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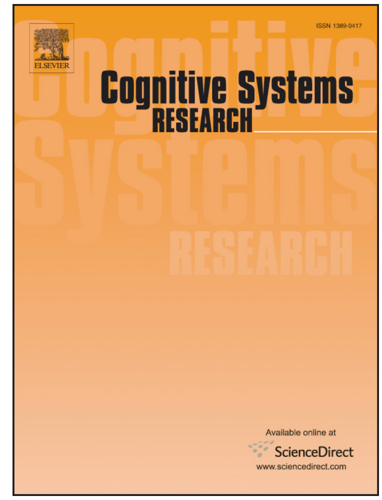

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Fuzzy Computation of Teaching Performance Based on Data Envelopment Analysis Method

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Abstract: Data Envelopment Analysis (DEA) is a system analysis method. It is suitable for evaluating the relative efficiency of Decision Making Units (DMU) with multiple input and output indicators, which is subject to no dimensional form of data and does not need to set the parameters. Subordinate colleges are an integral part of a university, and the university's comprehensive competitiveness can be improved only when each college reaches the optimal state of teaching performance. From the perspective of faculty structure, this paper constructs the evaluation system for the teaching performance of subordinate colleges. In the evaluation system, there are two fuzzy variables, employment quality and quality of enrollment of graduates, so the fuzzy DEA method is adopted. The introduction of fuzzy theory can well solve the problem of fuzzy numbers in input or output. The commonly used fuzzy numbers include triangular fuzzy numbers and trapezoid fuzzy numbers. The triangular one is used in this paper. The research results will help the university strengthen the understanding of subordinate colleges, which is of practical significance to improve the university's comprehensive competitiveness.

Keywords: Fuzzy theory; Triangular fuzzy number; Data envelopment analysis method; Teaching performance;

1. Introduction

Data mining has been widely applied in various fields [12-14], among them, data Envelopment Analysis (DEA) is a system analysis method. It is suitable for evaluating the relative efficiency of Decision Making Units (DMU) with multiple input and output indicators, which is subject to no dimensional form of data and does not need to set the parameters. Therefore, it is widely used in multiple research fields, such as evaluation of resource utilization efficiency [1], performance evaluation [2-3] of institutions of higher learning, environmental performance evaluation [4] and node importance ranking [5] in social network. Many scholars have also proposed a variety of derived forms of DEA based on specific research scenarios, such as rough DEA [6] and fuzzy DEA [7-8]. This paper discusses the application of fuzzy DEA-CCR model in the teaching performance evaluation of subordinate colleges of the university through examples.

In the traditional DEA model, input and output values are accurate. In reality, however, input or output values tend to be uncertain, such as the measurement of reputation and satisfaction of DMU, etc. The introduction of fuzzy theory can well solve the problem of fuzzy numbers in input or output. The commonly used fuzzy numbers include triangular fuzzy numbers and trapezoid fuzzy numbers. The triangular fuzzy numbers can be regarded as the special case of trapezoid fuzzy numbers, which are expressed in this paper as $\tilde{A} = (a_1, a_2, a_3)$. Where, a_1, a_2 and a_3 represent the lower limit value, principal value and upper limit value of $\tilde{A}$, respectively. In the fuzzy number set, these three values are not equal at the same time.

Generally speaking, the implementation of fuzzy DEA-CCR can be divided into four steps as below:

Step 1: Assuming that there are n DMUs (k=1,2,3,...,n), each DMU has g input indicators and t output indicators. The inputs and outputs of kth DMU contain fuzzy numbers, which are expressed as $\widetilde{x_{ik}}$(i=1,2,...,g) and $\widetilde{y_{rk}}$(r=1,2,..,t), and $\widetilde{x_{ik}}=(x_{ik1}, x_{ik2}, x_{ik3})$ and $\widetilde{y_{rk}}=(y_{rk1}, y_{rk2}, y_{rk3})$, respectively. At this time, the fuzzy DEA-CCR model is expressed as shown in Formula (1) [9-10]:

$$\min \theta$$
$$\text{s.t.} \sum_{k=1}^{n} \lambda_k \widetilde{x_k} + s^- = \theta \widetilde{x_0}$$
$$\sum_{k=1}^{n} \lambda_k \widetilde{y_k} - s^+ = \widetilde{y_0}$$
$$\lambda_k \geq 0, k \geq 1$$
$$\text{unrestraint}, s^+ \geq 0, s^- \geq 0$$

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The dual programming formula of fuzzy DEA-BCC can be deduced if the restraint variable $\sum_{k=1}^{n}\lambda_k = 1$ is further introduced in the above-mentioned formula. Since this paper is designed to evaluate the impact of faculty structure on the teaching performance of subordinate colleges, fuzzy DEA-CCR model is used.

