EFFICIENCY EVALUATION OF CHINESE TRANSPORTATION SYSTEM’S RESOURCE ALLOCATION BASED ON DATA ENVELOPMENT ANALYSIS

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Abstract: This paper discusses the issue of Chinese transportation system’s resource allocation in the background of integrative transportation system. Firstly, the definition of “resource allocation” in this paper is given, then a brief introduction about data envelopment analysis is presented. After that, the data envelopment analysis is used to evaluate resource allocation of Chinese transportation system, different periods’ resource allocation efficiency, scale income, ideal input/output are calculated as well. In the end, some suggestions about Chinese transportation system’s resource allocation are put forward.

Key Words: Transportation System, Resource Allocation, Data Envelopment Analysis

1. INTRODUCTION

Transportation is an important industry in social life, and the strategy of building an convenient, efficient and safe integrated transportation system has been put forward to in Chinese “11th Five-year Plan”, which needs some benchmarks to evaluate the actual resource allocation efficiency of transportation system. But few research has been done to investigate such kind of benchmarks and compare different periods’ allocation efficiency so far, this article aims at evaluating Chinese transportation system’s resource allocation efficiency of different times. And we try to give some suggestions about resource allocation of Chinese transportation system based on our results.

The evaluation model in our thesis is data envelopment analysis (DEA), which is a technique that measures the relative efficiency of decision-making units (DMU) with multiple inputs and outputs. Since its introduction by Charnes et al. (1978), DEA has become an increasing popular technique for carrying out an examination of comparative efficiency when a simple monetary measure such as profit is not appropriate. The number of application of DEA is large, covering fields as finance, health, education, manufacturing, transportation, etc. Only in transportation field, there are many articles in recent years: Matthew G. Karlaftis (2004) uses DEA and globally efficient frontier production functions to investigate urban transit system; Sebastian Lozano and Gabriel Villa (2006) propose a MILP DEA model that guarantees the required integrality of the computed targets; M. Zarepisheh et al. (2006) deal with the CCR formulation for estimating returns to scale, and reviews its problem in the presence of alternative optimal solutions. Juan Carlos Martin and Concepcion Roman (2001) apply DEA to analyze the technical efficiency and performance of each individual Spanish airport; Jose Tongzon (2001) uses DEA to evaluate port efficiency, etc.
Even though there are many applications of DEA in transportation field, the DMUs are always different objects at the same time, research about compare of the same object’s different period situation is not found so far. This thesis focus on the resource allocation efficiency of Chinese transportation system’s different periods, that is to say, the comparative objects are different periods in Chinese history, which are described as “1st Five-year Plan”, “2nd Five-year Plan”, “3rd Five-year Plan”, etc. Besides contributing to the discuss of changes in Chinese transport resource allocation efficiency, this paper provides each period’s returns to scale, standard of input and output. Section 2 gives definition of “resource allocation”; section 3 discusses the data envelopment analysis method; section 4 present the data, model of evaluation, and results of model. In the last part, conclusions are summed up.

2. DEFINITION

Exact meaning of “resource allocation efficiency of transportation system” in this thesis is as follows: utilizing extent and efficiency of various resources which were put into transportation system, such as capital, labour force, and technology.

3. DEA METHOD

DEA is a non-parametric method for evaluating DMUs, CCR is one kind of basic DEA models, and CCR’s formulation is as follows:

\[
\begin{align*}
\min & \quad \theta - \epsilon (e^T_m s^- + e^T_s s^+) = V_D \\
\text{s.t.} & \quad \sum_{j=1}^{n} \lambda_j x_j + s^- = \theta x_0 \\
& \quad \sum_{j=1}^{n} \lambda_j y_j - s^+ = y_0 \\
& \quad \lambda_j \geq 0 \\
& \quad s^+ \geq 0, s^- \geq 0
\end{align*}
\]

Where \( \epsilon \) is a non-Archimedean infinitesimal, which is normally set by \( 10^{-6} \); \( e_m = (1,\cdots,1)^T \), \( e_s = (1,\cdots,1)^T \); \( s^- \) and \( s^+ \) are vectors of input and output slacks respectively; \( x_j=(x_{1j},x_{2j},\ldots,x_{mj})^T \geq 0 \) and \( y_j=(y_{1j},y_{2j},\ldots,y_{sj})^T \geq 0 \) are input and output column vectors for DMU \( j \) respectively; and \( \lambda_j \) denotes the vector of DMU \( j \)’s weights chosen by the liner program.

