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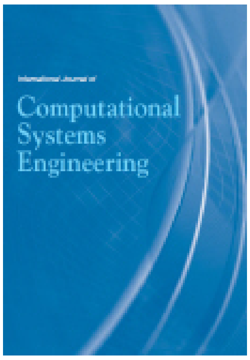

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A study on the application of data envelopment analysis in evaluating the quality of physical education teaching in universities

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Abstract: The evaluation of DEA in physical education teaching quality in colleges and universities is a bold attempt to adapt to the new era of educational innovation. On the premise of DEA, C2R model is applied to the evaluation of physical education teaching quality in colleges and universities, and the first and second indexes are determined by the Del method. Finally, five input indexes and output indexes are obtained. The results show that the numerical relationship between the input index and the output index is inverted U-shape, and there are 18, 20 and 19 DMU with the technical efficiency value, pure technical efficiency value and scale efficiency value of 1, respectively. 75% of the 24 DMU are effective DEA. The research provides a new way for the development of physical education teaching quality in colleges and universities, and the model can be applied to the teaching evaluation of other courses.

Keywords: data envelopment analysis; DEA; university sport; teaching evaluation.

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1 Introduction

The reform of physical education teaching quality evaluation has become an urgent problem in the education sector. And the process of teaching evaluation has problems such as low subjectivity of evaluation and insufficient depth of cognition (Shivley et al., 2018). The evaluation content of physical education teaching quality mainly includes the construction of the evaluation system and the related factors of physical education teaching quality evaluation (Fan, 2021). At the same time, data envelopment analysis (DEA) takes the concept of relative efficiency as the premise, and regards linear programming and convex analysis as an evaluation method of tools (Pahlavan et al., 2018). It can be simply understood that DEA constructs evaluation models through mathematical planning with cone structure such as generalised optimisation, stochastic planning, semi-elementary limit planning, multi-objective planning, and linear planning. And the relative efficiency (DEA efficiency) between the units (departments) of input (multiple inputs) and output (multiple outputs) is evaluated (Deilmann et al., 2018). In recent years, the research literature found that in the research of physical education teaching evaluation system, methods accounted for the majority, and the research with index system was less. The current status of DEA in the field of physical education is mainly in the fields of school sport, sports industry, mass sport and competitive sport. And in the evaluation research of physical education teaching quality, it has also made corresponding achievements. The innovation of this study is to use DEA model and Delphi method to evaluate the quality of physical education in colleges and universities. At the same time, the final evaluation index is determined by integrating other disciplines into the evaluation index system. The main contributions of the research are as follows, including two points. Firstly, a scientific and reasonable evaluation system of physical education teaching is established, which provides a reference for the follow-up research on the evaluation of physical education teaching quality. Secondly, the main problems have been studied and analysed, which are existing in the evaluation of physical education teaching quality in colleges and universities. It puts forward a new direction for the normal development of the next teaching work in a new direction. The study analyses the role of DEA in the quality of physical education teaching in universities on the basis of DEA, aiming to provide support for the smooth development of physical education activities.

2 Review of the literature

Moghaddam et al. applied the DEA model to the relative efficiency analysis of public transport systems, proposing a relevant conceptual framework for performance assessment. And specific performance evaluation is conducted for the ten public transport systems in Tehran. The framework has successfully identified the performance efficiency and service efficiency of each bus route, and determined the bus routes that need to be reconfigured and optimised (Moghaddam and Saedi, 2020). Hutzler et al. (2019) combined with his own practical work experience, analysed the common modes of physical education in colleges and universities in China at the present stage, and analysed the advantages and disadvantages of different modes. Finally, he pointed out the development trend of physical education teaching modes in colleges and universities in the future. Duan (2019) used a DEA model to conduct a long-term relative efficiency of 36 Australian universities from three perspectives: overall university operational efficiency, university teaching efficiency, and university research efficiency assessment. The results showed that Australian universities maintained high relative efficiency in overall operations and academic research over the assessment period. Zhu et al. (2018) used the DEA model to construct an evaluation system for the teaching performance of university second-level colleges from the perspective of faculty structure and introduced triangular fuzzy numbers to deal with fuzzy variables. The conclusions showed that the model helped the university to have a better understanding of the second-level faculties. And it can identify the relatively poor performing second-level faculties and take relevant measures to improve the overall teaching quality of the university. Azimovna (2021) analyses four steps to develop an effective physical education teaching evaluation index system. 'Analytic hierarchy process is used to determine the weight values of indicators at all levels, and the single weight and comprehensive weight of each indicator are calculated respectively'. Finally, the indicators of teaching evaluation are determined as four first-level indicators, 14 second-level indicators and 44 third-level indicators. Zhang and Shi (2019) used specific data from 24 universities in China in 2017 as a research sample based on the establishment of a reasonable evaluation index system. And it introduced a DEA model to analyse the teaching efficiency of different universities. The study successfully identified decision-making units (DMU) with low efficiency and pointed out the direction of improvement and specific adjustment strategies.

Deilmann et al. (2018) used the DEA model for urban land planning and demonstrated that medium-sized cities typically develop their land as residential areas and transportation go, which is the most efficient way to use land. Also, by combining variable and constant returns to scale, it is possible to calculate a scale efficiency score for cities, which can help indicate the direction of urban land planning. Lee and Johnes (2022) applied the concepts of DEA and relative evaluation to study the teaching effect of teachers. At the same time, the DEA secondary relative benefit value method was introduced into the teaching effect evaluation, which was used to evaluate the efficiency of management. In the experiment, the difference of initial conditions was eliminated through empirical demonstration, and a new teaching management evaluation method was established. Nenkova and Borisova-Mihaylova (2021) used DEA model to measure and evaluate the technical efficiency of Bulgarian cities. The results show that there are significant cost efficiency differences between local territorial units. Specifically, from the perspective of local level management, 25% of the investment has not been effectively used. Most cities are in the operation state of increasing returns to scale, and most of them are small local territorial units. Ashuri et al. (2019) used the DEA model to improve baseline building energy calculations. The related findings were used in real cases and the model helped to improve practice. The research conclusion has been proved to be helpful for managers and owners to accurately identify buildings with low energy efficiency, so that they can formulate measures to improve the energy efficiency of buildings.

In summary, the DEA model has been widely used in a number of industries and sectors. And it has been applied to the analysis of overall university efficiency, teaching quality and the relative efficiency of competitive sports-related industries. But no researcher has yet used the DEA model for the specific area of physical education teaching quality assessment. This research is based on the analysis of the DEA model and its application to quality assessment of physical education teaching in higher education.