Step 2: In the given confidence interval $\alpha \in [0,1]$, the solution set of fuzzy number $\tilde{A}$ is $\tilde{A}_\alpha = \{x|\mu_A(x) \geq \alpha\}$, which is expressed as $A_\alpha = [A_\alpha^L, A_\alpha^R]$. The solution formula of right and left boundaries is shown in Formula (2) and Formula (3), respectively:

$A_\alpha^L = a_1 + (a_2 - a_1)\alpha$ (2)

$A_\alpha^R = a_3 - (a_3 - a_2)\alpha$ (3)

The decision marker needs to predetermine the value of α. It means that the degree of certainty of fuzzy numbers is higher if the value of α gets closer to 1.

Step 3: Based on the set cutting method and the idea of DEA evaluation, the said model at the confidence level of α can be separately translated into maximum programming (Formula (4)) and minimum programming (Formula (5)) [9]:

$$\min \theta$$
$$\text{s.t.} \sum_{k=1}^{n} \lambda_k x_{k\alpha}^R + \lambda_{k0} x_{0\alpha}^L + s^- = x_{0\alpha}^L$$
$$\sum_{k=1}^{n} \lambda_k y_{k\alpha}^L + \lambda_{k0} y_{0\alpha}^R - s^+ = y_{0\alpha}^R$$
$$\lambda_k \geq 0, k \geq 1$$
$$\text{unrestraint}, s^+ \geq 0, s^- \geq 0$$

$k \neq k_0$ (4)

$$\min \theta$$
$$\text{s.t.} \sum_{k=1}^{n} \lambda_k x_{k\alpha}^L + \lambda_{k0} x_{0\alpha}^R + s^- = x_{0\alpha}^R$$
$$\sum_{k=1}^{n} \lambda_k y_{k\alpha}^R + \lambda_{k0} y_{0\alpha}^L - s^+ = y_{0\alpha}^L$$
$$\lambda_k \geq 0, k \geq 1$$
$$\text{unrestraint}, s^+ \geq 0, s^- \geq 0$$

$k \neq k_0$(5)

The output efficiency can be evaluated if the optimal solution θ^0、λ^0、s^{0+}、s^{0-} in Programming Formula (4) and (5) is separately obtained. The results can be divided into the following four types for discussion [10]:

With regard to Formula (4):

(1) When $(\theta^0)_\alpha^R = 1$, it means that the optimistic weak fuzzy DEA of evaluated DMU is significant at the level of α;

(2) When $(\theta^0)_\alpha^R = 1$ and $(s^{0+})_\alpha^R = (s^{0-})_\alpha^R = 0$, it means that the optimistic fuzzy DEA of the evaluated DMU is significant at the level of α;

With regard to Formula (5):

(3) When $(\theta^0)_\alpha^L = 1$, it means that the pessimistic weak fuzzy DEA of the evaluated DMU is significant at the level of α;

(4) When $(\theta^0)_\alpha^L = 1$ and $(s^{0+})_\alpha^L = (s^{0-})_\alpha^L = 0$, it means that the pessimistic fuzzy DEA of the evaluated DMU is significant at the level of α.

Step 4: After the relative efficiency of each DMU is calculated based on the fuzzy DEA-CCR model, $(\theta^0)_{\alpha i}^L$and$(\theta^0)_{\alpha i}^R$ can be obtained. The efficiency of DMUs can be ranked using "Average Confidence Efficiency" method, and the calculation formula is shown in Formula (6):

$\overline{\ } = \sum_{p=1}^{m} \alpha_p [(\ ^0)_{\alpha p}^L + (\theta^0)_{\alpha p}^R]/2 * \sum_{p=1}^{m} \alpha_p$ (6)

Where, m represents estimated total number of α values, and the value of each α is $\alpha_p = p/m$, (p=1,2,...,m).

2. Evaluation system for teaching performance of the university's subordinate colleges

The reasonable faculty structure and high-level teacher quality provides a basic guarantee for the development of colleges. Teachers play two main roles in the university, teaching and educating people and conducting academic research. Based on these two principles and the availability of data, this paper establishes the evaluation system for teaching performance of the university's subordinate colleges, where the input indicators include the teachers' teaching ability and scientific research ability. Teachers'

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education background, professional title and scientific research level will have an impact on their teaching ability and scientific research ability. Therefore, four secondary indicators are used to measure the overall teaching ability and scientific research ability of each college, which are basic teaching level, high-level education background, high-level professional title and teachers' scientific research level, respectively. The output indicators include the achievements of scientific research and the quality of graduates of the college, among which the achievements of scientific research include two secondary indicators, the number of scientific research projects and the number of papers published publicly; the quality of graduates also includes two secondary indicators, the quality of employment and the quality of enrollment.

