

Research on Evaluation of resource allocation efficiency of transportation system based on DEA

Zhehui Zhang, Linan Du*

China Waterborne Transport Research Institute, P.R.China

*Corresponding author e-mail: dulinan@vip.163.com

Abstract. In this paper, we select the time series data onto 1985-2015 years, construct the land (shoreline) resources, capital and labor as inputs. The index system of the output is freight volume and passenger volume, we use Quantitative analysis based on DEA method evaluated the resource allocation efficiency of railway, highway, water transport and civil aviation in China. Research shows that the resource allocation efficiency of various modes of transport has obvious difference, and the impact on scale efficiency is more significant. The most important two ways to optimize the allocation of resources to improve the efficiency of the combination of various modes of transport is promoting the co-ordination of various modes of transport and constructing integrated transportation system.

1. Instruction

Transportation is an important basic, guiding and strategic industry of the national economy. In the new era, the internal and external environment and the demand of the development of the reform and development of transportation have changed deeply. The transportation industry has started entering the key stage of the main feature in structural adjustment, the quality and efficiency of development and integration. Construction of modern integrated transport system, is to adapt to grasp the new normal economic development, promote supply-side reform and support the objective requirement of building a moderately prosperous society in an all-round way. Study and evaluation of the efficiency of resources allocation in the integrated transport system is an important basis to improve the effectiveness of various modes of transport and to promote the coordinated development of various modes of transport, which is a great significance to play the role of comprehensive transportation supported to lead the development of the social economy and to improve the core competitiveness of the country.

2. DEA methods and models

Data envelopment analysis, DEA, is an evaluation method of efficiency for multi input and multi output decision-making units. DEA method is the intersection of mathematics, operations research, mathematical economics and management science, which use Mathematical programming models to evaluate the relative effectiveness of multiple input, multiple output units, or decision making units (DMU). The data envelopment analysis model is based on the relative efficiency evaluation. According to Multi input and multi output, this model evaluated the relative effectiveness or benefit from the same type of department or unit. Among them, the model can be used to evaluate the overall effectiveness of the scale of the decision making unit. Therefore, this paper evaluated resource allocation efficiency of



integrated transportation system in China with Archimedean infinite ε in DEA model. In practical application, the dual programming model is used to make the calculation more convenient. And the formula for the model is as follows:

$$(DC^2R) \begin{cases} \min[\theta - \varepsilon(S^- + S^+)] \\ \sum_{j=1}^n X_j \lambda_j + S^- = \theta X_0 \\ \sum_{j=1}^n Y_j \lambda_j - S^+ = Y_0 \\ \lambda_j \geq 0, \quad j = 1, \dots, n \\ S^- \geq 0, \quad S^+ \geq 0 \end{cases} \quad (1)$$

In which: θ is effective value for DMU_{j_0} , The effective utilization of DMU_{j_0} of inputs relative to output, is technical efficiency which means that In the case of a given set of inputs, the actual output of a department is the ratio of the maximum output under the same input.

ε is an Archimedean infinite small number which is less than and real number and always larger than 0.

S^- And S^+ are Slack variables which represent Excessive investment and Output deficiency.

λ_j Related to DMU_{j_0} is Re construct an effective DMU in the ratio of j times to combine the decision making units.

When $\theta = 1$, $S^- = S^+ = 0$ that means DEA is effective which means that the output has been achieved an optima with Original input. When $\theta = 1$ and $S^- \neq 0$ or $S^+ \neq 0$, that means Weak DEA is effective which means the original output does not change when input is reduced or increase the output while the original input does not change. When $\theta < 1$, that means that the DEA is inefficiency which can be combined to reduce the proportion of the original input and maintain that the original output does not change.

3. Evaluation index selection

This paper studies the comprehensive transportation mode of highway, railway, water transport, civil aviation and other transportation mode. Time range is defined to evaluate the efficiency of the resource allocation of various modes of transport which is the number and value of the products and services that is obtained by the unit resource input of various transportation modes. In this sense, the resource allocation of transportation system is divided into two parts, which are resource input and output. The input factors include various transport land (coastlines), capital and labor. Output is reflected on the transport services - freight and passenger volume.

Table 1. The Input and Output Index System of Transportation Industry

Items		Indicators	Representative symbol	unit
Input	Land (shoreline) resources	Transit mileage (roads, railways, inland waterways)	X_1	Million kilometres
		Terminal shoreline length	X_1'	Meter
	funds	Investment in Fixed Assets	X_2	Billion
	labor force	Number of Employees	X_3	Million people
Output	shipment service	Freight volume	Y_1	Million tons
		Passenger traffic	Y_2	Million people

(1) Input indicators: X_1 is for railway, highway, and the land with Water transport (including inland and coastal transportation), shoreline, waterways and other resources. X_2 is investment in fixed assets for railways, highways, water transport and civil aviation. X_3 is number of employees for various modes of transport.

