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An Improved RAHP/DEA Method and the Application of the Physical Education Teaching Quality Assessment

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Abstract

The teaching quality assessment of physical education for the undergraduates has a very important role for the development of the college physical education teaching. In the age of information, we can improve effectively the speed and accuracy of the assessment through using rationally the computer technology. The AHP method and the DEA method are two kinds of evaluation methods which are used widely by the scholars. However, whether we use AHP or DEA, there are some defects on the using and scope. In order to overcome these shortcomings, we propose the RAHP/DEA method. This method combines the advantages of the RAHP method and the DEA methods. And we enlarge the range of use. Finally, in the computer simulation experiment, we adopt the method to evaluate the teaching quality of college physical education. The experimental results verify the rationality of the project evaluation and the decision making process. This shows that the evaluation system and the evaluation method meet the decision making ideas and the practical requirements.

Keywords: *RAHP/DEA; College physical education teaching quality; Computer simulation*

1. Introduction

The evaluation of college physical education teaching quality can reflect the quality of the physical education for one college. It can also point out the advantages and the disadvantages of the college physical education teaching quality. Through the evaluation of college physical education teaching quality, we can see easily the existed questions in the college physical teaching. At the same time, the evaluation of college physical education teaching quality lays a solid foundation for prompting more effectively the college students to do the physical exercise. In the information age, more and more colleges introduce the computer technology to improve the physical teaching, such as performance prediction, training and teaching quality assessment. In these applications, the teaching quality evaluation is very important for the development of the physical teaching for the colleges.

With the college physical teaching becoming more and more important, the colleges and the students pay more and more attention to the physical teaching. Many scholars study the evaluation of college physical education teaching quality. Xiang Lili studied and developed the ordinary college physical evaluation management information system. She adopted the traditional Client/Server(C/S) structure model and used Visual Studio, the NET and Crystal Report development environment and SQL Server 2000 database to develop a management information system [1]. The management information system has the functions of data statistics, assessment and auxiliary decision. Zhu Chuanjian studied the influence of the Meta evaluation theory on improving the physical evaluation quality.

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In this paper, he defined that the Meta evaluation was not only the reflection and summary for the evaluation itself, but also it was a higher level critique and examine. This reflected the practical value of the Meta evaluation in the optimization and improvement educational assessment activities [2]. Chen Yingjie studied the selection of weights in the college physical evaluation system based on the information entropy. He proposed an evaluation index weight selection method based on the information entropy. On the one hand, the method has the objectivity of the rigorous mathematical theory. On the other hand, it had the subjectivity of the expect experience assessment [3]. By Dan studied the construction of the physical working evaluation index system of the ordinary college in Jiang Su province [4]. Ruan Qingti studied the evaluation standard of the ordinary college physical working in Vietnam [5].

AHP and DEA are two important methods for the evaluation. AHP was proposed by Saatty. And AHP is a method which combines the qualitative research with the theory research [6]. The method has been attracted the concern of many scholars when it was produced. In the subsequent decades, the scholars derived from a lot of the improved AHP methods [7-11]. The DEA method was proposed by America famous strategist A.Charnes and W.W.Copper in 1978. The main idea is to compare the relative efficiency of the evaluated institutions through the mathematical programming calculation. Like the AHP method, the method has also been the concern of many scholars. Through the continuous development and innovation, the method has become one of the main methods for the evaluation [12-15].

After reading the relevant literature, we found that the AHP method relied on the past experience. DEA method did not consider all of the target factors when it made the decision. Moreover, these two methods had limitations in the range of application. Based on this, we proposed the RAHP/DEA method. The method combined the AHP method with the DEA method. It can overcome the above shortcomings effectively. The structure of this paper is as follows. The first past is introduction. The second part is the basic steps of AHP and DEA. In this part, we recommend the basic steps of AHP and DEA. The third part is RAHP/DEA method. In this part, we propose the new assessment method: AHP/DEA. The fourth part is the numerical analysis and the last part is the conclusion.

2. The Basic Steps of AHP and DEA

2.1. The Basic Steps of AHP Methods

When we adopt AHP method to solve the decision questions, the basic steps are as follows.

