table 1: Post-assessment index system for technology development category science and technology projects.

Target layer	Primary index	Secondary indicators	Explanation of indicators
Technology Development Category Project A	Project acceptance status A1	Project completion status A11	Completion of the agreed contents in the signed project contract letter
		Project Acceptance Compliance A12	Whether the project acceptance unit has acceptance qualifications, project acceptance procedures compliance
	Technology Value A2	Technical level A21	The factors representing the advanced level of research achievements, such as advanced nature, innovation and feasibility, etc.
		Technical Achievement A22	Generation of new processes, new materials, number of patents, acquisition of inventions, other technological achievements
	Economic benefits A3	Sales revenue A31	Project implementation and completion of sales revenue, the completion of the project profit and tax amount
		Market Impact A32	The impact of the technology results to the enterprise and the market after the production, whether it is competitive
	Social benefits A4	Talent Development A41	Talent developed. during project implementation
		Impact on the social environment A42	Impact on social progress, employment environment, security of residents, culture and education, politics, etc.

		Impact on the natural environment A43	Contribution to the local environment, energy saving and emission reduction, harmonious development of the environment, air quality and other impacts
	Persistent Impact A5	Promotion of academic research in the field A51	Contribution and sustained impact of project research results to the discipline to which they belong
		Economic effect to the local area A52	Continued economic income growth and further investment of funds
		Social effects to the local community A53	New employment, enhance regional competitiveness, drive industrial upgrading
		Promote scientific and technological progress A54	Contribution of research results to local science and technology

3.2 Calculate indicator weights

In this paper, we choose the hierarchical analysis method to determine the weights, which can quantify the indicators that need qualitative analysis that are relatively vague.

Calculation steps: The first step is to sort out the hierarchical relationship and construct the hierarchical structure; the second step is to establish the judgment matrix of two comparisons; the third step is to calculate the weights of the judgment matrix by the square root methodWi The fifth step calculates the maximum eigenvalue of the judgment matrix**λ**x ; the sixth step, calculate the consistency index CI; the seventh step, calculate the consistency ratio CR If the value of the judgment matrix CR value is less than or equal to 0.10, then it passes the consistency test, and the corresponding W can be used as the weight, as shown in the formula of Equation 1-4.

$$W_i = \frac{\sqrt[n]{\prod_{j=1}^{n} A_{ij}}}{\sum_{i=1}^{n}\sqrt[n]{\prod_{j=1}^{n} A_{ij}}} \quad (1)$$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{[AW]_i}{n \cdot w_i} \quad (2)$$

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (3)$$

$$CR = \frac{CI}{RI} \quad (4)$$

Calculation process: According to the formula 1-4 to calculate the index weights, the judgment matrix, index weights and consistency test table are shown in Table 2-7.

Table 2: Primary index weight and consistency check table.

A	A1	A2	A3	A4	A5	W	Consistency check
A1	1	1/3	1/4	1/4	1/5	0.0557	λ_{max}=5.0515 CI=0.0129 RI=1.1200 CR=0.0115<0.1
A2	3	1	1/2	1/2	1/3	0.1263	
A3	4	2	1	1	1/2	0.2200	
A4	4	2	1	1	1/2	0.2200	
A5	5	3	2	2	1	0.3781	

Table 3: Index weight and consistency check table of project acceptance.

A1	A11	A12	W	Consistency check
A11	1	3	0.7500	λ_{max}=2, CI=0, RI=0, CR=0<0.1
A12	1/3	1	0.2500	

Table 4: Index weight and consistency check table of technical value.

A2	A21	A22	W	Consistency check
A21	1	1	0.5000	λ_{max}=2, CI=0, RI=0, CR=0<0.1
A22	1	1	0.5000	

Table 5: Index weight and consistency check table of economic benefits.

A3	A31	A32	W	Consistency check
A31	1	1	0.5000	λ_{max}=2, CI=0 RI=0, CR=0<0.1
A32	1	1	0.5000	

Table 6: Index weight and consistency check table of social benefits.