(2) Output indicators: Y1 and Y2, respectively, represent the volume of freight and passenger traffic completed in the year of various modes of transport.

(3) Data collection: The time range of this study was 1985-2015 years. The land resources, the coastal port quay, number of employees, freight and passenger traffic volume data are from the China Statistical Yearbook. Fix asset investment data is from Statistical yearbook of Chinese fixed assets investment, Chinese Transportation Industry Development Statistics Bulletin and national railway administration and the State Civil Aviation Administration.

4. Model calculation results and analysis

This paper uses DEAP2.1, the software, to evaluate the Dynamic efficiency of resource allocation for Railway, highway, waterway and civil aviation in 1985-2015, and analyzes both horizontal and vertical ways based on evaluation results deeply. The first, from the perspective of time series, to analyze the dynamic evolution process of resource allocation efficiency of various modes of transport; the second, from a horizontal contrast, to compare and research differences in resource allocation efficiency of various modes of transport.

4.1. Dynamic efficiency analysis

4.1.1 Railway transportation. It can be seen from the following table that in 1985-2015, the comprehensive efficiency of railway transportation in China was 1 in 1985/1990/2005/2011/2013-2015, which means that DEA is effective, and scale income is unchanged and also reach the optima. And in the remaining years, the performance of the DEA shows inefficiency. All of these years, return to scale increase gradually. In the case of other unchanged conditions, the ratio of output to increase is greater than the proportion of inputs of various factors of production, which means that namely, the increase in the input factors of railway transportation brings the economic benefit.

In 1995 and 2000, the pure technical efficiency of railway transport is 1 which mean that input and output do not need increase. And scale effective is less than 1. Return to scale is increasing. That indicates its size, input and the output does not match. The scale need to be increased.

Table 2. DEA Evaluation of Railway Transportation

firm	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
crste	1	1	0.985	0.972	1	0.947	1	0.977	1	1	1
vrste	1	1	1	1	1	0.99	1	0.985	1	1	1
scale	1	1	0.985	0.972	1	0.956	1	0.992	1	1	1
	-	-	irs	irs	-	irs	-	irs	-	-	-

4.1.2 Road transport. It can be seen from the following table that form 1985 to 2015, the comprehensive efficiency of highway transportation in 1985/1990/2000/2011/2012 was 1, which means that the DEA is effective. The scale income does not change which reach the optima. And the remaining years, the DEA is ineffective. Only in 2010, return to scale increase gradually. In others, return to scale is decreasing, which means that Production factor inputs of road transport to fail to bring about the same proportion of output, showing diseconomy of scale.

In which, the pure technical efficiency of highway transportation was 1 in 2010, which means that the input and output do not need to be increased. The scale efficiency is less than 1, and the return to scale is increasing, which means that its size does not match input and output, so the scale should be increased. On the contrary, the pure technical efficiency of the road transport in 2014 was 1, but the return to scale is diminishing, so the scale should be narrowed.

Table 3. DEA Evaluation of Road Transportation

firm	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
crste	1	1	1	1	0.941	0.994	1	1	0.925	0.979	0.903
vrste	1	1	1	1	0.959	1	1	1	0.938	1	0.914
scale	-	1	1	1	0.981	0.994	1	1	0.987	0.979	0.988
		-	-	-	drs	irs	-	-	drs	drs	drs

In 2015, our country road transport performance for DEA is no efficiency. And the input redundancy and output problems exist at the same time. Three input indicators can decline 39.252, 4010.53 and 111.191 input to reach effective DEA.

Table 4. Road transport DEA input, output effectiveness

variable		original value	radial movement	slack movement	projected value
output	1	3150000	0	0	3150000
output	2	1619100	0	1894846	3513946
input	1	457.73	-39.252	0	418.478
input	2	16513.3	-1416.08	-2594.45	12502.77
input	3	387.966	-33.27	-77.921	276.775

4.1.3 Water transport. Road transport. It can be seen from the following table that from 1985 to 2015, the comprehensive efficiency of water transportation in 1985/1995/2000/2015 was 1, which means that the DEA is effective. The scale income does not change which reach the optima. And the remaining years, the DEA is ineffective. All of these years, return to scale increase gradually. Among them, in 2012 /2014, water transport pure technical efficiency was 1, while the scale effective is less than 1, return of scale is increasing, which means that Its size does not match input and output, so the scale should be increased.

Table 5. DEA Evaluation of Water Transportation

firm	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
crste	1	0.982	1	1	0.765	0.887	0.935	0.999	0.967	0.989	1
vrste	1	1	1	1	0.957	0.989	0.99	1	0.995	1	1
scale	1	0.982	1	1	0.799	0.896	0.945	0.999	0.972	0.989	1
	-	irs	-	-	irs	irs	irs	irs	irs	irs	-

4.1.4 Airport transport. It can be seen from the following table that from 1985 to 2015, The comprehensive efficiency of airport transportation in 1990/2000/2005/2010 was 1, which means that the DEA is effective. The scale income does not change which reach the optima. And the remaining years, the DEA is ineffective. Only in 1985 and 1995, return to scale increase gradually. Form 2011, the return to scales increase gradually.