1. Constructing the Hierarchical Structure Model

We divide the complex questions into many elements. These elements are divided into several groups because of their properties. These elements compose the different ladder level. In general, there are the target layer, the criterion layer and the solution layer *etc.* With the same level elements as the standard, we judge the importance of each sub-goal for the upper target. The first layer is the target layer. In general, there is one factor. The middle layer is the criterion layer. It can be divided into one or several. The following is the scheme layer.

2. Establishing the Judgment Matrix

We construct the hierarchical structure to determine the relationship among the different levels. For example, we make the high level element C_k as the criterion. C_k Can dispose the next level elements $A_1, A_2, \cdots, A_n$. Then we judge the relative importance of $A_1, A_2, \cdots, A_n$ for C_k in order to ensure the corresponding weight for each other. AHP can adopt the

digital scaling which is less than 10 to weight the importance. According to the scale, we establish the two and two comparison matrix.

$$A=(a_{ij})_{n\times n} \quad (i=1,2,\cdots,n), a_{ij}=1, a_{ij}=1/a_{ji}$$

Among them, $a_{ij}>0, \frac{1}{a_{ij}}=a_{ji}, a_{ii}=1$.

3. Solving the relative weight of each element in a single criterion

According to C_k criterion, the judgment matrix A can solve the relative importance among each element $A_1, A_2, \cdots, A_n$ and obtain the characteristic roots. According to $A\omega=\lambda_{\max}\omega$, we get the weight of $A_1, A_2, \cdots, A_n$. The specific steps are as follows.

The first step is to set vector $\omega_0=(\frac{1}{n},\frac{1}{n},\cdots,\frac{1}{n})^T$.

The second step is to set $k=1,2,\cdots,n$ and calculate $\omega_k=A\omega_{k-1}$.

The third step is to calculate $\lambda_{\max}$ and ω_{kj}.

$$\lambda_{\max}=\frac{1}{n}\cdot\sum_{j=1}^{n}\frac{\omega_{kj}}{\omega_{(k-1)j}}$$

$$\omega_{kj}=\frac{\omega_{kj}}{\sum_{j=1}^{n}\omega_{kj}}$$

When the precision is not high, we can use the same approximation to calculate $\lambda_{\max}$ and ω.

4. Consistency check

We define $CI=\frac{\lambda_{\max}-n}{n-1}$.

CI Is the index of consistency.

When the judgment matrix has the character of consistency, $CI=0$

If $\lambda_{\max}-n$ is large, CI is large. And the consistency is worse.

For checking whether the judgment matrix has the character of consistency, we compare CI with the index of consistency RI that is shown in table.1.

Table 1. The Index of Consistency from 1-9 Orders

order	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

2.2. The Basic Steps of DEA

DEA is short for the data envelopment analysis. It is a new cross field of the mathematics, operations research, mathematical economics and the management science. It was propsed s by A.Chames and W.W.Cooper in 1978. And it is named DEA. DEA model uses the mathematical programming (including the linear programming, multi-objective programming, the generalized optimization with cone structure, semi-infinite programming, stochastic programming *etc*.) to evaluate the target. It has multiple inputs. Especially, it has many output sector and units. We call these units as the decision units. It is short for the relative validity among the DMU.

On the basis of the concept of the relative efficiency, DEA method is a kind of evaluated method based on the convex analysis and the linear programming. The method uses the mathematical programming model to calculate the relative efficiency among the decision units. And then it evaluates the evaluation object. It can consider the optimal input-output scheme for the decision unit itself. Therefore, it can better reflect the

characteristics and the information of the object itself. In addition, it has the unique characteristics to analyze the multiple inputs and output system for the evaluation.

The characteristics of DEA method

① It is suitable for the effective comprehensive evaluation problems of the multiple output-input. It has the absolute advantage in the effectiveness of the treatment for the multiple output-input.

② The DEA method is not directly to synthesize the data. Therefore, the optimal efficiency indicators of the decision unit are independent of the choice of the input index and the output index. Using the DEA method to establish model does not the non-dimensional processing for the data.

③ It is not any weight hypothesis. It uses the actual data of the input and output of the decision unit to obtain the optimal weights. This excludes many subjective factors and has the very strong objectivity.

