# Research on Evaluation of Scientific and Technological Innovation Ability Based on AHP-EWM-TOPSIS Method

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**Abstract.** Thoroughly assessing a company's ability to innovate technologically is essential for ensuring that the company can maintain a competitive edge in the constantly evolving market. At present, there is a limited availability of dynamic quantitative assessment and analysis methods for evaluating enterprises' scientific and technological innovation capabilities. This scarcity poses challenges for companies engaging in scientific and technological innovation activities. To address this issue, considering the current state of science and technology innovation in Chinese enterprises, this study develops an evaluation index framework for assessing innovation capabilities. The framework encompasses two key dimensions: innovation input and innovation output. Additionally, a comprehensive approach utilizing Analytic Hierarchy Process (AHP) and Entropy Weight Method (EWM) is employed to calculate the weights for each index. This ensures that the evaluation results incorporate both expert opinions and experiences while also accounting for the inherent distribution patterns within the data. Subsequently, the enhanced Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is applied to perform a dynamic quantitative evaluation of enterprises. This method facilitates a detailed analysis of the specific evolution of technological innovation capabilities for each year. Finally, the paper takes the power grid enterprise in L City as an example for application research. Through in-depth analysis of the evaluation results, the advantages and improvement space of the power grid enterprise in L City in the process of scientific and technological innovation are revealed, and reasonable promotion and improvement suggestions are put forward for the enterprise. The results show that the evaluation research method can provide effective suggestions and valuable references for the development path setting and work layout of technological innovation in enterprises.
CCS CONCEPTS • Applied computing • Enterprise computing • Enterprise computing infrastructures

**Keywords:** Scientific and technological innovation ability, AHP, EWM, TOPSIS, Innovation ability evaluation

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## 1 Introduction

Scientific and technological innovation serves as the primary driving force propelling the social and economic development of the country [1]. In recent years, provinces and cities have increasingly prioritized scientific and technological innovation, leading to improvements in both the capacity and level of innovation. Despite notable progress, there remains a scarcity of dynamic quantitative evaluation and analysis concerning scientific and technological innovation capabilities. This scarcity poses significant challenges to targeted innovation initiatives across various provinces and cities. Hence, there is a pressing need to research the evaluation model for scientific and technological innovation capabilities. This involves designing an evaluation algorithm based on big data, enabling dynamic quantitative assessments of scientific and technological innovation capabilities. Such evaluations are essential to provide effective recommendations and valuable insights, guiding the formulation of technological innovation development strategies and operational frameworks for enterprises in different provinces and cities.

Researchers both domestically and internationally have extensively explored the evaluation of scientific and technological innovation capabilities, primarily concentrating on the development of evaluation index systems and algorithms. In the realm of scientific and technological innovation ability index systems, Cheng et al. conducted a comprehensive analysis, encompassing eight dimensions: planning and commitment, marketing, innovation, research and development, operations, knowledge and skills, information and communication, and external environment [2]. Liping Xu et al. organized the index system into six categories: innovation input capacity, research and development prowess, production capabilities, innovation output, marketing proficiency, and management skills [3]. Approaching the subject from a different angle, Hongyun Luo et al. established an index system based on five facets: creativity generation, research and development capabilities, pilot production, commercialization proficiency, and promotion of new technology standards [4]. Liming Xiao's focus was on constructing an index system incorporating five aspects: the entire innovation process, innovation inputs, outputs, diffusion, and the innovation environment [5]. While these evaluation index systems provide valuable frameworks, some indices overlap across different systems, leading to complexity in the evaluation process. Therefore, the current approach to constructing evaluation index systems should not only emphasize perfection and detail but also prioritize alignment with actual business contexts. This alignment ensures a more precise assessment of scientific and technological innovation capabilities.

