# College students' cultivation evaluation index system and grey performance measurement model

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**Abstract**

The performance evaluation of the quality of higher schools' talents cultivation is an effective way of measuring higher schools' abilities of cultivating high talents. It also works efficiently for measuring higher schools' adaptabilities and abilities to serve the society. The process of evaluating performance of higher schools' talent cultivation is complicated and affected by many factors. With analyses of the factors that can affect the quality of higher schools' talents cultivation, a talents cultivation evaluation index system is established. With a metric analytical investigation of relevant evaluation criteria of the index system, and based on the grey system theory, a grey performance measurement model of higher schools' talents cultivation is proposed. The grey relevancy of the performance evaluation of higher schools' talents cultivation is obtained by considering weights of different evaluations. Then higher schools' abilities and qualities of cultivating talents can be evaluated and analysed based on the grey relevancy. Lastly, the model and algorithm are analysed and verified through specific application cases: it is proven that the model and algorithm are operable and functional

*Keywords:* Higher school; talents cultivation; performance evaluation; grey system; model)

## 1 Introduction

Along with the rapid development and universal implementation of the quality education in the modern society, the issues of educating and cultivating high talents in higher schools are of great importance. An effective performance evaluation of higher schools' talents cultivation is not only a crucial means of measuring higher schools' abilities of cultivating students, but is also urgently required during the educational reform and sustainable development of high talents cultivation in the modern society[1-3]. Thus, establishing a scientific and effective performance evaluation system and related model of higher schools' talents cultivation is of great theoretical and application values. To date, some researchers have already conducted researches and investigations in this area and have proposed some related performance evaluation systems and models with valuable theoretical insights [4-8]. Nevertheless, limitations exist due to several reasons: 1) the process of evaluating and analysing higher schools' talents cultivation is a system engineering that has a high complexity and can be affected and constrained by factors of various forms and types; 2) existing performance evaluation systems in most cases only consider local influencing factors of students' cultivation quality thus 3) the related models and criteria of specific forms are also limited. Therefore, on the basis of existing research achievements, this thesis proposes a new performance evaluation system of higher schools' talents cultivation and establishes a performance evaluation model based on the grey system theory, attempting to realize effective evaluation and analysis of higher schools' abilities to cultivate talents and the cultivation quality.

## 2 The performance evaluation index system of higher schools' talents cultivation quality

Talents cultivation quality is the core of higher schools education, the quality and capacity of talents cultivation is the key part reflecting directly how well higher schools perform in the allocation of educational resources, implementing educational development and reform, and how well they teach. Therefore, establishing a scientific, reasonable and comprehensive performance evaluation index system that can reflect higher schools' abilities to educate students and their talents cultivation quality can potentially help higher schools with their planning and formulation of talents cultivation methods in an effective and targeted way and enhance the quality of higher schools' talents cultivation. Most of the existing performance evaluation index systems of higher schools' talents cultivation look at higher schools' development only from local perspectives. They often fail to analyse the issues thoroughly and comprehensively. The ideas of building the evaluation index systems and related index design have certain limitations. For this purpose, this thesis attempts to develop a new performance evaluation index system of higher schools' talents cultivation that complies with scientific, comprehensive, integrated, reasonable and practical principles. The structure and contents of the system are shown below.

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TABLE 1 Performance evaluation index system of higher schools' talents cultivation quality