Table 1 Evaluation System for TeachingTeaching Performance of the University's Subordinate Colleges

Primary indicator		Secondary indicator	Performance of secondary indicator
Input indicator	Teaching ability and scientific research ability	Basic teaching level (x1)	Number of lecturers
		High-level education background (x2)	Number of masters and doctors
		High-level professional title (x3)	Number of associate professors and professors
		Scientific research level of teachers (x4)	Number of teachers who are awarded with some titles that can prove scientific research level
Output indicator	Achievements of scientific research of the college	Number of scientific research projects (y1)	Number of projects that are funded by national and provincial relevant organizations
		Number of papers published publicly (y2)	Number of papers published publicly on academic journals at home and abroad
	Quality of graduates	Quality of employment (y3)	Comprehensive evaluation of employment rate, employment level and income level of graduates in recent years
		Quality of enrollment (y4)	Comprehensive evaluation of quality of universities where graduates further study in recent years

3 .Evaluation process of college teaching performance based on fuzzy DEA

This paper selects analysis objects from 11 subordinate colleges of a certain university in Guangzhou, Guangdong, China. The university is a key university of Guangdong Province with distinctive international characteristics. It is an important base for the cultivation of international talents and foreign language culture, foreign trade and international strategic research in South China. Based on the indicators of Table 1, this paper searches data from the website of each subordinate college of the university. With regard to basic teaching level (x1), high-level education background (x2), high-level professional title (x3), scientific research level of teachers (x4), number of scientific research projects (y1) and number of papers published publicly (y2), accurate data is available on each website. As for the two secondary indicators (quality of employment (y3) and quality of enrollment (y4)) of the quality of graduates, they can be comprehensively evaluated based on the information available on the official website of each college and expressed as triangular fuzzy numbers. Specifically, we can first obtain and collate data related to the quality of employment and quality of enrollment of graduates on the website, and then invite 55 junior students of each college to score the quality of employment and quality of enrollment of the college's graduates in the form of triangular fuzzy numbers based on relevant data and their understanding of the college, and the final data obtained is shown in Table 2.

Table 2 Input and Output Data of Each College

College	x1	x2	x3	x4	y1	y2	y3	y4
DMU1	9	54	43	6	49	507	$\tilde{}_{31}$=(2.28,3.80,4.82)	$\tilde{}_{41}$=(2.50,3.75,4.11)
DMU2	41	68	38	1	123	595	$\tilde{}_{32}$=(1.94,3.65,4.24)	$\tilde{}_{42}$=(2.89,3.90,4.29)
DMU3	20	253	56	6	290	400	$\tilde{}_{33}$=(2.77,3.90,4.47)	$\tilde{}_{43}$=(3.17,4.00,4.82)
DMU4	97	132	31	8	16	400	$\tilde{}_{34}$=(2.61,3.65,4.18)	$\tilde{}_{44}$=(2.44,3.70,4.47)
DMU5	19	22	23	4	50	300	$\tilde{}_{35}$=(2.39,3.65,4.23)	$\tilde{}_{45}$=(2.33,3.35,4.12)

DMU6	46	88	44	3	70	358	$\tilde{}_{36}$=(2.56,3.80,4.53)	$\tilde{}_{46}$=(2.56,3.85,4.71)
DMU7	40	60	52	10	26	358	$\tilde{}_{37}$=(2.61,3.80,4.59)	$\tilde{}_{47}$=(2.72,3.75,4.65)
DMU8	50	102	44	1	15	252	$\tilde{}_{38}$=(2.59,3.85,4.65)	$\tilde{}_{48}$=(2.50,3.85,4.71)
DMU9	27	76	43	1	46	724	$\tilde{}_{39}$=(2.88,3.80,4.47)	$\tilde{}_{49}$=(2.72,3.75,4.41)
DMU10	15	48	35	4	75	750	$\tilde{}_{310}$=(2.83,3.95,4.53)	$\tilde{}_{410}$=(2.83,3.55,4.29)
DMU11	10	25	15	5	72	321	$\tilde{}_{311}$=(2.83,3.60,4.53)	$\tilde{}_{411}$=(2.85,3.95,4.65)

Note: x1 represents basic teaching level, x2 represents high-level education background; x3 represents high-level professional title; x4 represents scientific research level of teachers; y1 represents number of scientific research projects; y2 represents number of papers published publicly; y3 represents quality of employment; y4 represents quality of enrollment;
DMU1-DMU11 represents Business College, College of Information Science and Technology, College of Economics and Trade, College of English Education, College of Journalism and Communication, College of Finance, College of English Language and Culture, College of International Business English, College of Oriental Language and Culture, College of Western Language and Culture and College of Translation and Interpretation of the university researched in this paper.

