Research on the Optimization of DEA Based on
the Perspective of Customer Satisfaction

—A Case Study of Compulsory Education Service

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Abstract—In order to solve the problem of high efficiency and
low satisfaction in the service industry, this paper constructed the
CS-DEA model from the perspective of input. From the
perspective of customer satisfaction, it could adjust the input to
achieve high efficiency and high satisfaction based on DEA-BCC
efficiency analysis. Finally, this paper took the compulsory
education service of the key cities as an example to verify the
effectiveness of the model and put forward corresponding
suggestions.

Keywords—DEA-BCC; Customer Satisfaction; CS-DEA;
Compulsory Education

I. INTRODUCTION

The Data Envelopment Analysis Method (DEA) is a
nonparametric method based on mathematics and operations
research to estimate the relative efficiency of a multi-input and
output system. It was first proposed by Charnes, Cooper, and
Rhodes in 1978[1]. At present, the DEA model has been
adopted by many scholars and applied in various fields, such as
fiscal expenditure efficiency assessment, tourism efficiency
assessment, energy efficiency assessment, air pollution control
efficiency assessment, and education service efficiency
assessment. Zhao Qi used the DEA analysis method to evaluate
the input-output efficiency of compulsory education resource
allocation and conducted an empirical analysis [2]. Zhang
Dongchao used the DEA analysis method to evaluate the
efficiency of China’s listed commercial banks [3]. Zhu Erxi and
Liu Jiawei used the DEA model to construct the BCC model
and the Malmquist index model to evaluate the efficiency of
the cultural financial service system [4].

Domestic and foreign scholars continue to improve the DEA
model in the process of using the DEA method to study the
efficiency evaluation problem in order to adapt to the
development of the times. The DEA model has been combined
with many analytical methods to form derivative models such as
years. At the same time, many derivative models such as the
super-efficiency DEA model [7], interval DEA model [8], inverse
DEA model [9], and network DEA model [10] are also produced.

With the continuous improvement of the economic level,
customers not only require efficient services but also demand
high service quality. The traditional DEA model mainly
evaluates the efficiency of service input and output results
without paying attention to customer satisfaction. However, the
quality of service is more focused on customer satisfaction in
the current customer-centric era. Therefore, this paper
improves the DEA-BCC model based on a customer
satisfaction perspective. The paper proposes that the CS-DEA
model is dedicated to solving the high efficiency-low
satisfaction problem existing in the service industry and
providing a reliable basis for the optimal allocation of
resources based on the input/output efficiency analysis.

II. OPTIMIZATION MECHANISM OF DEA MODEL FROM THE
PERSPECTIVE OF CUSTOMER SATISFACTION

A. Measurement of service efficiency and customer
satisfaction

1) Measurement of the efficiency of the service

Efficiency refers to the ratio of input and output of
resources. Efficiency is the most direct purpose of economic
behavior in the economy. In addition, the ultimate goal of any
economic behavior is to achieve a certain degree of efficiency.
Efficiency is usually divided into comprehensive efficiency,
pure technical efficiency, and scale efficiency inefficiency
research. Service efficiency refers to the ratio of the input of
Service efficiency refers to the ratio of the input of enterprise
service resources to the output of service effects. Finally, the
effectiveness of enterprise service resource allocation is
verified by efficiency.

The efficiency scores of the input and output indicators of
resources calculated by the DEA model are between [0-1.0].
According to the classification of satisfaction interval, the
interval of efficiency score is divided into five levels: low
It can be judged whether the decision-making results.

These four areas include high efficiency - high satisfaction, effectiveness of services into four areas based on the two satisfaction and low efficiency - low satisfaction. The article divides the satisfaction degree of the service into five parts: the dissatisfaction, the dissatisfaction, the general, the satisfaction, and the satisfaction based on the five-point Likert scale multiplied by 0.2. The article identified the unit calculation method is the interval value of the five-point Likert scale multiplied by 0.2.

0.8 as a low satisfaction level. The result is shown in Fig. 1.

