# PSO-FAHP Model-based Comprehensive Performance Evaluation of New Research and Development Institutions

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**Abstract**
Scientific and technological innovation has become a powerful lever to promote economic transformation and development. As a new force to promote regional innovation and development, new R&D institutions have boosted regional economic transformation and upgrading to a certain extent. How to evaluate the integration of new R&D institutions scientifically is still a theoretical and practical problem, which needs to be explored and solved by the academic community. This paper introduces the perspective of market evaluation, focuses on the organizational characteristics of new R&D institutions, summarizes the factors influencing the performance evaluation of new R&D institutions through expert interview method, and obtains the weight of evaluation indicators based on PSO-FAHP model, and reconstructs the scientific and effective comprehensive performance evaluation system of new R&D institutions. In order to provide theoretical reference for the tracking evaluation and normative development of new R&D institutions.

***Keywords:*** *new R&D institutions; PSO-FAHP; the performance evaluation*

## 1. Introduction

After the first new R&D institution was born in 1996, it grew spontaneously with the support of local government for a long time, so there are few research results about new type of R&D institution. Only one related research result was published until 2002. During the 10 years from 2002 to 2011, the research result was only published 1-2 papers per year, and the research result reached the peak of 136 papers between 2019 and 2020. The research on new R&D institutions entered the stage of rapid development. Especially with the openness, digitization and platformization of technological innovation, innovation elements flow across industries, fields and regions, and the paradigm change of technological innovation development accelerates iteration [1]. New R&D institutions integrating innovation and industrial chains have broken down the geographical, organizational and technological barriers of traditional innovation activities, and become a powerful lever to promote basic and applied research.

With the continuous expansion of the development scale of new R&D institutions, the academic circles began to study the performance evaluation methods and models of new R&D institutions. According to the literature [2], 177 new R&D institutions in Guangdong province were analyzed from the perspective of Niche Ecostate-ecorole, and the core capability evaluation model was established. The entropy-mutation progression method was used for empirical analysis. The literature [3] emphasizes that in order to meet the construction needs, the Delphi method is integrated to design and build a performance evaluation index system, and ANP method is used for calculation. In one article [4], based on the operating mechanism of new R&D institutions and their influence on R&D activity performance, principal component analysis was adopted to construct a performance evaluation index model. Another paper [5] theoretically analyzed the relationship between R&D investment, government support, nature of organization and innovation performance, and took Guangdong Province as an example to build a regression model of the impact of different variables on innovation performance of new R&D institutions.

New R&D institutions break the boundary between organizations, release the vitality of innovation factors,