The evaluation of scientific and technological innovation capability is a complex and crucial process, encompassing numerous factors and indicators. Once the evaluation index system is established, selecting the appropriate evaluation algorithm is paramount to obtaining accurate results. Currently, prevalent methods for evaluating scientific and technological innovation capabilities include the AHP [6,7], factor analysis [8,9], data enveloping analysis [10,11], and fuzzy comprehensive evaluation [12,13]. AHP breaks down intricate problems into manageable components through hierarchical comparison of evaluation indicators. However, it may lack objectivity due to subjective influences. Factor analysis demands extensive and precise observational data. Data enveloping analysis requires highly accurate and stable data and may be influenced by indicator selection. The fuzzy comprehensive evaluation method involves subjective determination of fuzzy mathematical parameters, potentially leading to evaluation result deviations. Regrettably, existing literature often fails to comprehensively consider both subjective and objective aspects in the analysis of scientific and technological innovation capability development. Integrating subjective and objective factors in a comprehensive manner is essential to achieving a more thorough and objective evaluation of scientific and technological innovation capabilities.

Building upon the aforementioned analysis, this study closely aligns with the current state of scientific and technological innovation in Chinese enterprises. It takes into account both the practical circumstances of enterprises and the insights of experts. Employing the AHP an evaluation index system for scientific and technological innovation capabilities is constructed, focusing on innovation input and innovation output. To ensure the scientific validity of weights, this paper employs two comprehensive weighting methods: AHP for subjective weighting and the EWM for objective weighting. These methods assign appropriate weights to each evaluation index. Subsequently, the TOPSIS comprehensive evaluation method is applied to assess scientific and technological innovation capabilities, leading to more comprehensive evaluation results. To validate the effectiveness of the evaluation algorithm, this study analyzes the technological innovation progress of power grid enterprises in L city. Through a holistic evaluation of the enterprise's scientific and technological innovation capabilities, it identifies innovation strengths and areas for improvement. Tailored strategies and recommendations are then proposed, aiming to assist the enterprise in enhancing its scientific and technological innovation capabilities and reinforcing its competitive market position.

# 2 Formulation of Evaluation Index System for Scientific And Technological Innovation Capability

## 2.1 Evaluation dimension and evaluation index system

**Table 1:** Index Framework for Scientific and Technological Innovation Capability

| Target layer | Criterion layer | Subcriterion layer | Factor level |
|---|---|---|---|
| Scientific and technological innovation ability | Innovation input | R&D investment intensity | Proportion of R&D investment |
| | | | Growth rate of R&D investment |
| | | Core department input intensity | Proportion of R&D investment in core departments |
| | | | Growth rate of input in core sectors |
| | | Collaborative innovation | Number of scientific and technological cooperation projects |
| | | | New power system research and development investment |
| | Innovation output | Scientific and technological achievements | Patent ownership |
| | | | Number of scientific papers |
| | | | Coefficient of national science and technology achievement award |
| | | Innovation benefit | Proportion of technological innovation |
| | | | R&D input-output ratio |

In the comprehensive assessment of scientific and technological innovation capabilities, the choice of evaluation indices is a pivotal step. The selection of suitable evaluation indices directly impacts the accuracy and credibility of the evaluation outcomes [14]. Thus, it is crucial to accurately choose appropriate evaluation indices when developing the evaluation index system and conducting subsequent research.

Drawing from an analysis of factors influencing enterprises' scientific and technological innovation capabilities, this study closely aligns with the current state of scientific and technological innovation in Chinese enterprises, adhering to relevant national guidelines and standards. The approach integrates expert opinions and real-world contexts, while upholding principles of scientific rigor, representativeness, comparability, operability, directionality, and versatility. Utilizing the AHP, the comprehensive evaluation index system was structured into two tiers: innovation input and innovation output. The resulting evaluation index system for scientific and technological innovation capabilities is presented in Table 1.

### 2.2 Meaning of each evaluation index

In the research process of evaluating and analyzing scientific and technological innovation capabilities, apart from the aforementioned tasks, it is essential to further define the characteristics, practical significance, and specific calculation methods for each evaluation index. Prior to evaluating the subject, the collected data related to the evaluation indices must undergo preprocessing to ensure their comparability and consistency within the evaluation system.