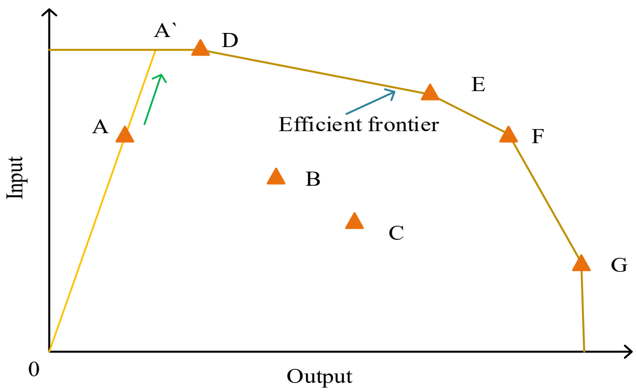
3 Evaluation of the quality of physical education teaching in universities combined with DEA model

3.1 DEA model selection

After the construction of physical education teaching evaluation system, students and teachers are judged and ranked directly according to their weights and the research on the secondary relative evaluation of students and teachers by using new technologies and methods needs to be enriched and improved. DEA model is scientific, effective, convenient and quick, not only in the choice of data analysis methods and DMU, but also in the optimisation of physical education teaching process. The basic principle of the DEA method is to maintain the input and output data of the DMU at a certain level and to keep it constant, to determine a very reasonable production frontier with the help of statistical data and mathematical planning, and to use the extent to which the DMU deviates from the DEA frontier to determine their relative efficiency. The DMU's position, i.e., the existence of a production frontier, is then analysed based on the results of the calculations. The production frontier, as a gradual attempt to convert the production function to multiple outputs, is a Pareto-optimal solution with the objective of maximising outputs and minimising inputs. This method enables not only the evaluation of the efficiency of the DMU but also the analysis of the results.

As shown in Figure 1, the equal output projections of the seven DMUs on the input plane, in which the DMU D, E, F and G are effective units, which together constitute the effective production frontier DEFG of the production system, while the DMU A, B and C are non-DEA effective units, and their projections are not located on the front edge.

Figure 1 7 DMUs and their envelopes (see online version for colours)



The most classic model of DEA is the C²R model, which sets up the input and output vectors of the DMU in a production activity as represented by equation (1).

$$\begin{cases} x = (x_1, x_2, \cdots, x_m)^T \\ y = (y_1, y_2, \cdots, y_m)^T \end{cases} \tag{1}$$

On the basis of equation (1), the entire production activity of the DMU is (x, y). If the production activity includes DMU_j with the number of n, the corresponding input vectors and output vectors of DMU_j are equation (2).

$$\begin{cases} x_j = (x_{1j}, x_{2j}, \cdots, x_{mj})^T \\ y_j = (y_{1j}, y_{2j}, \cdots, y_{mj})^T \end{cases} \tag{2}$$

In equation (2), $j = 1, 2, \cdots, n$. Due to the large problem of the role and status of each output and input in relation to each other in the production process, the output and input need to be processed separately to obtain a value in the evaluation of the DMU process, for which each indicator needs to be given a weight to represent the proportion of a certain indicator in the overall evaluation (Zhang et al., 2019). Given the difficulty of replacing the output-input vectors with each other and in order to overcome the influence of subjective reasons of the experimenter on the results. The study needed to use the model for practical problem solving without setting the fixed-weight vectors, but only as variable vectors, and then gradually go on to determine them according to the principles during the analysis (Zadmirzaei et al., 2018). The formula for the fixed weight vectors is equation (3).

$$\begin{cases} v = (v_1, v_2, \cdots, v_m)^T \\ u = (u_1, u_2, \cdots, u_s)^T \end{cases} \tag{3}$$

In equation (3), one of the metrics for the i type input and the r type output are v_i and u_i respectively. The efficiency evaluation index corresponding to each DMU DMU_j is equation (4).

$$h_j = u^T y_j / v^T x_i = \sum_{r=1}^{s} u_r y_{rj} \bigg/ \sum_{i=1}^{m} v_i x_{ij} \tag{4}$$

In equation (4), the study can choose the appropriate u and v to ensure that $h_j \leq 1$. In general, a larger value of h_j indicates that DMU_j can obtain relatively more output with the help of fewer inputs (Mohseni et al., 2018). Therefore, the study can be completed using the optimisation model C²R for the evaluation of DMU_j with the computational expression in equation (5).

$$\max h_{j0} = \sum_{r=1}^{s} u_r y_{rj0} \Big/ \sum_{i=1}^{m} v_i x_{ij0} \quad s.t. \sum_{r=1}^{s} u_r y_{rj} \Big/ \sum_{i=1}^{m} v_i x_{ij} \leq 1 \tag{5}$$

In equation (5), both $v \geq 0$ and $u \geq 0$ have the same meaning. $v \geq 0$ means that for i, if $v_i \geq 0$, then there is at least i_0 makes $v_{i0} > 0$. The linear programming model is obtained by setting $t = 1/v^T x_0$, $\varpi = tv$ and $\mu = tu$ after the Charnes-Cooper variation, see equation (6) (Salahi et al., 2019).

$$(P)\begin{cases} \max h_{j0} = \mu^T y_0 \\ s.t. \varpi^T x_j - \mu^T y_j \geq 0 \\ \varpi^T x_0 = 1 \\ \varpi \geq 0 \quad \mu \geq 0 \end{cases} \tag{6}$$

The optimal solution of the linear programming can be used to determine whether the DMU j_0 is efficiency. Equation (6) shows that the final result of the C²R model for evaluating the efficiency of the DMU j_0 is compared to other DMUs. If the value of any unknown variable is zero, the input/output weight is zero, which is solved by reference (Mogha et al., 2016, 2014a, 2014b). The value of 0 should be avoided in DEA input-output data as much as possible because it does not conform to the input-output principle of production economics; a smaller positive number (such as 0.0001) can be used instead, which will directly cause efficiency distortion and have a great impact on other DMU results. The C²R model can be directly referred to by the linear programming P, the most efficient theory in linear programming being the pairwise theory. The computational expression for pairwise programming is (7).

$$(D')\begin{cases} \min \theta \\ s.t. \sum_{j=1}^{n} \lambda_j x_j \leq \theta x_0 \\ \sum_{j=1}^{n} \lambda_j x_j \leq y_0 \\ \lambda_j \geq 0 \quad j = 1, 2, \cdots, n \\ \theta \quad \text{Unconstrained} \end{cases} \tag{7}$$

For further analysis, the study treats equation (7) by introducing the residual variable s^- and the slack variable s^+. Equation (8) is the equation constraint obtained after the treatment (Yu, 2021).

$$(D)\begin{cases} \min \theta \\ s.t. \sum_{j=1}^{n} \lambda_j x_j + s^+ = \theta x_0 \\ \sum_{j=1}^{n} \lambda_j x_j - s^- = \theta y_0 \\ \lambda_j \geq 0 \quad j = 1, 2, \cdots, n \\ \theta \ \text{Unconstrained}\ s^+ \geq 0,\ s^- \geq 0 \end{cases} \tag{8}$$