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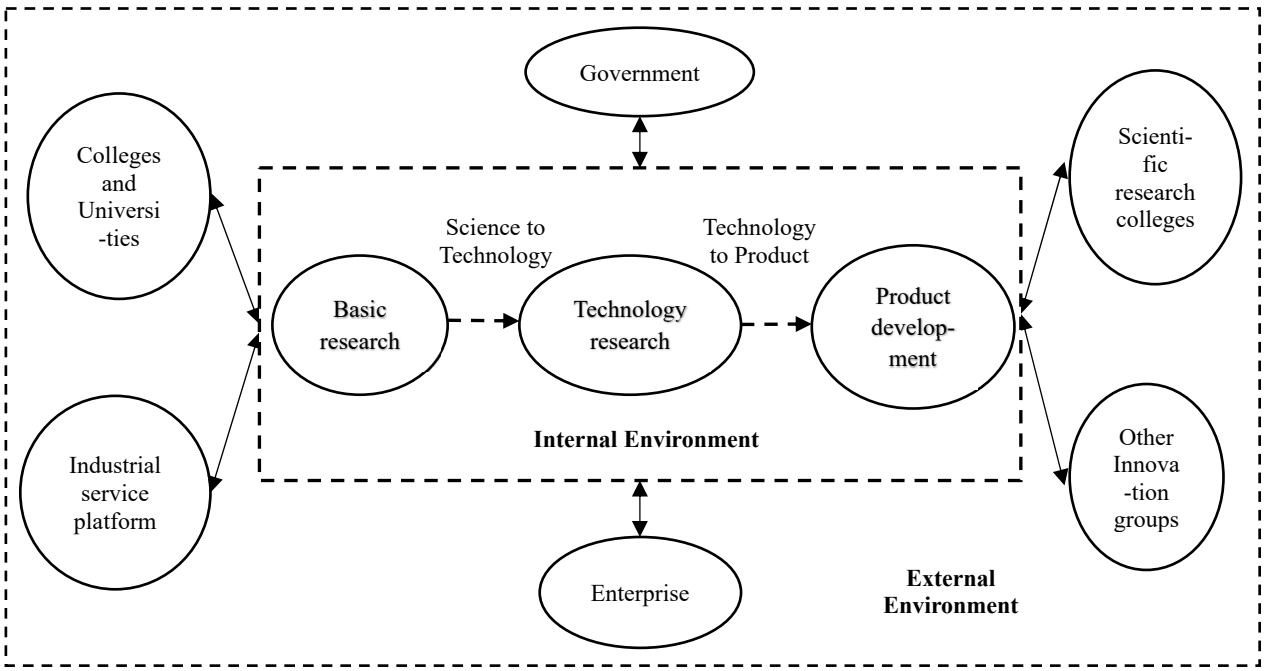
effectively connect basic frontier research, technology research and product development, give full play to the collaborative innovation ability of all subjects, and further promote the optimization and improvement of innovation environment [6]. On the one hand, pooling the resources of multiple subjects to carry out innovation activities, realizing the transformation from "science" to "technology" and then to "product", further stimulating the innovation passion of multiple subjects while improving the innovation ability; In addition, the embedding of basic innovation research activities accelerates the transmission of basic research to applied research and technology development, promotes the transfer and transformation of innovation achievements, realizes the industrialization of innovation, Bridges the valley of death between innovation and industrial development, and solves the problem of isolated island of scientific and technological innovation. At the same time, industrialization brings continuous injection of R&D funds, attracts more innovative forces and institutions to settle in, further optimizes the innovation environment, and thus forms a virtuous cycle of new R&D organization system: as shown in Table 1.

**Table 1** Operation mode diagram of new R&D organization system




In this paper, market evaluation is introduced on the basis of academic evaluation, discarding the single performance perspective of input and academic output, and focusing more on diversified investment subjects, management modernization and marketization. By combining qualitative and quantitative methods, a new comprehensive performance evaluation system of R&D institutions is reconstructed.

## 2. Evaluation System Construction

In the construction of the comprehensive performance indicator system of new R&D institutions, this study mainly sorted out and extracted relevant indicators based on the classic literature at home and abroad, and demonstrated the comprehensive performance evaluation indicator system in this paper by combining the results of expert interviews. In figure 1 based around construction, operation and management, market orientation, achievements, innovation, quality and social impact of six dimensions to build a new R&D effectiveness comprehensive performance evaluation index system, to ensure the scientific nature, rationality of index system building and operability, implement effective assessment of the new R&D organization effectiveness.

| Level indicators | Secondary indicators | Index content |
|---|---|---|
| Building infrastructure (A) | R&D input ($A_1$) | Number of investors ($a_{11}$) |
| | | R&D investment quota($a_{12}$) |
| | | Total value of available instruments and equipment($a_{13}$) |
| | Knowledge support ($A_2$) | Ownership of research achievements and patent standards($a_{21}$) |
| | | Number of high-level talents($a_{22}$) |
| | | Ownership of scientific and technological information and industrial data($a_{23}$) |

