Study on the optimization of comprehensive transportation system in China under the perspective of total factor efficiency

Mei SHANG 1, Lu ZHANG 2

1,2 School of Management, Xi’an University of Science and Technology, Xi’an Shaanxi, China
1 940615683@qq.com, 2 709311192@qq.com

Abstract. Using BCC model of DEA technique, this paper estimate the energy effectiveness of China’s local transportation industry. Based on data from China’s statistical yearbook from 1998 to 2014, operating kilometers of regional railway, highway and water-way industry and employees of civil aviation industry and consumption of transportation energy are chosen as input variables and GDP of regional transportation industry every year as output variable to estimate the operational energy efficiency. It is found that energy efficiency of provinces such as Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Shandong, Hainan, Qinghai, Ningxia and Xinjiang are relatively effective, compare to national average, provinces such as Shanxi, Anhui, Liaoning, Jiangxi, Jilin, Hunan, Shaanxi, Heilongjiang, Guangxi, Hubei, Guizhou, Inner Mongolia, Gansu, Sichuan, Yunnan are on the low side, which mainly concentrated in the northeast and central and western regions, then, the paper grouped these provinces which energy efficiency on the low side according to the redundancy, the major and minor reasons lead to their lower efficiency are analyzed, and optimization suggestions are put forward.

1 Introduction
With China reforming and opening up to the outside world, transportation industry, as lifeblood of domestic economic development, grewed quickly. The railway covered all provinces and cities of China, ranking second in the world. By the end of 2014, total mileage of the highway is 104900 kilometers, ranking second in the world. Civil aviation has developed rapidly after the 21st century, Beijing, Shanghai and Guangzhou have built hub airports, connecting airport network of major countries inland. In the aspect of waterway transportation, domestic waterways have been completed by Heilongjiang and Songhua River (serving for the three northeast provinces of China), Yangtze River and Pearl River (serving for the southwest), Huaihe River and the Beijing-Hangzhou Canal (serving for mid-east). Foreign scholars Matthew G. Kariaffis 1 uses data envelopment analysis to study the coordination of transport system in transport efficiency and effectiveness. Ding Xiaodong and Xu Ling 2 use DEA method to evaluate the performance of Chinese transportation industry, finding investment in transportation routes and turnover are key factors affecting transportation efficiency. Chang Yaqing and Song Lai 3 use DEA model to calculate total factor productivity (TFP) of various modes of transport, thinking that transport system are in good condition. Chen Shuai and Sun Youwang 4 analyze energy consumption of transportation system, and propose to built a conservation-oriented integrated transport system.

It is obvious, there are lots of reasearches analyzing comprehensive transport system, but few study taken energy consumption into consideration, which give oppotunity to this paper. In the paper, based on statistic data of regional transport mileage, energy consumption and output of various transportation...
modes to measure their TFP, analyze causes of total factor inefficiencies, and put forward proposal to optimize the existing comprehensive transport system.

2 Theoretical Review
Data Envelopment Analysis (DEA) first proposed by the United States’ famous scientist Charnes and other researchers in 1970's.[5,6] The basic idea is to put each appraisal object as a DMU (Decision Making Units), and each DMU has two types (inputs and outputs) of evaluation indexes. By analyzing the input-output ratio, the validity of the DMU is determined. DEA evaluation model is divided into two categories: one is CCR model (suitable for constant returns to scale), another is BCC model (suitable for variable returns to scale)[7].

3 China provincial TFP of comprehensive transport system measuring with DEA

3.1 Evaluation model, input and output index selection
In the paper, China provincial TFP of comprehensive transport system will be measured using DEA method. In DEA model, input and output generally refers to cost and benefit. Taking into account the data availability and purpose of this study, operating mileage and energy consumption are chosen as input variables, and GDP as output variables for various provincial transportation modes. Taking increased growth of transportation industry into consideration, BCC model is suitable for this study.

3.2 Data analysis and processing
Following data are collected from year 1997 to 2014. (1) Operating mileage and energy consumption: Using operating mileage of the railway, highway, river transport as one of the input indexes, which reflects the constitution of the regional transportation system. Regional civil aviation employees is chosen to substitute for civil aviation operating mileage for lacking of civil aviation mileage in statistic book. As mentioned above, energy consumption is chosen as another input index. (2) GDP of various transportation modes: This index could be used to reflect output efficiency of provincial transport systems.

3.3 Empirical Analysis

3.3.1 Empirical results. According to collected statistical data and the BCC model of DEA, TFP of provincial transport system from year 1997 to 2014 could be measured as in Figure 1. (If TFP is 1, the provinces will not be listed here). It is obvious that TFP of 11 provincial integrated transport systems (including Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Shandong, Hainan, Qinghai, Ningxia, Xinjiang) have been relatively effective. Compared with the national average level, Fujian, Henan and Guangdong are one the higher side comparing to average; and Shanxi, Anhui, Liaoning, Jiangxi, Jilin, Hunan, Shaanxi, Helongjiang, Guangxi, Hubei, Guizhou, Neimenggu, Gansu, Sichuan and Yunnan are one the lower side comparing to average.

