Design and optimization of research performance allocation scheme based on TOPSIS entropy weight Method

Chenxuan Song, Zhaoqing Zhu, Yuantong Kong, Dongsheng Gao, Tong Fu, Dongping Sheng, Chun Su*

Changzhou Institute of Technology, Changzhou, China

ABSTRACT

Technology is the foundation of national strength, and technological innovation is the strategic support for improving social productivity and comprehensive national strength. It is the driving force for promoting social progress. Higher education institutions occupy a core position in the national innovation system, and their scientific research evaluation is not only the core strategy for controlling university scientific and technological activities, but also plays a crucial role in the top-level planning and resource allocation of higher education. For the convenience of analyzing the problem, we first use principal component analysis to evaluate the annual scientific research achievement rewards of employees; Using the entropy weight method again, TOPSIS scores the national level science and technology awards, national standards/specifications, provincial or industry standards/specifications, publication of works, number of current graduate students, newly approved national level projects, Chinese core, academic part-time jobs, and horizontal funding for employees. In addition, the entropy weight method is first used to analyze the weight of various indicators for each team. Each team selects 20 achievements for the school's annual performance evaluation ranking, and the total prize pool is allocated according to the ranking. Then, based on the number and weight of individual submitted works, a tiered allocation is carried out to reasonably calculate the performance distribution results for each member of the team. To achieve the optimal overall performance of the target group while balancing internal balance and fairness, the given formula is first used to quantitatively evaluate the annual individual achievements of each member, and the overall technological achievement score of the team is summarized. Then, based on these data, a performance allocation optimization model is constructed, and a genetic algorithm is used to set reasonable constraints to ensure fairness, motivation, and relative balance within the team, in order to develop a scientific and fair performance allocation plan and maximize the overall performance of the team.

Keywords: Scientific Research Performance Allocation, Principal Component Analysis, TOPSIS Of Entropy Weight Method, Optimization Model, Genetic Algorithm

1 INTRODUCTION

Performance evaluation in the field of scientific research is a complex research and policy work in the daily management of university researchers. The Ministry of Science and Technology, the Ministry of Education, the Chinese Academy of Sciences, the Academy of Engineering and other science and technology management departments have been taking measures to promote the transformation and output of scientific and technological achievements, the construction of scientific research ethics, reduce reliance on papers, and increase the income of scientific and technological personnel [1]. The relevant departments have issued documents such as the Interim Measures for Performance Evaluation of Central level Scientific Research Institutions, the Implementation Plan for Deepening Science and Technology System Reform, and the Opinions of the Central Committee of the Communist Party of China and the State Council on Deepening Science and Technology System

Reform and Accelerating the Construction of the National Innovation System. At the same time, the performance evaluation policies of various research institutions are constantly being updated, which to some extent affects the work plans and task priorities of researchers for the next year [2]. The aim of this study is to investigate the factors that influence the formulation of performance plans, and to conduct modeling and data analysis to develop appropriate performance allocation plans for technology personnel.

2 MATHEMATICAL MODEL

2.1 Model assumptions

Based on the actual situation and comprehensive analysis, in order to avoid unnecessary or relatively small factors that may interfere with the accuracy and rationality of the model, the following assumptions are proposed:

(1) The factors that affect performance are only the various indicators given in the attachment;

(2) The functions, research level, and professional title level of each employee are commensurate;

(3) No significant changes in national policies.

2.2 Model building

2.2.1 Performance allocation plan based on a certain total bonus

Firstly, standardize the data and use principal component analysis to transform multiple indicators into a few comprehensive indicators, evaluating the achievement rewards of each employee. Afterwards, the entropy weight method is used to obtain the weights of each indicator. Based on this, TOPSIS is used to calculate the score, obtain the comprehensive score, and sort it. Finally, bonuses are allocated according to the ranking situation [3].

(a) Component analysis method

Standardize the data and establish a principal component analysis model to objectively evaluate employee achievement rewards. Principal Component Analysis (PCA) is a multivariate statistical method that uses the "dimensionality reduction" approach to transform multiple indicators into a few comprehensive indicators, which are known as principal components. Each principal component is a linear combination of the original variables, independent of each other, and retains most of the information of the original variables [4]. The essence of this method is based on the correlation of the original variables, seeking comprehensive alternative solutions for related variables, and minimizing information loss during the transformation process.