④ The DEA method assumes that each input is related to one or more output and input. And it exist a certain relationship among the outputs. However, it needs not to determine the expression of this relationship.

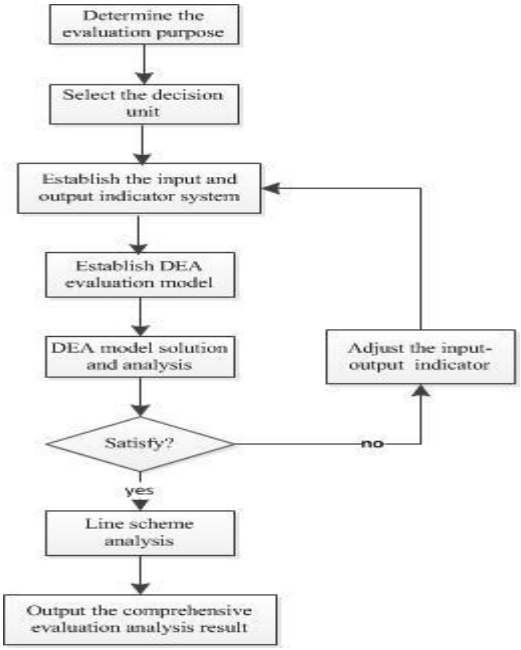

Figure 1. The Application Steps of DEA Method

The basic principle of DEA method is as follows.

DEA is a mathematical programming model aiming to establish the most favorable model for each decision unit. It can get the weight of the indicator according to solve the optimal solution. Different decision units have different index weights and they are relatively optimal. Therefore, the DEA evaluation is a kind of variable weight evaluation method. It belongs to the non-uniform evaluation. The most commonly DEA model is C^2R model. The basic principle is to assume that there is n decision units $DMU_j\ (j=1,2,\cdots,n)$. Their input and output are as follows.

$$X_j=\left(x_1,x_2,\cdots,x_{mj}\right)^T>0,\ j=1,2,\cdots,n \quad (1)$$

$$Y_j=\left(y_1,y_2,\cdots,y_{kj}\right)^T>0,\ j=1,2,\cdots,n \quad (2)$$

We use the matrix to express. It is shown as table 2.

Table 2. The Input and Output Table of the Decision Unit

Decision unit	0	1	2	...	n
Input	x_0	x_1	x_2	...	x_n
Output	y_0	y_1	y_2	...	y_k

In the production process, the status and the role of various input and output are different. Therefore, if we evaluate the DMU, we need to synthesize the input and the output. That is, we treat them as the whole production process of a general input and a general output. So we need to give each input and output an appropriate weight. For example, the weight of x_j is v_j. The weight of y_j is u_j. We assume that the weight vectors of the input and output are $v = (v_1, v_2, \cdots, v_m)^T$ and $u = (u_1, u_2, \cdots, u_s)^T$. Firstly, we see them as variables. Then we determine them in the process of the analysis according to a certain principles. Firstly, we evaluate i_0 decision unit.

$$h_j = \frac{u^T y_j}{v^T x_j} = \frac{\sum_{k=1}^{s} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}}, \ j = 1, 2, \cdots, n \tag{3}$$

h_j is the efficiency evaluation index of the j decision unit DMU_j. We can always select appropriate weight coefficient v and u. And it makes $h_j \le 1, \ j = 1, 2, \cdots, n$ .Then we evaluate the j_0 decision unit. In general, the bigger the h_{j0} is, DMU_{j_0} can use relatively litter input to obtain the relatively more output.
Then the C^2R model is as follows.

$$\begin{aligned} &\max \frac{\sum_{k=1}^{s} u_k y_{kj0}}{\sum_{i=1}^{m} v_i x_{ij0}} \\ &S.T. \\ &\frac{\sum_{k=1}^{s} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, \ j - 1, 2, \cdots, n \\ &u_k \ge 0, k = 1, 2, \cdots, s \\ &v_j \ge 0, i = 1, 2, \cdots, m \end{aligned} \tag{4}$$

This is a fractional programming problem. By the charnes-Coopre transform,

$$\begin{cases} t = \dfrac{1}{v^T x_0} \\ \omega = tv \\ \mu = tu \end{cases} \tag{5}$$