1. Innovation Input. Innovation input encompasses the overall resources, including human resources, financial investments, materials, and other factors, allocated by enterprises for conducting scientific and technological innovation activities. The intensity of R&D investment serves as a measure of the capital and resource commitment made by enterprises to scientific and technological innovation. The investment intensity in core departments indicates the depth and strength of R&D efforts in strategic core areas. Collaborative innovation signifies the capability and level of joint innovation among enterprises, universities, research institutes, and external entities.

2. Innovation Output. Innovation output represents the culmination of diverse accomplishments and the economic and social benefits garnered by enterprises through scientific and technological innovation endeavors. Within this scope, scientific and technological achievements encompass the quantity, quality, and innovative nature of scientific and technological accomplishments, reflecting the tangible output and quality standards achieved by enterprises in the realm of scientific and technological innovation. Innovation benefits denote the aggregate of economic and social advantages acquired by enterprises through technological innovation.

## 3 Integrated Evaluation Algorithm for Scientific and Technological Innovation Capability

### 3.1 Data Sources

In the contemporary landscape of enterprise advancement, scientific and technological innovation holds a pivotal position. It is not merely an essential factor driving the ongoing advancement of businesses but also plays a strategically significant role in the sustainable development of the national economy and the preservation of national competitive advantages. In this context of The Times, this paper chooses the power grid enterprise in L city as the research object, aiming to explore its experience and practice in scientific and technological innovation, and provide beneficial enlightenment for promoting a wider range of industrial scientific and technological innovation.

## 3.2 Evaluation model

In the established evaluation index system, each evaluation index carries distinct meanings, practical functions, and impacts. Therefore, setting the weight coefficient for each index is crucial to ensure accurate evaluation results. This process forms the foundation and is a key aspect of evaluation analysis, directly impacting the precision of the comprehensive assessment. This paper integrates the AHP for subjective weighting and the EWM for objective weighting. Building upon this foundation, the TOPSIS evaluation method is employed to comprehensively consider extreme values of evaluation indicators and overall evaluation values. This approach establishes a more scientific and effective model for evaluating scientific and technological innovation capabilities. It offers robust decision support and guidance for enhancing technological innovation within L power grid enterprises.

### 3.2.1 Weight calculation of evaluation indicators.

1. AHP calculates subjective weights

AHP is a comprehensive decision analysis technology, its core idea is to decompose complex problems into several relatively separate level elements, and then compare them step by step. Unlike the traditional expert scoring method, this approach not only captures the profound insights of experts but also mitigates subjective errors through consistency testing. It mainly includes the following steps: First, construct the judgment matrix at all levels. The "1-9 scale method" was introduced to quantitatively judge each factor, and the judgment matrix was constructed by comparing the relative importance degree of each layer of indicators. Next, the indicator weight vector is established. The eigenvalue method is employed to compute the maximum eigenvalue of the judgment matrix, and the normalized outcome is considered as the weight vector for each factor. Finally, the consistency test is carried out. In this paper, the consistency ratio $C_R$ is chosen as the standard of consistency test. If the consistency ratio $C_R < 0.1$, it indicates that the matrix has consistency. If inconsistent, revisit the comparison matrix or gather expert opinion until consistency is achieved.

2. EWM calculates objective weights

EWM primarily computes weights based on the information content within the evaluation indices. A larger information entropy value of an evaluation index signifies a greater amount of information contained, leading to higher weight in the calculation. The process typically involves the following steps: Within the comprehensive evaluation system, the evaluation indicators often have different meanings and natures, resulting in varying quantitative levels. To ensure precise evaluation outcomes, it is essential to standardize data processing to balance the impact of each index. In this paper, the min-max calculation method is used to distribute the data between [0,1] by linear transformation. Then, the information entropy of each index is calculated. $P_{ij}$ is used to represent the contribution degree of $A_i$ in $i$ evaluation scheme under $j$ evaluation index. Lastly, the weights for each index are determined. The information entropy of each evaluation index is employed to indicate the collective contribution of all evaluation criteria to that specific index. The weight coefficient for each evaluation index is then calculated accordingly. A higher weight coefficient value indicates a more significant influence of the evaluation index on the overall comprehensive assessment.