Given the above model, there are 3 theorems as follows:

Theorem 1: If for DMU \( 0 \), the optimum solution is “\( \theta=1 \) and \( s_j^- \neq 0 \)” or “\( \theta=1 \) and \( s_j^+ \neq 0 \)”, then DMU \( 0 \) is weak CCR-efficient; If for DMU \( 0 \), the optimum solution is “\( \theta=1 \) and \( s_j^- = s_j^+ = 0 \)”, then DMU \( 0 \) is CCR-efficient.

Theorem 2: If DMU \( 0 \) isn’t CCR-efficient, efficiency can be achieved by projecting DMU \( 0 \).
onto the CCR-efficiency frontier as follows: \( x_0 = \theta x_0 - s^{-} \), \( y_0 = y_0 + s^{+} \), then 
\((1-\theta)x_0 + s^{-} \) and \( s^{+} \) are redundant input and deficient output respectively.

Theorem 3: If \( \sum_{j=1}^{n} \lambda_{j}^{*} = 1 \), then the returns to scale(RTS) of DMU \( 0 \) is constant; If 
\( \sum_{j=1}^{n} \lambda_{j}^{*} < 1 \), then the RTS of DMU \( 0 \) is increasing; If 
\( \sum_{j=1}^{n} \lambda_{j}^{*} > 1 \), then the RTS of DMU \( 0 \) is decreasing.

4. APPLICABILITY OF DEA METHOD

There are several advantages to using DEA as a performance or efficiency evaluation compared to parametric methods. First, DEA allows a certain flexibility in the treatment of the inputs and the outputs into an easy and comprehensible efficiency measure. In addition, not only does this method identify the efficient units and estimates, but it also indicates for those inefficient units, what needs to be done in order for them to become efficient without fixing a relation between the variables.

And from the above DEA model, we can see that a DMU is qualified as efficient if no other DMU can produce more outputs by using an equal or smaller quantity of inputs, or if no other DMU can use fewer inputs to produce an equivalent or higher quantity of outputs. In that case, the DMU is located on the frontier of excellence. When it is not, the DMU is qualified as inefficient. This kind of definition for “efficiency” is compatible with the meaning of “efficiency” in “resource allocation efficiency of transportation system” of this paper, so DEA could be used to evaluate resource allocation efficiency of transportation system.

5. EVALUATION PROCESSES

5.1 Evaluating indicators

As efficiency of resource allocation is the amount of service and value received by those inputs, such as human resources, physical resources and financial resources. So we divide input indicators and output indicators as follows: inputs include all kinds of resources invested in transportation system, outputs include physical outputs and monetary outputs, the former could be denoted by volume of freight traffic, rotation volume of freight transport and length of infrastructure, the latter could be represented by production value of transport industry.

The input indicators are:
Input 1\((X_1)\)—the ratio of capital construction investment in transport industry to capital construction investment in all industries(\%);
Input 2\((X_2)\)—the ratio of fixed assets investment in transport industry to fixed assets investment in all industries(\%);
Input 3(X3)—the ratio of crew size in transport industry to crew size in all industries(%);

The output indicators are:
Output 1(Y1)—the ratio of production value in transport industry to production value in all industries(%);
Output 2(Y2)—the ratio of current period’s new hauling track length to last period’s total hauling track length(%);
Output 3(Y3)—the growth speed of freight traffic volume(%);
Output 4(Y4)—the elastic coefficient of freight rotation volume(ratio of freight rotation volume’s increment to total industrial output value’s increment)
Output 5(Y5)—the freight intensity(ratio of ton-kilometer to RMB)

5.2 Data collection

Through poring over various Chinese transportation yearbooks, the data of every DMU’s input and output is obtained, which is in table 1.