And we get the following linear programming model.

$$P_{C^2R}=\begin{cases}\max \mu^T y_0=\overline{V}_p \\ S.T. \\ \omega^T x_j-\mu^T y_j\geq 0,\ j=1,2,\cdots,n \\ \omega^T x_0=1 \\ \omega\geq 0,\mu\geq 0\end{cases} \quad (6)$$

When we use the above model to evaluate the line, it often appears the efficiency indexes is the same or similar. It leads that we cannot rank these schemes effectively. In order to overcome this shortcoming, the model needs to be improved. Therefore, we introduce a virtual decision unit in order to distinguish the difference among the effective decision units. For the schemes which the efficiency evaluation indexes are the same or similar, we make

$$x_j=\min_{1\leq j\leq n}\{x_{ij}\}(i=1,2,\cdots,n),\ y_r=\min_{1\leq j\leq n}\{y_{rj}\}(i=1,2,\cdots,s),\ X_{n+1}=(x_1,x_2,\cdots,x_m)^T$$

And

$$Y_{n+1}=(y_1,y_2,\cdots,y_s)^T.$$

We make X_{n+1} and Y_{n+1} as the virtual decision units. And we merge the virtual decision unit into the n decision units. Then we can get the evaluation model which is based on the virtual decision unit.

$$P_{C^2R}=\begin{cases}\max \mu^T y_0=\overline{V}_p \\ S.T. \\ \omega^T x_j-\mu^T y_j\geq 0,\ j=1,2,\cdots,n,n+1 \\ \omega^T x_0=1 \\ \omega\geq 0,\mu\geq 0\end{cases} \quad (7)$$

3. RAHP/DEA Method

3.1. The Steps of RAPH/DEA

In the traditional AHP method, because the importance degree of each element is given by experts, the subjectivity of experts can affect the final evaluation results. The AHP method relies on the past experience as the judgment, the subjective factor is too large. Therefore, it cannot persuade others. Compared with AHP method, DEA method has the absolute advantage on handling the multi-input and output problems. However, it relies on DEA method simply to evaluate. It gives little information for the effective decision making units. The respective characteristics of AHP method and DEA method determine the complementarity between them. Aiming to the above problem, we propose a new method RAHP/DEA. Firstly, this method uses regression analysis AHP method to get the weight of each factor. Then it uses DEA method to obtain the efficiency evaluation index. Finally, according to the weight and efficiency evaluation index, we get the evaluation results.

In this paper, we propose RAHP/DEA method

Firstly, it uses the regression analysis AHP method to calculate the weight vector of each factor which relates to the overall goal.

Secondly, it classifies the indexes and establishes respectively the decision unit set. It makes the negative index as the input indicators and uses the positive index and the output indicators. Then it uses the data envelope analysis method to get the optimal value h_{ij}. h_{ij} expresses the efficiency evaluation index of the i factor for j scheme.

Thirdly, it uses the weight which is calculated in step1 to calculate the overall priority vector $\sigma_j = \sum_{i=1}^{4} h_{ij} c_i$. Compared σ_j , we can get the order of each scheme.

3.2. The Comparison of AHP, DEA and RAHP/DEA Methods

3.2.1. AHP Method: The advantage of AHP evaluation

Firstly, when using AHP method to solve the complex decision questions, according to the combination of the qualitative and quantitative analysis, we need to introduce the preference information of the decision makers at the same time. Therefore, the results make the decision more scientific and reasonable.

Secondly, using the AHP method to decide and making the thing process mathematic, it can improve the effectiveness of the decision making.

The disadvantage of AHP evaluation

Firstly, this method is based on the previous experience as the judgment basis. Although the method can avoid the serious non-conformance in the thinking process, it still cannot avoid the one-sided judgment problems of the subjective factors.

Secondly, when using the method to make a decision, due to the imperfect process, it could not use the method in the high required question.

The scope of AHP

The application condition of AHP is the combination of the qualitative and quantitative scheme. When analyzing the complex question, the question which is needed to solve exists independently. There are some qualitative and quantitative relationships among each item. For such problem, in order to handle these questions, AHP method provides a new thinking way. At the same time, the method has the characteristics of mathematically rigorous, simple, and easy to understand. It is more conductive for the decision makers.