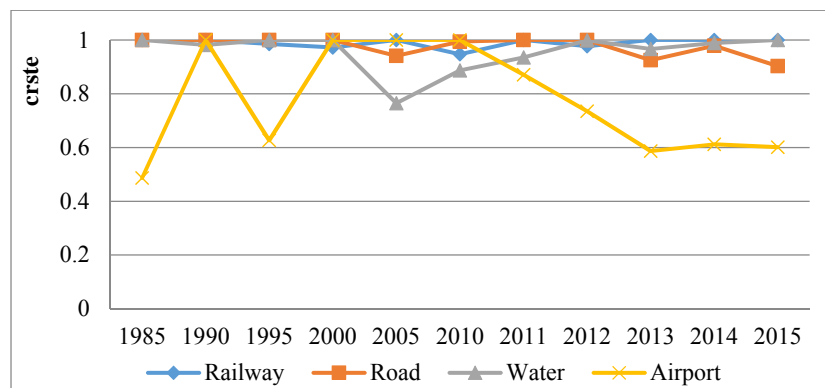
In 2015, our country airport transport performance for DEA is 1. And the input redundancy and output problems do not exist. On the other hand, the scale efficiency is less than 1, showing that the income scales decreases gradually, which means that only when the scale is narrowed, can the input matches the output.

Table 6. DEA Evaluation of Airport Transportation

firm	1985	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
crste	0.487	1	0.627	1	1	1	0.871	0.735	0.587	0.612	0.601
vrste	1	1	0.805	1	1	1	1	0.944	0.836	0.942	1
scale	0.487	1	0.778	1	1	1	0.871	0.779	0.703	0.65	0.601
irs	-		irs	-	-	-	drs	drs	drs	drs	drs

4.2. Horizontal comparative analysis

Comparing the comprehensive efficiency of four modes of transport, railways, highways, water transport and civil aviation (graph 1), we can see the first, comprehensive efficiency of DEA of railway transport is higher. More than half of these years achieve DEA effective, and the efficiency fluctuation is not obvious, and is relatively stable. The second, comprehensive efficiency of DEA of road transport is related high. But in recent years, the performance of returns to scale diminishes, and the relative efficiency tend to reduce. The third, comprehensive efficiency of DEA of water transport is form decrease to increase. The lowest point is at 2005 and from 2005 to 2015, the DEA reaches valid. The forth, the fluctuation of comprehensive efficiency of DEA of civil aviation transportation is the most obvious. Except 1990/2000/2005/2010 years, DEA achieved effective. Other years of comprehensive efficiency value are almost significantly lower than other modes of transport.

**Figure 1.** Comparison of Comprehensive Efficiency of Various Transportation Modes

5. Conclusions and implications

For a long time, our country various transportation modes are independent of each other, and follow the respective technical and economic characteristics and development needs, which is less based on the integrated transport system integration development requirements to design the total network size, scale structure, layout structure, which lead to uneven development of various transport modes uncoordinated and unbalanced. Allocation of resources is unreasonable. This paper uses data envelopment analysis to evaluate resources allocation efficiency of railway, highway, water transport and civil aviation and other transport modes in 1985-2015. The result is that the resource allocation efficiency of various modes of transport is not balanced. The scale efficiency of water transport and railway transport increased significantly. The return to scale of Road transport and civil aviation is diminishing. Reasonable adjustments according to the advantages and characteristics of various modes of transport push Co-ordination of various transport modes, which make the formation of the integrated transport network of the Division of labor, organic combination, reasonable layout and association. Construction of integrated transportation system is the important way to optimize the allocation of resources to improve the efficiency of the combination of various transport modes.

References

- [1] Wang Dan, Yang Zan. Evaluation on the Resource Allocation of the Transportation System Based on DEA. *Journal of Wuhan University of Technology*, 2009,33 (2): 275~278.
- [2] Zhou Qing-feng, Ma Si, Luo Yuan-yuan. Harmonious Relations of Transportation Energy Consumption in Integrated Transport Development. *Journal of Transportation Systems Engineering and Information Technology*, 2012,12(4): 11~16.
- [3] GENG Yanbin, LI Ke, CHEN Jing, XIE Dian. Study on the Realization Routes of Comprehensive Transportation System With Chinese Characteristics. *China Transportation Outlook*, 2016,38 (5): 1~9.
- [4] TANG Wen, KONG Hui-zhen, HUI Hong-qi. Analysis on Scientific Efficiency Based and on Technical Resource Allocation Data Envelopment Model. *Science and Technology Management Research*, 2011(13): 187~191.