<table>
<thead>
<tr>
<th>DMU</th>
<th>Period</th>
<th>Input 1</th>
<th>Input 2</th>
<th>Input 3</th>
<th>Output 1</th>
<th>Output 2</th>
<th>Output 3</th>
<th>Output 4</th>
<th>Output 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>“1st Five- year”</td>
<td>1952-1957</td>
<td>14.5</td>
<td>4.12</td>
<td>3.2</td>
<td>4.4</td>
<td>0.54</td>
<td>18.9</td>
<td>1.75</td>
<td>1.49</td>
</tr>
<tr>
<td>“2nd Five- year”</td>
<td>1958-1962</td>
<td>12.9</td>
<td>3.72</td>
<td>3.4</td>
<td>5.9</td>
<td>0.08</td>
<td>4.3</td>
<td>1.26</td>
<td>2.2</td>
</tr>
<tr>
<td>“3 years adjustment”</td>
<td>1963-1965</td>
<td>12.2</td>
<td>3.6</td>
<td>3</td>
<td>4.3</td>
<td>0.16</td>
<td>15.7</td>
<td>1.02</td>
<td>1.96</td>
</tr>
<tr>
<td>“3rd Five- year”</td>
<td>1966-1970</td>
<td>14.7</td>
<td>4.1</td>
<td>2.7</td>
<td>4.3</td>
<td>0.22</td>
<td>5.7</td>
<td>0.73</td>
<td>1.94</td>
</tr>
<tr>
<td>“4th Five- year”</td>
<td>1971-1975</td>
<td>17.1</td>
<td>5.1</td>
<td>2.6</td>
<td>4.6</td>
<td>0.18</td>
<td>9.8</td>
<td>1.28</td>
<td>2.32</td>
</tr>
<tr>
<td>“5th Five- year”</td>
<td>1976-1980</td>
<td>12.1</td>
<td>3.8</td>
<td>3.54</td>
<td>4.7</td>
<td>0.12</td>
<td>9.6</td>
<td>1.35</td>
<td>2.6</td>
</tr>
<tr>
<td>“6th Five- year”</td>
<td>1981-1985</td>
<td>12.3</td>
<td>2.4</td>
<td>4.3</td>
<td>4.5</td>
<td>0.23</td>
<td>7.7</td>
<td>0.79</td>
<td>2.21</td>
</tr>
<tr>
<td>“7th Five- year”</td>
<td>1986-1990</td>
<td>12</td>
<td>3.4</td>
<td>3.8</td>
<td>4.9</td>
<td>0.44</td>
<td>6.7</td>
<td>0.67</td>
<td>1.63</td>
</tr>
<tr>
<td>“8th Five- year”</td>
<td>1991-1995</td>
<td>17</td>
<td>4.6</td>
<td>3.5</td>
<td>6</td>
<td>0.26</td>
<td>5.7</td>
<td>0.57</td>
<td>0.83</td>
</tr>
<tr>
<td>“9th Five- year”</td>
<td>1996-2000</td>
<td>15.5</td>
<td>7.4</td>
<td>4.4</td>
<td>5.4</td>
<td>0.24</td>
<td>5</td>
<td>0.69</td>
<td>0.5</td>
</tr>
<tr>
<td>“10th Five-year”</td>
<td>2001-2005</td>
<td>16.1</td>
<td>10.9</td>
<td>5.6</td>
<td>7.2</td>
<td>0.32</td>
<td>14.3</td>
<td>1.1</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Data source: Chinese Transport Yearbooks

5.3 Related coefficient of data

In order to avoid magnifying the solution of the CCR model, the linear correlation tests were given to input indicators and output indicators with the software Eviews, and the result of the test is marked in table 2 and table 3.

