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On the Career Development of College Graduates-An Empirical Analysis Based on Improved Bilateral Matching Decision-Making Method

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Abstract-The employment quality of college graduates is related to their happy life and social stability. Considering the preference of enterprises and college graduates in the process of bilateral matching between employment posts and college graduates, this paper describes the problem of bilateral matching between employment posts and college graduates by using bilateral matching theory. Further, we construct a matching optimization model based on the maximum preference and the minimum deviation of each subject, and transform the multi-objective matching model into a single-objective optimization model to get a matching scheme by using the linear weighting method. Finally, the model is used to discuss the matching decision-making problem between graduates of information management and information system specialty and employment posts.

Keywords- *Matching Problem, Employment Quality, College Graduates, Grey Relational Analysis*

I. INTRODUCTION

With the post-popularization development of higher education in China, the employment of college graduates has attracted the attention of many scholars and managers. According to the statistics, the employment situation is very difficult with 8.34 million college graduates in 2019.The solution of employment problem of college students is not only related to their happy life and future, but also the key point to maintain social stability. Therefore, how to improve the employment quality of graduates has become an urgent social problem. Some experts analyzed the factors that influence the employment problem of college students from the government, universities, society and graduate themselves [1-8], and drew the conclusion that the job satisfaction of college graduates was closely related to the matching degree of employment posts. However, most college graduates choose their jobs based on their own interests and personal attributes. If the relationship between personal employment choice and the position is not properly handled, it is common for graduates to change jobs frequently and get deeply disappointed in employment, resulting in a series of problems such as negative employment. Therefore, in order to eliminate the uncertainty and asymmetry of employment information, employment guidance in colleges and universities should fully consider the needs of enterprises and college graduates, rationally coordinate the relationship between employment posts and personal preference and professional knowledge structure of college graduates, and carry out two-way selection. It is a decision-making method with theoretical and practical value to improve the employment quality of college graduates based on bilateral matching theory. However, most recent studies analyzed the influencing factors and matching degree between employment posts and college graduates by means of a qualitative method, without considering the preference and bilateral matching of employment posts offered by enterprises and college graduates, which results in a great deviation between the employment effect and the reality. In this view, by means of the matching theory and grey relational analysis method, this paper qualitatively analyzes the preference of enterprises and college graduates and quantitatively constructs a bilateral matching decision-making model between employment posts provided by enterprises and graduates, aiming at improving the matching degree between individual will of college graduates and employment posts, and further improving the employment quality.

II. MEASUREMENT AND ANALYSIS OF MATCHING DEGREE BETWEEN EMPLOYMENT POSTS AND INDIVIDUAL EMPLOYMENT PREFERENCE

Let $A = \{a_1, \dots, a_i, \dots, a_m\}$ and $B = \{b_1, \dots, b_j, \dots, b_n\}$ represent the sets of jobs provided by enterprises and college graduates respectively, where $m \geq 2$, $n \geq 2$, $a_i, b_j (i = 1,2, \dots, m; j = 1,2, \dots, n)$ refers to the i-th employment post and j-th college graduate respectively. Employment managers in colleges follow the set $C = \{c_1, \dots, c_k, \dots, c_p\}$ to measure and evaluate the suitability of graduates for the corresponding employment, where c_k is the K-TH evaluation attribute, a_{ijk} is the evaluation value of a_i for the jobs, $w_k (k = 1,2, \dots, p)$ as

the weights of attributes and $\sum_{k=1}^{p} w_k = 1$; The preference of b_j for each a_i can be derived from the set $D = \{d_1, \dots, d_t, \dots, d_q\}$ to measure. d_t is the first t-th attribute to match a_i attribute values for the weights of attributes, and $\sum_{t=1}^{q} \eta_t = 1$. Based on the variability, subjectivity, complexity and other limitations of the objective reality, the expected values of the matching objects are within an interval, that is, there are attribute values $a_{ijk} \in [\underline{a}_{ijk}, \overline{a}_{ijk}]$ and $b_{ijt} \in [\underline{b}_{ijt}, \overline{b}_{ijt}]$.