| System | Criterion | Criterion |
|---|---|---|
| Performance evaluation index system of higher schools' talents cultivation quality A | Input in teaching $A_1$ | Proportion of teachers with high-grade professional titles in all teaching staff $a_{11}$ |
| | | Number of quality courses at and above the provincial level $a_{12}$ |
| | | Number of teaching awards at and above the provincial level $a_{13}$ |
| | | Investment in teaching $a_{14}$ |
| | Input in scientific research $A_2$ | Annual number of scientific and research projects at and above the provincial level $a_{21}$ |
| | | Annual number of scientific and research awards at and above the provincial level $a_{22}$ |
| | | Number of key laboratories at and above the provincial level $a_{23}$ |
| | Teaching and training capacity $A_3$ | Average annual number of qualified personnel trained $a_{31}$ |
| | | Year average ratio of qualified talents $a_{32}$ |
| | | Innovation ability trained $a_{33}$ |
| | | Application ability trained $a_{34}$ |
| | | Leadership trained $a_{35}$ |
| | Scientific research training capacity $A_4$ | Average annual number of high-level papers published $a_{41}$ |
| | | Average annual number of patents $a_{42}$ |
| | | Average annual number of scientific and innovative contests participated at and above the provincial level $a_{43}$ |
| | | Average annual number of scientific and innovation awards at and above the provincial level $a_{44}$ |
| | Social Service capacity $A_5$ | Graduate employment rate $a_{51}$ |
| | | Science and technology service ability $a_{52}$ |
| | | Social satisfaction $a_{53}$ |

## 3 The grey measurement model for performance evaluation of higher schools' talents cultivation quality

### 3.1THE ACCURATE GREY MEASUREMENT MODEL FOR PERFORMANCE EVALUATION OF TALENTS CULTIVATION QUALITY

In the performance evaluation index system of higher schools' talents cultivation quality, some indicators can be measured by specific values. Meanwhile, among these indicators which can be measured by precise values, some are benefit-type and some are cost-type. In order to adopt a unified metric in the grey measurement model for performance evaluation, standardizing the indicators that are measured by specific figures is necessary.

Hypothetically, in the performance evaluating process of higher schools' talent cultivation quality, the accurate magnitude of the evaluation indexes $j$ in the higher school $G_i$ is $f_j(G_i)$; then if $j$ refers to indicators of benefit-type, the standardized magnitude $v_j(G_i)$ of the evaluation indexes $j$ in the higher school $G_i$ is:

$$v_j(G_i)=\frac{f_j(G_i)}{\sup\limits_{1\le k\le n}\left(f_j(G_i),\cdots,f_j(G_k),\cdots,f_j(G_n)\right)} \tag{1}$$

If $j$ refers to indicators of cost-type, then the standardized magnitude $v_j(G_i)$ of the evaluation indexes $j$ in the higher school $G_i$ is:

$$v_j(G_i)=\frac{\inf\limits_{1\le k\le n}\left(f_j(G_i),\cdots,f_j(G_k),\cdots,f_j(G_n)\right)}{f_j(G_i)} \tag{2}$$

If the optimum magnitude of the evaluation indexes $j$ which is already known as $v_j(G_0)$, then:

$$d_{ij} = \left| v_j(G_0) - v_j(G_i) \right| \tag{3}$$

Especially, if the optimum magnitude exists, then:

$$v_j(G_0) = \sup_{1\le k\le n}\left(v_j(G_i),\cdots,v_j(G_k),\cdots,v_j(G_n)\right) \tag{4}$$

Formula (3) can be transformed as well as:

$$d_{ij} = \left| \sup_{1\le k\le n}\left(v_j(G_i),\cdots,v_j(G_k),\cdots,v_j(G_n)\right) - v_j(G_i) \right| \tag{5}$$

According to the grey system theory, the grey relational coefficient $\gamma_{ij}$ between the evaluation indexes $j$ and the optimum magnitude $v_j(G_0)$ in the higher school $G_i$ is:

$$\gamma_{ij} = \frac{\min\limits_i \min\limits_j d_{ij} + \rho \max\limits_i \max\limits_j d_{ij}}{\left|d_{ij}\right| + \rho \max\limits_i \max\limits_j d_{ij}}, \tag{6}$$

where $\rho$ represents resolution ratio, normally $\rho$ =0.5.