<table>
<thead>
<tr>
<th></th>
<th>X1</th>
<th>X2</th>
<th>X3</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>1.00</td>
<td>0.62</td>
<td>-0.29</td>
</tr>
<tr>
<td>X2</td>
<td>0.62</td>
<td>1.00</td>
<td>0.12</td>
</tr>
<tr>
<td>X3</td>
<td>-0.29</td>
<td>0.12</td>
<td>1.00</td>
</tr>
</tbody>
</table>

With confidence level of $\alpha = 0.05$ and sample number n=11, the critical value of r=0.632, all the numbers(except those on diagonal line) in table2 and table 3 are less than 0.632, so there is no strong linear correlation between every two input indicators and every two output indicators. These indicators could be used to evaluate resource allocation efficiency of transport system.
Table 3  Related coefficient of output indicators

<table>
<thead>
<tr>
<th></th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
<th>Y4</th>
<th>Y5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>1.00</td>
<td>0.54</td>
<td>-0.61</td>
<td>0.50</td>
<td>-0.47</td>
</tr>
<tr>
<td>Y2</td>
<td>0.54</td>
<td>1.00</td>
<td>-0.57</td>
<td>-0.32</td>
<td>-0.59</td>
</tr>
<tr>
<td>Y3</td>
<td>-0.61</td>
<td>-0.57</td>
<td>1.00</td>
<td>-0.25</td>
<td>0.16</td>
</tr>
<tr>
<td>Y4</td>
<td>0.50</td>
<td>-0.32</td>
<td>-0.25</td>
<td>1.00</td>
<td>0.27</td>
</tr>
<tr>
<td>Y5</td>
<td>-0.47</td>
<td>-0.59</td>
<td>0.16</td>
<td>0.27</td>
<td>1.00</td>
</tr>
</tbody>
</table>

5.4 Model of evaluation

Take example for DMU of the “1st Five year”, DEA-CCR model of evaluation is as follows, which of indicator set of X1, X2, X3; Y1, Y2, Y3, Y4, Y5.

\[
\min \left[ \theta - e \left( e^T_s s^- + e^T_i s^+ \right) \right] = V_0
\]  

(2)

\[
14.5\lambda_1 + 12.9\lambda_2 + 12.2\lambda_3 + 14.7\lambda_4 + 17.1\lambda_5 + 12.1\lambda_6 + 12.3\lambda_7 + 12.0\lambda_8 + 17.0\lambda_9 + 15.5\lambda_{10} + s^-_i = 14.5\theta
\]

\[
4.12\lambda_1 + 3.72\lambda_2 + 3.6\lambda_3 + 4.1\lambda_4 + 5.1\lambda_5 + 3.8\lambda_6 + 2.4\lambda_7 + 3.4\lambda_8 + 4.6\lambda_9 + 7.4\lambda_{10} + s^-_i = 4.12\theta
\]

\[
3.2\lambda_1 + 3.4\lambda_2 + 3\lambda_3 + 2.7\lambda_4 + 2.6\lambda_5 + 3.54\lambda_6 + 4.3\lambda_7 + 3.8\lambda_8 + 3.5\lambda_9 + 4.4\lambda_{10} + s^-_i = 3.2\theta
\]

\[
4.4\lambda_1 + 5.9\lambda_2 + 4.3\lambda_3 + 4.6\lambda_4 + 4.7\lambda_5 + 4.5\lambda_6 + 4.9\lambda_7 + 6.0\lambda_8 + 5.4\lambda_{10} - s^+_i = 4.4
\]

st.

\[
0.54\lambda_1 + 0.08\lambda_2 + 0.16\lambda_3 + 0.22\lambda_4 + 0.18\lambda_5 + 0.12\lambda_6 + 0.23\lambda_7 + 0.44\lambda_8 + 0.26\lambda_9 + 0.24\lambda_{10} - s^-_i = 0.54
\]

\[
18.9\lambda_1 + 4.3\lambda_2 + 15.7\lambda_3 + 5.7\lambda_4 + 9.8\lambda_5 + 9.6\lambda_6 + 7.7\lambda_7 + 6.7\lambda_8 + 5.7\lambda_9 + 1.1\lambda_{10} - s^-_i = 18.9
\]