The dual plan of linear programming (P) is D. This model is the same as the model used in the three literature reports related to the technical efficiency of public hospitals, and has outstanding research contributions in the field of efficiency technical analysis. At the same time, this model has perfect theory, simple model form, and clear modelling ideas. The weight of each input and output is not based on the subjective determination of the evaluator, but rather the optimal weight obtained from the actual data of the decision-making unit (Mogha et al., 2016, 2014a, 2014b). C²R model contains two theorems, one of which is that both the dual plan of linear programming (D) and linear programming (P) have efficiency solutions within a certain range, and therefore they both have optimal value. The concept of 'relaxation variable' is introduced. The smaller the distance between the sample and the boundary of the dotted line, the smaller the degree of constraint dissatisfaction, and the larger the degree of constraint dissatisfaction. Each sample has its corresponding 'relaxation variable', which indicates the extent to which the sample does not meet the constraint. 'The introduction of 'relaxation variable' will not affect the objective function in equation (8) (Zhao et al., 2020). Setting the corresponding values to h_{i0}^* and θ^*, respectively, then $h_{i0}^* = \theta^* \leq 1$. Assuming that the optimal value of the linear programming is 1, the DMU_{j0} DMU can be called weakly DEA efficiency. Setting the optimal value of 1 in the solution of the linear programming (P), $\varpi^* > 0$, the $\mu^* > 0$ DMU_{j0} DMU is considered to be called strongly DEA effective. Weak DEA efficiency can be understood as the possibility that the model has efficiency. DEA efficiency can be considered as a very important role for all input and output indicators. Secondly, the determination of weak DEA at DMU_{j0} leads to the inference that the optimal value of the linear programming (P) is θ^* and that for each optimal solution λ^* the variables s^{*-} and s^{*+} take the value 0. Thus, we can use the C²R model to determine whether scale and technology are simultaneously efficiency in production activities. When and the variables $\theta^* = 1$ s^{*-} and s^{*+} take the value 0, then j_0 can be considered as *DEA* efficiency and the production activity of j_0 can be considered as scale and technology efficiency (Alireza and Elkafi, 2018). When $\theta^* = 1$ and there is at least one input and output slack variable that takes values higher than the value 0, at that point j_0 is seen as weak j_0. It can be seen as either scale efficient or technically efficient, i.e., the economic activity can be considered to be unable to achieve both scale effects and technical efficiency optimality. When $\theta^* < 1$, then j_0 can be seen as unable to achieve DEA-efficiency. j_0 of production activities cannot achieve either scale efficiency optimality or technical efficiency optimality. In the C^2R model, the process of calculating too little output and too much input is as follows. When DMU_i is considered non-DEA efficient, the production activities of the study sample can be considered to have too little output ΔY_i or too much input ΔX_i, i.e., ΔX_i can be appropriately reduced in the context of the same output fixed; or ΔY_i can be appropriately adjusted to increase output in the context of fixed input material fixed. The study sets up a linear model with solutions at S_i^{*+}, S_i^{*-} and θ^*, and the combination of inputs and outputs at $(\bar{X}_i, \bar{Y}_i)$ can be considered efficiency relative to the previous one at DMU_i. The formula for the underestimation of output ΔY_i is equation (9).

$$\Delta Y_i = Y_i - \bar{Y}_i = S_i^{*+} \tag{9}$$

In equation (9), Y_i is the actual amount of output produced in the production economy. On this basis the rate of underproduction is obtained and the formula for calculating it is equation (10).

$$\rho_i = \Delta X_i / X_i = \left(\left(1 - \theta_i^* \right) X_i + S_i^{*-} \right) / X_i = 1 - \theta_i^* + S_i^{*-} / X_i \tag{10}$$

The expression for the calculation of the excess input ΔX_i is equation (11).

$$\Delta X_i = X_i - \bar{X}_i = \left(1 - \theta_i^* \right) X_i + S_i^{*-} \tag{11}$$

In equation (11), X_i refers to the actual amount of inputs in the production of economic activities. The same formula for calculating the excess of inputs can be obtained as in equation (12).

$$\eta_i = \Delta Y_i / = S_i^{*+} / Y_i \tag{12}$$

3.2 *Evaluation of the quality of physical education teaching in universities under the DEA model*

In order to realise the accurate classification of data in DEA model, binary theory is introduced for analysis. The binary theory was first applied to the economic field to analyse the correlation between the industrial sector and the agricultural sector. Now it is applied to analyse the data relationship between the two sectors to improve the confidence of data classification. It is assumed that there is no capital accumulation in the rural sector, and the production of the urban sector will increase automatically over time. At the same time, it is assumed that technological progress is neutral. At this time, the urban sector does not increase production factors, but the result of increasing production is brought about by technological progress. Population growth depends on the per capita food supply. If the per capita food supply is sufficient, the population growth rate will reach the maximum, but if the per capita food supply exceeds the maximum population growth rate, agricultural production surplus will be generated at this time, so the rural sector can liberate a batch of labour and transfer to the urban sector for industrial production. DEA method can consider DMU's own optimal input-output scheme. The study will collect the output indicators and input indicators of various DMUs in colleges and universities in a province, and use DEA method to judge whether DEA is effective in each DMU. Because there are many factors influencing the evaluation of physical education teaching quality in colleges and universities, four first-level indicators and 24 second-level indicators are preliminarily determined through the results of two rounds of expert questionnaires and analysis, as shown in Table 1 (Chen and Li, 2019; Kiwuwa, 2018). The first-level indicators include physical education class students, physical education class teachers, teaching methods and teaching environment. The four first-level indicators include seven, seven, five and five second-level indicators respectively.

For the determination of the weights of the indicators for the evaluation of the quality of physical education in colleges and universities, the study chose the Delphi method, which has the advantages of statistical, feedback and anonymity. The importance of each evaluation indicator was first assessed on a five-point scale of 1–5, namely no, low, moderate, significant and very important. Then experts assess the importance of the indicators. Finally, the assigned weighted average score of each indicator is calculated and normalised to obtain the weight of each indicator. Figure 2 is a schematic representation of the Delphi method.

Figure 2 Schematic diagram of Delphi method (see online version for colours)

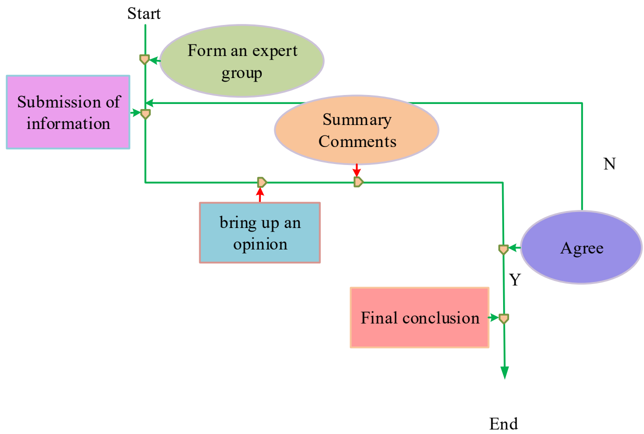
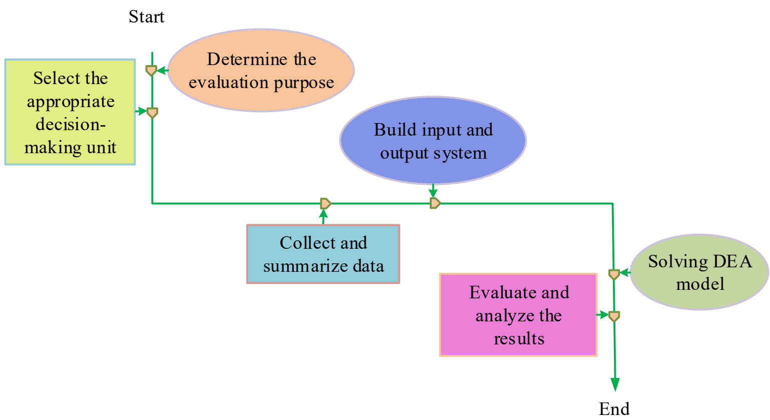