TABLE II. SATISFACTION SCORE CONVERSION AND RATING TABLE

<table>
<thead>
<tr>
<th>Likert scale</th>
<th>Adjusted quality score intervals equivalent</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0-1)</td>
<td>(0-0.2)</td>
<td>Very dissatisfied</td>
</tr>
<tr>
<td>(1-2)</td>
<td>(0.2-0.4)</td>
<td>dissatisfied</td>
</tr>
<tr>
<td>(2-3)</td>
<td>(0.4-0.6)</td>
<td>general</td>
</tr>
<tr>
<td>(3-4)</td>
<td>(0.6-0.8)</td>
<td>satisfied</td>
</tr>
<tr>
<td>(4-5)</td>
<td>(0.8-1.0)</td>
<td>Very satisfied</td>
</tr>
</tbody>
</table>

Fig. 1. Analysis of the relationship between service efficiency and satisfaction in the plane Cartesian coordinate system

III. PROCESS OF CS-DEA MODEL CONSTRUCTION

This paper optimizes the DEA model based on the BC2 model. This part proposes the concrete steps of the CS-DEA model construction based on the introduction of the BC2 model.

A. BC2 model

The BC2 model removes the important premise assumption that the scale return is unchanged of the C2R model. Moreover, the BC2 model introduces constraints based on the C2R model [11]. The model structure is as follows:

\[ \begin{align*}
\min_{\theta} & \sum_{j=1}^{n} \lambda_j + s^- = 0x_0 \\
\sum_{j=1}^{n} y_j \lambda_j - s^- = 0y_0 \\
\sum_{j=1}^{n} \lambda_j &= 1 \\
s^- &\geq 0, s^+ \geq 0, \lambda_j \geq 0, j = 1, 2 \ldots n
\end{align*} \] (1)

The result of the objective function measurement is called pure technical efficiency. Scale efficiency (SE) is obtained by dividing technical efficiency (TE) by pure technical efficiency (PTE). The article adjusts the constraint \( \sum_{j=1}^{n} \lambda_j = 1 \) in the above model to \( \mathbf{X} \). It can be judged whether the decision-making unit is in the stage of increasing or decreasing the scale of returns based on the established model. The improvement direction of scale efficiency is analyzed based on the above judgment results.
B. CS-DEA-BC² model

This paper optimizes the DEA-BC² model from the perspective of customer satisfaction on the basis of the DEA-BC² model. It mainly solves the problem of high efficiency and low satisfaction of the current service industry. Specific steps are as follows:

Step 1: DEAP2.1 is used to calculate the efficiency of a unit.

Step 2: The satisfaction measurement of the service industry is based on the five-point Likert scale and converted to [0-1.0].

Step 3: The decision unit is divided according to the efficiency score and the satisfaction score. The classification levels include HE-HS (high efficiency and high satisfaction), LE-HS (low efficiency-low satisfaction), HE-LS (high efficiency-low satisfaction), and LE-LS (low efficiency and low satisfaction).

Step 4: The efficiency of the HE-LS unit is adjusted. The input index value of the HE-LS unit is recalculated under the efficiency-high satisfaction), and LE-LS (low efficiency and low satisfaction).

The adjusted indicator data will then be re-input index value of the HE-LS unit is recalculated under the efficiency-high satisfaction), and LE-LS (low efficiency and low satisfaction).

This article takes the actual points and hypothetical points in Figure 1 as an example. \( a' \) and \( eA' \) are assumed to be submitted into the DEAP2.1 software for calculation and unchanged. The adjusted indicator data will then be re-submitted into the DEAP2.1 software for calculation and ultimately converted to HE-HS units. If the number of HE-LS units is null, then stop.

This article takes the actual points and hypothetical points in Figure 1 as an example. \( s_4 \) and \( e_\alpha \) are assumed to be arbitrary values between [0.8-1.0] and [0.2-1.0], respectively. The relationship equation is as follows.

\[
(A_\beta B_\alpha) = (s_\beta - 0.20)(0.20 - 1.0) \tag{2}
\]

Given the distance function formula: \((AB) = \sqrt{(x_2 - x_1)^2 + (x_2 - y_1)^2}\)

and substituting in (2) we take:

\[
\frac{(x_\beta - 0.20)^2 + (0.20 - 1.0)}{(x_\beta - 0.20)^2 + (0.20 - e_\alpha)} = \frac{(x_\beta - 0.20)(0.20 - 1.0)}{(x_\beta - 0.20)(0.20 - e_\alpha)} \tag{3}
\]