## 3.3 WEIGHTS OF PERFORMANCE EVALUATION INDEXES OF TALENTS CULTIVATION QUALITY BASED ON AHP (ANALYTIC HIERARCHY PROCESS)]

After obtaining various types of evaluation indicators in the evaluation index system, the weights of the different evaluation indicators need to be analyzed. This thesis allocates the weights of evaluation index according to AHP method, adopting a rating scale ranging from 1 to 9 to represent the significances of different evaluation index. A questionnaire analysis in the form of expert scoring is conducted to ultimately generate a comparative judgment matrix P of the performance evaluation index of higher schools' talents cultivation quality:

$$\boldsymbol{P} = \begin{vmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{vmatrix}, \tag{12}$$

where $1 \le p_{ij} = \frac{1}{p_{ij}} \le 9$

And the equation of the eigenvalue $\lambda$ and the eigenvector $W$ in the comparative judgment matrix P is:

$$\boldsymbol{P} * W = \lambda * W \tag{13}$$

## 3.2 THE FUZZY GREY MEASUREMENT MODEL FOR PERFORMANCE EVALUATION OF TALENTS CULTIVATION QUALITY

In the performance evaluation index system of higher schools' talents cultivation quality, some performance evaluation indicators of talents cultivation quality need to be described qualitatively and some indicators have fuzziness. At the same time, among these fuzzy indicators some are benefit-type and some are cost-type. Therefore, it is required to standardize these fuzzy indicators for the purpose of using them in a more appropriate way in the grey measurement model for performance evaluation of higher schools' talents cultivation quality.

Presumably, the fuzzy magnitude of the evaluation indexes $j$ in the higher school $G_i$ is

$$f_j(G_i) = \left(f_j^a(G_i), f_j^b(G_i)\right),$$

and if the indexes are particularly qualitative, the magnitude can be transformed by means of ratio scale. If the evaluation indexes $j$ are of benefit-type, then the standardized magnitude $v_j(G_i)$ is:

$$v_j(G_i) = \left(v_j^a(G_i), v_j^b(G_i)\right) = \left(\frac{v_j^a(G_i)}{\sup\limits_{1\le k\le n}\left(f_j(G_k)\right)}, \frac{v_j^b(G_i)}{\sup\limits_{1\le k\le n}\left(f_j(G_k)\right)}\right) \tag{7}$$

And if the evaluation indexes $j$ are of cost-type, then the standardized magnitude $v_j(G_i)$ is:

$$v_j(G_i) = \left(v_j^a(G_i), v_j^b(G_i)\right) = \left(\frac{\inf\limits_{1\le k\le n}\left(f_j(G_k)\right)}{v_j^a(G_i)}, \frac{\inf\limits_{1\le k\le n}\left(f_j(G_k)\right)}{v_j^b(G_i)}\right) \tag{8}$$

If the optimum magnitude of evaluation indexes $j$ is already known as:

$$v_j(G_0) = \left(v_j^a(G_0), v_j^b(G_0)\right) = \left(\sup_{1\le k\le n} v_j^a(G_i), \sup_{1\le k\le n} v_j^b(G_i)\right) \tag{9}$$

Then:

$$D_{ij} = \frac{1}{2}\left(\left|v_j^a(G_0) - v_j^a(G_i)\right| + \left|v_j^b(G_0) - v_j^b(G_i)\right|\right) \tag{10}$$

According to the grey system theory, the grey relational coefficient $\gamma_{ij}$ between the evaluation indexes $j$ and the optimum magnitude among the indexes $v_j(G_0)$ in higher school $G_i$ is:

$$\gamma_{ij} = \frac{\min\limits_i \min\limits_j D_{ij} + \rho \max\limits_i \max\limits_j D_{ij}}{\left|D_{ij}\right| + \rho \max\limits_i \max\limits_j D_{ij}}. \tag{11}$$

where $\rho$ represents resolution ratio, normally $\rho$ =0.5.