This paper will adopt the fuzzy DEA-CCR model to evaluate the teaching performance of 11 colleges as mentioned above. According to the data in Table 2, the fuzzy DEA evaluation programming corresponding to College DMU1 is P1.

min θ

$$\text{s.t. } 9\lambda_1 + 41\lambda_2 + 20\lambda_3 + 97\lambda_4 + 19\lambda_5 + 46\lambda_6 + 40\lambda_7 + 50\lambda_8 + 27\lambda_9 + 15\lambda_{10} + 10\lambda_{11} \le 9\theta,$$
$$54\lambda_1 + 68\lambda_2 + 235\lambda_3 + 132\lambda_4 + 22\lambda_5 + 88\lambda_6 + 60\lambda_7 + 102\lambda_8 + 76\lambda_9 + 48\lambda_{10} + 25\lambda_{11} \le 54\theta,$$
$$43\lambda_1 + 38\lambda_2 + 56\lambda_3 + 31\lambda_4 + 23\lambda_5 + 44\lambda_6 + 52\lambda_7 + 44\lambda_8 + 43\lambda_9 + 35\lambda_{10} + 15\lambda_{11} \le 43\theta,$$
$$6\lambda_1 + 1\lambda_2 + 6\lambda_3 + 8\lambda_4 + 4\lambda_5 + 3\lambda_6 + 10\lambda_7 + 1\lambda_8 + 1\lambda_9 + 4\lambda_{10} + 5\lambda_{11} \le 6\theta,$$
$$49\lambda_1 + 123\lambda_2 + 290\lambda_3 + 16\lambda_4 + 50\lambda_5 + 70\lambda_6 + 26\lambda_7 + 15\lambda_8 + 46\lambda_9 + 75\lambda_{10} + 72\lambda_{11} \ge 49,$$
$$507\lambda_1 + 595\lambda_2 + 400\lambda_3 + 400\lambda_4 + 300\lambda_5 + 358\lambda_6 + 358\lambda_7 + 252\lambda_8 + 724\lambda_9 + 750\lambda_{10} + 321\lambda_{11} \ge 507,$$
$$\tilde{}_{31}\lambda_1 + \tilde{}_{32}\lambda_2 + \tilde{}_{33}\lambda_3 + \tilde{}_{34}\lambda_4 + \tilde{}_{35}\lambda_5 + \tilde{}_{36}\lambda_6 + \tilde{}_{37}\lambda_7 + \tilde{}_{38}\lambda_8 + \tilde{}_{39}\lambda_9 + \tilde{}_{310}\lambda_{10} + \tilde{}_{311}\lambda_{11} \ge \tilde{}_{31}$$
$$\tilde{}_{41}\lambda_1 + \tilde{}_{42}\lambda_2 + \tilde{}_{43}\lambda_3 + \tilde{}_{44}\lambda_4 + \tilde{}_{45}\lambda_5 + \tilde{}_{46}\lambda_6 + \tilde{}_{47}\lambda_7 + \tilde{}_{48}\lambda_8 + \tilde{}_{49}\lambda_9 + \tilde{}_{410}\lambda_{10} + \tilde{}_{411}\lambda_{11} \ge \tilde{}_{41}$$
$$\lambda_k \ge 0, k = 1,2,3 \ldots ,11$$

Whereas:

$$(\tilde{A}_{31})_\alpha^L = 2.28 + 1.52\alpha(\tilde{A}_{31})_\alpha^R = 4.82 - 1.02\alpha(\tilde{A}_{32})_\alpha^L = 1.94 + 1.71\alpha$$
$$(\tilde{A}_{32})_\alpha^R = 4.24 - 0.59\alpha(\tilde{A}_{33})_\alpha^L = 2.77 + 1.13\alpha(\tilde{A}_{33})_\alpha^R = 4.47 - 0.57\alpha$$
$$(\tilde{A}_{34})_\alpha^L = 2.61 + 1.04\alpha(\tilde{A}_{34})_\alpha^R = 4.18 - 0.53\alpha(\tilde{A}_{35})_\alpha^L = 2.39 + 1.26\alpha$$
$$(\tilde{A}_{35})_\alpha^R = 4.23 - 0.58(\tilde{A}_{36})_\alpha^L = 2.56 + 1.24\alpha(\tilde{A}_{36})_\alpha^R = 4.53 - 0.73\alpha$$
$$(\tilde{A}_{37})_\alpha^L = 2.61 + 1.19\alpha(\tilde{A}_{37})_\alpha^R = 4.59 - 0.79\alpha(\tilde{A}_{38})_\alpha^L = 2.59 + 1.26\alpha$$
$$(\tilde{A}_{38})_\alpha^R = 4.65 - 0.8\alpha(\tilde{A}_{39})_\alpha^L = 2.88 + 0.92\alpha(\tilde{A}_{39})_\alpha^R = 4.47 - 0.67\alpha$$
$$(\tilde{A}_{310})_\alpha^L = 2.83 + 1.12\alpha(\tilde{A}_{310})_\alpha^R = 4.53 - 0.58\alpha(\tilde{A}_{311})_\alpha^L = 2.83 + 0.77\alpha$$
$$(\tilde{A}_{311})_\alpha^R = 4.53 - 0.93\alpha(\tilde{A}_{41})_\alpha^L = 2.50 + 1.25\alpha(\tilde{A}_{41})_\alpha^R = 4.11 - 0.36\alpha$$
$$(\tilde{A}_{42})_\alpha^L = 2.88 + 1.01\alpha(\tilde{A}_{42})_\alpha^R = 4.29 - 0.39\alpha(\tilde{A}_{43})_\alpha^L = 3.16 + 0.83\alpha$$
$$(\tilde{A}_{43})_\alpha^R = 4.82 - 0.82\alpha(\tilde{A}_{44})_\alpha^L = 2.44 + 1.26\alpha(\tilde{A}_{44})_\alpha^R = 4.47 - 0.77\alpha$$
$$(\tilde{A}_{45})_\alpha^L = 2.33 + 1.02\alpha(\tilde{A}_{45})_\alpha^R = 4.12 - 0.77\alpha(\tilde{A}_{46})_\alpha^L = 2.56 + 1.29\alpha$$
$$(\tilde{A}_{46})_\alpha^R = 4.71 - 0.86\alpha(\tilde{A}_{47})_\alpha^L = 2.72 + 1.03\alpha(\tilde{A}_{47})_\alpha^R = 4.65 - 0.9\alpha$$
$$(\tilde{A}_{48})_\alpha^L = 2.50 + 1.35\alpha(\tilde{A}_{48})_\alpha^R = 4.71 - 0.86\alpha(\tilde{A}_{49})_\alpha^L = 2.72 + 1.03\alpha$$
$$(\tilde{A}_{49})_\alpha^R = 4.41 - 0.66\alpha(\tilde{A}_{410})_\alpha^L = 2.83 + 0.72\alpha(\tilde{A}_{410})_\alpha^R = 4.29 - 0.74\alpha$$
$$(\tilde{A}_{411})_\alpha^L = 2.85 + 1.10\alpha(\tilde{A}_{411})_\alpha^R = 4.65 - 0.70\alpha$$

Therefore, the solution of programming problem (P1) at the confidence interval with level α can be translated into the solution of the following two common linear programming problems according to the set cutting method, which are Pl_1 and Pl_2, respectively. In the solution process, the right and left boundaries of the triangular fuzzy numbers calculated in the previous step are substituted into Pl Formula, respectively.

min θ

$$\text{s.t. } 9\lambda_1 + 41\lambda_2 + 20\lambda_3 + 97\lambda_4 + 19\lambda_5 + 46\lambda_6 + 40\lambda_7 + 50\lambda_8 + 27\lambda_9 + 15\lambda_{10} + 10\lambda_{11} \le 9\theta,$$
$$54\lambda_1 + 68\lambda_2 + 235\lambda_3 + 132\lambda_4 + 22\lambda_5 + 88\lambda_6 + 60\lambda_7 + 102\lambda_8 + 76\lambda_9 + 48\lambda_{10} + 25\lambda_{11} \le 54\theta,$$

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$$43\lambda_1 + 38\lambda_2 + 56\lambda_3 + 31\lambda_4 + 23\lambda_5 + 44\lambda_6 + 52\lambda_7 + 44\lambda_8 + 43\lambda_9 + 35\lambda_{10} + 15\lambda_{11} \le 43\theta,$$
$$6\lambda_1 + 1\lambda_2 + 6\lambda_3 + 8\lambda_4 + 4\lambda_5 + 3\lambda_6 + 10\lambda_7 + 1\lambda_8 + 1\lambda_9 + 4\lambda_{10} + 5\lambda_{11} \le 6\theta,$$
$$49\lambda_1 + 123\lambda_2 + 290\lambda_3 + 16\lambda_4 + 50\lambda_5 + 70\lambda_6 + 26\lambda_7 + 15\lambda_8 + 46\lambda_9 + 75\lambda_{10} + 72\lambda_{11} \ge 49,$$
$$507\lambda_1 + 595\lambda_2 + 400\lambda_3 + 400\lambda_4 + 300\lambda_5 + 358\lambda_6 + 358\lambda_7 + 252\lambda_8 + 724\lambda_9 + 750\lambda_{10} + 321\lambda_{11} \ge 507,$$
$$(\tilde{A}_{31})^R_\alpha\lambda_1 + (\tilde{A}_{32})^L_\alpha\lambda_2 + (\tilde{A}_{33})^L_\alpha\lambda_3 + (\tilde{A}_{34})^L_\alpha\lambda_4 + (\tilde{A}_{35})^L_\alpha\lambda_5 + (\tilde{A}_{36})^L_\alpha\lambda_6 + (\tilde{A}_{37})^L_\alpha\lambda_7 + (\tilde{A}_{38})^L_\alpha\lambda_8 + (\tilde{A}_{39})^L_\alpha\lambda_9 + (\tilde{A}_{310})^L_\alpha\lambda_{10} + (\tilde{A}_{311})^L_\alpha\lambda_{11} \ge (\tilde{A}_{31})^R_\alpha,$$
$$(\tilde{A}_{41})^R_\alpha\lambda_1 + (\tilde{A}_{42})^L_\alpha\lambda_2 + (\tilde{A}_{43})^L_\alpha\lambda_3 + (\tilde{A}_{44})^L_\alpha\lambda_4 + (\tilde{A}_{45})^L_\alpha\lambda_5 + (\tilde{A}_{46})^L_\alpha\lambda_6 + (\tilde{A}_{47})^L_\alpha\lambda_7 + (\tilde{A}_{48})^L_\alpha\lambda_8 + (\tilde{A}_{49})^L_\alpha\lambda_9 + (\tilde{A}_{410})^L_\alpha\lambda_{10} + (\tilde{A}_{411})^L_\alpha\lambda_{11} \ge (\tilde{A}_{41})^R_\alpha,$$
$$\lambda_k \ge 0, k = 1,2,3 \ldots,11$$