Table 1 Evaluation index system of physical education teaching quality in colleges and universities

Primary index number	*Secondary index number*	*Content of secondary indicators*
Student D1	D11	Students' learning attitude
	D12	Students' interest in learning
	D13	Students' sports theoretical knowledge
	D14	Student sports skills
	D15	Student physique
	D16	Student health behaviour
	D17	Students' emotional expression and cooperative spirit
PE teacher D2	D21	Teachers' professional knowledge
	D22	Teachers' teaching ability
	D23	Basic qualities of teachers
	D24	Teachers' ideology and morality
	D25	Student satisfaction
	D26	Teachers' lesson preparation
	D27	Teachers' teaching attitude
Teaching methods D3	D31	Teaching plan
	D32	Teaching programme
	D33	Evaluation methods for students
	D34	Unit or lesson plan
	D35	Arrangement of teaching courseware and teaching image
Teaching environment D4	D41	Venue facilities
	D42	School spirit and class spirit
	D43	Teaching environment
	D44	Class size
	D45	Teaching atmosphere

Figure 3 Application of DEA model in college physical education teaching quality (see online version for colours)



The DEA method can be analysed to evaluate the efficiency of the two models of satisfying no change in returns to scale and changes in returns to scale on the quality of physical education in colleges and universities. Satisfying no change in returns to scale means that output can be expanded in equal proportion by increasing inputs in colleges and universities, i.e., (Tavana et al., 2018; Ebrahimnejad and Lotfi, 2012; Ebrahimnejad et al., 2016; Bagheri et al., 2022). Changes in the scale of inputs do not have an effect on efficiency, but in practice they can be influenced by imperfect competition, reform policies and other factors that make it difficult to produce practical runs (Ebrahimnejad and Tavana, 2014; Mogha et al., 2016, Mogha et al., 2014a, 2014b). The study uses a DEA model that satisfies the non-varying returns to scale for the evaluation of the quality of university physical education. Setting the sample unit software and the DMU to be evaluated are denoted by and respectively, then they can be expressed by output indicators and input indicators can be expressed by equation (13).

$$\begin{cases} x_p = \left(x_{1p}, x_{2p}, \cdots, x_{mp}\right)^T \\ y_p = \left(y_{1p}, y_{2p}, \cdots, y_{sp}\right)^T \\ \overline{x}_p = \left(\overline{x}_{1p}, \overline{x}_{2p}, \cdots, \overline{x}_{mp}\right)^T \\ \overline{y}_p = \left(\overline{y}_{1p}, \overline{y}_{2p}, \cdots, \overline{y}_{sp}\right)^T \end{cases} \tag{13}$$

In equation (13), a DMU and a sample unit are denoted by p and j respectively, $x_p = (x_{1p}, x_{2p}, \cdots, x_{mp})^T$ and refer to the input and output indicator values of the $y_p = (y_{1p}, y_{2p}, \cdots, y_{sp})^T$ p DMU respectively, and the input and output indicator values of the j sample unit are denoted by $\overline{x}_p = (\overline{x}_{1p}, \overline{x}_{2p}, \cdots, \overline{x}_{mp})^T$ and $\overline{y}_p = (\overline{y}_{1p}, \overline{y}_{2p}, \cdots, \overline{y}_{sp})^T$ respectively (Mogha et al., 2014a, 2014b; Tyagi et al., 2009; Charnes et al., 1978). All indicator values are positive and the DMU is required to satisfy the G-C^{2}R model with the calculated expression in equation (14).

$$(G)\begin{cases} \max u^T y_p = V(d) \\ s.t.\ v^T \overline{x}_j - \mu^T d\overline{y}_j \geq 0 \\ v^T x_p = 1 \\ v \geq 0 \quad \mu \geq 0 \end{cases} \tag{14}$$

In equation (14), the weights of the input and output indicators are $\varpi = (\varpi_1, \varpi_2, \cdots, \varpi_m)^T$ and $\mu = (\mu_1, \mu_2, \cdots, \mu_s)^T$, respectively, and d is the movement factor, which takes a positive value. The pairwise model of the G-C^{2}R model is calculated by equation (15).

$$(DG)\begin{cases} \min \theta = D(d) \\ s.t. \sum_{j=1}^{n} \overline{x}_j \lambda_j \leq \theta x_p \\ \sum_{j=1}^{ji} \overline{y}_j \lambda_j \geq y_p \\ \lambda_j \geq 0 \end{cases} \tag{15}$$

If the optimal value of the linear programming G-C R model is, then the DMU^2 $V(d) \geq 1p$ is considered weakly efficiency if it is shifted by a factor of d relative to the frontier of the sample data. If the G-C^{2}R model code satisfies $V(d) > 1$ or $\varpi^0 > 0$ and then the DMU $\mu^0 > 0$ p is considered efficiency.

The specific application steps of DEA model in the quality of physical education teaching in colleges and universities can be divided into six steps, as shown in Figure 3. One, determine the purpose of evaluation. Through the evaluation objective, analyse the correlation between the evaluation indexes obtained by this, i.e., judge which DMUs can be translated together, and at the same time construct an input and output system to complete the translation of the objective. Secondly, the selection of suitable DMUs is based on consistent objectives and tasks, output and input indicators, and the external environment. Thirdly, construct the input and output system, the evaluation of the efficiency of the DEA model is based on the output and input data of the DMU, different evaluation indicators will produce different evaluation results. Fourth, the data is collected and summarised; the DEA model needs to refer to the values of inputs and outputs in order to carry out the relative efficiency of the DMU, so the correctness and reliability of the indicator values are closely related to the final results. Fifthly, the DEA model is solved. After the model has been constructed, the DEA model can be solved according to the actual study. Sixthly, the results are evaluated and analysed. After the model has been solved, the study can obtain most of the management decision information, collating and analysing this part is an important part of the work at this stage, including the DEA efficiency of DMUs. When there are DMUs where DEA is not efficiency, the reasons for this need to be analysed and targeted improvement strategies developed according to the specific situation. For DEA efficiency DMUs, the evaluation can be further subdivided into parameters to complete the evaluation. For the selection of input and output indicators in the process of university physical education quality evaluation, the principles followed are that the indicators are easy-to-measure targets; input and output indicators are considered separately, so that the calculation process is simple and the weights of output and input indicators do not need to be known in advance; there is no need to make uniform requirements on the scale of input and output indicators; the higher the value of output indicators, the lower the value of input indicators. The final selection of input and output indicators for the evaluation of physical education quality in universities is shown in Table 2. According to the DEA model, the total number of DMUs must be twice or more than the sum of input indicators and output indicators. The sum of input indicators and output indicators in the study is 10, so 24 DMUs are selected in the study. Eight DMUs were selected from each of the three schools by average and random methods, which were denoted by numbers 1–8, 9–16 and 17–24 respectively.