Successful matching between employment post a_i and college graduate b_j depends on the degree of their mutual satisfaction. The higher the preference degree is, the higher the matching degree between employment posts and college graduates is, and the better the employment quality is. Suppose the preference degree of the ideal object is 1. If the attribute sets C and D are used, the closer the relational degree between employment post a_i and the graduate's individual choice b_j is, the higher the preference degree between employment posts and college graduates is, the better the relative effect of the employment quality is; on the contrary, the smaller the preference degree is, the worse the relative effect of the employment quality is. In view of this, the matching degree of preference between a_i and b_j can be further measured by means of similarity and relational degree of attribute sets about matching objects, and their relationships can be judged by means of grey relational analysis method on the basis of geometric shape of sequence curves. The following definitions are used to measure the ideal matching objects, preference coefficients and preference degree.

Definition 1. If $\forall a_i \in A, \forall b_j \in B (i = 1,2, \dots, m; j = 1,2, \dots, n)$, C and D.

$$a^0 = \left(a_1^0, \dots, a_k^0, \dots, a_p^0\right) = \left(\max_i \max_j \{a_{ij1}\}, \dots, \max_i \max_j \{a_{ijk}\}, \dots, \max_i \max_j \{a_{ijp}\}\right)$$

$$= \left([\underline{a}_{ij1}^0, \overline{a}_{ij1}^0], \dots, [\underline{a}_{ijk}^0, \overline{a}_{ijk}^0], \dots, [\underline{a}_{ijp}^0, \overline{a}_{ijp}^0\right. \quad (1)$$

$$b^0 = \left(b_1^0, \dots, b_t^0, \dots, b_q^0\right) = \left(\max_i \max_j \{b_{ij1}\}, \dots, \max_i \max_j \{b_{ijt}\}, \dots, \max_i \max_j \{b_{ijq}\}\right) = \left(\left[\underline{b}_{ij1}^0, \overline{b}_{ij1}^0\right], \dots, \left[\underline{b}_{ijt}^0, \overline{b}_{ijt}^0\right], \dots, \left[b_{ijq}^0, \overline{b}_{ijq}^0\right]\right) \quad (2)$$

If $a_k^0 = \left[\underline{a}_{ijk}^0, \overline{a}_{ijk}^0\right] = \max_i \max_j \{a_{ijk}\}$ and

$b_t^0 = \left[\underline{b}_{ijt}^0, \overline{b}_{ijt}^0\right] = \max_i \max_j \{b_{ijt}\}$,

$a^0$and b^0 are respectively called the ideal matching objects of employment post A and college graduate B.

Definition 2. For $\forall a_i \in A, \forall b_j \in B (i = 1,2, \dots, m; j = 1,2, \dots, n)$,

$$\alpha_{ijk} = \frac{\max_i \max_j \max_k a_{ijk}^+ + \rho \max_i \max_j \max_k a_{ijk}^+}{a_{ijk}^+ + \rho \max_i \max_j \max_k a_{ijk}^+} \quad (3)$$

$$\beta_{ijt} = \frac{\max_i \max_j \max_t b_{ijt}^+ + \rho \max_i \max_j \max_t b_{ijt}^+}{a_{ijk}^+ + \rho \max_i \max_j \max_t b_{ijt}^+} \quad (4)$$

If:

$a_{ijk}^0 = \left[\underline{a}_{ijk}^0, \overline{a}_{ijk}^0\right], a_{ijk} \in \left[\underline{a}_{ijk}, \overline{a}_{ijk}\right], b_{ijt}^0 = \left[\underline{b}_{ijt}^0, \overline{b}_{ijt}^0\right], b_{ijt} \in [\underline{b}_{ijt}, \overline{b}_{ijt}]$, $\alpha_{ijk}$and β_{ijt} are called preference coefficients under attributes c_k and d_t. Where $a_{ijk}^+ = \sqrt{\frac{(\underline{a}_{ijk}^0 - \underline{a}_{ijk})^2 + (\overline{a}_{ijk}^0 - \overline{a}_{ijk})^2}{2}}$, $b_{ijt}^+ = \sqrt{\frac{(\underline{b}_{ijt}^0 - \overline{b}_{ijt}^0)^2 + (\underline{b}_{ijt} - \overline{b}_{ijt})^2}{2}}$

Definition 3. For $\forall a_i \in A, \forall b_j \in B$, attribute sets C and D, $\alpha_{ijk}, \beta_{ijt}, w_k, \eta_t$, are respectively called the preference degree of matching objects a_i and b_j to matching objects b_j and a_i.

$$\alpha_{ij} = \sum_{k=1}^{p} \alpha_{ijk} w_k \quad (5)$$

$$\beta_{ij} = \sum_{t=1}^{q} \beta_{ijt} \eta_t \quad (6)$$

Definition 4. Let μ: A → B as a rule. For $\forall a_i \in A$ and $\forall b_j \in B$, if they meet $\mu(a_i) = b_j$, μ and (a_i, b_j) are called matching schemes and matching pairs of employment posts and college graduates respectively.

Note: $\mu(a_i) = b_j$ means that employment post a_i matches college graduate b_j in μ, $\mu(a_i) = a_j$ means that the subject a_i of party A does not match in μ, and $\mu(b_j) = b_j$ means that the subject b_j of party B does not match in μ.

Considering different preference of enterprises and college graduates on employment and their different matching status, the preference degree of employment posts and college graduates on matching schemes or matching objects can be described with a deviation and measured. Based on this, the matching scheme for the matching subject can be defined.

Definition 5. Let $\mu = \{\mu_1, \dots, \mu_s, \dots, \mu_l\}$ represent the set of all matching schemes determined by the sets of matching subjects A and B; if the preference degree of matching subjects in matching pair (a_i, b_j) is

$$f(\mu_s) = \sum_{\mu_s(a_i) = b_j} |\alpha_{ij} - \beta_{ij}| \quad (7)$$

μ_s, the s -th matching scheme in μ, is called the bilateral subject matching scheme.

Where $s = 1,2, \dots, l$, $\mu_s = \arg\min\{f(\mu_1), \dots, f(\mu_s), \dots, f(\mu_l)\}$If $f(\mu_s) = 0$, then μ_s is the absolute matching scheme of bilateral subjects.

If $f(\mu_s) = 0$, then μ_s is the absolute matching scheme of bilateral subjects.