A4	A41	A42	A43	W	Consistency check
A41	1	1/3	1/3	0.1429	λ_{max}=3, CI=0 RI=0.58, CR=0<0.1
A42	3	1	1	0.4286	
A43	3	1	1	0.4286	

Table 7: Index weight and consistency check table of sustainability impact.

A5	A51	A52	A53	A54	W	Consistency check
A51	1	1/3	1/3	1/4	0.0883	λ_{max}=4.0206 CI=0.0069 RI=0.9000 CR=0.076<0.1
A52	3	1	1	1/2	0.2395	
A53	3	1	1	1/2	0.2395	
A54	4	2	2	1	0.4327	

3.3 Construction of a comprehensive evaluation cloud model

Cloud models are used to describe the concept in a holistic way by three cloud numerical characteristics: expectation, entropy and super entropy. Currently, cloud models have a wide range of applications, but no scholars have applied cloud models to the field of post-evaluation of science and technology projects. In this paper, we choose cloud model to conduct a comprehensive evaluation of science and technology projects, which can translate the qualitative analysis into numerical values distributed in various places, and in turn, we can qualitatively analyze the evaluation results from the distribution pattern of the values.

Secondary indicator cloud parameter calculation: The complex index system of post-assessment of science and technology projects, the determination of the scores on technical level and academic level needs to have strong professionalism, so the author invited experts in the field to assign values to each secondary index score, the score range [0,100], the higher the score proves that the higher the success of the index, through the experts' scoring situation, using the inverse cloud generator, calculate the cloud digital characteristics of the secondary index layer, the calculation steps are as follows.

① According to X_i Calculate the sample mean

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \tag{5}$$

② Sample variance

$$S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X})^2 \tag{6}$$

③ Calculate the expected value

$$E_x = \bar{X} \tag{7}$$

④ Calculate the entropy value

$$E_n = \sqrt{\frac{\pi}{2}} \times \frac{1}{n} \times \sum_{n}^{i=1} |X_i - \bar{X}| \tag{8}$$

⑤ Calculate the super entropy value

$$He = \sqrt{\left|En^2 - S^2\right|} \tag{9}$$

Expectation value E_x is the average of experts' scores, the higher the expectation value indicates that the project evaluation result is more successful; entropy indicates the evaluation fuzziness, the smaller its value indicates that the evaluation scope is clearer, the smaller the dispersion is, the evaluation scope is more concentrated; super entropy indicates the stability of the evaluation value, the smaller its value indicates that the evaluation value is more stable.

First-level indicator cloud parameter calculation: The first level index cloud model is to calculate the cloud parameters of the criterion layer. According to the cloud digital characteristics of the second level index, we use the reverse cloud generator to determine the cloud digital characteristics of the first level index, as shown in Equation 10:

$$\begin{cases} E_x = \dfrac{\sum_n^{i=1} E_{x_i} w_i}{\sum_n^{i=1} w_i} \\ E_n = \dfrac{\sum_n^{i=1} E_{n_i} {w_i}^2}{\sum_n^{i=1} {w_i}^2} \\ H_e = \dfrac{\sum_n^{i=1} H_{e_i} {w_i}^2}{\sum_n^{i=1} {w_i}^2} \end{cases} \tag{10}$$

Among them, $(E_{x_i}, E_{n_i}, H_{e_i})$ represents the cloud numerical characteristics of each secondary index, and n represents the number of second-level evaluation indicators, andw_i represents the weight of the second-level indicators.

Comprehensive evaluation of cloud model calculations: Determine the comprehensive evaluation cloud model for post-assessment of science and technology projects, to count its cloud numerical characteristics according to the cloud numerical characteristics of the primary indicators combined with the weights, the calculation formula is shown in 11. According to each evaluation cloud parameters of science and technology projects, draw the cloud diagram of post-assessment of science and technology projects, compare with the standard cloud diagram, draw final conclusions, and finally give recommendations.

$$\begin{cases} E_x = \dfrac{\sum_n^{i=1} E_{x_i} E_{n_i} w_i}{\sum_n^{i=1} E_{n_i} w_i} \\ E_n = \sum_n^{i=1} E_{n_i} w_i \\ H_e = \dfrac{\sum_n^{i=1} H_{e_i} E_{n_i} w_i}{\sum_n^{i=1} E_{n_i} w_i} \end{cases} \tag{11}$$

Among them, $(E_{x_i}, E_{n_i}, H_{e_i})$ represents the cloud number characteristics of each level indicator, andnrepresents the number of first-level evaluation indicators, and w_i represents the weight of the first-level indicators.