| | | |
|---|---|---|
| Operations management (B) | Crossover research ability ($B_1$) | The types and scope of subjects covered($b_{11}$) |
| | | Category and scope of application of research results($b_{12}$) |
| | Mechanism optimization level ($B_2$) | The modernization level of management system($b_{21}$) |
| | | Degree of marketization of operation mechanism($b_{22}$) |
| Market orientation (C) | Relevant subject recognition ($C_1$) | Recognition of research results by funded enterprises($c_{11}$) |
| | | Recognition of research results by other subjects($c_{12}$) |
| | Market Positioning($C_2$) | Is it consistent with the reality of the organization ($c_{21}$) |
| | | Is there a clear target customer($c_{22}$) |
| | Market competitiveness ($C_3$) | Market share of R&D products($c_{31}$) |
| | | Decline in market share of competitive products($c_{32}$) |
| Achievement transformation (D) | Industrialization level ($D_1$) | The number of core technologies and new products formed by the transformation of achievements($d_{11}$) |
| | | The number of deliverables($d_{12}$) |
| | Achievement transformation benefit ($D_2$) | The ratio of revenue from achievement transformation to revenue of the organization($d_{21}$) |
| | | Return on investment of derivative industry($d_{22}$) |
| | Achievement protection capability ($D_3$) | Whether there is a sound publishing policy($d_{31}$) |
| | | Is there a rigorous patent policy($d_{32}$) |
| Quality of innovation (E) | Academic Quality($E_1$) | Number of international high-level papers published($e_{11}$) |
| | | Scientific and technological achievements($e_{12}$) |
| | | Number of high-level R&D projects undertaken($e_{13}$) |
| | | Number of high-level academic conferences attended or held($e_{14}$) |
| | Proprietary technology and standard quality ($E_2$) | Patent level($e_{21}$) |
| | | Annual number of patents granted($e_{22}$) |
| | | 0rganize or participate in the amount of standard development($e_{23}$) |
| | Product innovation ($E_3$) | Type and quantity of product innovation($e_{31}$) |
| | | Market share of innovative products($e_{32}$) |
| | | Promote social investment through product innovation($e_{33}$) |
| Social impact (F) | Relevant members' satisfaction ($F_1$) | The satisfaction of researchers participating in the project($f_{11}$) |
| | | Other members' Satisfaction($f_{12}$) |
| | Economic Contribution ($F_2$) | Drive industrial output to increase income($f_{21}$) |
| | | New service revenue($f_{22}$) |
| | Social Contribution ($F_3$) | Accumulative number of service enterprises($f_{31}$) |
| | | Cumulative valuation of incubation technology enterprises($f_{32}$) |

**Figure 1** Comprehensive performance evaluation index system for R&D institutions

## 3. Methods

### *3.1. Fuzzy analytic hierarchy process (FAHP)*

Due to the characteristics of the new R&D institutions, such as the diversification of subjects, the modernization of institutions and the marketization of mechanisms, the causes that affect their comprehensive performance are complex and diverse. Only by combining qualitative and quantitative methods can the comprehensive performance of new R&D institutions be accurately evaluated. Thus, this paper adopts FAHP method to establish a hierarchical relationship model reflecting the indicators in the comprehensive performance evaluation system of new R&D institutions, and analyzes the impact of each factor on their performance, in order to obtain objective and effective index weight.

The main steps of AHP method are as follows:①Establish an index system model by integrating target factors;②The importance of each index is scored, the priority relationship matrix is constructed and the corresponding fuzzy consistent judgment matrix is established;③Calculation of weight and sensitivity analysis;④Calculate the combination weight.

| Definition of importance | The meaning of scale | The value of the scale |
|---|---|---|
| As important | Two factors are equally important | 0.5 |
| General important | One factor is slightly more important than the other | 0.6 |
| More important | One factor is obviously more important than the other | 0.7 |

| | | |
|---|---|---|
| Very important | One factor is more strongly important than the other | 0.8 |
| Extremely important | One factor is more important than the other | 0.9 |
| The comparison | Compared with the two factors, the latter is more important than the former | 0.1, 0.2, 0.3, 0.4 |