3.2.2 The Advantage of DEA Method： The advantage of DEA is that it is not influenced by the subjective factors. The results are based on the corresponding data to count. In this process, it does not need to set the weights of input and output. This makes the method can reduce some error which is caused by the subjective factors. At the same time, in the using process, DEA method does not exist the restricted relationship of the sub-item. It can evaluate and decide at the same time. In addition, it adopts the complex production relations.

The disadvantage of DEA method

When deciding the target, we do not consider all of the factors. In fact, we use the extreme value evaluation factors. Therefore, the characteristics of some units do not display. The disadvantage of this method is the range. It has the certain restrictive conditions. And these restrictive conditions affect the efficiency.

The application range of DEA range

The DEA method is applied to the field of economic analysis, the efficiency and benefit analysis and the evaluation technological level.

3.2.3 THE Advantage of RAHP/DEA： RAHP/DEA has not only the merits of DEA method, but also it can avoid the disadvantages that DEA method can only judgment the decision units. In addition, it can reduce effectively the subjectivity of the decision makers when they use the AHP method to order the scheme layer. RAHP/DEA is more reasonable and effective for the ranking of the decision units. It not only inherits the advantages of AHP and DEA which is used alone, but also it solves the sidedness and limitations.

The disadvantages of RAHP/DEA

Compared with DEA method, RAHP/DEA method cannot completely eliminate the unreasonable parts.

4. Numerical Analysis

We use RAHP/DEA method to evaluate college physical education teaching quality of three colleges. Firstly, we establish the evaluation index. The evaluation index is shown in the following Table 2.

Table 2. The Evaluation Index

The first layer evaluation index	The second layer evaluation index
Content of courses	Explicit the teaching goal
	Reasonable time arrangement
	Suitable to the students
	Forming the lifelong sports concept
Teaching attitude	Dressing
	Teaching preparation
	Students attendance
	The communication between teachers and students
Teaching method	Clear action and specification
	Students' interest and learning enthusiasm
	Exercising the method diversification
	Information feedback
Teaching efficiency	Class vividly
	Mastering the skills
	Guiding the students to learn autonomously
	Cultivating sports ethics, team spirit and sense of competition

Firstly, we use RAHP method to calculate the weights of the index. In this paper, we use SPSS18.0 software to calculate the weights of the first layer by the regression analysis. We use AI to express the evaluation indicators and content of courses. The teaching content is expressed by CC. Teaching attitude is expressed by TA. Teaching method is expressed by TM. Teaching efficiency is expressed by TE. After the regression analysis, we can see that the regression coefficient of the content of courses is 0.312. The regression coefficient of the Teaching attitude is 0.234. The regression coefficient of the Teaching method is 0.229. The regression coefficient of the Teaching efficiency is 0.326. Therefore, the regression equation for college physical education teaching quality assessment is as follows.

Table 3. The Analysis Result of the Dimension Regression

Model	Non-standard coefficient		Standard coefficient	t	sig
	B	Standard error	Trial version		
Constant term	1.047	0.12		0.003	0.000
Content of courses	0.312	0.12	0.328	5.383	0.000
Teaching attitude	0.346	0.12	0.372	5.971	0.000
Teaching method	0.339	0.12	0.325	6.262	0.000
Teaching efficiency	0.483	0.12	0.501	7.340	0.000

The regression equation is as follows.

$$AI = 1.047 + 0.312CC + 0.346TA + 0.339TM + 0.483TE$$

Then we calculate the weights. The calculation process is as follows.

The weight of the convent dimension is as follows.

$$X_1 = \frac{0.312}{0.312 + 0.346 + 0.339 + 0.483} = 0.211$$

The weight of the convent dimension is as follows.

$$X_2 = \frac{0.346}{0.312 + 0.346 + 0.339 + 0.483} = 0.234$$

The weight of the convent dimension is as follows.

$$X_3 = \frac{0.339}{0.312 + 0.346 + 0.339 + 0.483} = 0.229$$

The weight of the convent dimension is as follows.

$$X_4 = \frac{0.483}{0.312 + 0.346 + 0.339 + 0.483} = 0.326$$

Therefore, the regression coefficients and the weights for all indictors are as follows.

