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A job placement intervention using fuzzy approach for two-way choice

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Abstract

A real-world personnel selection or job placement problem based on a two-way choice frame in an enterprise-and-school partnership system is addressed in this paper. This study aims to develop a job placement intervention by taking into account the fuzzy assessment results of the persons involved on both sides to facilitate placement opportunities and satisfaction so that the problem is tackled in a more convincing and workable way. According to the classified results of enterprises and students, the distinction results are screened for final matching. The utility similarities of fuzzy assessments with very good are used to measure the satisfaction grade for the placement results, including enterprise–student matches and student–student combinations. A mixed integer programming model is performed to fulfill the "efficient fit from the right" policy. Numerical results and simulated application results demonstrate the effectiveness and benefits of the proposed method. Since the proposed method is a value-added matchmaker and can be easily performed, it can also be used to effectively deal with the analogue problems with two-way choice characteristic, such as the choices between advisers and graduate students and between government-expense graduates and different posts.

Keywords: Personnel selection; Two-way choice; Fuzzy sets; Mixed integer program

1. Introduction

Personnel selection directly and significantly affects the quality of employees, and hence, it has always been an important topic for organizations, including public agencies and private enterprises. Various approaches have been developed to help organizations make best personnel selection decisions to place the right people in the right jobs. Owing to the development and advancement in information technology, a great deal of studies focused on proposed expert systems (ESs) or decision support systems to assist personnel selection. Roberts (1988) studied the capability of ES and pointed out that it has the potential to assist with tasks for selecting new employees, matching people with jobs, training new and old employees, and so on. Later, a working ES named EXPER (Suh, Byun, & An, 1993) was developed to assist managers in making job placement decisions, where employees were evaluated with respect to test scores, performance ratings, aptitude scores, and so on, and then were matched with specific jobs within an organization. Hooper, Galvin, Kilmer, and Liebowitz (1998) developed and tested a rule-based ES, BOARDEX, to perform the Yes/No vote to screen officer personnel records in the first phase of board procedure. Experiment on a mock officer personnel records showed that BOARDEX was successful at selecting the records. Chien and Chen (2008) proposed a data mining framework based on decision tree and association rules to generate the useful rules for personnel selection. The useful rules were extracted from the relationships between personnel profile data and their work behaviors. Finally, 30 meaningful rules were chosen to develop the recruitment strategies.

In reality, personnel selection problems usually involve the characteristic of group decision-making under multiple

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criteria, uncertain and imprecise data. This necessitates an approach to deal with fuzzy factors appropriately. Liang and Wang (1994) developed a fuzzy algorithm by combining both interview-oriented subjective approach and test-oriented objective approach to obtain the final ranking values for candidates. The triangular fuzzy numbers (TFNs) were used to quantify the linguistic assessments about subjective criteria weightings and ratings and then the fuzzy suitability indices were calculated. The ranking value, also known as total utility, formula was proposed to derive the fuzzy assessment results. Later, Yaakob and Kawata (1999) also studied workers' placement problem by using fuzzy method. The relationship among workers is included in the workers' assignment to make an accurate decision. Some simple, but rough ways were adapted in their analysis. First, the center values of TFNs were used to rank the orders of candidates approximately. Second, the decision-makers (DMs) subjectively assigned the minimal grade value required for each job to assure the combinations of workers are possible. The drawback of the method is that when the number of jobs is more than one, overlapped assignments of some workers may be occurred, which bring careful checks and avoidances in the total combination construction.

All the previous studies are based on one-way frame, where the evaluations, including the ratings of workers for jobs under various criteria, the importance weights of criteria and the relationship between two workers out of the candidates, are determined by the DMs. That is, the DMs are substituted for the persons involved on both sides. Researchers (Beckers & Bsat, 2002; Borman, Hanson, & Hedge, 1997; Hough & Oswald, 2000; Liao, 2003; Robertson & Smith, 2001) reviewed the personnel selection studies, based on one-way selection frame, and found that many issues have influenced personnel selection practices, including change in work, change in personnel, change in society, change in work behavior, change of laws, advancements in information technology, and so on. Rothstein and Goffin (2006) reviewed recent research on the use of personality measures in personnel selection and concluded that the appropriately used personality measures may add value to personnel selection practices.

Due to the dynamic and changing nature of employers and employees in knowledge-base economy, attention should also be paid to the two-way choice frame. Examples of cases where two-way choice arises fall into the choices between practical trainees and training organizations, between advisers and graduate students and between government-expense graduates and different posts, where the first case is studied in this paper. Since the research related to two-way choice is rare, this study aims to fill the gap by developing a job placement intervention based on two-way choice frame to facilitate placement opportunities and satisfaction. The concept and initiatives of placement interventions were illustrated by Rumrill, Steffen, Kaleta, and Holman (1996). In their studies, the placement interventions were undertaken by the rehabilitation professionals who consider ways to assist people with multiple sclerosis in seeking and securing jobs that are compatible with their interests and experiences.

The rest of this paper is organized as follows. Section 2 describes the addressed problem along with the current placement procedure arisen in a case university for placing the students in the jobs provided by partner enterprises. In Section 3, the placement intervention based on two-way choice frame is presented. Section 4 illustrates a numerical example. The effectiveness of simulated application results is evaluated in Section 5. Finally, Section 6 contains some conclusions.

2. The addressed problem and current placement procedure

2.1. The addressed problem

Human resource is the important competence for enterprises to enhance their competitive advantages, especially for small and medium firms. In addition to the conventional methods for personnel recruitment and training, more and more enterprise-and-school partnership systems have been established between institutions of higher learning, including the case university, and small and medium firms in Taiwan. Enterprise-and-school partnership system is one type of the known cooperative education models, which creates a bridge to interflow the school-base and work-base learning, and therefore makes benefits and contributions to both sides of enterprises and schools. For examples, the partner schools could offer real-world cases for the classes and practical training programs for the students so that technical and vocational education system could be vigorously developed; meanwhile, the well pre-vocational trained students are valuable reserve talents for the partner enterprises. Chen, Lin, and Lee (2004) studied the cooperation patterns between enterprises and schools in Taiwan and proposed an analytical network process approach to effectively select the partner enterprise.

The addressed problem is drawn from a major university of the technical and vocational education system in Taiwan. A one-year practical training program, including some work-based learning and operating curriculums, is offered in the last phase for undergraduate students who have interests in receiving the training. The work-based curriculums are formulated and reviewed by professors, together with managers of human resource divisions of partner enterprises and domain experts. According to the memorandum about cooperative partnership and human resource development plan, each partner enterprise provides some training jobs for students of the case university. In some particular partner enterprises, the training students should work cooperatively or coordinately within a team of the respective enterprises.