In general, even if diverse quality and efficiency cut-off points are chosen (cut-off points \( 1, 0.2 \)), (3) is expressed by the following equation:

\[
\left(\frac{x_\beta - 0.20}{x_\beta - 0.20} + \frac{(0.20 - 1.0)}{(0.20 - e_\alpha)}\right) = \left(\frac{x_\beta - 0.20(0.20 - 1.0)}{(x_\beta - 0.20)(0.20 - e_\alpha)}\right) \tag{4}
\]

Formula (5) can be obtained a base on Formula (4).

\[
e_{\beta} = e_\alpha + \sqrt{\frac{(x_\beta - 0.20)^2 + (0.20 - 1.0)}{(x_\beta - 0.20)^2 + (0.20 - e_\alpha)}} \tag{5}
\]

Since the new efficiency score \( e_{\beta} \) has been calculated, the inputs of the hypothetical operational units should be adjusted holding the outputs fixed (input orientation). Its efficiency score is expressed as formula (6)

\[
e = \sum_{r=1}^{n} \alpha_r y_r \frac{\sum_{r=1}^{n} \beta_r x_r}{\sum_{r=1}^{m} \beta_r x_r} \tag{6}
\]

Where: \( e \) = efficiency score

\( y_i \) = amount of output

\( x_i \) = amount of input i

\( \alpha_r \) = weight assigned to output r

\( \beta_i \) = weight assigned to input i

Alternatively, the precedent equation (6) is expressed in matrix form:

\[
e = \sum_{r=1}^{n} \alpha_r y_r \frac{\sum_{r=1}^{m} \beta_r x_r}{\sum_{r=1}^{m} \beta_r x_r} \tag{7}
\]

Assuming technical efficiency prevails, then:

\[
1.0 = \left[ y_1, y_2, \cdots, y_m \right] \left[ \begin{array}{c} \alpha_1 \\ \vdots \\ \alpha_m \end{array} \right] \left[ \begin{array}{c} \beta_1 \\ \vdots \\ \beta_m \end{array} \right] \tag{8}
\]

Therefore,

\[
\left[ x_1, x_2, \cdots, x_m \right] = \left[ y_1, y_2, \cdots, y_m \right] \left[ \begin{array}{c} \alpha_1 \\ \vdots \\ \alpha_m \end{array} \right] \left[ \begin{array}{c} \beta_1 \\ \vdots \\ \beta_m \end{array} \right] \tag{9}
\]

According to the changes of formulas (6)-(8), the adjusted efficiency can be expressed as:

\[
e' = \sum_{r=1}^{n} \alpha_r y_r \frac{\sum_{r=1}^{n} \beta_r x_r}{\sum_{r=1}^{m} \beta_r x_r} \tag{10}
\]

where \( e' \neq e \) and \( x_i' \neq x_i \). The formula (10) is transformed into a matrix form as shown below.

\[
e' = \sum_{r=1}^{n} \alpha_r y_r \frac{\sum_{r=1}^{n} \beta_r x_r}{\sum_{r=1}^{m} \beta_r x_r} \tag{11}
\]

The formula (11) is divided by \( 1/e' \) and the results are as follows.

\[
1 = \frac{1}{e' [x_1', x_2', \cdots, x_m']} \tag{12}
\]

The formula (12) is brought into the formula (11) and the results are as follows.

\[
[e' x_1', e' x_2', \cdots, e' x_m'] = [x_1, x_2, \cdots, x_m] \left[ \begin{array}{c} v_1 \\ \vdots \\ v_m \end{array} \right] \left[ \begin{array}{c} \nu_1 \\ \vdots \\ \nu_m \end{array} \right] \tag{13}
\]

Therefore,
In the above system of equations, $e'$ is the ordinate of $A'$ and $e'$ is also the ordinate of each LE-HS. $X$ represents the actual input index of the HE-LS and it is known. The adjusted input value can be calculated based on the above conditions. It is substituted into the DEAP.2.1 software to get the adjusted efficiency value. Finally, the category of the decision unit can be re-identified.

### IV. MODEL VERIFICATION

#### A. Construction of compulsory education resource allocation indicators and the sources of indicator data

1) Compulsory education resource allocation indicator system

When using the DEA model to evaluate efficiency, it is necessary to establish a set of realistic input-output index systems. Education is a special service industry. The basic input indicators for measuring the efficiency of education should include human, material and financial aspects. Its output indicators should include both direct output and affect output. Considering the scientific nature of indicators and the availability of data, this paper constructs an index system for the efficiency of China's compulsory education resource allocation from the perspective of input and output. It includes 2 first-level indicators, 5 second-level indicators, and 16 third-level indicators. The results are shown in Table III.