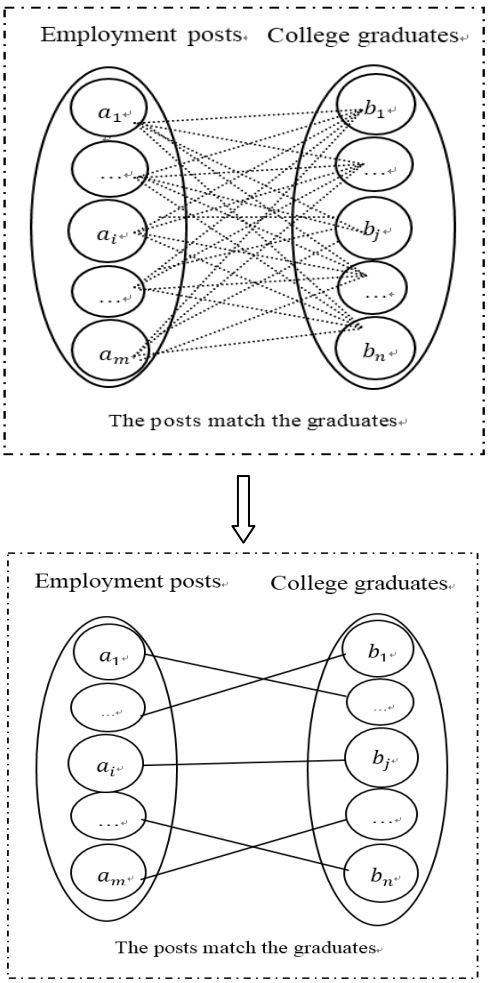

Figure 1. Bilateral matching between employment posts and graduates

According to Definitions 4 and 5, (a_i, b_j) and (b_j, a_i) are main matching pairs for μ. According to the above analysis, the matching between employment posts and college graduates depends on their preference degree and reasonable degree. Accordingly, the problem of bilateral matching between employment posts and college graduates can be shown in Figure 1. The left chart shows the matching combination of employment and college graduates, and the right chart shows the matching pairs of employment and college graduates considering the preference of matching subjects and reasonable degree of matching schemes.

III. A MATCHING DECISION-MAKING MODEL BETWEEN EMPLOYMENT POSTS AND COLLEGE GRADUATES

Set $x_{ij} \in \{0,1\}$ as the decision variable and $x_{ij} = 1$ indicates that employment post a_i has been matched with college graduate b_j; $x_{ij} = 0$ indicates that there is no match between employment post a_i and college graduate b_j. The matching degree between employment posts and college graduates mainly depends on the deviation of preference between them. According to the choice of post and the preference of individual will, a multi-objective optimization model can be further constructed.

$$\max Z_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} \alpha_{ij}\, x_{ij} \tag{8a}$$

$$\max Z_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} \beta_{ij}\, x_{ij} \tag{8b}$$

$$\min Z_3 = \sum_{i=1}^{m}\sum_{j=1}^{n} |\alpha_{ij} - \beta_{ij}|\, x_{ij} \tag{8c}$$

$$\begin{cases} \sum_{j=1}^{m} x_{ij} \le \theta_i, i = 1,2,\dots,m \\ s.t. \quad \sum_{i=1}^{n} x_{ij} \le \mu_j, j = 1,2,\dots,n \\ 1 \le \theta_i, 1 \le \mu_j, x_{ij} \in \{0,1\}, i = 1,2,\dots,m; j = 1,2,\dots,n \end{cases} \tag{8d}$$

8(a − c) are the objective functions, and 8a is the maximum sum of employment posts to graduates preference. 8b is the maximum sum of graduates preference to employment posts; 8c is the values of difference between employment posts and graduates preference; in 8d, θ_i and μ_j mean the most The above multi-objective matching model can be transformed into a single-objective maximization model to get the matching results by using linear weighting method, as shown below.

$$\begin{aligned} &\max Z = \delta_1 \sum_{i=1}^{m}\sum_{j=1}^{n} \alpha_{ij}\, x_{ij} + \delta_2 \sum_{i=1}^{m}\sum_{j=1}^{n} \beta_{ij}\, x_{ij} - \\ &\delta_3 \sum_{i=1}^{m}\sum_{j=1}^{n} |\alpha_{ij} - \beta_{ij}| x_{ij} = \sum_{i=1}^{m}\sum_{j=1}^{n} e_{ij}\, x_{ij} \\ &\sum_{j=1}^{m} x_{ij} \le \theta_i, i = 1,2,\dots,m \\ &\text{s.t.} \sum_{i=1}^{n} x_{ij} \le \mu_j, j = 1,2,\dots,n \\ &1 \le \theta_i, 1 \le \mu_j \\ &x_{ij} \in \{0,1\}, \mathrm{i} = 1,2,\dots,\mathrm{m}; \mathrm{j} = 1,2,\dots,\mathrm{n} \end{aligned} \tag{9}$$

In $e_{ij} = \delta_1\alpha_{ij} + \delta_2\beta_{ij} - \delta_3|\alpha_{ij} - \beta_{ij}|$, δ_1, δ_2, δ_3 respectively represent employment post a_i, college graduate b_j and the weight among matching groups. It reflects the importance of each objective in the actual bilateral matching problem, usually determined by group negotiation or one certain party, and $\delta_1 + \delta_2 + \delta_3 = 1$.