Every summer, each partner enterprise holds interviews to test and appraise the students applying for training jobs. Each student voluntarily applies and takes part in interviews of some partner enterprises for obtaining a job to

Table 1
Momentous notations

E_e: enterprise e, $e = 1, 2, \ldots, m$
S_s, S_i and S_j: student s, i and j, respectively, s, i, and $j = 1, 2, \ldots, n$
f_e: predetermined number of students to be employed by E_e
$\{S_1, S_2, \ldots, S_n\}$: a set of n students who take part in interviews of the enterprises
$\{E_1, E_2, \ldots, E_m\}$: a set of m enterprises that hold interviews to test and appraise the students
$\{D_1^e, D_2^e, \ldots, D_J^e\}$: a set of J DMs of E_e
$\{C_1^E, C_2^E, \ldots, C_K^E\}$: a set of K criteria used by the enterprises to evaluate the students
$\{C_1^S, C_2^S, \ldots, C_Q^S\}$: a set of Q criteria used by the students to evaluate the enterprises
(E_e, S_s):S_s is placed in the job of E_e, i.e., E_e is matched with S_s. Referred as an enterprise–student *match*
(S_i, S_j): a combination of two students, S_i and S_j. Referred as a student–student *combination*
Ω_e: a set of possible distinction matches of E_e
Ω: a set of possible distinction matches of all enterprises, $\Omega = \cup_{e=1}^{m} \Omega_e$
S_{Ω_e}: number of students included in Ω_e
S_{Ω}: number of students included in Ω
E^R: a set of particular enterprises that the training students should work cooperatively or coordinately within a team of the respective enterprises
Π_e: a set of combinations of the students included in Ω_e
I_{es}: satisfaction grade of the match, (E_e, S_s)
J_{ij}: satisfaction grade of the combination, (S_i, S_j)
$y_{es} = 1$, if E_e is finally matched with S_s; otherwise $y_{es} = 0$

implement the practical training program. Enterprises and students are evaluated through interviews and then selected by each other under various criteria, which essentially constitutes a two-way choice. For convenience, the momentous notations used in the following description are listed in Table 1. The partner enterprises and students of the case university are abbreviated as *enterprises* and *student*s, respectively, throughout this paper.

2.2. Current placement procedure

The current placement procedure consists of two separate phases, which is a traditional and widely using method. In the first phase, each enterprise holds interviews to evaluate and rank students under various criteria, and then goes its own way to select the distinction students. Each enterprise aspires to employ distinction students and then train them for reserve talents. For an enterprise, say E_e, intends to employ f_e students, the rankings of the students are the selection guide to employ and announce at most f_e students with distinction assessment results.

In the second phase, the student, S_s, employed by one or more than one enterprise goes his/her own way to make the report decision. The assessments and rankings of the employer enterprises evaluated by S_s under various criteria during the interviews are the decision guides. S_s reports to at most one employer enterprise with superior ranking and distinction assessment. If there is no distinction employer enterprise for S_s to select, then S_s abandons the employment.

The major drawbacks of the current placement procedure include: (i) As each enterprise goes its own way to select the distinction students, the announced lists of employed students may be reduplicated, i.e., overlapped employments of some students, which reduces the total number of employed students meaning a pity to exclude some distinction students. (ii) For an overlapped employment case, i.e., a student is employed by more than one enterprise, as each student goes his/her own way to report to one distinction employer enterprise at most, some enterprises may have vacancies. (iii) For a single employment case, i.e., a student is employed by just one enterprise, if the student abandons the employment because the employer enterprise is not a distinction enterprise for him/her, then the enterprise has a vacancy. (iv) The relationship among the students employed by an enterprise has not been taken into account, which is a disadvantage when the students should work and act in concert within a team.

3. The placement intervention based on two-way choice frame

As the success of the partnership depends on long term "win–win" collaboration, it is a contribution to develop a method that simultaneously accommodate the learning and training wills of students and the human resource developments of enterprises. A finding by talking with the students and DMs of the enterprises indicates that the rankings are just convenient indices for selection decision. The core issue concerned by the enterprises is that they should employ distinction students. Analogously, the students concern that the enterprises they report for training should be of distinction. Hence, a placement intervention based on two-way choice frame that can facilitate placement opportunities and satisfaction is workable. Evaluations of enterprise–student matches and student–student combinations in some particular enterprises are conducted by the involved persons to obtain the two-way assessment results. The ratings of enterprises and students for various criteria are considered as linguistic variables. The judgment values of linguistic data are quantified with TFNs. The linguistic variable scheme in the rating set (Yaakob & Kawata, 1999) shown in Table 2 is used in this study. Tsaur, Chang, and Yen (2002) utilized the analytic hierarchy process (AHP) method (Saaty, 1980) in the fuzzy multiple criteria decision-making theory and pointed out that AHP method should be an exact measure of the difference of attribute preference for DMs and the results of this method are better than the others. Therefore, this study includes AHP weighting for calculating the importance weights of the criteria. According to the classified results of enterprises and students, those distinction results are sieved out for final matching. The utility similarities of fuzzy assessments with VG are used to measure the satisfaction grade of the placement results. A mixed integer programming (MIP) model is performed to fulfill the "efficient fit from the

Table 2
Linguistic variables for rating of enterprise and student

Linguistic data ($\widetilde{L}_i$)	TFN	$U_T(\widetilde{L}_i)$
Very good (VG)	(18, 19, 20)	0.9211
Good (G)	(13, 16, 18)	0.7333
Normal (N)	(9, 11, 13)	0.5000
Bad (B)	(4, 6, 9)	0.2667
Very bad (VB)	(2, 3, 4)	0.0789

right" policy. The computation flow of the proposed method is shown as Fig. 1.

3.1. Evaluate students by enterprises

The fuzzy approach for evaluating students by enterprises consists of the following steps:

Step 1: Obtain the linguistic rating of each student for each criterion from the DMs of each enterprise. Then, quantify the linguistic judgment values with TFNs as shown in Table 2. Let TFNs

$$\widetilde{X}^e_{skj} = (\alpha^e_{skj}, \beta^e_{skj}, \gamma^e_{skj}), \quad s = 1, 2, \ldots, n, \quad k = 1, 2, \ldots, K, \; j = 1, 2, \ldots, J$$

be the linguistic ratings assigned to S_s for C^E_k by D^e_j. If S_s has not taken part in the interview of E_e, the evaluation for S_s is skipped.