Through formula (13) we can get the maximum eigenvalue $\lambda_{max}$, then the coincidence indicator CI as:

$$CI = (\lambda_{max} - n)/(n-1) \tag{14}$$

If $CR = \frac{CI}{RI}$ meets the demands of consistency check where RI is the random coincidence indicator corresponding to the evaluation index, the eigenvector $W$ of the maximum eigenvalue $\lambda_{max}$ can be generated as

$W = (W_1, \cdots, W_j, \cdots W_n)$.

And after the normalization processing of $W$, the weight $w_j$ of the evaluation index $j$ is obtained as:

$$w_j = \frac{W_j}{(W_1 + \cdots + W_j + \cdots + W_n)} \tag{15}$$

### 3.4 THE GREY MEASUREMENT ALGORITHM IMPLEMENTATION OF THE PERFORMANCE EVALUATION OF HIGHER SCHOOLS' TALENTS CULTIVATION QUALITY

According to the hierarchical structure of the performance evaluation index system of higher schools' talents cultivation quality, the evaluation has a two-tier hierarchical structure. And based on the weights of different tiers, the grey measurement models of different tiers can be generated. If the weight of evaluation index is $w_{ijk}$ :

Then the grey metric $\phi_{ij}$ of the evaluation index $k$ at the level of index under criterion $j$ in the higher school $G_i$ is:

$$\phi_{ij} = \sum_{k=1}^{n} (w_{ijk} * \gamma_{ijk}) \tag{16}$$

Similarly, if the weight of evaluation criterion is $w_{ip}$, the grey metric $\varphi_i$ of the evaluation index $p$ at the level of criterion in the higher school $G_i$ is:

$$\varphi_i = \sum_{p=1}^{m} (w_{ip} * \phi_{ip}) \tag{17}$$

According to the physical significance of the grey metric $\varphi_i$, it is stated that the bigger $\varphi_i$ is, the closer it is from the optimum value, the better is the talents cultivation quality in the higher school $G_i$. Consequently the evaluation criterion of performance evaluation of higher schools' talents cultivation quality can be generated on the basis of the grey metric $\varphi_i$, which is:

$$\varphi_0 = max(\varphi_i, \cdots, \varphi_i, \cdots, \varphi_i) = \varphi_s \tag{18}$$

It can be claimed that the evaluation results of talents cultivation quality in the higher school $G_s$ are the best.

## 4 Application cases and explanations

This thesis attempts to take the comprehensive appraisals of 3 higher schools within the same system in a specific place as examples. The examples help to analyze and explain the performance evaluation index system and the grey measurement model of higher schools' talents cultivation quality. As shown below in Table 2, the specific evaluation indexes of these 3 higher schools are collected on the basis of investigation and survey and statistical analysis.

TABLE 2 The performance evaluation indexes of higher schools' talents cultivation quality

| Criterion | Criterion | Weight | Indicator value | | |
|---|---|---|---|---|---|
| | | | college 1 | college 2 | college 3 |
| Input in teaching $A_1$ | Proportion of teachers with high-grade professional titles , in all teaching staff $a_{11}$ | 0.193 | 0.95 | 0.93 | 0.93 |
| | Number of quality courses at and above the provincial level $a_{12}$ | 0.166 | 26 | 21 | 24 |
| | Number of teaching awards at and above the provincial level $a_{13}$ | 0.122 | 47 | 36 | 28 |
| | Investment in teaching $a_{14}$ | 0.531 | 8-9 | 8-9 | 7-8 |
| Input in scientific research $A_2$ | Annual number of scientific and research projects at and above the provincial level $a_{21}$ | 0.613 | 308 | 364 | 347 |
| | Annual number of scientific and research awards at and above the provincial level $a_{22}$ | 0.269 | 11 | 15 | 18 |
| | Number of key laboratories at and above the provincial level $a_{23}$ | 0.117 | 16 | 18 | 14 |