3. The comprehensive weight is calculated using the linear weighting method

In this paper, the linear weighting method is used to calculate the comprehensive weight of each index, which not only reflects the profound insight of experts' experience, but also effectively reduces the one-sided influence of a single weighting method.

Suppose the subjective weight calculated by AHP is $w_i^{'}$ and the objective weight calculated by EWM is $w_i^{''}$ , then the comprehensive weight obtained by AHP-EWM is

$$w_i = \alpha w_i^{'} + (1-\alpha) w_i^{''} \quad (1)$$

After comprehensive consideration of various aspects, this paper finally selects the relative importance coefficient $\alpha = 0.5$ , that is, experts' experience and objective data information are equally important. The specific results are shown in Table 2.

After conducting the aforementioned calculations and analysis within the established evaluation index system, it has been determined that the key factors significantly influencing the scientific and technological innovation capabilities of enterprises include the proportion of R&D investment in core departments, the percentage of technological innovation, and the allocation of funds towards R&D activities. By prioritizing the enhancement of these pivotal indicators, enterprises can bolster their scientific and technological innovation capacities, enhance market competitiveness, and attain sustainable development. This, in turn, enables them to make valuable contributions to both their own growth and socio-economic development.

**Table 2:** Comprehensive weighting value for each evaluation index.

| Factor level | Subjective weight value | Objective weight value | Combined weight value |
|---|---|---|---|
| Proportion of R&D investment | 0.1435 | 0.0898 | 0.1167 |
| Growth rate of R&D investment | 0.0287 | 0.0695 | 0.0491 |
| Proportion of R&D investment in core departments | 0.3539 | 0.0966 | 0.2252 |
| Growth rate of input in core sectors | 0.0708 | 0.0537 | 0.0622 |
| Number of scientific and technological cooperation projects | 0.0582 | 0.0514 | 0.0548 |
| New power system research and development investment | 0.0116 | 0.1066 | 0.0591 |
| Patent ownership | 0.0899 | 0.0855 | 0.0877 |
| Number of scientific papers | 0.0272 | 0.1075 | 0.0674 |
| Coefficient of national science and technology achievement award | 0.0495 | 0.0779 | 0.0637 |
| Proportion of technological innovation | 0.1389 | 0.1344 | 0.1366 |
| R&D input-output ratio | 0.0278 | 0.1271 | 0.0775 |

### 3.2.2 Comprehensive evaluation

TOPSIS method is a multi-factor evaluation method. Its core idea is to comprehensively analyze the evaluation value of enterprises under different indicators by comparing the evaluation object with its ideal performance on each indicator. Based on the traditional TOPSIS method [15], this paper makes an improvement to analyze in detail the specific development of technological innovation capability of enterprises in each year. It mainly includes the following steps: First, the original indicator data collected is carried out forward and standardized preliminary processing, and all types of evaluation indicators are uniformly transformed into extremely large indicator data. In the next step, the combined weight vector derived from the AHP-EWM analysis is employed to assign weights to the evaluation matrix, resulting in a comprehensive evaluation matrix for the technological innovation capabilities of enterprises for each year. Utilizing this matrix, the positive and negative ideal solutions for the evaluation indicators are determined. Subsequently, the relative proximity degree between the sub-criterion level indices and the positive and negative ideal solutions for each enterprise in every year is calculated using the factor level indices. This calculated value serves as the index, which is further re-weighted and utilized to compute the relative proximity degree. Consequently, the comprehensive evaluation value of the target level is ultimately derived. The TOPSIS method, by representing the distance between each evaluation object and the ideal solution, yields higher comprehensive evaluation values for greater distances, indicating superior scientific and technological innovation capabilities.

$$C_i = \frac{\sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}}{\sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2} + \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}} \tag{2}$$