Step 2: Apply the mean aggregation rule to pool the DMs' opinions. The aggregate fuzzy assessments of S_s for C^E_k by E_e will be

$$\widetilde{R}^e_{sk} = (\alpha^e_{sk}, \beta^e_{sk}, \gamma^e_{sk}), \quad s = 1, 2, \ldots, n, \quad k = 1, 2, \ldots, K, \tag{1}$$

where

$$\alpha^e_{sk} = \sum_{j=1}^{J} \alpha^e_{skj}/J, \quad \beta^e_{sk} = \sum_{j=1}^{J} \beta^e_{skj}/J, \quad \gamma^e_{sk} = \sum_{j=1}^{J} \gamma^e_{skj}/J.$$

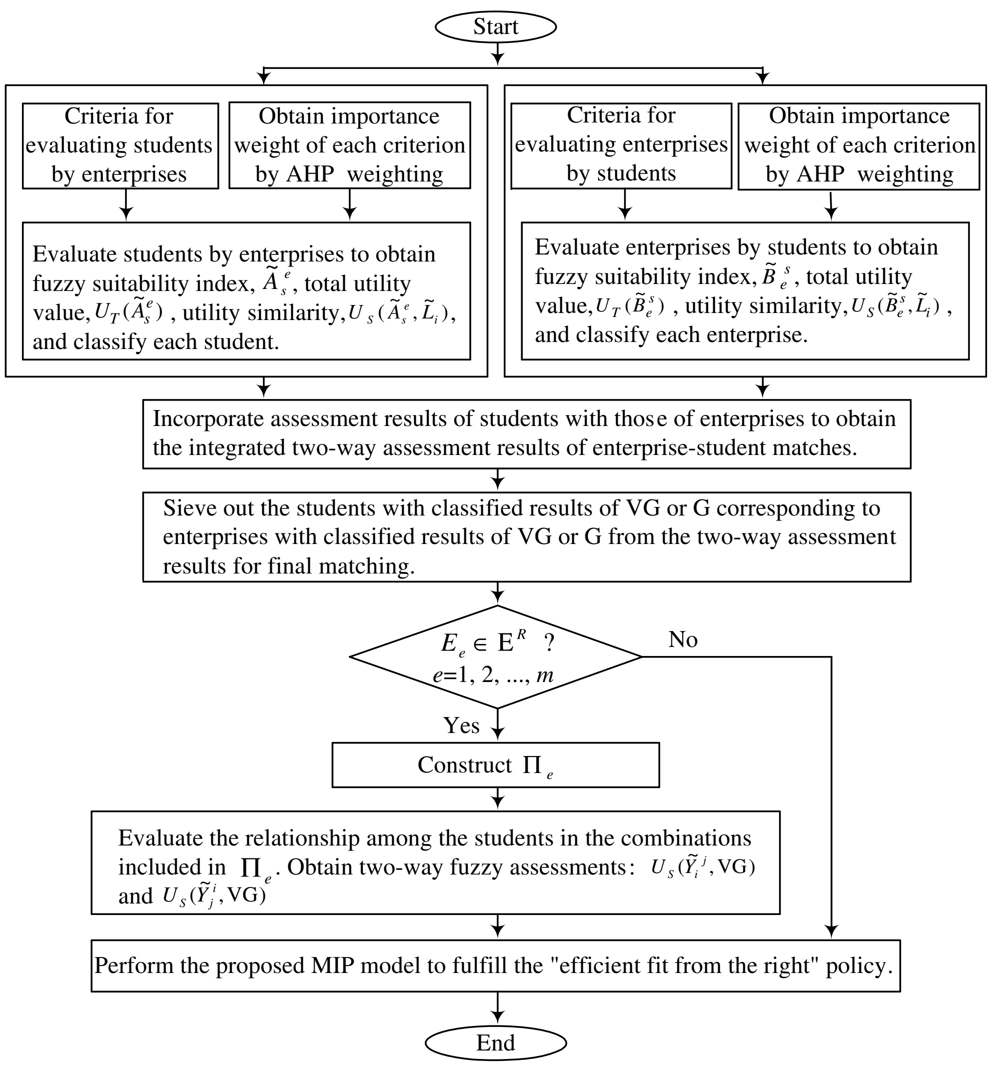

Fig. 1. Flowchart of the proposed method.

Step 3: Employ the AHP weighting method to find the comparative importance weight of C_k^E for E_e, denoted by W_k^e. Then, $\widetilde{R}_{sk}^e$ and W_k^e are aggregated by summing up the products between the criteria ratings and the corresponding importance weights to obtain the fuzzy suitability index of S_s, denoted by $\widetilde{A}_s^e$, which is calculated by using the fuzzy sum and fuzzy multiplication as

$$\widetilde{A}_s^e = (\widetilde{R}_{s1}^e \otimes W_1^e) \oplus (\widetilde{R}_{s2}^e \otimes W_2^e) \oplus \cdots \oplus (\widetilde{R}_{sK}^e \otimes W_K^e). \quad (2)$$

Step 4: Calculate the total utility value of $\widetilde{A}_s^e$, denoted by $U_T(\widetilde{A}_s^e)$, and then rank the students according to the descending order of $U_T(\widetilde{A}_s^e)$. By using the definitions and formulas of right utility value $U_R(\widetilde{A}_s^e)$ based on maximizing set R and left utility value $U_L(\widetilde{A}_s^e)$ based on minimizing set L (Cochran & Chen, 2005; Hsieh & Chen, 1999), $U_T(\widetilde{A}_s^e)$ can be calculated by employing the total utility function (Chen, 1985) as

$$U_T(\widetilde{A}_s^e) = [U_R(\widetilde{A}_s^e) + 1 - U_L(\widetilde{A}_s^e)]/2. \quad (3)$$

Step 5: Calculate the utility similarity of each student's fuzzy assessment with each linguistic data in Table 2. Choose the corresponding best linguistic data of each student with the largest utility similarity to classify the students. The total utility value of linguistic data $\widetilde{L}_i$ is denoted by $U_T(\widetilde{L}_i)$ and shown in Table 2. By using the utility similarity method proposed by Hsieh and Chen (1999), the utility similarity of $\widetilde{A}_s^e$ with $\widetilde{L}_i$, denoted by $U_S(\widetilde{A}_s^e, \widetilde{L}_i)$, can be calculated as

$$U_S(\widetilde{A}_s^e, \widetilde{L}_i) = \frac{\min\{U_T(\widetilde{A}_s^e), U_T(\widetilde{L}_i)\}}{\max\{U_T(\widetilde{A}_s^e), U_T(\widetilde{L}_i)\}}. \quad (4)$$

The classified results will be used in the two-way selection process and the utility similarity of $\widetilde{A}_s^e$ with VG, $U_S(\widetilde{A}_s^e, \text{VG})$, will be used as the satisfaction grade measure of the matches.

3.2. Evaluate enterprises by students

The fuzzy approach for evaluating enterprises by students is described as follows:

Step 6: Obtain the linguistic rating of each enterprise for each criterion from the students. Then, quantify the linguistic judgment values with TFNs as shown in Table 2. Let TFNs

$$\widetilde{R}_{ek}^s = (\mu_{ek}^s, \nu_{ek}^s, \upsilon_{ek}^s), \quad e = 1, 2, \ldots, m, \quad k = 1, 2, \ldots, Q$$

be the linguistic ratings assigned to E_e for C_k^S by S_s. If S_s has not taken part in the interview of E_e, the evaluation for E_e is skipped.