**Figure 2** Table of relative importance levels of indicators

Construct the priority relation matrix $F = (f_{ij})_{n\times n}$, according to the formula:

$$r_{ij} = \frac{(r_i - r_j)}{2n} + 0.5 \quad (1)$$

To a fuzzy uniform matrix $R = (r_{ij})_{n\times n}$ .Among them$r_i = \sum_{j=1}^{n} f_{ij}, i = 1,2,\dots,n.$

Formula for calculating weight vector$W^{(0)}$:

$$W^{(0)} = \left[\frac{\sqrt{\prod_{j=1}^{n} r_{1j}}}{\sum_{1}^{n}\sqrt{\prod_{j=1}^{n} r_{ij}}}, \frac{\sqrt{\prod_{j=1}^{n} r_{2j}}}{\sum_{1}^{n}\sqrt{\prod_{j=1}^{n} r_{ij}}}, \dots, \frac{\sqrt{\prod_{j=1}^{n} r_{nj}}}{\sum_{1}^{n}\sqrt{\prod_{j=1}^{n} r_{ij}}}\right]^{T} \quad (2)$$

The weights are obtained from this formula. The accuracy can be set through MATLAB, and the combination weight with higher accuracy can be obtained after iteration [7]. Test the sensitivity of index weights in the evaluation system. Assuming that the weight of index $C_{ij}$ is $\omega_j$, the new weight $\omega_j + \sigma_j$can be obtained according to the change of weight $\sigma_j$ ( $\sigma_j$ can be negative). Since $\omega_1 + \omega_2 + \cdots + \omega_n = 1$ is always true, n-1 index changes $-\frac{\sigma_j}{n-1}$, and the adjusted evaluation is as follows:

$$\mathrm{f_i} = \left(\omega_1 - \frac{\sigma_j}{n-1}\right)\mathrm{C_{i1}} + \left(\omega_2 - \frac{\sigma_j}{n-1}\right)\mathrm{C_{i2}} + \cdots + \left(\omega_j + \sigma_j\right) + \mathrm{C_{ij}} + \cdots + \left(\omega_n - \frac{\sigma_j}{n-1}\right)\mathrm{C_{in}} \quad (3)$$

### *3.2. Particle Swarm Optimization*

PSO algorithm is a swarm intelligence optimization model proposed by Kennedy et al. [8] in 1995. The algorithm gets inspiration from the foraging behavior of birds and conducts simulation. Its basic idea is to order the disordered group by iteratively updating the velocity and position of each particle in the group, so as to obtain the optimal solution. In the iterative process, particles adjust their speed and position by analyzing two "extreme values"(pbest, gbest) : one is the optimal solution of the respective extreme values, the particle itself; the other is the global extremum, the optimal solution of the group [9]. Particle velocity and position update formula is as follows:

$$V_{i+1} = V_i + c_1 \times rand(0\sim1) \times (Pbest - x_i) + c_2 \times rand(0\sim1) \times (Gbest - x_i) \quad (4)$$

$$x_{i+1} = x_i + V_i \quad (5)$$

$\mathrm{i} = 1,2,\dots,\mathrm{M}$, M represents the total number of particles in the population; $V_i$ is the velocity of each particle, $V_{max}$ is the maximum velocity; $X_i$ represents the current position of the particle, and Pbest represents the historical optimal position information of the particle. Gbest represents the global optimal location information of the group. Rand (0~1) is a random number in this range. $c_1$ and $c_2$ are acceleration constants. It is generally assumed that$c_1 = c_2 = 2$.

### *3.3.PSO-FAHP*

In order to improve the accuracy and scientificity of the results in the FAHP, and avoid the difference in subjective consciousness in the expert scoring, or the failure of the questionnaire due to other factors, so that the judgment matrix is not completely consistent, FAHP and PSO algorithm are combined in this paper. MATLAB programming is used to complete the adjustment test, weight calculation and ranking of fuzzy judgment matrix to ensure that a reasonable and scientific index weight set $W_i$ is finally obtained [10].