$$\min \theta$$
$$\text{s.t. } 9\lambda_1 + 41\lambda_2 + 20\lambda_3 + 97\lambda_4 + 19\lambda_5 + 46\lambda_6 + 40\lambda_7 + 50\lambda_8 + 27\lambda_9 + 15\lambda_{10} + 10\lambda_{11} \le 9\theta,$$
$$54\lambda_1 + 68\lambda_2 + 235\lambda_3 + 132\lambda_4 + 22\lambda_5 + 88\lambda_6 + 60\lambda_7 + 102\lambda_8 + 76\lambda_9 + 48\lambda_{10} + 25\lambda_{11} \le 54\theta,$$
$$43\lambda_1 + 38\lambda_2 + 56\lambda_3 + 31\lambda_4 + 23\lambda_5 + 44\lambda_6 + 52\lambda_7 + 44\lambda_8 + 43\lambda_9 + 35\lambda_{10} + 15\lambda_{11} \le 43\theta,$$
$$6\lambda_1 + 1\lambda_2 + 6\lambda_3 + 8\lambda_4 + 4\lambda_5 + 3\lambda_6 + 10\lambda_7 + 1\lambda_8 + 1\lambda_9 + 4\lambda_{10} + 5\lambda_{11} \le 6\theta,$$
$$49\lambda_1 + 123\lambda_2 + 290\lambda_3 + 16\lambda_4 + 50\lambda_5 + 70\lambda_6 + 26\lambda_7 + 15\lambda_8 + 46\lambda_9 + 75\lambda_{10} + 72\lambda_{11} \ge 49,$$
$$507\lambda_1 + 595\lambda_2 + 400\lambda_3 + 400\lambda_4 + 300\lambda_5 + 358\lambda_6 + 358\lambda_7 + 252\lambda_8 + 724\lambda_9 + 750\lambda_{10} + 321\lambda_{11} \ge 507,$$
$$(\tilde{A}_{31})^L_\alpha\lambda_1 + (\tilde{A}_{32})^R_\alpha\lambda_2 + (\tilde{A}_{33})^R_\alpha\lambda_3 + (\tilde{A}_{34})^R_\alpha\lambda_4 + (\tilde{A}_{35})^R_\alpha\lambda_5 + (\tilde{A}_{36})^R_\alpha\lambda_6 + (\tilde{A}_{37})^R_\alpha\lambda_7 + (\tilde{A}_{38})^R_\alpha\lambda_8 + (\tilde{A}_{39})^R_\alpha\lambda_9 + (\tilde{A}_{310})^R_\alpha\lambda_{10} + (\tilde{A}_{311})^R_\alpha\lambda_{11} \ge (\tilde{A}_{31})^L_\alpha,$$
$$(\tilde{A}_{41})^L_\alpha\lambda_1 + (\tilde{A}_{42})^R_\alpha\lambda_2 + (\tilde{A}_{43})^R_\alpha\lambda_3 + (\tilde{A}_{44})^R_\alpha\lambda_4 + (\tilde{A}_{45})^R_\alpha\lambda_5 + (\tilde{A}_{46})^R_\alpha\lambda_6 + (\tilde{A}_{47})^R_\alpha\lambda_7 + (\tilde{A}_{48})^R_\alpha\lambda_8 + (\tilde{A}_{49})^R_\alpha\lambda_9 + (\tilde{A}_{410})^R_\alpha\lambda_{10} + (\tilde{A}_{411})^R_\alpha\lambda_{11} \ge (\tilde{A}_{41})^L_\alpha,$$
$$\lambda_k \ge 0, k = 1,2,3 \ldots,11$$