Step 7: Employ the AHP weighting method to find the comparative importance weight of C_k^S for S_s, denoted by V_k^s. Then, $\widetilde{R}_{ek}^s$ and V_k^s are aggregated to obtain the fuzzy suitability index of E_e, denoted by $\widetilde{B}_e^s$, which is calculated as

$$\widetilde{B}_e^s = (\widetilde{R}_{e1}^s \otimes V_1^s) \oplus (\widetilde{R}_{e2}^s \otimes V_2^s) \oplus \cdots \oplus (\widetilde{R}_{eQ}^s \otimes V_Q^s). \quad (5)$$

Step 8: Calculate the total utility values of $\widetilde{B}_e^s$, denoted by $U_T(\widetilde{B}_e^s)$, and then rank the enterprises according to the descending order of $U_T(\widetilde{B}_e^s)$. By using the right utility value, $U_R(\widetilde{B}_e^s)$, and left utility value, $U_L(\widetilde{B}_e^s)$, $U_T(\widetilde{B}_e^s)$ can be calculated as

$$U_T(\widetilde{B}_e^s) = [U_R(\widetilde{B}_e^s) + 1 - U_L(\widetilde{B}_e^s)]/2. \quad (6)$$

Step 9: Calculate the utility similarity of each enterprise's fuzzy assessment with each linguistic data in Table 2 and then classify each enterprise. The utility similarity of $\widetilde{B}_e^s$ with $\widetilde{L}_i$, denoted by $U_S(\widetilde{B}_e^s, \widetilde{L}_i)$, is calculated as

$$U_S(\widetilde{B}_e^s, \widetilde{L}_i) = \frac{\min\{U_T(\widetilde{B}_e^s), U_T(\widetilde{L}_i)\}}{\max\{U_T(\widetilde{B}_e^s), U_T(\widetilde{L}_i)\}}. \quad (7)$$

The classified results will be used in the two-way selection process and the utility similarity of $\widetilde{B}_e^s$ with VG, $U_S(\widetilde{B}_e^s, \text{VG})$, will be used as the satisfaction grade measure of the matches.

3.3. Generalize two-way evaluations of enterprise–student matches

Step 10: Incorporate the assessment results of S_s evaluated by E_e with the corresponding assessment results of E_e evaluated by S_s to obtain the integrated two-way assessments of enterprise–student matches. In order to match the distinction E_e with distinction S_s, enterprises with classified results of VG or G corresponding to students with classified results of VG or G in two-way assessments are sieved out for final matching.

Step 11: For each enterprise, say E_e, construct the sets Ω_e and Ω, and then count the numbers of students included in the associated sets to obtain S_{Ω_e} and S_Ω. For each particular enterprise, say $E_e \in E^R$, construct the set Π_e.

3.4. Evaluate the relationship among students

Step 12: For a particular enterprise, say E_e, the student–student combinations included in Π_e are used to conduct the relationship assessment. For a combination (S_i, S_j), the relationship between S_i and S_j is evaluated by each other employing the previous linguistic rating and AHP weighting schemes. The fuzzy suitability indices of S_i evaluated by S_j and of S_j evaluated by S_i, denoted by $\widetilde{Y}_i^j$ and $\widetilde{Y}_j^i$, respectively, along with the associated utility similarities of $\widetilde{Y}_i^j$ with VG and of $\widetilde{Y}_j^i$ with VG, denoted by $U_S(\widetilde{Y}_i^j, \text{VG})$ and $U_S(\widetilde{Y}_j^i, \text{VG})$, respectively, can be obtained.

Step 13: Incorporate $U_S(\widetilde{Y}_i^j, \text{VG})$ with $U_S(\widetilde{Y}_j^i, \text{VG})$ to obtain the integrated two-way assessments of student–student combinations.

3.5. Satisfaction grade of placement

The satisfaction grade measure of placement is elaborated here. For a match (E_e, S_s), the larger the $U_S(\widetilde{A}_s^e, \text{VG})$, the greater the closeness between S_s and VG evaluated by E_e, and hence, the greater the preference of S_s for E_e. Analogously, the larger the $U_S(\widetilde{B}_e^s, \text{VG})$, the greater the closeness between E_e and VG evaluated by S_s, and hence, the greater the preference of E_e for S_s. An index, I_{es}, is proposed to measure the satisfaction grade of (E_e, S_s) according to the following equation:

$$I_{es} = U_S(\widetilde{A}_s^e, \text{VG}) + U_S(\widetilde{B}_e^s, \text{VG}).$$

Each of the values of $U_S(\widetilde{A}_s^e, \text{VG})$ and $U_S(\widetilde{B}_e^s, \text{VG})$ is less than or equal to one, and hence, the maximal or ideal value of I_{es} is two.

For a combination (S_i, S_j), the larger the $U_S(\widetilde{Y}_j^i, \text{VG})$, the greater the closeness between S_j and VG evaluated by S_i, and hence, the greater the preference of S_j for S_i, and vice versa. The satisfaction grade of (S_i, S_j) is calculated as

$$J_{ij} = U_S(\widetilde{Y}_j^i, \text{VG}) + U_S(\widetilde{Y}_i^j, \text{VG}).$$

By the same inferences, the maximal or ideal value of J_{ij} is two. The total satisfaction grade of placement, including a match (E_e, S_s) and a combination (S_i, S_j), is $I_{es} + J_{ij}$.

3.6. Placement intervention

Step 14: Perform the following MIP model to obtain efficient placement results to fulfill the "efficient fit from the right" policy.

$$\text{Minimize} \quad Z = F^- + G^- + H^-, \tag{m0}$$

$$\text{Subject to} \quad \sum_{e=1}^{m} \sum_{\substack{s=1 \\ (E_e,S_s)\in\Omega}}^{n} y_{es} + F^- = \min\left\{\sum_{e=1}^{m} f_e, S_\Omega\right\}, \tag{m1}$$

$$\sum_{e=1}^{m} \sum_{\substack{s=1 \\ (E_e,S_s)\in\Omega}}^{n} y_{es} \cdot I_{es} + G^- = 2 \cdot \min\left\{\sum_{e=1}^{m} f_e, S_\Omega\right\}, \tag{m2}$$

$$\sum_{\substack{e,i,j \\ (S_i,S_j)\in\Pi_e \\ E_e\in E^R}} y_{ei} \cdot y_{ej} \cdot J_{ij} + H^- = 2 \cdot \sum_{\substack{e,i,j \\ (S_i,S_j)\in\Pi_e \\ E_e\in E^R}} y_{ei} \cdot y_{ej}, \tag{m3}$$

$$\sum_{\substack{s=1 \\ (E_e,S_s)\in\Omega_e}}^{n} y_{es} \leqslant \min\{f_e, S_{\Omega_e}\}, \quad e = 1,2,\ldots,m, \tag{m4}$$

$$\sum_{\substack{e=1 \\ (E_e,S_s)\in\Omega}}^{m} y_{es} \leqslant 1, \quad s = 1,2,\ldots,n, \tag{m5}$$

$$y_{es} = (0,1), \quad e = 1,2,\ldots,m, \; s = 1,2,\ldots,n, \tag{m6}$$

$$F^-, G^-, H^- \geqslant 0. \tag{m7}$$

The objective function (m0) is a compromise solution for minimizing the deviations below the ideal values. Constraint (m1) represents a flexible goal in which the total number of students to be placed in all enterprises may be below the ideal number. Constraint (m2) represents a flexible goal in which the satisfaction grade of all matches may be below the ideal value. Constraint (m3) arises in the cases of particular enterprises; it represents a flexible goal in which the satisfaction grade of student–student combinations may be below the ideal value. Constraint (m4) restricts the maximal number of students to be placed in E_e. Constraint (m5) indicates that each student is placed in one enterprise at most. The meaning of other constraints is evident.