4 Application of post-assessment index system for technology development category science and technology projects

Based on the index system and the comprehensive evaluation cloud model established above, the technology development-oriented science and technology projects of A City Science and Technology Bureau were post-evaluated. Due to the complexity and professionalism of science and technology projects, a panel of ten experts in the field was invited to score the secondary indicators for the post-evaluation, and then a comprehensive evaluation was conducted based on the scoring results.

4.1 Project Overview

The project was selected from the science and technology plan project of A City Science and Technology Bureau, titled Catalytic Treatment Technology Development Project for Typical Air Pollutants, which was established in 2017 and concluded in 2019. The project has completed the contents of the contract, while the acceptance procedure meets the requirements. According to the characteristics of the gas source of the treated waste gas, the development of the purification process and system integration were carried out, and the task of building the catalyst production line was completed. The removal efficiency of pollutants is greater than 98%, providing an operable catalytic purification technology solution and system for the treatment of air pollutants. Through the market application of the technology to achieve the sales revenue target, the project products are still in the domestic application, the market potential is large. NOx and VOCs are very toxic and have a serious impact on the surrounding environment and the health of the operators. The project will treat the organic waste gas and discharge it after meeting the standard, which improves the environment for people to work and live, and has a positive meaning for workers and the surrounding environment. Apply for 2 invention patents, publish 2 academic papers, and complete industrial demonstration projects to promote to industrial enterprises for application.

Table 8: Typical air pollutant catalytic treatment technology development project secondary index score and cloud figure characteristics table.

Indicators	1	2	3	4	5	6	7	8	9	10	[Ex, En, He]	Weights
A11	100	100	100	100	100	100	100	100	100	100	(100.00,0.00,0.00)	0.7500
A12	100	100	100	100	100	100	100	100	100	100	(100.00,0.00,0.00)	0.2500
A21	90	88	89	92	87	89	93	86	89	90	(89.30,1.96,0.80)	0.5000
A22	87	86	85	89	92	96	85	87	89	86	(88.20,3.31,1.11)	0.5000
A31	90	92	95	91	89	95	91	88	90	88	(90.90,2.38,0.81)	0.5000
A32	89	88	85	86	84	87	86	82	81	86	(85.40,2.41,0.69)	0.5000
A41	75	78	76	79	76	75	78	74	74	72	(75.70,2.13,0.37)	0.1429
A42	85	87	90	85	89	84	88	87	86	89	(87.00,2.01,0.15)	0.4286

A43	90	92	89	88	92	87	89	90	91	95	(90.30,2.21,0.69)	0.4286
A51	89	87	90	93	94	88	92	86	88	87	(89.40,2.86,0.75)	0.0883
A52	82	86	79	87	77	80	74	76	81	80	(80.20,3.81,1.53)	0.2395
A53	89	91	86	88	87	91	90	89	87	87	(88.15,1.88,0.61)	0.2395
A54	88	87	86	89	90	91	86	87	89	88	(88.10,1.65,0.17)	0.4327

4.2 Application of the index system

Determine secondary metric cloud model: According to the specific completion of the above projects and the sustained impact brought about by the statistical collation of questionnaires, the experts' scoring was summarized, and the cloud numerical characteristics of each secondary index were calculated according to the inverse cloud algorithm formula 5-9, as shown in Table 8, with 1-10 representing the ten scoring experts.

Determine the first-level indicator cloud model: The numerical features of the cloud model for the first-level indicators are calculated based on the data in Table 8 using Equation 10. The specific feature values are shown in Table 9.