Calculate the covariance matrix R based on the standardized data set:

$$R = \left(r_{ij}\right)_{n\times n} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \tag{1}$$

Calculate the eigenvalues of matrix R, $\gamma_1 \geq \gamma_2 \geq \cdots \geq \gamma_n \geq 0$, And corresponding feature vectors, $u_1, u_2, \cdots, u_n$, Compose n new indicator variables from feature vectors:

$$\left.\begin{aligned} y_1 &= u_{11}\bar{x}_1 + u_{21}\bar{x}_2 + \cdots + u_{n1}\bar{x}_n \\ y_2 &= u_{12}\bar{x}_1 + u_{22}\bar{x}_2 + \cdots + u_{n2}\bar{x}_n \\ &\vdots \\ y_n &= u_{1w}\bar{x}_1 + u_{2n}\bar{x}_2 + \cdots + u_{nn}\bar{x}_n \end{aligned}\right\} \tag{2}$$

Where, y_1 is the first main component, y_2 is the first main component, ..., y_n is the nth main component. Contribution b_j of each main componenty_j and accumulated contribution rate α_p of $y_1, y_2, \dots y_n (p \leq n)$.

$$b_j = \frac{\lambda_j}{\sum_{k=1}^{n} \lambda_k} (j = 1,2,\cdots,n) \tag{3}$$

$$\alpha_p = \frac{\sum_{k=1}^{p} \lambda_k}{\sum_{k=1}^{n} \lambda_k} (p \leq n) \tag{4}$$

(a) TOPSIS entropy weighting method

First, remove the standardized dimensions of the data, then use the entropy weight method to obtain the weights of each indicator, and finally allocate bonuses based on the weight of each employee [5].

The traditional TOPSIS method (approximate ideal ranking method) uses multi-objective decision-making to find the optimal and worst solutions among limited options, where the optimal solution satisfies the condition of being close to the optimal solution while being far from the worst solution. The determination of the weights of each indicator in the traditional TOPSIS method is highly subjective, while the use of entropy weight method can effectively solve the problem of human subjectivity [6].

The TOPSIS entropy weighting method is an objective weighting method that draws on the theory of information entropy and improves the classic TOPSIS algorithm. Assuming there are m samples and n indicators, the algorithm steps are as follows:

(1) Construct an evaluation matrix $\{X_{ij}\}$ with m rows and n columns, where X_{ij} represents the ith indicator of the jth sample;

(2) Normalize the range of the evaluation matrix, and the formulas for negative and positive indicators are:

$$Z_{ij} = \begin{cases} \dfrac{X_j - X_{min}}{X_{max} - X_{min}} \\ \dfrac{X_{max} - X_j}{X_{max} - X_{min}} \end{cases} \tag{5}$$

(3) Calculate the entropy weight of the th indicator using the formula:

$$e_j = -\frac{1}{\ln m} \sum_{i}^{m} p_{ij} \ln p_{ij} \tag{6}$$

(4) Calculate the weight of each indicator, $d_j = 1 - e_j$ is called the information redundancy value. The formula is:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{7}$$

(5) Calculate the comprehensive score for each sample:

$$s_i = \sum_{j=1}^{m} w_j x_{ij}, i = 1,\cdots,n \tag{8}$$

(6) The basic idea of TOPSIS method is to construct a normalization matrix after the original data is trended, calculate the difference between the evaluation object and the optimal and worst vectors, and measure the difference between the evaluation object [7].

The basic steps of the TOPSIS method are;

(1) Normalize the range of the evaluation matrix, and the formulas for negative and

positive indicators are:

$$Z_{ij} = \begin{cases} \frac{X_j - X_{min}}{X_{max} - X_{min}} \\ \frac{X_{max} - X_j}{X_{max} - X_{min}} \end{cases} \tag{9}$$

(2) Calculate optimal and worst solutions

$$\text{Optimal solution: } (Z_1^+, Z_2^+, \ldots, Z_m^+) \tag{10}$$

$$\text{Worst solution: } (Z_1^-, Z_2^-, \ldots, Z_m^-) \tag{11}$$

(3) Calculate the difference between each evaluation indicator and the optimal and worst vectors

$$D_i^+ = \sqrt{\sum_{j=1}^{m} w_j A = (Z_j^+ - z_{ij})^2}, D_i^- = \sqrt{\sum_{j=1}^{m} w_j (Z_j^- - z_{ij})^2} \tag{12}$$

Where, w_j is the weight (importance) of the j^{th} attribute.

(4) Calculate the closeness between the evaluation object and the optimal solution

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{13}$$

Where, the larger value C_i, the better the evaluation object is

2.2.2 Personal performance allocation model

Each team is required to submit a maximum of 20 cumulative achievements for performance evaluation, allocate the total reward pool based on the evaluation score ranking, and then calculate the performance allocation results for each member in each team [8]. This work firstly uses the entropy weight method to calculate the weights of various evaluation indicators for each team. Based on the calculated four weights, select the 20 projects to submit. Based on the number of projects submitted by each team member, evaluate and allocate them in a step-by-step manner.