IV. CASE ANALYSIS

In order to better promote the cultivation of talents and improve cultivation quality of talents and employment quality, employment managers in a class of information management and information system specialty of X university collected employment information and matched employment posts for graduates in need. Employment posts offered mainly included: logistics management engineer, production management engineer, process engineer, process improvement engineer, quality management engineer and R&D engineer, respectively recorded as a_1, a_2, a_3, a_4, a_5, a_6. Employment managers evaluated college graduates from the following four aspects: internship experience, credit points, awards and employment quality (enthusiasm, attitude), respectively recorded as c_1, c_2, c_3, c_4. Their weights were 0.3, 0.15, 0.35 and 0.2 respectively according to the expert scoring. College graduates in need mainly included Adam, Ming Li, Mike, Alisa and Brown, and they are recorded as b_1, b_2, b_3, b_4, b_5 respectively.

College graduates often evaluated their employment from the three aspects of salary, job tasks and job treatment, respectively recorded as d_1,d_2, d_3. Their weights were 0.55,0.10 and 0.35 respectively according to the expert scoring. According to the mutual evaluation information between enterprises and college graduates, the expected values of attribute of both sides can be obtained (expected value 1 indicates full acceptance and 0 indicates no acceptance.) The values were shown in Table 1 and Table 2, respectively.

TABLE I. EXPECTED VALUES OF ATTRIBUTE OF EMPLOYMENT POSTS TO COLLEGE GRADUATES

A	A/B	c_1	c_2	c_3	c_4
a_1	b_1	[0.87,0.89]	[0.65,0.68]	[0.82,0.82]	[0.78,0.79]
	b_2	[0.76,0.76]	[0.78,0.80]	[0.74,0.75]	[0.77,0.79]
	b_3	[0.70,0.73]	[0.81,0.81]	[0.76,0.77]	[0.74,0.74]
	b_4	[0.78,0.80]	[0.77,0.79]	[0.88,0.89]	[0.91,0.91]
	b_5	[0.66,0.66]	[0.84,0.86]	[0.84,0.84]	[0.85,0.85]
a_2	b_1	[0.77,0.78]	[0.78,0.80]	[0.64,0.65]	[0.73,0.73]
	b_2	[0.66,0.67]	[0.60,0.63]	[0.71,0.72]	[0.76,0.77]
	b_3	[0.84,0.84]	[0.78,0.80]	[0.84,0.85]	[0.81,0.82]
	b_4	[0.75,0.77]	[0.74,0.75]	[0.79,0.80]	[0.70,0.71]
	b_5	[0.76,0.77]	[0.81,0.82]	[0.76,0.76]	[0.56,0.57]
a_3	b_1	[0.76,0.78]	[0.62,0.62]	[0.66,0.67]	[0.65,0.66]
	b_2	[0.86,0.86]	[0.78,0.80]	[0.74,0.74]	[0.78,0.79]
	b_3	[0.70,0.71]	[0.66,0.68]	[0.76,0.76]	[0.72,0.73]
	b_4	[0.80,0.80]	[0.84,0.85]	[0.76,0.78]	[0.78,0.78]
	b_5	[0.68,0.70]	[0.75,0.76]	[0.71,0.72]	[0.65,0.66]
a_4	b_1	[0.58,0.59]	[0.71,0.73]	[0.66,0.66]	[0.73,0.74]
	b_2	[0.78,0.78]	[0.60,0.64]	[0.70,0.72]	[0.85,0.86]
	b_3	[0.63,0.64]	[0.69,0.71]	[0.78,0.78]	[0.64,0.64]
	b_4	[0.75,0.75]	[0.74,0.75]	[0.71,0.72]	[0.66,0.68]
	b_5	[0.82,0.83]	[0.79,0.79]	[0.78,0.80]	[0.73,0.75]
a_5	b_1	[0.77,0.79]	[0.76,0.77]	[0.68,0.70]	[0.72,0.72]
	b_2	[0.56,0.58]	[0.60,0.62]	[0.55,0.56]	[0.63,0.64]
	b_3	[0.78,0.78]	[0.66,0.66]	[0.73,0.74]	[0.60,0.62]
	b_4	[0.66,0.67]	[0.84,0.85]	[0.76,0.78]	[0.76,0.77]
	b_5	[0.81,0.82]	[0.75,0.76]	[0.79,0.80]	[0.64,0.66]
a_6	b_1	[0.77,0.79]	[0.72,0.73]	[0.76,0.78]	[0.74,0.74]
	b_2	[0.86,0.86]	[0.78,0.80]	[0.80,0.81]	[0.77,0.79]
	b_3	[0.64,0.65]	[0.63,0.65]	[0.66,0.67]	[0.60,0.60]
	b_4	[0.75,0.77]	[0.70,0.71]	[0.68,0.70]	[0.69,0.71]
	b_5	[0.66,0.67]	[0.64,0.66]	[0.60,0.64]	[0.71,0.71]