4. Numerical example

Suppose four enterprises, E_1, E_2, E_3 and E_4, provide the practical training jobs for the students with $f_1 = 3$, $f_2 = 1$, $f_3 = 4$ and $f_4 = 3$. The students employed by E_1 and E_4 should work cooperatively or coordinately, and hence, the relationship among the employed students is concerned by E_1 and E_4, respectively. The numbers of DMs of the four enterprises in the interviews are three, three, two and three, respectively. Five criteria are used by the DMs to assess the students, which include professional knowledge (C_1^E), creativity (C_2^E), sense of responsibility (C_3^E), organizing ability (C_4^E) and emotional stability (C_5^E). Nineteen students took part in interviews of some enterprises with their own learning volition and future career plans. The criteria used by the students to assess the enterprises include reputation (C_1^S), salary and welfare (C_2^S), further education (C_3^S) and working location (C_4^S).

4.1. Obtain the efficient placements

The proposed method is performed as follows:

Steps 1 and 2: The linguistic ratings of the students for each criterion evaluated by the DMs of E_1 along with the aggregate fuzzy assessments calculated by formula (1) are depicted, for example, in Table 3.

Step 3: The AHP weighting method employed by E_1 to find the comparative importance weights of criteria is shown, for example, in Table 4. By formula (2), the fuzzy suitability indices of the students evaluated by E_1, $\widetilde{A}_s^1$, are calculated and shown in the second column of Table 5.

Steps 4 and 5: The total utility value of $\widetilde{A}_s^1$, $U_T(\widetilde{A}_s^1)$, is calculated by formula (3) and shown, for example, in the third column of Table 5 and then the students are ranked. The rankings are the selecting sequence while E_1 goes its own way to make the employment decision. The utility similarity of $\widetilde{A}_s^1$ with $\widetilde{L}_i$, $U_S(\widetilde{A}_s^1, \widetilde{L}_i)$, is calculated by formula (4) and then each student is classified according to the corresponding best linguistic data, as shown in Table 5.

Table 3
Assessments of students evaluated by E_1

Student	DM/aggregate	Criteria				
		C_1^E	C_2^E	C_3^E	C_4^E	C_5^E
S_1	D_1^1	G	N	G	N	G
	D_2^1	G	N	G	N	VG
	D_3^1	G	G	G	N	G
	$\widetilde{R}_{1k}^1$	(13,16,18)	(10.33,12.67,14.67)	(13,16,18)	(9,11,13)	(14.67,17,18.67)
S_2[a]	–	–	–	–	–	–
⋮						
S_{19}	D_1^1	B	B	B	VB	B
	D_2^1	B	N	B	VB	B
	D_3^1	VB	N	B	VB	B
	$\widetilde{R}_{19k}^1$	(3.33,5,7.33)	(7.33,9.33,11.67)	(4,6,9)	(2,3,4)	(4,6,9)

[a] S_2 has not taken part in the interview of E_1.

Table 4
Importance weights of criteria for E_1

	C_1^E	C_2^E	C_3^E	C_4^E	C_5^E	W_k^1
C_1^E	1	1/3	2	3	2	0.1986
C_2^E	3	1	4	6	5	0.4864
C_3^E	1/2	1/4	1	3	3	0.1627
C_4^E	1/3	1/6	1/3	1	1/2	0.0603
C_5^E	1/2	1/5	1/3	2	1	0.0920

Consistency ratio=0.0458 < 0.1

The membership functions of R, L and $\widetilde{A}_1^1$ are depicted in Fig. 2 for briefly illustrating.

Steps 6 and 7: The linguistic ratings of the enterprises for each criterion evaluated by S_2 along with the fuzzy suitability index of E_e calculated by formula (5) are depicted, for example, in Table 6.

Steps 8 and 9: The total utility value of $\widetilde{B}_e^2$, $U_T(\widetilde{B}_e^2)$, is calculated, for example, by formula (6) and then the enter-

Table 5
Fuzzy suitability indices, total utility values, utility similarities and classified results of the students evaluated by E_1

S_s	$\widetilde{A}_s^1$	$U_T(\widetilde{A}_s^1)$	$U_S(\widetilde{A}_s^1, \widetilde{L}_i)$					Classified result
			VG	G	N	B	VB	
S_1	(11.62, 14.17, 16.14)	0.6502 (5[a])	0.7058	*0.8867*	0.7692	0.4102	0.1215	G
S_3	(12.10, 14.88, 16.88)	0.6819 (4)	0.7403	*0.9298*	0.7333	0.3911	0.1158	G
S_5	(13.63, 16.22, 18.05)	0.7501 (3)	0.8144	*0.9777*	0.6666	0.3555	0.1052	G
S_7	(2.13, 3.20, 4.33)	0.0924 (13)	0.1003	0.1259	0.1847	0.3463	*0.8548*	VB
S_8	(17.22, 18.53, 19.69)	0.8898 (2)	*0.9660*	0.8242	0.5620	0.2997	0.0887	VG
S_9	(17.57, 18.74, 19.83)	0.9036 (1)	*0.9811*	0.8116	0.5533	0.2951	0.0874	VG
S_{10}	(2.18, 3.28, 4.46)	0.0975 (12)	0.1059	0.1330	0.1951	0.3658	*0.8094*	VB
S_{12}	(10.30, 12.45, 14.39)	0.5698 (6)	0.6187	0.7771	*0.8774*	0.4680	0.1385	N
S_{13}	(9.05, 11.27, 13.43)	0.5128 (7)	0.5568	0.6993	*0.9750*	0.5200	0.1539	N
S_{15}	(5.58, 7.58, 10.26)	0.3391 (9)	0.3681	0.4624	0.6782	*0.7864*	0.2328	B
S_{16}	(8.98, 11.18, 13.34)	0.5085 (8)	0.5521	0.6934	*0.9832*	0.5244	0.1552	N
S_{17}	(2.59, 3.88, 5.47)	0.1375 (11)	0.1492	0.1874	0.2749	0.5154	*0.5744*	VB
S_{19}	(5.37, 7.24, 9.66)	0.3195 (10)	0.3469	0.4357	0.6390	*0.8346*	0.2471	B

[a] Ranking of S_1 evaluated by E_1.