#### TABLE III. Compulsory Education Resource Allocation Indicator System

<table>
<thead>
<tr>
<th>Primary indicator</th>
<th>Secondary indicators</th>
<th>Three-level indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input indicator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material input</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial investment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output indicator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect output</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) Compulsory education resource allocation indicator system

Combined with the authenticity and availability of the data, the article selects Qingdao, Hangzhou, Jinan, The educational resource allocation efficiency of the seven major cities of Shenyang, Changchun, Guangzhou and Xi'an is the research object. Based on the results of the China Education Development Report (2016), which was formed by the 21st Century Institute of Education's monitoring of the balanced development of compulsory education in 19 key cities. The statistics of Qingdao and Jinan are derived from the Qingdao Statistical Yearbook, the Jinan Education Statistics Briefing in the 2012 Year, the Shandong Statistical Yearbook and the “2013 Shandong Education Statistics Bulletin. The data of Hangzhou City comes from the Zhejiang Statistical Yearbook, Hangzhou Statistical Yearbook and 2015 Zhejiang Education Industry Statistics Bulletin. The data of Changchun City comes from the Statistical Bulletin of Education in Changchun City. The data of Shenyang City comes from the Statistical Bulletin of Educational Statistics Manual. The data of Xi'an are derived from the 2015 Shaanxi Provincial Education Statistics Bulletin and the Xi'an Statistical Yearbook. The per capita years of education in each city are derived from the data of each province. The input and output indicator data of compulsory education resource allocation in major cities are shown in Tables IV and V.

#### TABLE IV. Compulsory Education Input Data Sheet for Seven Major Cities

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Qingdao</th>
<th>Hangzhou</th>
<th>Jinan</th>
<th>Shenyang</th>
<th>Changchun</th>
<th>Guangzhou</th>
<th>Xi'an</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>34457</td>
<td>31280</td>
<td>25795</td>
<td>22321</td>
<td>26301</td>
<td>49336</td>
<td>30579</td>
</tr>
<tr>
<td>X2</td>
<td>38042</td>
<td>18909</td>
<td>30239</td>
<td>14862</td>
<td>30521</td>
<td>27534</td>
<td>19306</td>
</tr>
<tr>
<td>X3</td>
<td>30949</td>
<td>30423</td>
<td>23097</td>
<td>21160</td>
<td>24171</td>
<td>48367</td>
<td>29212</td>
</tr>
<tr>
<td>X4</td>
<td>20936</td>
<td>17752</td>
<td>14800</td>
<td>13108</td>
<td>26974</td>
<td>24881</td>
<td>17180</td>
</tr>
<tr>
<td>X5</td>
<td>6</td>
<td>7</td>
<td>8.2</td>
<td>9.3</td>
<td>7.2</td>
<td>6.46</td>
<td>7.14</td>
</tr>
<tr>
<td>X6</td>
<td>13.39</td>
<td>18.3</td>
<td>13.39</td>
<td>11.1</td>
<td>13.3</td>
<td>19.87</td>
<td>14.81</td>
</tr>
<tr>
<td>X7</td>
<td>24.7</td>
<td>26.8</td>
<td>29.02</td>
<td>19.71</td>
<td>24.35</td>
<td>24.56</td>
<td>29.53</td>
</tr>
<tr>
<td>X8</td>
<td>41.2</td>
<td>45.7</td>
<td>51.58</td>
<td>30.19</td>
<td>41</td>
<td>53.17</td>
<td>45.98</td>
</tr>
<tr>
<td>X9</td>
<td>13.81</td>
<td>17.1</td>
<td>16.8</td>
<td>16.67</td>
<td>12.06</td>
<td>15.28</td>
<td>11.68</td>
</tr>
<tr>
<td>X10</td>
<td>20.33</td>
<td>28.3</td>
<td>27.5</td>
<td>20.83</td>
<td>15</td>
<td>30.78</td>
<td>16.72</td>
</tr>
<tr>
<td>X11</td>
<td>2340</td>
<td>2234</td>
<td>1163</td>
<td>1075</td>
<td>1068</td>
<td>2870</td>
<td>1183</td>
</tr>
</tbody>
</table>
that compulsory education services in the seven major cities are in a state of low satisfaction.