TABLE II. EXPECTED VALUES OF GRADUATES TO EMPLOYMENT POSTS

B	B/A	d_1	d_2	d_3
b_1	a_1	[0.70,0.71]	[0.79,0.80]	[0.68,0.68]
	a_2	[0.74,0.75]	[0.68,0.70]	[0.84,0.85]
	a_3	[0.86,0.86]	[0.75,0.76]	[0.74,0.75]
	a_4	[0.90,0.91]	[0.81,0.82]	[0.80,0.80]
	a_5	[0.64,0.65]	[0.71,0.72]	[0.75,0.76]
	a_6	[0.66,0.69]	[0.74,0.75]	[0.70,0.72]
b_2	a_1	[0.80,0.81]	[0.83,0.84]	[0.85,0.86]
	a_2	[0.76,0.77]	[0.72,0.75]	[0.74,0.76]
	a_3	[0.81,0.82]	[0.80,0.80]	[0.90,0.90]
	a_4	[0.80,0.81]	[0.85,0.86]	[0.88,0.88]
	a_5	[0.74,0.75]	[0.81,0.82]	[0.76,0.78]
	a_6	[0.78,0.78]	[0.74,0.75]	[0.70,0.71]
b_3	a_1	[0.58,0.60]	[0.62,0.62]	[0.70,0.73]
	a_2	[0.74,0.75]	[0.71,0.72]	[0.66,0.68]
	a_3	[0.76,0.76]	[0.80,0.81]	[0.64,0.65]
	a_4	[0.77,0.79]	[0.83,0.84]	[0.85,0.85]
	a_5	[0.71,0.72]	[0.81,0.82]	[0.73,0.74]
	a_6	[0.83,0.81]	[0.68,0.69]	[0.76,0.78]
b_4	a_1	[0.68,0.70]	[0.76,0.78]	[0.73,0.75]
	a_2	[0.78,0.78]	[0.66,0.69]	[0.74,0.75]
	a_3	[0.84,0.86]	[0.76,0.80]	[0.78,0.78]
	a_4	[0.54,0.55]	[0.69,0.72]	[0.63,0.85]
	a_5	[0.74,0.75]	[0.77,0.78]	[0.75,0.75]
	a_6	[0.66,0.66]	[0.76,0.78]	[0.63,0.64]
b_5	a_1	[0.75,0.75]	[0.66,0.68]	[0.71,0.71]
	a_2	[0.82,0.83]	[0.78,0.79]	[0.74,0.75]
	a_3	[0.74,0.75]	[0.76,0.76]	[0.70,0.71]
	a_4	[0.72,0.73]	[0.74,0.75]	[0.76,0.76]
	a_5	[0.76,0.78]	[0.71,0.72]	[0.74,0.74]
	a_6	[0.64,0.66]	[0.63,0.65]	[0.58,0.60]