We can select different values of confidence level α to separately solve the common linear programming Pl_1 and Pl_2, and then we can obtain the significant interval $[(\theta^0)^L_\alpha, (\theta^0)^R_\alpha]$ of fuzzy DEA of Business College (DMU1). This paper uses MATLAB to solve the significant interval of fuzzy DEA when the confidence level α is 0.5. Firstly, we need to substitute the confidence level (α=0.5) into common linear programming Pl_1 and Pl_2 to calculate the right and left boundaries of each fuzzy number. Later, we shall use MATLAB to solve the significant interval $[(\theta^0)^L_\alpha, (\theta^0)^R_\alpha]$ of fuzzy DEA of each college. Taking Business College (DMU1) for example, the calculation process and results are shown in Figure 1 and Figure 2, and we can solve the significant interval of fuzzy DEA of other colleges by repeating the said steps. Finally, we collate the results as shown in Table 3.

```
>> f=[0,0,0,0,0,0,0,0,0,0,0,1];
A=[9,41,20,97,19,46,40,50,27,15,10,-9;%x1
54,68,253,132,22,88,60,102,76,48,25,-54;%x2
43,38,56,31,23,44,52,44,43,35,15,-43;%x3
6,1,6,8,4,3,10,1,1,4,5,-6;%x4
-49,-123,-290,-16,-50,-70,-26,-15,-46,-75,-72,0;%y1
-507,-595,-400,-400,-300,-358,-358,-252,-724,-750,-321,0;%y2
-4.31,-2.795,-3.335,-3.13,-3.02,-3.18,-3.205,-3.22,-3.34,-3.39,-3.215,0;%y3
-3.93,-3.395,-3.585,-3.07,-2.84,-3.205,-3.235,-3.175,-3.235,-3.19,-3.4,0];%y4
lb=[0,0,0,0,0,0,0,0,0,0,0,-inf];ub=[];
b=[0,0,0,0,-49,-507,-4.31,-3.93];
linprog(f,A,b,[],[],lb,ub)
Optimization terminated.

ans =

    1.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    1.0000
```

Figure 1 Solution of Linear Programming Pl_1 of DMU1 at the Confidence Level of 0.5

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```
>> f=[0,0,0,0,0,0,0,0,0,0,0,1];
A=[9,41,20,97,19,46,40,50,27,15,10,-9;%x1
54,68,253,132,22,88,60,102,76,48,25,-54;%x2
43,38,56,31,23,44,52,44,43,35,15,-43;%x3
6,1,6,8,4,3,10,1,1,4,5,-6;%x4
-49,-123,-290,-16,-50,-70,-26,-15,-46,-75,-72,0;%y1
-507,-595,-400,-400,-300,-358,-358,-252,-724,-750,-321,0;%y2
-3.04,-3.945,-4.185,-3.915,-3.94,-4.165,-4.195,-4.25,-4.135,-4.24,-4.065,0;%y3
-3.125,-4.095,-4.41,-4.085,-3.735,-4.28,-4.2,-4.28,-4.08,-3.92,-4.3,0];%y4
lb=[0,0,0,0,0,0,0,0,0,0,0,-inf];ub=[];
b=[0,0,0,0,-49,-507,-3.04,-3.125];
linprog(f,A,b,[],[],lb,ub)
Optimization terminated.