Table 2 Input and output indicators of physical education teaching quality evaluation in colleges and universities

Input index	*Output indicators*
T1 sports facilities	U1 expert evaluation
T2 teacher title	U2 student satisfaction
T3 teacher workload	U3 students' mastery of sports skills
T4 teaching age of teachers	U4 students' passing rate of physical examination at the end of the semester
T5 students' passing rate of physical examination at admission	U5 teaching methods

4 Combining the results of the DEA model for evaluating the quality of physical education teaching in universities

This study needs to analyse the evaluation of college physical education teaching quality combined with DEA model. The research first determines the evaluation index system of college physical education teaching quality according to the questionnaire method and Delphi method. It includes the weight of the primary and secondary indicators, the weighted average of the assigned value, and the standard error. A total of 18 questionnaires were distributed, recovered and efficiency in the second round of expert opinion questionnaires. The Kendall coefficient of the questionnaire after the second round of expert opinion survey is 0.712. Therefore, expert opinions have a high degree of coordination, and their opinions are almost the same, the evaluation index of physical education obtained by the research has high reliability. The relevant numerical results of the primary indicators are shown in Figure 4. The value range of the weighted average score of the assignment of the four primary indicators is 4.11–4.99, the standard error is 0.00–0.25, and the value range of the weight is 0.22–0.26.

Figure 5 shows the results of the associated numerical values for the secondary indicators. 24 secondary indicators were assigned a weighted average score in the range of 4.00–4.99, with a standard error of 0.00–0.50 and weights in the range of 0.22–0.26. Thus, the expert assignment scores have a low degree of dispersion, while the experts' opinions tend to be uniform.

Units for T1, T2, U1, U2, U3, U5 indicators are points, units for T3 indicators are lesson hours, units for T4 indicators are years, and units for T5 and U4 indicators are %. Table 3 refers to the survey data related to the evaluation of physical education teaching. The DEA model does not require dimensionless processing of DMU and weight assignment. So the data obtained do not need to be standardised in terms of units. And the optimal solution can be obtained without weight calculation for each generated indicator and input indicator. For input indicators, the range of values is 89–99 for T1, 1–4 for T2, 101–187 hours for T3, 3–29 years for T4 and 79%–90% for T5; for output indicators, 83–97 for U1, 65–74 for U2, 74–94 for U3, 76%–89% for U4 and 67%–90% for U5 indicators are 67–90 points.

The study was analysed by means of the DEAP 2.1 software package, with all data subject to normalisation. And the data in Table 3 were normalised to obtain Figure 6. Overall, T3 had the highest value, taking values in the range of around 150. The next five indicators are U1, U2, U3, U5 and T1, with a value range of 100 left and right. The indicators with the lowest values are U4 and T5.

Figure 7 refers to the correlation between the five input indicators and the five output indicators. Overall, the input and output indicators show an extremely clear positive correlation. Each index in the input index is positively correlated with each index in the output index, and all of them were significant. The input indicators include students' physical side pass rate at enrolment, teachers' years of teaching experience, teachers' workload, teachers' titles and sports facilities. Output indicators include teaching methods, students' physical side pass rate at the end of the semester, students' mastery of motor skills, students' satisfaction and experts' evaluation of teaching.

The study goes on to analyse the results of the DEA model outputs in three areas, specifically the overall analysis of the data, the DEA efficiency analysis and the DEA ineffectiveness analysis. Figure 8 refers to the efficiency of the 24 DMUs. Overall, there are 18, 20 and 19 DMUs with a technical efficiency value, a pure technical efficiency value and a scale efficiency value of 1 respectively. Therefore, based on the technical efficiency values it was possible to initially determine whether the DMUs were DEA effective. 75% of the 24 DMUs were considered DEA effective and the rest DEA ineffective. Therefore, the overall level of teaching quality of physical education in the province's colleges and universities is high, but there are a small number of teachers whose teaching quality is low.

Figure 4 Relevant values of the first-class indicators for the evaluation of physical education teaching quality in colleges and universities (see online version for colours)

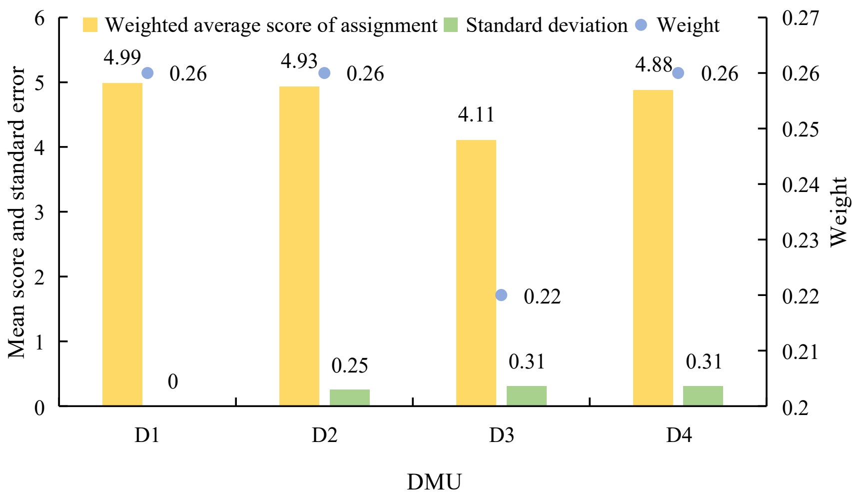


Figure 5 Relevant numerical results of secondary indicators (see online version for colours)

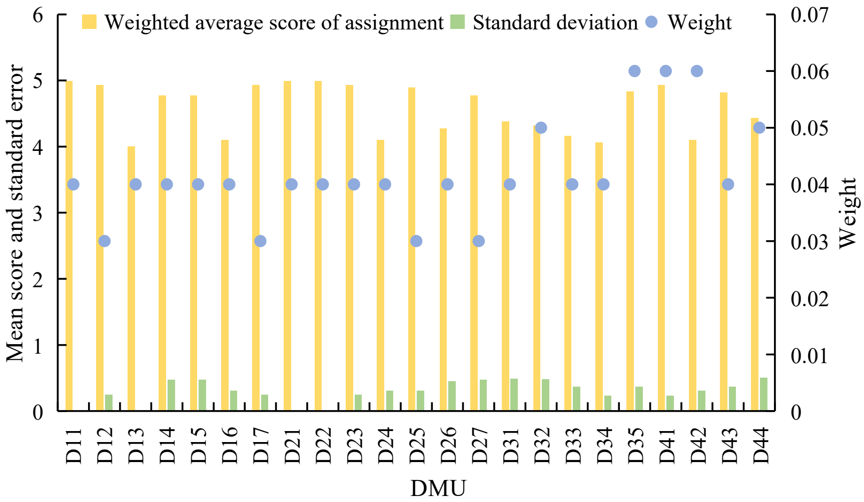


Figure 6 Normalisation results of raw data (see online version for colours)