According to expected values of attribute of mutual assessment between enterprises and college graduates, the effective matching results between ideal post A and college graduate B can be obtained by using the formulas (1) and (2), respectively.

$$a^0 = \left(a_1^0, \dots, a_k^0, \dots, a_p^0\right)$$
$$= ([0.87,0.89], [0.84,0.85], [0.88,0.89], [0.69,0.71])$$

$$b^0 = \left(b_1^0, \dots, b_t^0, \dots, b_q^0\right)$$
$$= ([0.90,0.91], [0.85,0.86], [0.90,0.90])$$

By using the formulas (3) and (4) of grey relational analysis method, the preference coefficients for employment posts and college graduates about each other's attributes can be obtained. The weights of internship experience, credit points, awards and employment quality (enthusiasm, attitude) were 0.3, 0.15, 0.35 and 0.2 respectively. The weights of salary, job tasks and job treatment were 0.55, 0.10 and 0.35 respectively. So the preference values of mutual evaluation between graduates in this class and posts can be calculated, as shown in Table 3.

TABLE III. PREFERENCE VALUES OF MUTUAL EVALUATION BETWEEN EMPLOYMENT POSTS AND COLLEGE GRADUATES

D/S	b_1	b_2	b_3	b_4	b_5
a_1	(0.744,0.493)	(0.598,0.723)	(0.586,0.416)	(0.856,0.504)	(0.702 ,0.515)
a_2	(0.545,0.611)	(0.483 ,0.560)	(0.769,0.501)	(0.594, 0.562)	(0.578 ,0.641)
a_3	(0.483,0.692)	(0.686 ,0.793)	(0.523 ,0.528)	(0.679,0.701)	(0.499 ,0.525)
a_4	(0.449,0.857)	(0.580,0.769)	(0.502,0.688)	(0.526 ,0.406)	(0.668 ,0.534)
a_5	(0.553,0.475)	(0.369 ,0.576)	(0.523,0.532)	(0.603,0.551)	(0.627,0.556)
a_6	(0.590,0.474)	(0.733,0.555)	(0.422,0.626)	(0.515,0.442)	(0.435,0.402)

Mutual evaluation between employment posts of information management specialty and college graduates. Through consultation with educational administrators, college graduates and experts, the weights of employment, college graduates and optimization objectives were 0.45, 0.40 and 0.15, respectively. At the same time, the multi-objective optimization model could be transformed into a single-objective model (9). In solving the model (9), the corresponding matching results could be obtained by means of WinSQB MatLab 13 and other software and the results were the same. The results were as follows: Alisa served as logistics management engineer; Mike served as production management engineer; Ming Li served as process engineer and R&D engineer; Adam and Brown served as quality management engineers.

Through case analysis, the improved bilateral matching model is helpful in getting the best combination of matching degree between posts and college graduates in decision-making. The model is simple to operate and easy to provide the decision-making basis for employment managers.

V. CONCLUSION

In view of the preference and matching of enterprises and college graduates in the process of bilateral matching between employment posts and college graduates, on the basis of grey relational analysis, this paper establishes a decision-making model of bilateral matching between employment posts and college graduates, and obtains the corresponding matching results by solving the optimization model. Through case analysis and the testing of practicability, the model is simple to operate and the results have little error. The model can get the optimum-matching scheme by measuring the satisfaction degree of matching subjects of both sides. This paper has strong practical application value, as well as enriches and develops the theoretical basis of bilateral matching model.

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