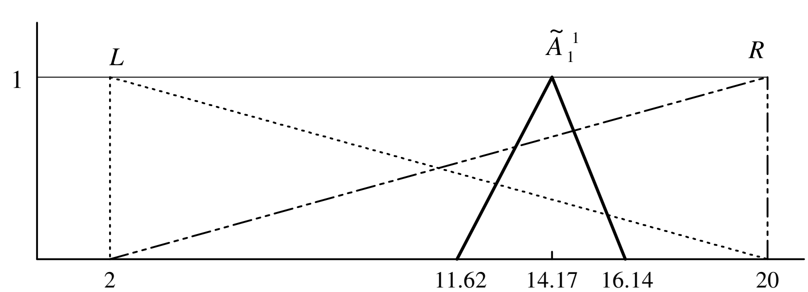

Fig. 2. The membership functions of R, L and $\widetilde{A}_1^1$.

Table 6
Assessments of the enterprises evaluated by S_2

Enterprise/ weight	Criteria				$\widetilde{B}_e^2$
	C_1^S	C_2^S	C_3^S	C_4^S	
E_1[a]	–	–	–	–	–
E_2	N	G	G	G	(12.52, 15.40, 17.40)
E_3	G	VG	N	G	(15.09, 17.14, 18.68)
E_4	N	B	N	G	(8.25, 10.63, 13.08)
V_k^2	0.1201	0.4543	0.0452	0.3804	

[a] S_2 has not taken part in the interview of E_1.

Table 7
Total utility values, utility similarities and classified results of the enterprises evaluated by S_2

E_e	$U_T(\widetilde{B}_e^2)$	$U_S(\widetilde{B}_e^2, \widetilde{L}_i)$					Classified result
		VG	G	N	B	VB	
E_2	0.7058 (2[a])	0.7663	*0.9625*	0.7084	0.3778	0.1118	G
E_3	0.8043 (1)	0.8732	*0.9118*	0.6217	0.3316	0.0982	G
E_4	0.4827 (3)	0.5241	0.6582	*0.9654*	0.5524	0.1636	N

[a] Ranking of E_2 evaluated by S_2.

prises are ranked. The rankings are the selecting sequence while S_2 goes his/her own way to make the decision of report for training job. The utility similarity of $\widetilde{B}_e^2$ with $\widetilde{L}_i$, $U_S(\widetilde{B}_e^2, \widetilde{L}_i)$, is calculated by formula (7) and then each enterprise is classified according to the corresponding best linguistic data, as shown in Table 7.

Step 10: The integrated two-way assessments of enterprise–student matches, including rankings, classified results and utility similarities of fuzzy assessments with VG, are shown in Table 8, where enterprises with distinction classified results of VG or G corresponding to students with distinction classified results of VG or G are sieved out and depicted in boldface.

Step 11: By using the screened information in Table 8, the associated sets are constructed as

$$\Omega_1 = \{(E_1, S_1),\ (E_1, S_3),\ (E_1, S_5),\ (E_1, S_8),\ (E_1, S_9)\},\quad S_{\Omega_1} = 5,$$
$$\Omega_2 = \{(E_2, S_2),\ (E_2, S_3),\ (E_2, S_5),\ (E_2, S_9)\},\quad S_{\Omega_2} = 4,$$
$$\Omega_3 = \{(E_3, S_2),\ (E_3, S_5),\ (E_3, S_8),\ (E_3, S_{14}),\ (E_3, S_{15}),\ (E_3, S_{16})\},\ S_{\Omega_3} = 6,$$
$$\Omega_4 = \{(E_4, S_7),\ (E_4, S_9),\ (E_4, S_{13}),\ (E_4, S_{14}),\ (E_4, S_{16}),\ (E_4, S_{18})\},\ S_{\Omega_4} = 6.$$

Then, construct Ω as $\Omega = \Omega_1 \cup \Omega_2 \cup \Omega_3 \cup \Omega_4$. Consequently, the distinction students included in Ω, meaning available for matching with the enterprises, are S_1, S_2, S_3, S_5, S_7, S_8, S_9, S_{13}, S_{14}, S_{15}, S_{16} and S_{18}, and hence, $S_\Omega = 12$. As E_1 and E_4 concern the relationship among the employed students, respectively, which constructs $E^R = \{E_1, E_4\}$. Then Π_1 and Π_4 are obtained as follows:

Table 8
Integrated two-way assessments of enterprise–student matches

	E_1	E_2	E_3	E_4
S_1	**5, G, 0.7058**[a] **1, G, 0.7907**[b]			
S_2		**5, G, 0.6673** **2, G, 0.7663**	**8, G, 0.6846** **1, G, 0.8732**	8, B, 0.2774 3, N, 0.5241
S_3	**4, G, 0.7403** **2, VG, 0.9071**	**3, VG, 0.9049** **1, VG, 0.9347**		
S_4		8, B, 0.3760 1, G, 0.7788	12, B, 0.1868 2, N, 0.6258	
S_5	**3, G, 0.8144** **2, VG, 0.9133**	**1, VG, 0.9757** **1, VG, 0.9606**	**1, VG, 0.9440** **3, G, 0.7220**	
S_6		10, VB, 0.1537 3, B, 0.3898	11, B, 0.2404 1, G, 0.8405	7, N, 0.5844 2, N, 0.6286
S_7	13, VB, 0.1003 4, B, 0.3801	6, N, 0.6181 3, G, 0.7023	10, N, 0.4405 1, VG, 0.9499	**3, VG, 0.8956** **2, G, 0.8238**
S_8	**2, VG, 0.9726** **2, VG, 0.9345**		**4, G, 0.7916** **1, VG, 0.9409**	
S_9	**1, VG, 0.9811** **3, G, 0.6864**	**2, VG, 0.9546** **2, G, 0.8189**		**1, VG, 0.9888** **1, VG, 0.9600**
S_{10}	12, VB, 0.1059 2, N, 0.6062	9, B, 0.3674 1, N, 0.6169		
S_{11}		4, G, 0.6860 1, B, 0.3590		
S_{12}	6, N, 0.6187 1, G, 0.8695	7, N, 0.5800 2, G, 0.8104	13, VB, 0.0904 3, N, 0.5800	9, VB, 0.1479 4, B, 0.2753
S_{13}	7, N, 0.5568 1, VG, 0.9210			**4, G, 0.7404** **2, G, 0.6812**
S_{14}			**2, VG, 0.9236** **2, G, 0.8473**	**5, G, 0.7101** **1, VG, 0.9159**
S_{15}	9, B, 0.3681 1, G, 0.7221		**5, G, 0.7813** **2, G, 0.7159**	
S_{16}	8, N, 0.5521 3, G, 0.6934		**6, G, 0.7014** **1, VG, 0.9173**	**2, VG, 0.9676** **2, G, 0.7141**
S_{17}	11, VB, 0.1492 2, B, 0.3505		9, N, 0.4767 1, G, 0.8533	
S_{18}			7, G, 0.6961 2, N, 0.4702	**6, G, 0.7033** **1, G, 0.8821**
S_{19}	10, B, 0.3469 1, VG, 0.9138		3, VG, 0.9074 2, N, 0.6133	