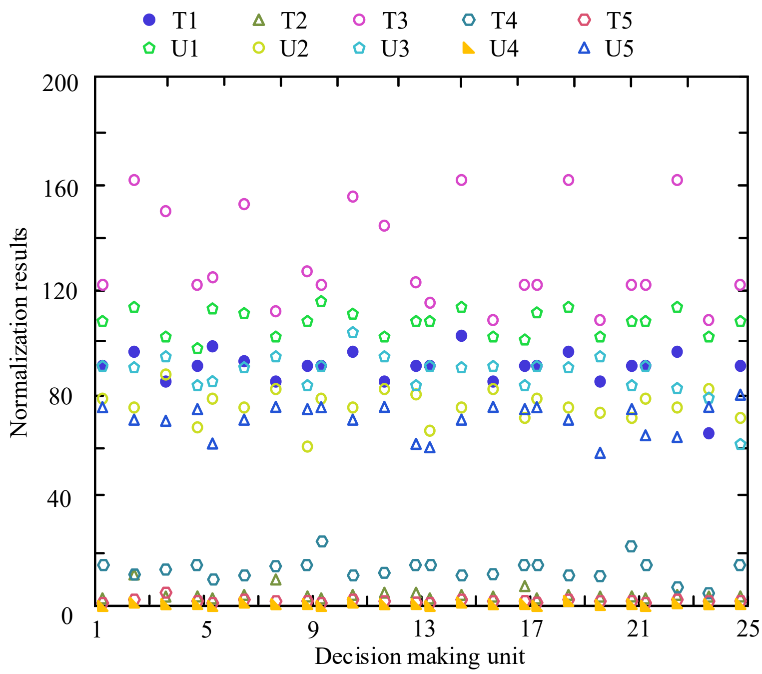


Table 3 Relevant survey data of physical education teaching evaluation

No.	*T1/branch*	*T2/branch*	*U1/branch*	*U2/branch*	*U3/branch*	*U5/branch*	*T3/class hour*	*T4/year*	*T5/%*	*U4/%*
1	98	4	97	74	91	84	109	28	84	81
2	94	3	89	72	74	79	167	20	84	82
3	92	2	97	73	81	81	187	20	86	84
4	92	3	89	69	79	89	143	29	86	78
5	94	2	96	71	92	80	161	29	79	86
6	97	3	90	72	90	73	167	22	87	89
7	90	2	93	70	94	82	143	18	90	86
8	97	1	96	73	83	90	155	4	85	88
9	99	2	95	74	77	74	160	13	86	88
10	90	3	97	73	84	88	178	15	87	87

Table 3 Relevant survey data of physical education teaching evaluation (continued)

No.	*T1/branch*	*T2/branch*	*U1/branch*	*U2/branch*	*U3/branch*	*U5/branch*	*T3/class hour*	*T4/year*	*T5/%*	*U4/%*
11	95	4	97	72	92	67	167	19	87	84
12	90	3	92	65	86	86	131	24	84	85
13	94	2	91	72	92	90	187	25	88	78
14	95	3	90	72	87	94	109	3	79	81
15	92	4	83	73	82	83	132	18	84	77
16	97	2	98	74	84	88	101	16	86	76
17	92	3	96	72	90	89	161	25	79	89
18	94	4	92	74	93	79	152	17	88	84
19	89	4	86	72	88	77	185	4	85	82
20	89	3	91	68	80	75	146	14	83	82
21	90	1	92	72	83	79	109	15	85	78
22	98	2	97	70	88	68	178	18	87	86
23	94	3	89	68	91	85	134	23	87	79
24	92	2	96	72	90	77	159	28	79	79

Table 4 Overall analysis of DEA efficiency and ineffectiveness by DMU

DMU	*Technical efficiency*	*Pure technical efficiency*	*Scale efficiency*	*Returns to scale*	*Generate relaxation variable*	*Input relaxation variable*
1	1.000	1.000	1.000	-	0	0
2	0.970	0.974	0.997	irs	No 0	No 0
3	0.995	1.000	0.995	drs	0	0
4	1.000	1.000	1.000	-	0	0
5	1.000	0.993	1.000	-	0	0
6	0.992	0.993	0.999	irs	No 0	No 0
7	1.000	1.000	1.000	-	0	0
8	1.000	1.000	0.999	-	0	0
9	0.993	1.000	1.000	irs	0	0
10	1.000	1.000	0.000	-	0	0
11	1.000	1.000	1.000	-	0	0
12	1.000	1.000	1.000	-	0	0
13	1.000	0.989	1.000	-	0	0
14	1.000	1.000	1.000	-	0	0
15	1.000	1.000	1.000	-	0	0
16	1.000	1.000	1.000	-	0	0
17	1.000	1.000	1.000	-	0	0
18	1.000	1.000	1.000	-	0	0
19	0.989	1.000	1.000	-	No 0	No 0
20	1.000	0.974	1.000	-	0	0
21	1.000	1.000	0.986	-	0	0
22	0.986	1.000	1.000	irs	0	0
23	1.000	0.993	1.000	-	0	0
24	1.000	0.993	1.000	-	0	0

Figure 7 Correlation between five input indicators and five output indicators, (a) U1, (b) U2, (C) U3, (d) U4, (e) U5 (see online version for colours)