## 3.3 Analysis of evaluation results

The comprehensive evaluation value and ranking of technological innovation capability of power grid enterprises in L City from 2019 to 2023 are shown in Table 3 and Table 4. First of all, it can be observed from Table 3 that power grid enterprises in L City have achieved steady growth in the field of scientific and technological innovation. Especially in 2022, the company increased its investment in research and development and made significant progress. Over time, the company's innovation achievements have increased, especially in 2023, showing that the company's research and development efforts have been widely recognized and practical applications. The improvement of the comprehensive evaluation value indicates that the enterprise has made a significant breakthrough in the overall scientific and technological innovation. Secondly, it can be observed from Table 4 that power grid enterprises in L City have made remarkable progress in R&D investment intensity, core sector investment intensity, collaborative innovation, scientific and technological achievements and innovation benefits. Especially in 2023, all indicators have reached a good level, showing that enterprises have made remarkable achievements in research and development investment and the application of scientific and technological achievements. This significant improvement is mainly due to the following key factors: First, enterprises have increased investment in research and development, increased the allocation of research and development facilities and talent, and improved innovation investment. Secondly, enterprises have strengthened close cooperation between internal and external departments, promoted collaborative innovation, and made scientific and technological achievements more widely applied. In addition, enterprises have adopted a more flexible and efficient innovation management model, which has improved the efficiency of innovation. These measures have jointly promoted the improvement of the enterprise's scientific and technological innovation ability and consolidated its competitive advantage in the industry.

**Table 3:** Comprehensive evaluation value and ranking of scientific and technological innovation ability

| Year | Innovation input | | Innovation output | | Synthesis | |
|---|---|---|---|---|---|---|
| | $C_i$ | Rank | $C_i$ | Rank | $C_i$ | Rank |
| 2019 | 0.8478 | 3 | 0.2929 | 4 | 0.5726 | 4 |
| 2020 | 0.6577 | 5 | 0.0000 | 5 | 0.0000 | 5 |
| 2021 | 0.6930 | 4 | 0.5095 | 3 | 0.7131 | 3 |
| 2022 | 1.0000 | 1 | 0.8153 | 2 | 0.9286 | 2 |
| 2023 | 0.9339 | 2 | 1.0000 | 1 | 1.0000 | 1 |

**Table 4:** Specific development of scientific and technological innovation capability

| Year | R&D investment intensity | | Core department input intensity | | Collaborative innovation | | Scientific and technological achievements | | Innovation benefit | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $C_i$ | Rank | $C_i$ | Rank | $C_i$ | Rank | $C_i$ | Rank | $C_i$ | Rank |
| 2019 | 0.0217 | 5 | 1.0000 | 1 | 0.4627 | 4 | 0.2896 | 4 | 0.0000 | 4 |
| 2020 | 0.1788 | 4 | 0.6440 | 3 | 0.0000 | 5 | 0.1908 | 5 | 0.0000 | 4 |
| 2021 | 0.5235 | 3 | 0.3251 | 5 | 0.6730 | 3 | 0.4478 | 3 | 0.1822 | 3 |
| 2022 | 0.9486 | 2 | 0.716 | 2 | 0.8904 | 2 | 0.5497 | 2 | 1.0000 | 1 |
| 2023 | 1.0000 | 1 | 0.5673 | 4 | 1.0000 | 1 | 1.0000 | 1 | 0.9868 | 2 |

## 4 Conclusions

This study offers a comprehensive analysis of the current state of technological innovation development among Chinese enterprises, establishing an evaluation index system for technological innovation capability based on both innovation input and output dimensions. To ensure the scientific validity of the weightings, a combination of AHP and EWM is employed for the evaluation and analysis. Subsequently, the TOPSIS comprehensive evaluation method is utilized to assess the scientific and technological innovation capabilities, providing robust and insightful comprehensive evaluation results for enterprises. To validate the effectiveness of the algorithm, this research conducts a comprehensive assessment of scientific and technological innovation abilities using power grid enterprises in L city as a sample. The study reveals the strengths and areas for improvement within these enterprises. These research findings serve as a crucial foundation for enterprises in formulating strategies and decisions for their scientific and technological innovation development. Furthermore, they offer valuable insights and reference points for enterprises in other regions.

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