| | | | | | |
|---|---|---|---|---|---|
| Teaching and training capacity $A_3$ | Average annual number of qualified personnel trained $a_{31}$ | 0.250 | 8785 | 7936 | 8922 |
| | Average annual ratio of qualified personnel trained $a_{32}$ | 0.250 | 0.98 | 0.98 | 0.95 |
| | Innovation ability trained $a_{33}$ | 0.250 | 7-8 | 8-9 | 8-9 |
| | Application ability trained $a_{34}$ | 0.250 | 8-9 | 7-8 | 8-9 |
| | Leadership trained $a_{35}$ | 0.250 | 8-9 | 8-9 | 7-8 |
| Scientific research training capacity $A_4$ | Average annual number of high-level papers published $a_{41}$ | 0.208 | 2032 | 1896 | 2411 |
| | Average annual number of patents $a_{42}$ | 0.083 | 68 | 85 | 71 |
| | Average annual number of scientific and innovative contests participated at and above the provincial level $a_{43}$ | 0.208 | 18 | 16 | 16 |
| | Average annual number of scientific and innovation awards at and above the provincial level $a_{44}$ | 0.501 | 6 | 4 | 3 |
| Social Service capacity $A_5$ | Graduate employment rate $a_{51}$ | 0.635 | 0.98 | 0.96 | 0.98 |
| | Science and technology service ability $a_{52}$ | 0.105 | 8-9 | 8-9 | 7-8 |
| | Social satisfaction $a_{53}$ | 0.261 | 8-9 | 8-9 | 8-9 |

The standardized results of the data in Table 2 via standardization model are shown in Table 3.

TABLE 3 the standardization of the evaluation index data

| Criterion | Indicator value | | |
|---|---|---|---|
| | college 1 | college 2 | college 3 |
| Proportion of teachers with high-grade professional titles in all teaching staff $a_{11}$ | 1.000 | 0.979 | 0.979 |
| Number of quality courses at and above the provincial level $a_{12}$ | 1.000 | 0.808 | 0.923 |
| Number of teaching awards at and above the provincial level $a_{13}$ | 1.000 | 0.766 | 0.596 |
| Investment in teaching $a_{14}$ | 0.889-1.000 | 0.889-1.000 | 0.778-0.889 |
| Annual number of scientific and research projects at and above the provincial level $a_{21}$ | 0.846 | 1.000 | 0.953 |
| Annual number of scientific and research awards at and above the provincial level $a_{22}$ | 0.611 | 0.833 | 1.000 |
| Number of key laboratories at and above the provincial level $a_{23}$ | 0.889 | 1.000 | 0.778 |
| Average annual number of qualified personnel trained $a_{31}$ | 0.985 | 0.889 | 1.000 |
| Annual average ratio of qualified talents $a_{32}$ | 1.000 | 1.000 | 0.969 |
| Innovation ability trained $a_{33}$ | 0.778-0.889 | 0.889-1.000 | 0.889-1.000 |
| Application ability trained $a_{34}$ | 0.889-1.000 | 0.778-0.889 | 0.889-1.000 |
| Leadership trained $a_{35}$ | 0.889-1.000 | 0.889-1.000 | 0.778-0.889 |
| Average annual number of high-level papers published $a_{41}$ | 0.843 | 0.786 | 1.000 |
| Average annual number of patents $a_{42}$ | 0.800 | 1.000 | 0.835 |
| Average annual number of scientific and innovative contests participated at and above the provincial level $a_{43}$ | 1.000 | 0.889 | 0.889 |
| Average annual number of scientific and innovation awards at and above the provincial level $a_{44}$ | 1.000 | 0.667 | 0.500 |

| | | | |
|---|---|---|---|
| Graduate employment rate $a_{51}$ | 1.000 | 0.980 | 1.000 |
| Science and technology service ability $a_{52}$ | 0.889-1.000 | 0.889-1.000 | 0.778-0.889 |
| Social satisfaction $a_{53}$ | 0.889-1.000 | 0.889-1.000 | 0.889-1.000 |

The specific indicator-level grey magnitudes generated based on the grey measurement model at the level of index are shown in Table 4.