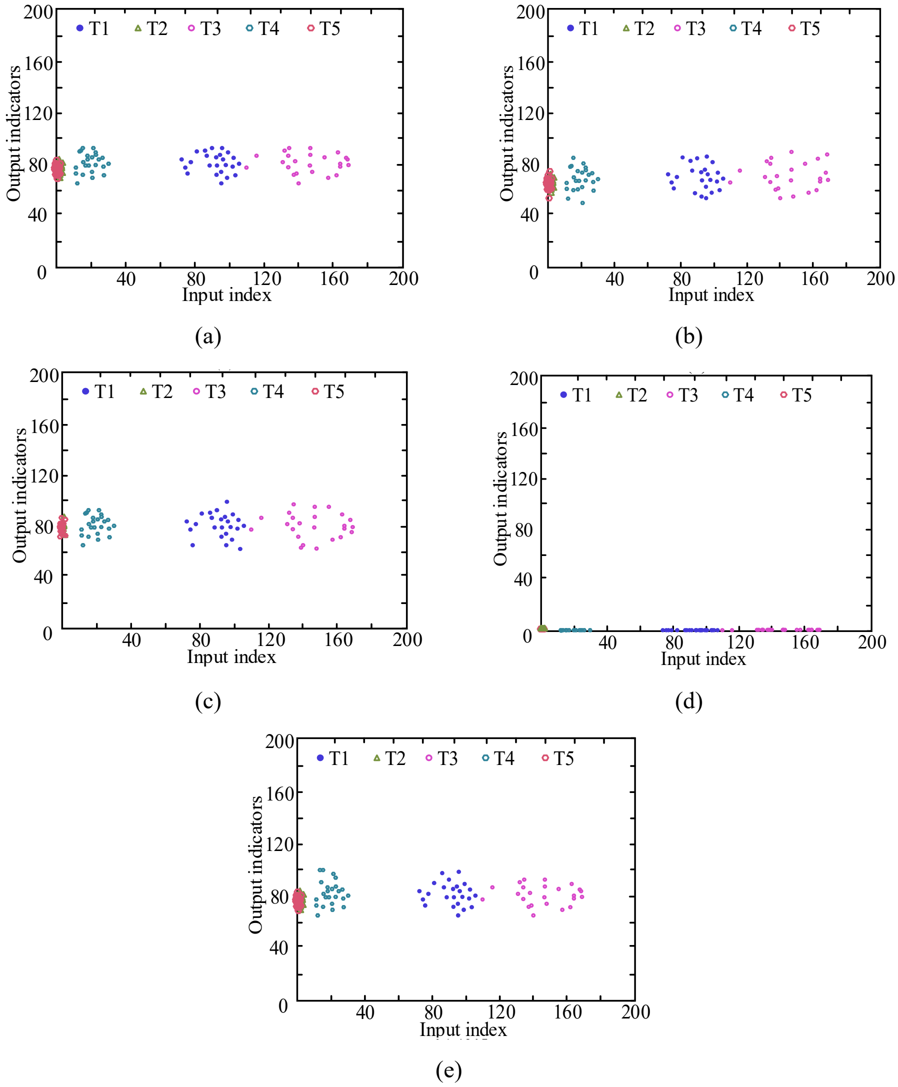


Figure 8 Efficiency of 24 DMUs (see online version for colours)

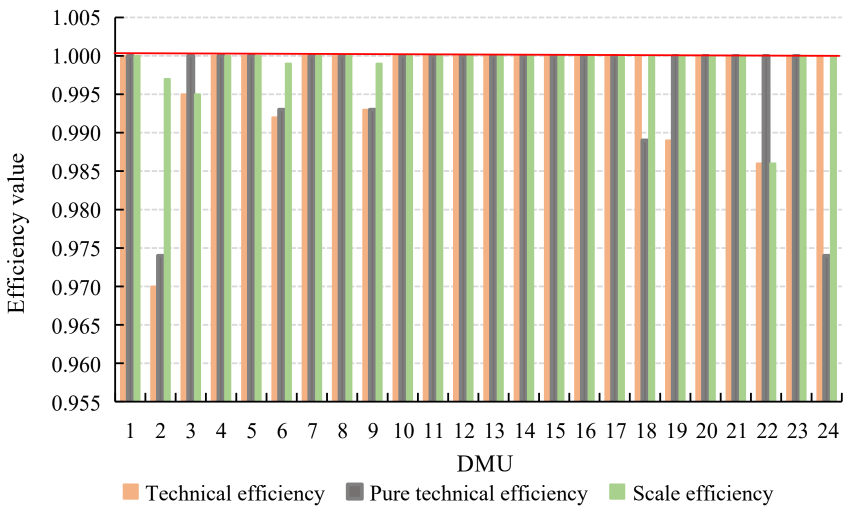


Table 4 refers to the overall analysis of DMU of DEA efficiency and ineffectiveness. In Table 4, ‘irs’, ‘drs’ and ‘–’ indicate that DMU is in three stages: increasing, decreasing and unchanged returns to scale. If the efficiency value is equal to 1, DEA is effective. If the efficiency value is less than 1, DEA is inefficiency. DEA efficiency can be divided into two types: first, strong DEA efficiency, the criterion is that the efficiency value is 1, and the slack variables of input and output are 0. Secondly, weak DEA is effective, and the criterion is that the efficiency value is 1. And the size of slack variables does not need to be considered. There are 18 DMUs with a technical efficiency value of 1. There are 20 DMUs with a pure technical efficiency value of 1. There are 19 DMUs with scale efficiency value of 1 and output relaxation variable of 0. Therefore, 18 DMUs are DEA inefficiency, accounting for 24%. The teaching efficiency of physical education in this province is high. And the teaching output is in direct proportion to the input and there is no redundancy ratio. However, the teaching efficiency of a few teachers or schools is still low, and the teaching input is redundant. Among the 24 DMUs, DMU3 is in the stage of diminishing returns to scale. DMU2, DMU6, DMU9 and DMU22 are in the stage of diminishing returns to scale. And the remaining 19 DMU are in the stage of constant returns to scale. Among the output relaxation variables, there are 20 DMUs with a value of 0. Among the input relaxation variables, there are 20 DMUs with a value of 0. There are 20 variables whose output and input relaxation variables are both zero. Therefore, there are 18 DMUs with DEA efficiency, and they belong to strong DEA efficiency.

5 Conclusions

With the continuous implementation of the concept of quality education in colleges and universities, the traditional methods of physical education teaching evaluation have failed to meet the objective needs of current education. The study applies the DEA model to the evaluation of physical education teaching quality in colleges and universities in order to solve the problems of the current teaching evaluation methods being complicated and ineffective. The results of the application analysis show that for input indicators, the range of values for T1 indicators is 89–99 points. T2 indicators are 1–4 points. T3 indicators are 101–187 lesson hours; T4 indicators are 3–29 years. T5 indicators are 79%–90%. For output indicators, U1 indicators are 83–97 points. U2 indicators are 65–74 points. U3 indicators are 74–94 points. U4 indicators are 76%–89%. U5 indicators are 67–90. The projection results for the 18 teachers show that the target unit is itself, with a corresponding weight of 1. However, there are differences in the number of target units. The number of DMU7 and DMU20 as target units is 1. The number of times for DMU5, DMU8, DMU11 and DMU24 is 2. The number of times for DMU14 is 3, the number of times for DMU10 is 4, and the rest are 0. The DEA inefficiency DMU will give target values of indicators and target objects that can be improved. The DEA model can accurately evaluate the characteristics and information of the evaluation object and the evaluation content itself. And it can also comprehensively analyse the problem of multiple inputs and outputs in the teaching quality evaluation process. It provides practical and concrete solutions for the improvement of the overall level of teaching. However, there are still two problems in the research. One of them provides a new research scope for the follow-up DEA model in the evaluation of teaching quality of other courses in colleges and universities. Secondly, colleges and universities need to establish incentive policies for teaching evaluation and further optimise the allocation of teaching resources.

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References

Alireza, T. and Elkafi, H. (2018) ‘Evaluating sustainability performance in fossil-fuel power plants using a two-stage data envelopment analysis’, *Energy Economics*, August, Vol. 74, pp.154–178.

Ashuri, B., Wang, J., Shahandashti, M. and Baek, M. (2019) ‘A data envelopment analysis (DEA) model for building energy benchmarking’, *Journal of Engineering Design and Technology*, Vol. 17, No. 1, pp.747–768.

Azimovna, F.M. (2021) ‘The quality assessment technology and development techniques in volleyball players’, *Web of Scientist: International Scientific Research Journal*, Vol. 2, No. 4, pp.242–248.