\[
1.75\lambda_1 + 1.26\lambda_2 + 1.02\lambda_3 + 0.73\lambda_4 + 1.28\lambda_5 + 1.35\lambda_6 + 0.79\lambda_7 + 0.67\lambda_8 + 0.57\lambda_9 + 0.69\lambda_{10} - s^-_i = 1.75
\]

\[
1.49\lambda_1 + 2.20\lambda_2 + 1.96\lambda_3 + 1.94\lambda_4 + 2.32\lambda_5 + 2.60\lambda_6 + 2.21\lambda_7 + 1.63\lambda_8 + 0.83\lambda_9 + 0.50\lambda_{10} - s^-_i = 1.49
\]

\[
\lambda_j \geq 0, j = 1,2,...,10, s^-_i \geq 0, s^-_i \geq 0, s^+_i \geq 0, s^+_i \geq 0, s^+_i \geq 0, s^+_i \geq 0, s^+_i \geq 0
\]

With software of Lindo, solution of the above model is:

\[
\theta = 1, \quad \lambda_1 = 1
\]

\[
\lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = \lambda_7 = \lambda_8 = 0, s^-_i = s^-_i = s^-_i = s^-_i = s^-_i = s^-_i = s^-_i = s^-_i = 0
\]

So transport resource allocation efficiency of the “1st Five year” in China is CCR- efficient.

5.5 Result of the model

5.5.1 Rank of efficiency

Table 4 gives the number of \( \theta \) in different sets of indicators and final rank of resource allocation efficiency.

In table 4, the rank of efficiency is deduced by the average of \( \theta \) in different indicator sets, and set1 includes indicators of “X1, X2, X3; Y1, Y2, Y3, Y4, Y5”; set 2 includes indicators of “X2, X3; Y1, Y2, Y3, Y4, Y5”; set 3 includes indicators of “X2, X3; Y1, Y2, Y3, Y4”, set 4 includes indicators of “X1, X5; Y2, Y3, Y4, Y5”; set 5 includes indicators of “X1, X2; Y2, Y3, Y4”; set 6 includes indicators of “X1, X5; Y1, Y2, Y4”; set 7 includes indicators of “X1; Y1, Y2, Y3.”
Table 4  Efficiency of different indicator sets and efficiency rank of different periods

<table>
<thead>
<tr>
<th>DMU</th>
<th>Period</th>
<th>Set 1</th>
<th>Set 2</th>
<th>Set 3</th>
<th>Set 4</th>
<th>Set 5</th>
<th>Set 6</th>
<th>Set 7</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;1st Five- year&quot;</td>
<td>1952-1957</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>&quot;2nd Five- year&quot;</td>
<td>1958-1962</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.91</td>
<td>0.81</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>&quot;3 years adjustment&quot;</td>
<td>1963-1965</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.99</td>
<td>0.87</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>&quot;3rd Five- year&quot;</td>
<td>1966-1970</td>
<td>0.74</td>
<td>0.99</td>
<td>0.95</td>
<td>0.95</td>
<td>0.42</td>
<td>0.95</td>
<td>0.69</td>
<td>8</td>
</tr>
<tr>
<td>&quot;4th Five- year&quot;</td>
<td>1971-1975</td>
<td>0.71</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.62</td>
<td>1</td>
<td>0.68</td>
<td>7</td>
</tr>
<tr>
<td>&quot;5th Five- year&quot;</td>
<td>1976-1980</td>
<td>1</td>
<td>1</td>
<td>0.93</td>
<td>1</td>
<td>0.92</td>
<td>1</td>
<td>0.96</td>
<td>4</td>
</tr>
<tr>
<td>&quot;6th Five- year&quot;</td>
<td>1981-1985</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.96</td>
<td>0.77</td>
<td>0.85</td>
<td>0.9</td>
<td>6</td>
</tr>
<tr>
<td>&quot;7th Five- year&quot;</td>
<td>1986-1990</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.99</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>&quot;8th Five- year&quot;</td>
<td>1991-1995</td>
<td>0.83</td>
<td>1</td>
<td>1</td>
<td>0.47</td>
<td>0.43</td>
<td>1</td>
<td>0.81</td>
<td>9</td>
</tr>
<tr>
<td>&quot;9th Five- year&quot;</td>
<td>1996-2000</td>
<td>0.8</td>
<td>0.71</td>
<td>0.71</td>
<td>0.42</td>
<td>0.42</td>
<td>0.8</td>
<td>0.8</td>
<td>10</td>
</tr>
<tr>
<td>&quot;10th Five- year&quot;</td>
<td>2001-2005</td>
<td>0.71</td>
<td>0.72</td>
<td>0.65</td>
<td>0.54</td>
<td>0.41</td>
<td>0.76</td>
<td>0.75</td>
<td>11</td>
</tr>
</tbody>
</table>