C. Compulsory Education Service Optimization Based on CS-DEA Model

According to the CS-DEA model, the article adjusts the allocation efficiency of compulsory education service resources in seven major cities in China. The purpose of the adjustment is to convert the decision unit of HE-LS into HE-HS unit. The specific calculation results are as follows.

1) Calculation of compulsory education efficiency

The calculation results obtained by importing the input and output data in Tables IV and V into the DEAP2.1 software are shown in Table VIII.

B. Construction of Compulsory Education Satisfaction Index and Source of Indicator Data

1) Construction of the satisfaction index of compulsory education

The article establishes a satisfaction evaluation index system based on the perspective of the local people based on the results of the China Education Development Report (2016). It mainly includes the distance to school, the choice of schools and Inter-school differences.

2) Construction of the satisfaction index of compulsory education

The total enrollment of primary and middle schools is divided into three points, including full realization, partial realization, and basic failure. The total score for school connected to the perspective of the local people, based on the results of the China Education Development Report (2016). It mainly includes the distance to school, the choice of schools and Inter-school differences.

The article converts it into [0-5] based on the classification of satisfaction in Table II. The results are shown in Table VII.

The article converts it into [0-5] base on the classification of satisfaction levels. It shows

It can be seen from Table VII that the satisfaction of compulsory education services in seven major cities is below 0.8 based on the classification of satisfaction levels. It shows

It can be seen from Table IX that the compulsory education services of the other six cities in China are in the HE-LS stage except for Hangzhou. Therefore, it is necessary to adjust the compulsory education efficiency of the six major cities of Qingdao, Jinan, Shenyang, Changchun, Guangzhou and Xi’an according to formula (3.6). The results are shown in Table X.
The calculation process is the same as above. The calculation until the final transformation of HE-LS status. The cities through the CS-DEA model, its efficiency has also been adjusted by the CS-DEA model. In addition, the compulsory education service in Hangzhou in other cities converted from the original adjusted index value of the compulsory education service in Hangzhou was converted from the original adjusted index value of the LE-HS status (low efficiency - high satisfaction) decision-making units. In this way, the LE-HS and LE-LS decision-making units can be adjusted according to the weights and values of the input indicators of the effective unit HE-HS (high efficiency - high satisfaction). It can improve the efficiency and satisfaction of LE-HS and LE-LS decision-making units. In the case, the problem of HE-LS only exists in addition to Hangzhou City. The final result did not appear in the LE-HS and LE-LS decision units after the adjustment. Therefore, the article does not use the effective unit as a standard to adjust the LE-LS and LE-LS input indicators. It should be noted that the CS-DEA model can adjust to this situation.

### V. Conclusion

In order to solve the problem of high efficiency-low satisfaction in the current service industry, this paper builds the CS-DEA model based on the DEA-BCC efficiency analysis, which pays more attention to customer satisfaction. The model divides the four levels of HE-HS, HE-LS, LE-HS, and LE-LS based on the critical values of efficiency and satisfaction. It transforms the decision unit of the HE-HS into a HE-HS unit by adjusting the input parameters of the decision unit. In addition, the efficiency of other decision-making units has also increased. This paper selects the compulsory education service satisfaction value and the resource allocation input-output value of the seven major cities in the China Education Development Report (2016) to verify the model. It can be seen from the calculation results that the current 7 cities are in the HE-LS state except for Hangzhou. The input indicators of the 6 cities are converted into HE-LS status through the adjustment of the CS-DEA model. The value of Hangzhou City has also been converted to HE-HS status after a new round of adjustment. The above results finally verify the validity of the model.

The CS-DEA model not only solves the problem of high efficiency - low satisfaction, but also improves the overall efficiency of inefficient decision making units. In addition, the model can also provide a reference for the adjustment of HE-LS (Inefficient - High Satisfaction) and LE-LS (Inefficient - Low Satisfaction) decision-making units. In this way, the HE-LS and LE-LS decision-making units can be adjusted according to the weights and values of the input indicators of the effective unit HE-HS (high efficiency - high satisfaction). It can improve the efficiency and satisfaction of LE-HS and LE-LS decision-making units. In the case, the problem of HE-LS only exists in addition to Hangzhou City. The final result did not appear in the LE-HS and LE-LS decision units after the adjustment. Therefore, the article does not use the effective unit as a standard to adjust the LE-LS and LE-LS input indicators. It should be noted that the CS-DEA model can adjust to this situation.

### References