Table 9: Typical air pollutant catalytic treatment technology development project level 1 index scores and cloud figure characteristics table.

Indicators	[Ex, En, He]	Weights
A1	(100.00,0.00,0.00)	0.0557
A2	(88.75,2.63,0.95)	0.1263
A3	(88.15,2.39,0.75)	0.2200
A4	(86.80,2.11,0.42)	0.2200
A5	(86.42,2.13,0.52)	0.3782

Determine the comprehensive evaluation cloud model: According to the data in Table 9, the numerical characteristics of the comprehensive evaluation cloud model were calculated using Equation 11, and the cloud numerical characteristics were, Ex=87.30, En=2.13, He=0.62.

4.3 Analysis of post-assessment results

The expected value Ex is the evaluation value of the project, and the expected value of this project is 87.3; the entropy value En represents the discrete degree of the evaluation, and its value is 2.13, and the evaluation range is concentrated; the super entropy value He represents the stable degree of the evaluation, and its value is 0.62, which is a relatively small value, indicating that the evaluation value is stable.

The blue, cyan, green, yellow and magenta in Figure 1 constitute the standard cloud diagram, which means the failure, unsuccessful, basic success, comparative success and complete success of the project, respectively. From the comprehensive evaluation cloud diagram, it can be seen that the black part is the evaluation cloud diagram of a typical air pollutant catalytic treatment technology development project. Comparing with the standard cloud diagram, it is easy to find that the black cloud is located between 80-90, which is close to 90, and it can be known that the black cloud is located between fully successful and relatively successful, which is closer to the more successful yellow cloud. Therefore, the evaluation level of this project is relatively successful.

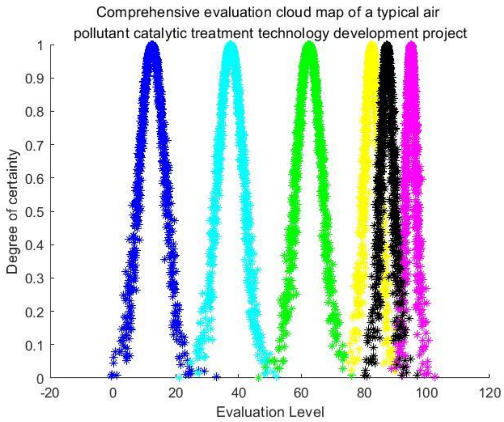

Figure 1: Comprehensive evaluation cloud of a typical air pollutant catalytic treatment technology development project

The post-evaluation of the technology development-based project selected for this paper shows that the post-evaluation results of the project were relatively successful. The results in terms of economic benefits were more outstanding, mainly because the project products were applied in China. The score is lower in terms of talent cultivation, because the project was undertaken by enterprises, which focused more on the practical value of the results compared to cultivating talents, so the cultivation of talents was neglected. Therefore, in the future, enterprises should pay attention to the cultivation of scientific and technological talent in science and technology projects. On the whole, the project implementation is good.

5 Conclusions and recommendations

According to the characteristics of technology development science and technology projects, the evaluation index system is designed, and the index weights are determined by expert consultation method and hierarchical analysis method. The cloud model is introduced into the post-evaluation of science and technology projects to conduct a comprehensive evaluation analysis and provide a new method to the post-evaluation of science and technology projects. The feasibility of the model is determined by bringing actual science and technology projects into the index system. Through the above study, the following recommendations are made for the post-assessment of science and technology projects.

The country should develop a post-evaluation system of science and technology projects suitable for China's national conditions, and gradually promote the evaluation of science and technology projects to legalization and standardization.

Science and technology management departments should adjust management issues according to the evaluation results in a timely manner, and should feedback the evaluation results to the project undertaking units to indirectly improve the management and decision-making implementation capabilities of the project undertaking units.

Scientific research project undertakings should conduct self-evaluation and identify problems for undertaking projects, and have better measures to cope with problems when undertaking science and technology projects in the future. At the same time, appropriate incentives should be provided to the researchers to make them motivated.

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