ans =

    1.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    1.0000
```

Figure 2 Solution of Linear Programming Pl_2 of DMU1 at the Confidence Level of 0.5

Table 3 Significant Interval of Fuzzy DEA of 11 Colleges at the Confidence Level of 0.5

College	DMU1	DMU2	DMU3	DMU4	DMU5	DMU6
Significant interval of fuzzy DEA	[1,1]	[1,1]	[0.6107,1]	[0.6024,1]	[0.9919,1]	[0.5708,0.9801]
Significant value of average confidence	1	1	0.8054	0.8012	0.9960	0.7755
College	DMU7	DMU8	DMU9	DMU10	DMU11	
Significant interval of fuzzy DEA	[0.7144,0.8163]	[0.9815,1]	[1,1]	[1,1]	[1,1]	
Significant value of average confidence	0.7654	0.9908	1	1	1	

From Table 3, it can be seen that there are five colleges whose teaching performance reaches 1 and fuzzy DEA is significant, which are Business College (DMU1), College of Information Science and Technology (DMU2), College of Oriental Language and Culture (DMU9), College of Western Language and Culture (DMU10) and College of Translation and Intepretation (DMU11), respectively; there are four colleges whose weak fuzzy DEA is significant, which are College of Economics and Trade (DMU3), College of English Education (DMU4), College of Journalism and Communication (DMU5) and College of International Business English (DMU8); College of Finance (DMU6) and College of English Language and Culture fail to reach the significant level of DEA. Seeing from the above results, the teaching efficiency of each college is greater than 70% at the confidence level of 0.5, indicating that each college of the university can reasonably allocate resources in the teaching process.

In addition, we can calculate the significant values of average confidence of 11 subordinate colleges using the formula of average confidence efficiency, which are 1, 1, 0.8054, 0.8012, 0.9960, 0.7755, 0.7654, 0.9908, 1, 1 and 1, respectively. Therefore, the teaching performance of each college can be ranked. Business College (DMU1), College of Information Science and Technology (DMU2), College of Oriental Language and Culture (DMU9), College of Western Language and Culture (DMU10) and College of Translation and Interpretation (DMU11) share the first place in terms of teaching performance; followed by College of International Business English (DMU8), College of Journalism and Communication (DMU5), College of Economics and Trade (DMU3), College of English Education (DMU4), College of English Language and Culture (DMU7) and College of

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Finance (DMU6).

Combined with the original data in Table 2, we further analyze various types of colleges. Firstly, we analyze those five colleges that share the first place in terms of teaching performance, and find that Business College (DMU1), College of Information Science and Technology (DMU2), College of Oriental Language and Culture (DMU9), College of Western Language and Culture (DMU10) and College of Translation and Interpretation (DMU11) have something in common, that is, lecturers account for a smaller proportion of the total faculty. It is probably because lecturers are weaker than associate professors or professors in terms of teaching level and scientific research level, so less lecturers may enable the college to distribute more resources to associate professors or professors who are more advantageous in teaching ability and scientific research ability and some teachers with higher scientific research level who are recognized by authorities. Secondly, those four colleges whose weak fuzzy DEA is significant have something in common, that is, teachers with high-level education background (such as masters and doctors) account for a larger proportion, but teachers with high-level professional title (such as associate professors and professors) account for a smaller proportion, which indicates from a different perspective that associate professors and professors are vital for the college's teaching performance. Although some teachers who have not obtained high professional titles but have high education background usually have stronger scientific research ability, they are slightly inferior to associate professors and professors in terms of scientific research experience or teaching experience. This is also consistent with the reality. To attain professional titles of associate professors and professors requires a comprehensive consideration of scientific research achievements, teaching quality and other aspects, which ensures that associate professors and professors have higher scientific research ability and teaching level. Thirdly, it can be found by comparing to five colleges whose strong fuzzy DEA is significant and four colleges whose weak fuzzy DEA is significant that although the five colleges whose strong fuzzy DEA is significant have a smaller faculty than those four colleges whose weak fuzzy DEA is significant, the former's scientific research achievements are obviously higher than the latter's. It is probably related to the incentive policy, the teaching atmosphere and objectives of the college. Finally, it can be seen from the data in Table 2 that the two colleges (College of Finance (DMU6) and College of English Language and Culture (DMU7)) whose fuzzy DEA is not significant have more lecturers but weaker scientific research achievements.

4. Conclusion

Subordinate colleges are an integral part of a university, and the university's comprehensive competitiveness can be improved only when each college reaches the optimal state of teaching performance. From the perspective of faculty structure, this paper constructs the evaluation system for the teaching performance of subordinate colleges. In the evaluation system, there are two fuzzy variables, employment quality and quality of enrollment of graduates, so the fuzzy DEA method is adopted. In the evaluation process, the evaluation values of the two fuzzy variables (quality of employment and quality of enrollment of graduates) are obtained based on facts and the understanding of each college's students of the college, and the fuzziness is lower, so the confidence level α is determined as 0.5. Results show that there are five colleges whose teaching efficiency reaches 1 at the confidence level α of 0.5, and the fuzzy DEA is significant; four colleges have significant weak fuzzy DEA; College of Finance (DMU6) and College of English (DMU7) fail to reach the significant level of DEA.

The results indicate that the number and quality of associate professors and full professors are the main key for improving the teaching performance since they are good at both teaching and researching. Meanwhile, the working surroundings can also affect the professors' job performance, therefore, the school managers also should pay closer attention to the working surroundings.

It should be pointed out that DEA method is used to give a relative evaluation of input and output data of each DMU, which means that at least one DMU is at the optimal front, that is, the efficiency value is 1. But it does not mean that the efficiency of the DMU reaches the optimal performance in reality, which is regarded as a limitation of the DEA method. However, the DEA method can be used for efficiency ranking and comparing the relative efficiency between DMUs. In addition, the confidence level α is determined as 0.5 in empirical analysis, but the teaching efficiency of each college is not calculated at other confidence levels. Based on existing researches [10-11], the confidence level has no effect on the ranking of each DMU, but we can have a better understanding of the current situation if we comprehensively consider the college's teaching performance at multiple confidence levels. Those readers who are interested in this can try to evaluate the teaching performance at the confidence levels of 0.2, 0.4, 0.6 and 0.8.

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