The entropy weighting method is an objective and uncertain method for determining the weights of various indicators, which can be used to estimate calculating the weight of each indicator is essentially using the difference in indicator information to calculate its weight and entropy value The higher the coefficient of heterogeneity, the greater the importance or weight of evaluation, and the greatest contribution to the evaluation results [9].

According to the weight of indicators, each team selects 20 achievements for evaluation ranking, and ranks them based on team performance scores. For team performance (individual individual individual indicators), the first ranked team will receive a reward of 350000 yuan, the second ranked team will receive a reward of 280000 yuan, the third ranked team will receive a reward of 220000 yuan, and the fourth ranked team will receive a reward of 150000 yuan. Calculate the individual performance score of each team member in the team based on the weight of the indicators, and allocate individual bonuses. A weight analysis was conducted on 17 evaluation indicators reflecting the performance level of four teams, and the top 20 achievements with the highest value were selected for each team [10].

2.2.3 Optimization plan of performance allocation

A suitable performance allocation plan needs to be provided to optimize the overall performance of the target group, while balancing internal balance and fairness. This work firstly evaluates based on the formula, calculating the annual individual achievement score and the overall scientific and technological achievement score, in order to obtain the total performance of each team. Establish a planning model again and develop appropriate performance allocation plans through constraint conditions.

Firstly, the entropy weight method and TOPSIS were used to calculate the annual individual achievement score and the overall scientific and technological achievement score, as shown in Fig. 1 and Fig.2, respectively.

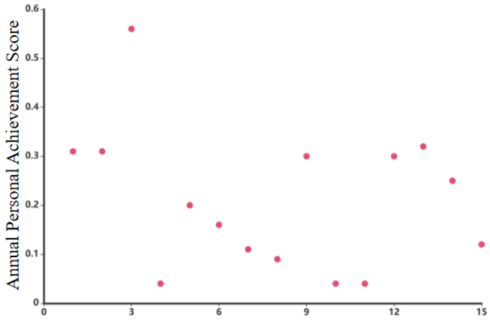


Fig.1: Annual Personal Achievement Score Chart

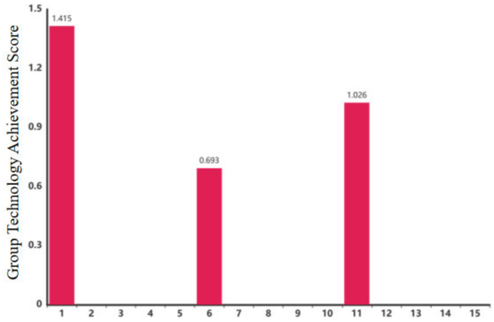


Fig.2: Score Chart of All Scientific and Technological Achievements

Substituting the annual individual achievement score and the overall technology achievement score into formula 13 to calculate the total performance of each team can obtain the overall performance table for each team. According to the calculation, the total performance score of the target team is 60010, the performance of other team 1 is 127510, and the performance of other team 2 is 45510. In order to ensure the highest performance of the target team, we establish a multi-objective planning model.

3 MODEL ANALYSIS

3.1 Solution of performance allocation plan

(a) Component analysis method for evaluating and solving

Based on the above method, the composition Matrix is obtained in Table 1.

Table 1: Composition Matrix Table

Composition Matrix			
Chinese Core Professional title	Main component		
	1	2	3
EI	-0.083	-0.006	0.182
Other intellectual property rights	-0.164	0.086	0.004
Publication of works	0.027	0.02	-0.312
Invention patent	-0.115	0.093	0.169
Provincial and ministerial level science and technology awards	0.116	0.166	0.197
Provincial or industry standards/specifications	-0.012	0.144	-0.119
SCI	0.129	0.179	0.095
National level science and technology awards	0.08	-0.229	-0.026
Talent Plan	-0.01	-0.274	0.132
Newly approved provincial and ministerial level projects	0.069	0.127	0.012
Newly approved national level projects	0.078	-0.07	-0.345
Number of current graduate students	0.042	-0.3	-0.095

Academic part-time jobs	0.077	0.188	-0.134
National standards/specifications	0.165	0.014	0.005
Horizontal transfer of funds/10000 yuan	0.129	-0.064	0.128
Chinese Core	0.087	-0.125	0.288
Professional title	0.146	0.071	0.056

The above table is a component matrix table, intended to illustrate the factor score coefficients (principal component loadings) contained in each principal component, used to calculate the component score, obtain the factor formula, and finally normalize it to obtain the factor weight score.