The matrix R is a fuzzy judgment matrix, which is tested and modified by PSO algorithm. If R is consistent, the value must be met $r_{ij} = 0.5 + a(\omega_i - \omega_j)$, Where, a represents the difference in importance between the two indicators, and its value range is a≥$\frac{n-1}{2}$. If R is not consistent, according to the formula:

$$\min\ CIF(n) = \sum_{i=1}^{n}\sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(Z_{ij} - \bar{Z}_{\iota}\right)^2}/n + \sum_{i=1}^{n}\sum_{j=1}^{n}\left[0.5 + a(\omega_i - \omega_j) - y_{ij}\right]^2/n^2 \quad (6)$$

Where CIF(n) is the consistency index function, and the modified fuzzy judgment matrix is $Y = \left(y_{ij}\right)_{n\times n}$,The constraint conditions are $y_{ii} = 0.5$, $y_{ij} + y_{ji} = 1$, $y_{ij} = y_{ik} - y_{jk} + o.5$, $\sum_{i=1}^{n}\omega_i = 1$, $\omega_i > 0$ . When CIF(n)<0.1, the optimal consistent fuzzy judgment matrix is obtained, and then the weight value of each index is calculated.

## 4. Conclusion

According to the comprehensive performance evaluation index system of the new R&D institution constructed in this paper, corresponding questionnaires were formulated and completed through field distribution, email delivery and platform push. A total of 130 questionnaires were distributed in this study, and 121 were effectively collected, with an effective rate of 93%, which met the requirements of questionnaire survey. In the questionnaire, experts were required to score the importance of the judgment matrix between each

indicator in pairs, and then summarize and process the data. According to the PSO-FAHP model, MATLAB software was used to obtain the weight of the effectiveness evaluation system of the new R&D institution. The specific results are shown in Figure 3.

| Level indicators | Weight | Secondary indicators | Weight | Comprehensive weights | Index type |
|---|---|---|---|---|---|
| A | 0.123 | A1 | 0.521 | 0.064 | Quantitative |
| | | A2 | 0.479 | 0.059 | Quantitative |
| B | 0.166 | B1 | 0.495 | 0.082 | Qualitative |
| | | B2 | 0.505 | 0.084 | Qualitative |
| C | 0.205 | C1 | 0.293 | 0.060 | Qualitative |
| | | C2 | 0.274 | 0.056 | Qualitative |
| | | C3 | 0.533 | 0.089 | Quantitative |
| D | 0.180 | D1 | 0.290 | 0.052 | Quantitative |
| | | D2 | 0.419 | 0.075 | Quantitative |
| | | D3 | 0.291 | 0.052 | Qualitative |
| E | 0.197 | E1 | 0.250 | 0.049 | Quantitative |
| | | E2 | 0.381 | 0.075 | Quantitative |
| | | E3 | 0.369 | 0.073 | Quantitative |
| F | 0.129 | F1 | 0.284 | 0.037 | Qualitative |
| | | F2 | 0.321 | 0.041 | Quantitative |
| | | F3 | 0.395 | 0.051 | Quantitative |

**Figure 3** Weight results of comprehensive performance evaluation system for new R&D institutions

According to the weight results of the effectiveness evaluation indexes of new R&D institutions, the first-level indexes show differences in different importance degrees. Market orientation has the largest weight and plays an important role in the effectiveness evaluation system of new R&D institutions. The social impact of new R&D institutions is conducive to further optimizing and improving the innovation environment. In terms of the current development status of new R&D institutions, the above evaluation results have important reference value for further improving the comprehensive evaluation system of new R&D institutions.

## 5. Discussion

Based on the characteristics and actual needs of new R&D institutions, this paper puts forward several discussions on promoting the construction of new R&D institutions and sustainable development on the basis of constructing the comprehensive performance evaluation index system of new R&D institutions and determining the weight.