[a] Assessment results of S_1 evaluated by E_1.
[b] Assessment results of E_1 evaluated by S_1.

$$\Pi_1 = \{(S_1, S_3),\ (S_1, S_5),\ (S_1, S_8),\ (S_1, S_9),\ (S_3, S_5),\ (S_3, S_8),\ (S_3, S_9),\ (S_5, S_8),\ (S_5, S_9),\ (S_8, S_9)\},$$
$$\Pi_4 = \{(S_7, S_9),\ (S_7, S_{13}),\ (S_7, S_{14}),\ (S_7, S_{16}),\ (S_7, S_{18}),\ (S_9, S_{13}),\ (S_9, S_{14}),\ (S_9, S_{16}),$$
$$(S_9, S_{18}),\ (S_{13}, S_{14}),\ (S_{13}, S_{16}),\ (S_{13}, S_{18}),\ (S_{14}, S_{16}),\ (S_{14}, S_{18})\ (S_{16}, S_{18})\}.$$

Steps 12 and 13: The combinations included in Π_1 and Π_4 are used to conduct the two-way evaluations of relationship, where the criteria include agreeableness, openness, kindness and accomplishment. Table 9 shows the results of incorporating $U_S(\widetilde{Y}_i^j, \text{VG})$ with $U_S(\widetilde{Y}_j^i, \text{VG})$.

Step 14: The placement results upon performing the MIP formula include 11 enterprise–student matches and six student–student combinations for E_1 and E_4, which are as follows:

Table 9
Integrated two-way assessments of relationship

	S_1	S_3	S_5	S_8	S_7	S_9	S_{13}	S_{14}	S_{16}
S_3	0.9138[a]								
	0.6973[b]								
S_5	0.6133	0.4702							
	0.8533	0.3505							
S_8	0.7119	0.7752	0.7935						
	0.9173	0.7141	0.6934						
S_9	0.5606	0.6770	0.5390	0.5963	0.7063				
	0.7221	0.6645	0.6697	0.7000	0.7188				
S_{13}					0.8473	0.6812			
					0.8695	0.8104			
S_{14}					0.8066	0.8055	0.5800		
					0.9600	0.8189	0.6864		
S_{16}					0.5292	0.5579	0.2753	0.8547	
					0.7017	0.8238	0.7023	0.3801	
S_{18}					0.9159	0.9020	0.9129	0.4392	0.6156
					0.9191	0.6286	0.3898	0.6892	0.6020

[a] Assessment results of S_3 evaluated by S_1.
[b] Assessment results of S_1 evaluated by S_3.

Eleven matches: $(E_1, S_1), (E_1, S_3), (E_1, S_8), (E_2, S_5), (E_3, S_2), (E_3, S_{14}), (E_3, S_{15}), (E_3, S_{16}), (E_4, S_7), (E_4, S_9), (E_4, S_{18})$.

Six combinations: $(S_1, S_3), (S_1, S_8), (S_3, S_8), (S_7, S_9), (S_7, S_{18}), (S_9, S_{18})$.

Eleven students are matched with four enterprises where the predetermined numbers of students to be employed for the four enterprises are totally satisfied. The total satisfaction grade of the 11 matches is 18.6855 with a mean of 1.6987; meanwhile, the total satisfaction grade of the six combinations is 9.5203 with a mean of 1.5867. The pooled satisfaction grade of the matches and combinations is 28.2058 (=18.6855 + 9.5203) with a mean of 1.6592 (=28.2058/17).

4.2. Effectiveness evaluation

To test the effectiveness of the proposed method, the current placement method is used to deal with the same problem. In the first phase, each enterprise goes its own way to select the distinction students according to the rankings of the students, as shown in Table 8. The students employed by E_1, E_2, E_3 and E_4 are shown in columns of Table 10. The overlapped employments arise for S_5, S_8 and S_9. S_5 is employed by E_1, E_2 and E_3, S_8 by E_1 and E_3 and S_9 by E_1 and E_4. In the second phase, each employed student reports to one employer enterprise at most with superior ranking and distinction assessment, or abandons employment for no distinction enterprise to be pleased with report. According to the assessments of enterprises shown in Table 8, S_5 reports to E_2 with the ranking of one, meanwhile the employments of E_1 and E_3 are abandoned; S_8 reports to E_3 with ranking of one, meanwhile the employment of E_1 is abandoned; S_9 reports to E_4 with ranking of one, meanwhile the employment of E_1 is abandoned. For the single employment cases for S_7, S_{14}, S_{16} and S_{19}, S_7, S_{14} and S_{16} report to E_4, E_3 and E_4 with rankings of two, two and two, respectively; while S_{19} abandons the employment of E_3, as it is not a distinction enterprise for him/her. The responses of the students are shown in Table 10. As a result, six students report to the enterprises along with five vacancies. The total satisfaction grade of the six enterprise–student matches, $(E_2, S_5), (E_3, S_8), (E_3, S_{14}), (E_4, S_7), (E_4, S_9)$ and (E_4, S_{16}), is 10.7896 with a mean of 1.7983; meanwhile, the total satisfaction grade of the three student–student combinations for $E_4, (S_7, S_9), (S_7, S_{16})$ and (S_9, S_{16}), is 4.0377 with a mean of 1.3459. The pooled satisfaction grade of the matches and combinations is 14.8273 (=10.7896 + 4.0377) with a mean of 1.6475 (=14.8273/9).

Table 10
Results of enterprises' employments and students' responses

E_1	E_2	E_3	E_4
S_9 ⊗	S_5 ☑ 1[a]	S_5 ⊗	S_9 ☑ 1
S_8 ⊗		S_{14} ☑ 2	S_{16} ☑ 2
S_5 ⊗		S_{19} ⊗	S_7 ☑ 2
		S_8 ☑ 1	

☑ The employed students report to the enterprises.
⊗ The employed students abandon the employments.
[a] The ranking of E_2 evaluated by S_5.

The effectiveness of the proposed method is evaluated by comparing its matching results with those obtained by the current placement procedure. The proposed method brings 11 matches while the current placement procedure produces six matches along with five vacancies. With respect to the satisfaction grade, the nature of the two-way choice problem reveals that the more the number of matches, the lower the satisfaction grade in the later match, and hence, the lower the mean of satisfaction grade. Such a nature is unfolded in the phenomenon that the mean of satisfaction grade for 11 matches obtained by the proposed method, 1.6987, is less than that for six matches obtained by the current placement procedure, 1.7983. However, the minor reduction of average satisfaction grade, a percentage deviation of 5.54% (=(1.7983 − 1.6987)/1.7983), brings the major increment of the number of matches, a percentage deviation of 83.33% (=(11 − 6)/6), exhibiting that it is an effective trade-off. Especially, from the viewpoint of the total number of matches and satisfaction grade, 11 matches with total satisfaction grade of 18.6855 are superior to six matches with the total satisfaction grade of 10.7896, meaning the proposed method is a value-added approach.