(b) TOPSIS Entropy weight method for solving

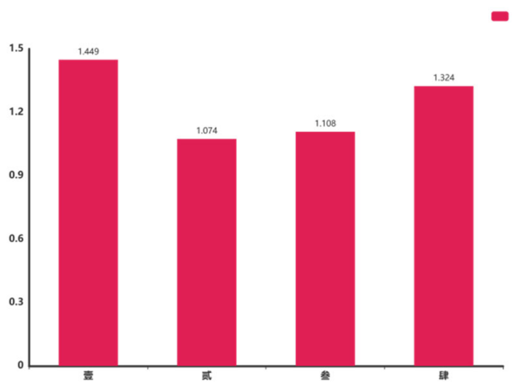
According to the above evaluation methods, the weight calculation results are shown in Table 2:

Table 2: Weight Calculation Results

Entropy weighting method			
Item	Information entropy valuee	information utility valued	weight (%)
term	0.607	0.393	8.96
National standards/specifications	0.738	0.262	5.975
Number of current graduate students	0.767	0.233	5.307
Academic part-time jobs	0.811	0.189	4.319
Talent Plan	0.78	0.22	5.01
Horizontal transfer of funds/10000 yuan	0.785	0.215	4.901
Newly approved provincial and ministerial level projects	0.75	0.25	5.707
Newly approved national level projects	0.623	0.377	8.615
Provincial or industry standards/specifications	0.782	0.218	4.975
Invention patent	0.659	0.341	7.788
Publication of works	0.617	0.383	8.747
Provincial and ministerial level science and technology awards	0.834	0.166	3.779
Other intellectual property rights	0.464	0.536	12.23
National level science and technology awards	0.888	0.112	2.553
SCI	0.871	0.129	2.933
EI	0.766	0.234	5.347
Chinese Core	0.875	0.125	2.855

3.2 Solution of personal performance allocation

According to the index weight calculation of entropy weight method, team bonus distribution and individual bonus distribution are obtained. This distribution method follows the principle of free distribution according to work, "more work, more pay", encourages hard work and creative labor to obtain corresponding rewards, and reflects the organic combination of fairness and efficiency. The final team performance score and individual performance score results are shown in Fig.3 and Fig.4.



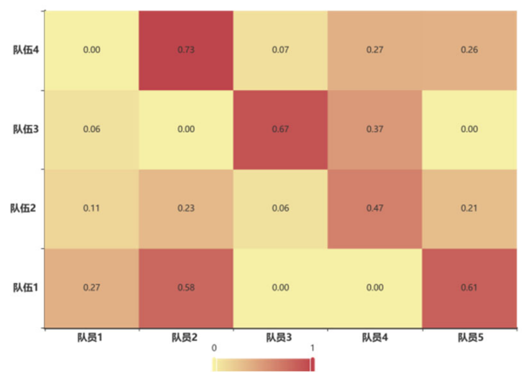


Fig.3: Team Performance Score Bar Chart *Fig.4: Individual Performance Score Heat Chart*

As can be seen from the graph, the performance reward system is linked to innovative achievements and is a specific practice and extension of the principle of distribution according to work. The correlation between performance reward and the three innovation processes (generation, use, and implementation) is significantly positively correlated. Through performance rewards, the aim is to stimulate the work enthusiasm, innovation, and teamwork spirit of scientific research staff, improve the overall efficiency and competitiveness of the organization, and achieve a win-win situation for both universities and employees.

3.3 Solution of Optimization plan of performance allocation

In order to maximize the performance of the target team, it is only necessary to make the performance score of the target team greater than that of the other team 1, so only the target team and other team 1 need to be considered. Then establish the following two objective functions:

objective function 1: $$maxP_1 = \sum_{i=1}^{5} P_{1i} \tag{14}$$

objective function 2: $$minP_2 = \sum_{i=1}^{5} P_{2i} \tag{15}$$

Where, P_1 represents the total performance of the target team, P_2 represents the total performance of other team 1, P_{1i} represents the performance of each person in the target team, P_{2i} represents the performance of each person in other team 1, and the performance calculation formula for each person is calculated according to formula 20.

We use genetic algorithm to solve the multi-objective programming model we have established. Introducing genetic algorithm to solve the optimal number of times, conducting combinatorial analysis, and ultimately achieving the optimal performance allocation plan for the target team.