5.5.2 Returns to scale

Every period’s RTS is obtained by calculated \( \sum_{j=1}^{n} \lambda_j^* \), which is showed in table 5.

Table 5  RTS of different periods

<table>
<thead>
<tr>
<th>DMU</th>
<th>Period</th>
<th>( \sum_{j=1}^{n} \lambda_j^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;1st Five- year&quot;</td>
<td>1952-1957</td>
<td>1</td>
</tr>
<tr>
<td>&quot;2nd Five- year&quot;</td>
<td>1958-1962</td>
<td>1.08</td>
</tr>
<tr>
<td>&quot;3 years adjustment&quot;</td>
<td>1963-1965</td>
<td>0.83</td>
</tr>
<tr>
<td>&quot;3rd Five- year&quot;</td>
<td>1966-1970</td>
<td>0.71</td>
</tr>
<tr>
<td>&quot;4th Five- year&quot;</td>
<td>1971-1975</td>
<td>0.73</td>
</tr>
<tr>
<td>&quot;5th Five- year&quot;</td>
<td>1976-1980</td>
<td>0.92</td>
</tr>
<tr>
<td>&quot;6th Five- year&quot;</td>
<td>1981-1985</td>
<td>0.98</td>
</tr>
<tr>
<td>&quot;7th Five- year&quot;</td>
<td>1986-1990</td>
<td>0.81</td>
</tr>
<tr>
<td>&quot;8th Five- year&quot;</td>
<td>1991-1995</td>
<td>0.92</td>
</tr>
<tr>
<td>&quot;9th Five- year&quot;</td>
<td>1996-2000</td>
<td>0.98</td>
</tr>
<tr>
<td>&quot;10th Five- year&quot;</td>
<td>2001-2005</td>
<td>0.98</td>
</tr>
</tbody>
</table>

From the above table, we can find that except those equal to 1, most of RTS are less than 1 except those equal to 1, so most period’s RTS are increasing. That is to say, if put more resources into transport system, there will be much higher ratio of output.

5.5.3 Slack values of input and output

Take example for the indicator set of “x1,x2;y2,y3,y4”, every period’s slack values of input and output are as in table 6:

In table 6, \( \Delta x_i = x_i - \hat{x}_1 = (1 - \theta )x_i + s_i^- \), \( \Delta x_2 = x_2 - \hat{x}_2 = (1 - \theta )x_2 + s_2^- \);

\( \Delta y_2 = y_2 - y_2 = s_2^+ \geq 0 \), \( \Delta y_3 = y_3 - y_3 = s_3^+ \geq 0 \), \( \Delta y_4 = y_4 - y_4 = s_4^+ \geq 0 \);

\( \hat{x}_1 = \theta x_1 - s_1^- \), \( \hat{x}_2 = \theta x_2 - s_2^- \), \( \hat{y}_2 = y_2 + s_2^+ \), \( \hat{y}_3 = y_3 + s_3^+ \), \( \hat{y}_4 = y_4 + s_4^+ \).
Table 6  Slack values of input/output and optimal input/output