Concerning the relationship among the employed students within the particular enterprise, the proposed method takes into account such an important issue, and hence, the average satisfaction grade of the combinations, 1.5867, is greater than that obtained by the current placement procedure, 1.3459, where the relationship factor has not been considered.

With respect to the pooled values, the pooled average satisfaction grade obtained by the proposed method, 1.6592, is superior to that obtained by the current placement procedure, 1.6475.

In the previous example, the total predetermined number of students to be employed by the enterprises is 11, which is less than the number of distinction students available for matching with the enterprises, 12. To test the robustness of the proposed method for the contrary case, the predetermined numbers of students to be employed are modified to be $f_1 = 3$, $f_2 = 2$, $f_3 = 5$ and $f_4 = 5$, which are added up to 15. By using the information shown in Table 8, the matches obtained by the proposed MIP model are as follows: match E_1 with S_1 and S_8; E_2 with S_3 and S_9; E_3 with S_2, S_5, S_{14}, S_{15} and S_{16}; E_4 with S_7, S_{13} and S_{18}. All the 12 distinction students are matched with four enterprises. The total satisfaction grade of the 12 enterprise–student matches is 19.8537 with a mean of 1.6545; meanwhile, the total satisfaction grade of the four student–student combinations for E_1 and E_4 is 6.4837 with a mean of 1.6209. The pooled satisfaction grade of matches and combinations is 26.3374 with a mean of 1.6461.

The employments of the enterprises and responses of the students obtained by current placement procedure are depicted in Table 11. The total satisfaction grade of the eight matches is 13.5635 with a mean of 1.6954; meanwhile, the total satisfaction grade of the ten combinations for E_4 is 14.1159 with a mean of 1.4116. The pooled satisfaction grade of the matches and combinations is 27.6794 with a mean of 1.5377.

Table 11
Results of employments and responses for the modified case

E_1	E_2	E_3	E_4
S_9 ⊗	S_5 ☑ 1	S_5 ⊗	S_9 ☑ 1
S_8 ⊗	S_9 ⊗	S_{14} ⊗	S_{16} ☑ 2
S_5 ⊗		S_{19} ⊗	S_7 ☑ 2
		S_8 ☑ 1	S_{13} ☑ 2
		S_{15} ☑ 2	S_{14} ☑ 2

☑ The employed students report to the enterprises.
⊗ The employed students abandon the employments.

Again, the proposed method performs better in respect of the number of matches, average satisfaction grade of student–student combinations and the pooled average satisfaction grade, as compared to the current placement procedure. Also, the proposed method exhibits an effective trade-off for reducing a minor average satisfaction grade of the matches, a percentage deviation of 2.41%, to bring a major increment of the number of matches, a percentage deviation of 50%.

5. Simulated application

In summer of 2007, interviews were held among seven enterprises, $E_1, E_2, \ldots, E_7$, to evaluate and select distinction students for a one-year practical training program. According to the respective human resource development plans, the predetermined numbers of students to be employed and trained are twelve, five, eight, five, five, four and six for the seven enterprises, respectively, which are added up to 45. The students employed by E_5 and E_6 should work and act in concert within a team of respective enterprises. According to the learning volition and future career plans, 28 students, $S_1, S_2, \ldots, S_{28}$, voluntarily applied and took part in the interviews of some enterprises for obtaining a job to implement the practical training program. The matching results obtained by the current placement procedure indicate that the numbers of employed students reporting to the seven enterprises are nine, zero, three, three, four, two and four, respectively, which are added up to 25. It's a pity that three students had not been matched with any enterprise; meanwhile, all enterprises had vacancies, especially for E_2 matching with zero students.

To test the empirical effectiveness of the proposed method, the real-world case is solved by the proposed method to obtain the simulated solutions. As some enterprises express that none of the students matched with an enterprise is disadvantageous for the human resource development and the long-term partnership between the enterprise and case university, and hence, by taking into account the whole advantages, the number of students matched with each enterprise is set at least half of the predetermined number. A constraint is then added to the MIP model to condition such a requirement as follows:

$$\sum_{\substack{s=1 \\ (E_e,S_s)\in\Omega_e}}^{28} y_{es} \geqslant \frac{f_e}{2}, \quad e = 1, 2, \ldots, 7.$$

Moreover, as the students employed by E_5 and E_6 should work and act in concert within the respective teams, the relationship among the students available for matching with E_5 and E_6, respectively, is taken into account.

By performing the proposed method, all the 28 students are matched with the enterprises. The numbers of students matching with the seven enterprises are nine, three, four, three, three, two and four, respectively. The total satisfaction grade of the 28 enterprise–student matches is 49.2290 with a mean of 1.7582; meanwhile, the total satisfaction grade of the four student–student combinations for E_5 and E_6 is 5.8979 with a mean of 1.4745. The pooled satisfaction grade of matches and combinations is 55.1269 with a mean of 1.7227. The corresponding results obtained by the current placement procedure are 25 matches along with an average satisfaction grade of 1.7954, seven combinations for E_5 and E_6 along with an average satisfaction grade of 0.9986 and a pooled average satisfaction grade of 1.6211. The simulated application results indicate the proposed method is an effective and value-added approach.

6. Conclusions

In this paper, a job placement intervention based on a two-way choice frame is proposed to tackle the real-world job placement problem more convincing and workable. Evaluations of enterprise–student matches and student–student combinations in some particular enterprises that concern the relationship among the students are conducted by the involved persons to obtain two-way assessments. In order to match distinction enterprises with distinction students, enterprises with classified results of VG or G corresponding to students with classified results of VG or G are sieved out for final matching. A performance measure, which is calculated by summing the utility similarities of two-way fuzzy assessments with VG, is proposed to measure the satisfaction grade for enterprise–student matches and student–student combinations within some particular enterprises. An MIP model is performed to fulfill the "efficient fit from the right" policy such that the distinction enterprises are matched with distinction students and the students employed by some particular enterprises can relate and collaborate well in the respective enterprises.

Computational results demonstrate that the proposed method performs better in respect of number of matches, average satisfaction grade of student–student combinations and the pooled average satisfaction grade, when compared to the current placement procedure; meanwhile, the proposed method exhibits an effective trade-off for reducing a minor average satisfaction grade of the matches to bring a major increment of the number of matches. The simulated application results also demonstrate the empirical effectiveness and benefits of the proposed method.

The proposed method can be employed as a value-added matchmaker by taking into account the assessment results of the persons involved on both sides to tackle the placements more convincing and workable. As the proposed scheme is simple and the MIP formula can be easily solved, it can also be used to deal with the analogous problems possessed by the two-way choice characteristic, such as the choices between advisers and graduate students and between government-expense graduates and different posts.

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