TABLE 4 Parameter-level grey magnitudes

| Criterion | Indicator value | | |
|---|---|---|---|
| | college 1 | college 2 | college 3 |
| Proportion of teachers with high-grade professional titles in all teaching staff $a_{11}$ | 1.000 | 0.906 | 0.906 |
| Number of quality courses at and above the provincial level $a_{12}$ | 1.000 | 0.513 | 0.724 |
| Number of teaching awards at and above the provincial level $a_{13}$ | 1.000 | 0.463 | 0.333 |
| Investment in teaching $a_{14}$ | 1.000 | 1.000 | 0.645 |
| Annual number of scientific and research projects at and above the provincial level $a_{21}$ | 0.559 | 1.000 | 0.806 |
| Annual number of scientific and research awards at and above the provincial level $a_{22}$ | 0.333 | 0.541 | 1.000 |
| Number of key laboratories at and above the provincial level $a_{23}$ | 0.637 | 1.000 | 0.468 |
| Average annual number of qualified personnel trained $a_{31}$ | 0.789 | 0.333 | 1.000 |
| Year average ratio of qualified talents $a_{32}$ | 1.000 | 1.000 | 0.644 |
| Innovation ability trained $a_{33}$ | 0.645 | 1.000 | 1.000 |
| Application ability trained $a_{34}$ | 1.000 | 0.645 | 1.000 |
| Leadership trained $a_{35}$ | 1.000 | 1.000 | 0.645 |
| Average annual number of high-level papers published $a_{41}$ | 0.614 | 0.539 | 1.000 |
| Average annual number of patents $a_{42}$ | 0.556 | 1.000 | 0.602 |
| Average annual number of scientific and innovative contests participated at and above the provincial level $a_{43}$ | 1.000 | 0.693 | 0.693 |
| Average annual number of scientific and innovation awards at and above the provincial level $a_{44}$ | 1.000 | 0.429 | 0.333 |
| Graduate employment rate $a_{51}$ | 1.000 | 0.779 | 1.000 |
| Science and technology service ability $a_{52}$ | 1.000 | 1.000 | 0.333 |
| Social satisfaction $a_{53}$ | 1.000 | 1.000 | 1.000 |

TABLE 5 The grey magnitudes at the level of criterion

| Criterion | Indicator value | | |
|---|---|---|---|
| | college 1 | college 2 | college 3 |
| Input in teaching $A_1$ | 1.000 | 0.721 | 0.652 |
| Input in scientific research $A_2$ | 0.510 | 0.847 | 0.758 |
| Teaching and training capacity $A_3$ | 0.887 | 0.796 | 0.858 |
| Scientific research training capacity $A_4$ | 0.793 | 0.665 | 0.657 |
| Social Service capacity $A_5$ | 1.000 | 0.926 | 0.778 |

The performance evaluation results of these 3 higher schools' talents cultivation quality are obtained based the grey magnitudes of different indexes and criterion in Table 5. They are $\varphi = (0.838, 0.791, 0.768)$, from which we can see that the grey magnitude of the performance evaluation of the higher school 1's talents cultivation quality is the biggest. That concludes that higher school 1 has the best ability of cultivating students

## 5 Conclusions

This thesis has analyzed and discussed the issues regarding the performance evaluation of higher schools' talents cultivation quality, and has constructed a new performance evaluation index system of higher schools' talents cultivation quality. Additionally, a grey measurement model for performance evaluation based on the grey system theory has been proposed. The evaluation index system analyzes the issues of higher schools' talents cultivation quality form the perspectives of comprehensiveness and integrity, thus it is believed that the system is scientific, objective and reasonable. In the meantime, relevant grey metrics are obtained in the grey measurement model through processing indexes of various types. It can be seen that the physical significance of this method is clear and the calculation is simple. It strongly supports the computer implementation of the performance evaluation of higher schools' talents cultivation quality. The effectiveness of the measurement model and related performance evaluation index system has also been proven by the application cases and analysis in this thesis

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