Fitness function: measures the degree of superiority or inferiority of an individual in the solution space, usually the objective function of the problem to be optimized.

$$Fitness(x) = f(x) \tag{16}$$

Selection operation: The probability of selecting individuals based on their fitness is usually achieved using the roulette wheel algorithm:

$$P_i = \frac{f_i}{\sum_{j=1}^{N} f_j} \tag{17}$$

Where, P_i represents the probability of the ith individual, f_i represents the fitness of the ith individual, and N represents the number of individuals in the population.

Perform crossover and mutation:

$$a_i' = \begin{cases} 1 - a_i & \text{if } x_i \leq p_m \\ a_i & \text{if } x_i \geq p_m \end{cases} \qquad i \in \{1,2,3, \dots, n\} \tag{18}$$

Finally, stop based on constraint conditions

The constraint conditions are:

$$F'(X) = \begin{cases} F(X) & \text{X meet constraint conditions} \\ F(X) - P(X) & \text{X not meet constraint conditions} \end{cases} \tag{19}$$

The above are the basic principles and related formulas of genetic algorithm. Through reasonable selection and design, genetic algorithm can be used to solve various complex optimization problems.

Solved through genetic algorithm, one of the results showed that the total performance of the target team was 133701, while the total performance of the other team was 131931, which meets the requirements of the work. We use the data analysis software SPSSPRO for result calculation.

The performance allocation plan is shown in Table 3.

Table 3: Performance Allocation Table

Team category	Item	Professional title	Annual Individual Achievement Score	Individual Annual Total Performance	Team Annual Total Performance
Target Team	1	Positive height	0.3103	27502.19295	133701
	2	intermediate	0.3062	23002.38896	
	3	intermediate	0.5607	26736.26347	
	4	primary	0.0386	27259.14838	
	5	deputy senior	0.199	29201.00623	

4 CONCLUSION

The first and second problems adopt entropy weight method and TOPSIS based on entropy weight method, which avoids the subjectivity of the data, does not require objective function or testing, and well characterizes the comprehensive influence of multiple indicators. Taking into account the correlation of the original data, the optimal weight is more reasonable; Problem three uses a genetic algorithm model to increase the flexibility of the search process, and can converge to the optimal solution with a high probability, with good global optimization solving ability; When calculating the weight of indicators, all possible factors were considered, and the results were credible; The entropy weight method is suitable for quantitative data, but it is difficult to process qualitative data or difficult to quantify indicators. It is necessary to first convert qualitative indicators into quantifiable forms, and subjective factors may be introduced during the transformation process; The model in work three adopts genetic algorithm, which has a slow convergence speed and poor local search ability, without a definite termination criterion.

5 ACKNOWLEDGEMENTS

This work was Supported by Special Research Project on Teaching Reform(Grant No. 30120300100-23-yb-jgkt03).

REFERENCES

[1] Zhu, L. L., Yang, Z. P., & Yuan, H. (2007). Analysis and development of particles warm optimization. *Computer Engineering and Applications* , 43(5): 24-27.

[2] Zong, X. P., & Yao, Y. L. (2010). Using Q-Q and P-P plots to quickly test the statistical distribution of data. *Statistics & Decision*, 20: 101-112.

[3] Liu, H. R., & Tang, S. L. (2016). The equalization of basic medical services in jiangsu province based on TOPSIS method and RSR method. *Chinese General Practice*, 19(07): 819-823.

[4] Li, C. Y., & Huang, B. (2017). Using S-curve method to determine the life cycle of 3D printing technology. *Science & Technology and Economy*, 30(02): 025-037.

[5] Xiang, H. J. (2019). The Risks and Countermeasures of Accounting in the Context of Artificial Intelligence Era. *Accounting Learning*, 24: 011-020.

[6] Zhou, J., Sun, S. N., & Xu, D. H. (2020). Research on Marine Disaster Prevention and Control Strategies in Shandong Province Based on SWOT Analysis. *Transactions of Oceanology and Limnology*, 10(05): 264-288.

[7] Wu, Z., & Wu, H. L. (2021). UAV route planning based on the improved genetic algorithm. *Electronic Measurement Technology*, 44(24): 52-58.

[8] Fan, J. W., & Wu, P. S. (2024). Analysis of Optimizing the Heat Dissipation Capacity of Electrical Cabinets Based on DMAIC Improved Model. *Application of IC*, 41(02): 285-299.

[9] Feng, D., & Wang, L. L. (2024). Analysis of Investment Opportunities in China's Robot Industry Based on Porter's Five Forces Model. *Robot Industry*, 01: 111-119.

[10] Yu, J. W., Xie, W., & Zhang, L. W. (2024). Multi-objective optimization of hyper chaotic face image encryption based on particle swarm optimization algorithm. *Control Theory & Applications*, 18(02): 034-044.