Table 4. The Regression Coefficients and the Weights

Dimension	Regression coefficients	Weights
Content of courses	0.321	0.211
Teaching attitude	0.346	0.234
Teaching method	0.339	0.229
Teaching efficiency	0.483	0.326

Because the evaluation indexes of college physical education teaching quality are qualitative indexes, we adopt the assessment scoring method. The objects are composed of 100 experts. The scoring standards are divided into excellent, good, general, poor grades. Firstly, we evaluate the content of courses for college one. The evaluation results are shown as follows.

Table 5. The Index Calculation of College Physical Education Teaching Quality Index

Grade	Explicit the teaching goal	Reasonable time arrangement	Suitable to the students	Forming the lifelong sports concept	Virtual decision making units
poor	5	0	5	13	3
qualified	35	30	28	8	17
general	40	47	36	52	42
good	15	22	17	16	27
excellent	10	1	14	11	11

$$\begin{aligned}
&\max \quad 15y_1 + 10y_2 \\
&S.T. \\
&\begin{cases}
5x_1 + 35x_2 + 40x_3 - 15y_1 - 10y_2 \geq 0 \\
0x_1 + 30x_2 + 47x_3 - 22y_1 - 1y_2 \geq 0 \\
5x_1 + 28x_2 + 36x_3 - 17y_1 - 14y_2 \geq 0 \\
13x_1 + 8x_2 + 52x_3 - 16y_1 - 11y_2 \geq 0 \\
3x_1 + 17x_2 + 42x_3 - 27y_1 - 11y_2 \geq 0 \\
5x_1 + 35x_2 + 40x_3 = 1 \\
x_1, x_2, x_3, y_1, y_2 \geq 0
\end{cases}
\end{aligned}$$

According to the function $\bar{h}_{ij} = \sum_{j=1}^{k} h_{ij} / k$, we can get the evaluation index of content of courses for the first college is 0.825. Similarly, we can get the evaluation indexes of content of courses for the second college and the third college three 0.863 and 0.868. The results are shown in the following

Table 6. The Results of Three Colleges

Evaluation index	College 1	College 2	College 3
Content of courses	0.825	0.863	0.838

In the same way, we can get the evaluation indexes for content of courses, teaching attitude, teaching method and teaching efficiency. The results are shown in the following table.

Table 7. The Evaluation Index of Threes Colleges

Evaluation index	College 1	College 2	College 3
Content of courses	0.825	0.863	0.838
Teaching attitude	0.813	0.841	0.820
Teaching method	0.714	0.728	0.693
Teaching efficiency	0.722	0.741	0.703

According to the function $\sigma_j = \sum_{i=1}^{4} h_{ij} c_i$, we can get the evaluation indicators for college physical education teaching quality of the three colleges.

Among them,

$$\sigma_1 = 0.825 \cdot 0.211 + 0.813 \cdot 0.234 + 0.714 \cdot 0.229 + 0.722 \cdot 0.326 = 0.763$$

$$\sigma_2 = 0.863 \cdot 0.211 + 0.841 \cdot 0.234 + 0.728 \cdot 0.229 + 0.741 \cdot 0.326 = 0.787$$

$$\sigma_3 = 0.838 \cdot 0.211 + 0.820 \cdot 0.234 + 0.693 \cdot 0.229 + 0.703 \cdot 0.326 = 0.757$$

Therefore, the three colleges ranking is $\sigma_2 > \sigma_1 > \sigma_3$.

5. Conclusion

The rapid development of the information technology promotes the efficiency of the college physical education teaching quality assessment improving continually. It also makes the evaluation result more reasonable. It has the wide application combined the information technology with the physical teaching. In this paper, we have done the following works. (1)Firstly, we introduce the basic principle of AHP method and DEA method. (2)Secondly, aiming to determining of AHP method and DEA method, we propose the RAHP/DEA method. (3)Thirdly, we establish the evaluation system of college physical education teaching quality. (4)Lastly, we adopt the RAHP/DEA method to the

college physical education teaching quality. According to the evaluation results, we make the decision. The experimental results prove that the method is rational.

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