<table>
<thead>
<tr>
<th>DMU</th>
<th>Period</th>
<th>Redundant input</th>
<th>Deficient output</th>
<th>Optimal input</th>
<th>Optimal output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Δx₁</td>
<td>Δx₂</td>
<td>Δy₂</td>
<td>Δy₃</td>
</tr>
<tr>
<td>“1st Five-year”</td>
<td>1952-1957</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>“2nd Five-year”</td>
<td>1958-1962</td>
<td>2.5</td>
<td>0.8</td>
<td>0.3</td>
<td>9.3</td>
</tr>
<tr>
<td>“3rd Five-year”</td>
<td>1963-1965</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>“4th Five-year”</td>
<td>1966-1970</td>
<td>8.6</td>
<td>2.4</td>
<td>0.0</td>
<td>2.2</td>
</tr>
<tr>
<td>“5th Five-year”</td>
<td>1971-1975</td>
<td>6.5</td>
<td>2.1</td>
<td>0.2</td>
<td>4.0</td>
</tr>
<tr>
<td>“6th Five-year”</td>
<td>1976-1980</td>
<td>1.0</td>
<td>0.6</td>
<td>0.3</td>
<td>5.0</td>
</tr>
<tr>
<td>“7th Five-year”</td>
<td>1981-1985</td>
<td>5.8</td>
<td>0.6</td>
<td>0.0</td>
<td>0.8</td>
</tr>
<tr>
<td>“8th Five-year”</td>
<td>1986-1990</td>
<td>0.2</td>
<td>0.0</td>
<td>0.0</td>
<td>8.7</td>
</tr>
<tr>
<td>“9th Five-year”</td>
<td>1991-1995</td>
<td>10.2</td>
<td>2.6</td>
<td>0.0</td>
<td>3.4</td>
</tr>
<tr>
<td>“10th Five-year”</td>
<td>1996-2000</td>
<td>9.0</td>
<td>5.5</td>
<td>0.0</td>
<td>7.3</td>
</tr>
</tbody>
</table>

As shown in table 6, take example for the “2nd Five-year”, if the resource allocation efficiency wants to become CCR-efficient, then redundant input of “X₁” and “X₂” are 2.5 and 0.8 respectively, and deficient output of “Y₂”, “Y₃”, and “Y₄” are 0.3, 9.3 and 0.0.

6. CONCLUSIONS

This study applies the DEA-CCR approach to evaluate the resource allocation efficiency of Chinese transportation system in different periods. The rank of efficiency, the returns to scale, and optimal input/output are calculated by the DEA-CCR model. Results of calculation reveals that transport resource allocation efficiency of earlier periods in Chinese history, such as “1st Five-year”(1952-1957), “3 years adjustment”(1963-1965) and “5th Five-year”(1976-1980) are higher than those later stage. This is relevant to Chinese different periods’ investment policy: the ratios of input to transport system are litter higher in later stage, but outputs don’t have the proportional increase. Most periods’ returns to scale of transport system are increasing, and this reflects that a great demand for transport hasn’t been satisfied, transportation infrastructure in China is in short supply, if put more resources into transport system, there will be much higher ratio of output. Calculation of slack value provides a standard amount of every period’s input and output, revealing every period’s redundant input and deficient output of resources in transport system.

The evaluation method used in this paper provides a benchmark for government to improve the resource allocation efficiency of transportation system through the comparison of the inputs and outputs observed in transport system. This information will be useful to detect weak points in resource allocation, as well as to help to guide the planning of resource allocation in transportation system.

From the evaluation result of this paper, we can put forward the following suggestions for Chinese transport system’s resource allocation: first, more resources should be put into transport system, transport infrastructures are in short supply; second, we should pay attention
to the ratio of output to input of transport system, or many resources will be wasted and won’t generate enough outputs.

Even though the evaluating indicators used in this paper are specified, which are hard to collect data in other countries, the DEA method and evaluation processes put forward in this paper still have universal applicability. If we want to use it to evaluate other countries’ resource allocation efficiency of transportation system, we only need to change the evaluating indicators.

A useful extension of this paper is the evaluation of resource allocation efficiencies of different countries’ transport system, which will provide information on how to learn from other countries’ experiences.

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