### *5.1. Evaluation perspective novelty*

In the process of developing a new evaluation index system of R&D institutions, the traditional evaluation perspective of research institutions should be abandoned. To establish the comprehensive performance evaluation system of new R&D institutions, a new concept and perspective should be adopted, and the recognition degree of multiple subjects and satisfaction degree of participating members should be included in the index system, which is conducive to stimulate the enthusiasm of multiple subjects and integrate resource input to realize the collaborative innovation development of all subjects. Market orientation will be included, and the evaluation of knowledge base, interdisciplinary research ability, achievement transformation and protection ability will be emphasized, so as to fully reflect the comprehensive advantages of innovation, management and market orientation of new R&D institutions.

### *5.2. Evaluation process flexibility*

The government is the promoter of the construction of new R&D institutions, and should promote the development of comprehensive performance evaluation system through management evaluation to promote the standardized development of new research and development institutions. According to the types and characteristics of the evaluated objects, develop different evaluation procedures; According to the different research fields and management operation mechanisms of the evaluated institutions, different experts should be organized to carry out the evaluation, which can increase the field research links of experts; In the form of evaluation, experts' offline on-site evaluation and online evaluation are combined. In the evaluation method, qualitative evaluation is the main, supplemented by quantitative evaluation.

### *5.3. Openness of evaluation criteria*

In the construction of the evaluation system, the evaluation criteria should be dynamically adjusted and continuously optimized to ensure that the standards are scientific and objective, so as to not only constrain the new research and development institutions, but also encourage them freely, so as to fully ensure that the evaluation criteria play a role in promoting the rapid

development of new research and development institutions. We should fully listen to the formulation of standards for social participation, incorporate social impact into the evaluation system, avoid undue focus on economic contribution and short-term results, strike a balance between instrumental rationality and value rationality, guide the correct positioning of new types of R&D institutions, and achieve deep integration of scientific and technological innovation with economic and social development.

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## References

[1] H. Meng, J. J. Song. (2019) Performance evaluation of new R&D institutions from the perspective of resource dependence and societal impact. Science Research Management, 40:20-21.

[2] G. Y. Zhang, S. Liu, Y. X. Liu and W. C. Ma. (2021) Evaluation of the Core Competence of New R&D Institutions: the Perspective of Niche Ecostate-ecorole. Science and Technology Progress and Policy, 38:136-144.

[3] B. T. Guo, S. B. Wang, J. N. Wang and Y. M. He. (2020) Research on Co-construction Performance Evaluation System of new R&D institutions based on ANP. Science and Technology Management Research, 40:72-79.

[4] L. L. Li. (2012) Research on operation and performance evaluation of new R&D organization. Wuhan University of Technology.

[5] E. D. Zhou, G. X. Liu. (2018) An empirical study on the factors affecting innovational performance of the new R&D institutions in China-taking guang dong as an example. Science and Technology Progress and Policy,35:42-47.

[6] P. F. Cheng, S. L. Li, L. Xie and X. H. Zhou. (2021) Evaluation and analysis on the coupling coordination degree of innovation environment and collaborative innovation ability of the university of science and technology city. Systems Engineering, 43:1-3.

[7] J. Wu, C. Liu, H. Xia. (2015) Application and modification of FAHP in evaluation system modeling. Statistics and Decision Making, 20:77-79.

[8] J. Kennedy, R. Eberhart. (1995) Particle swarm optimization. In: IEEE International Conference on Neural Networks. Piscataway. 1942-1948.

[9] Q. Zhang, P. C. Li. (2020) An adaptive multi-strategy behavior particle swarm optimization algorithm. Control and Decision, 35:115-122.

[10] J. Li, H, Mang, T. Sun. et al. Method for designing the optimal trajectory for drilling a horizontal well, based on Particle Swarm Optimization (PSO) and Analytic Hierarchy Process (AHP). Chemistry and Technology of Fuels and Oils, 55:105-115.