Bagheri, M., Ebrahimnejad, A., Razavyan, S., Hosseinzadeh Lotfi, F. and Malekmohammadi, N. (2022) ‘Fuzzy arithmetic DEA approach for fuzzy multi-objective transportation problem’, *Operational Research*, Vol. 22, No. 2, pp.1479–1509.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978) ‘Measuring the efficiency of decision-making units’, *European Journal of Operations Research*, Vol. 2, No. 6, pp.429–441.

Chen, L. and Li, Y. (2019) ‘The significance and practical path of outward bound training in college physical education teaching’, *Management Science and Research: Chinese and English Version*, Vol. 8, No. 1, pp.22–26.

Deilmann, C., Hennersdorf, J., Lehmann, I. and Reißmann, D. (2018) ‘Data envelopment analysis of urban efficiency-interpretative methods to make DEA a heuristic tool’, *Ecological Indicators*, Vol. 84, pp.607–618.

Duan, S.X. (2019) ‘Measuring university efficiency: an application of data envelopment analysis and strategic group analysis to Australian universities’, *Benchmarking An International Journal*, Vol. 26, No. 4, pp.1161–1173.

Ebrahimnejad, A. and Lotfi, F.H. (2012) ‘Equivalence relationship between the general combined-oriented CCR model and the weighted minimax MOLP formulation’, *Journal of King Saud University Science*, Vol. 24, No. 1, pp.47–54.

Ebrahimnejad, A. and Tavana, M. (2014) 'An interactive MOLP method for identifying target units in output-oriented DEA models: the NATO enlargement problem', *Measurement*, Vol. 52, No. 1, pp.124–134.

Ebrahimnejad, A., Tavana, M. and Santos-Arteaga, F.J. (2016) 'An integrated data envelopment analysis and simulation method for group consensus ranking', *Mathematics and Computers in Simulation*, Vol. 119, pp.1–171.

Fan, K. (2021) 'Research on the relationship between computer educational teaching and college physical education reform', *Journal of Physics: Conference Series*, Vol. 1915, No. 3, pp.032040–032044.

Hutzler, Y., Meier, S., Reuker, S. and Zitomer, M. (2019) 'Attitudes and self-efficacy of physical education teachers toward inclusion of children with disabilities: a narrative review of international literature', *Physical Education and Sport Pedagogy*, Vol. 24, No. 3, pp.249–266.

Kiwuwa, L.F. (2018) 'User-friendly libraries for active teaching and learning: a case of business, technical and vocational education and training colleges in Uganda', *Information and Learning Science*, Vol. 119, No. 5, pp.275–294.

Lee, B.L. and Johnes, J. (2022) 'Using network DEA to inform policy: the case of the teaching quality of higher education in England', *Higher Education Quarterly*, Vol. 76, No. 2, pp.399–421.

Mogha, S.K., Yadav, S.P. and Singh, S.P. (2014a) 'Estimating technical and scale efficiencies of private hospitals using a non-parametric approach: case of India', *Int. J. Operational Research*, Vol. 20, No. 1, pp.21–40.

Mogha, S.K., Yadav, S.P. and Singh, S.P. (2014b) 'New slack model-based efficiency assessment of public sector hospitals of Uttarakhand: state of India', *International Journal of System Assurance Engineering and Management*, Vol. 5, No. 1, pp.32–42.

Mogha, S.K., Yadav, S.P. and Singh, S.P. (2016) 'Estimating technical efficiency of public sector hospitals of Uttarakhand (India)', *Int. J. Operational Research*, Vol. 25, No. 3, pp.371–399.

Moghaddam, B.F. and Saedi, Z. (2020) 'Performance management of public transportation by the network data envelopment analysis (DEA) model', *The Journal of Planning and Budgeting*, No. 2, pp.45–58.

Mohseni, P., Borghei, A.M. and Khanali, M. (2018) 'Coupled life cycle assessment and data envelopment analysis for mitigation of environmental impacts and enhancement of energy efficiency in grape production', *Journal of Cleaner Production*, Vol. 197, No. 1, pp.937–947.

Nenkova, P. and Borisova-Mihaylova, G. (2021) 'Measuring and analyzing the technical efficiency of Bulgarian municipalities €' an application of data envelopment analysis (DEA)', *Ikonomiceski i Sotsialni Alternativi*, No. 3, pp.5–17.

Pahlavan, R., Omid, M. and Akram, A. (2018) 'Application of data envelopment analysis for performance assessment and energy efficiency improvement opportunities in greenhouses cucumber production', *Journal of Agricultural Science & Technology*, Vol. 3, No. 14, pp.1465–1475.

Salahi, M., Toloo, M. and Hesabirad, Z. (2019) 'Robust Russell and enhanced Russell measures in DEA', *Journal of the Operational Research Society*, Vol. 70, No. 8, pp.1275–1283.

Shivley, J.M., Brookshire, W.C., Bushby, P.A., Woodruff, K.A. (2018) 'Clinically prepared veterinary students: enhancing veterinary student hands-on experiences and supporting hospital caseload using shelter medicine program', *Frontiers in Veterinary Science*, No. 5, pp.95–103.

Tavana, M., Ebrahimnejad, A., Santos-Arteaga, F.J., Mansourzadeh, S.M. and Matin, R.K. (2018) 'A hybrid DEA-MOLP model for public school assessment and closure decision in the City of Philadelphia', *Socio Economic Planning Sciences*, March, Vol. 61, pp.70–89.

Tyagi, P., Yadav, S.P. and Singh, S.P. (2009) 'Relative performance of academic departments using DEA with sensitivity analysis', *Evaluation and Program Planning*, Vol. 32, No. 2, pp.168–177.

Yu, H.H. (2021) 'Research on production efficiency and ownership concentration – taking steel industry and logistics industry as examples', *Turkish Journal of Computer and Mathematics Education (TURCOMAT)* Vol. 12, No. 11, pp.3958–3969.

Zadmirzaei, M., Limaei, S.M. and Amirteimoori, A. (2018) 'Efficiency analysis of paper mill using data envelopment analysis models (case study: Mazandaran wood and paper company in Iran)', *Journal of Agricultural Science & Technology*, Vol. 17, No. 6, pp.1381–1391.

Zhang, L., Zeng, Y. and Yan, J. (2019) 'Evaluating the efficiency of nursing homes in Xiamen city and its influencing factors by using data envelopment analysis', *Chinese Journal*, Vol. 36, No. 1, pp.13–17.

Zhang, X. and Shi, W. (2019) 'Research about the university teaching performance evaluation under the data envelopment method', *Cognitive Systems Research*, August, Vol. 56, pp.108–115.

Zhao, J., Xiu, Y. and Cui, W. (2020) 'An empirical study on marine economic efficiency of the Liaoning Coastal Economic Belt', *Journal of Coastal Research*, Vol. 106, No. SI, pp.358–328.

Zhu, W., Wan, M., Zhou, Y. and Pan, W. (2018) 'Fuzzy computation of teaching performance based on data envelopment analysis method', *Cognitive Systems Research*, December, Vol. 52, pp.351–358.