![Figure1. Provincial transportation system efficiency](image1)

![Figure2. The provincial highway redundancy (unit: km)](image2)

![Figure3. The provincial railway redundancy (unit: km)](image3)

![Figure4. The provincial waterway redundancy (unit: km)](image4)
In order to further analyze the reasons for the low TFP provinces of the overall transportation system, various inputs redundancy of provincial transportation system is estimated (Figure 2-6) by the result of DEA. Based on the national average, factors affecting provincial transportation system is grouped into primary cause and secondary causes as listed in table 1.

### Table 1: Domain factors affecting TFP of provincial integrated transport system

| Provincial classification | Primary cause           | Secondary cause         |
|--------------------------|-------------------------|-------------------------|
| Yunnan                   | highway                 | energy                  |
| Shanxi, Henan            |                         |                         |
| Hubei, Chongqing, Guizhou| railway                 | inland waterway         |
| Inner Mongolia, Heilongjiang|                       | civil aviation          |
| Liaoning, Jilin          | water transportation    |                         |
| Anhui, Jiangxi, Hunan    | highway                 |                         |
| Guangxi                  |                         | civil aviation+highway  |
| Sichuan                  |                         |                         |
| Guangdong, Shaanxi       | civil aviation          |                         |
| Fujian                   |                         |                         |
| Gansu                    | energy                  | highway                 |

From table 1, it is obvious that provincial TFP is different. Limited by length of paper, primary cause and secondary cause of lower provincial TFP is analyzed for typical province in views redundancy of highway, railway, water transportation, civil aviation and energy.

1. Approach to solve the problem of highway redundancy: Yunnan highway redundancy is higher than the national average more than 5 times. Chongqing, Hunan, Hubei are about 3 times higher than the average respectively. It is recommended that investment in new highway project shall be decided carefully, lower-use highway shall be redesign or extended in order to make full use of highway resources.

2. Approach to solve the problem of railway redundancy: the railway redundancy level of four provinces (Inner Mongolia, Liaoning, Jilin and Heilongjiang) is significantly higher than the national average, it is recommended that railway technology innovation shall be used to make the original line meet the current and future transportation needs.

3. Approach to solve the problem of water transportation redundancy: Water transportation redundancy of Hunan is six times higher than that of the national average. Sichuan, Jiangxi and other provinces are also about three times higher than that of national average. It is recommended that high efficiency waterways shall be make further full use of, and some low efficiency waterway shall be shut down.

4. Approach to solve the problem of civil aviation redundancy: Civil aviation employees redundency of Guangdong Province is 11 times higher than the average. Liaoning is 4 times higher than average. Sichuan, Jilin, Fujian and Shaanxi provinces also about 2 times higher than the average. It is recommended that repeat and unused lines shall be cut down, and effort shall be made to establish collaborative relationships among highway, railway and air transportation.

5. Approach to solve the problem of energy redundancy: There are 14 provinces have some problems in energy redundancy, in which, 5 provinces including Hubei, Liaoning, Shanxi, Shaanxi and Inner Mongolia are in the higher side. Excepting Hubei, other 4 provinces are all resources mining-oriented provinces. It is recommended that passenger and cargo transportation shall be arranged properly.
pipe-transportation or multi-purpose transport equipment shall be developed quickly to improve energy efficiency.

4 Conclusions
China’s economic development led to the development of highway, railways, waterway and civil aviation industry, “mutual competition and ahead construction” concept is deeply impact the development all modes of transportation, which resulted in incoordination waste of resources. In this paper, referring to DEA method, BCC model is used to evaluate provincial transportation TFP. And following conclusions are drawn as follows:
(1) The efficiency of Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Shandong, Hainan, Qinghai, Ningxia, Xinjiang and other provincial integrated transport system has reached a relatively effective; taking the national average as a standard, Shanxi, Anhui, Liaoning, Jiangxi, Jilin, Hunan, Shaanxi, Heilongjiang, Guangxi, Hubei, Guizhou, Inner Mongolia, Gansu, Sichuan, Yunnan are lower than the average efficiency. Those regions are mainly concentrated in the eastern and western regions.
(2) Classifying by the size of input redundancy for lower comprehensive transportation system TFP, the primary and secondary causes lead to its inefficient TFP is analyzed, and counter-measures are put forwarded accordingly.

Acknowledgments
I would like to express my gratitude to all those who helped me during the writing of this paper. My deepest gratitude goes first and foremost to Professor Shang Mei, my supervisor, for her constant encouragement and guidance. In the preparation of this paper, she spent much time helping me to finish my problems during the difficult course of this paper. Secondly, I feel grateful to all the scholars who had contributed a lot academic achievements in this field. I finally owe my sincere gratitude to my friends and fellow classmates who gave me their help and time in listening to me and helping me work out my problems during the difficult course of this paper.

References
[1] Matthew, G.K. 2004 DEA Approach for evaluating the effectiveness of urban transit systems. European Journal of Operational Research, 152354-364.
[2] Ding Xiao-dong, XU Ling, YAO Zhi-gang. 2011 Performance Evaluation of Chinese Transportation Industry Based on DEA Method. Journal of Wuhan University of Technology, 0377-81.
[3] Chang Ya-qing, Song Lai 2008 A Study on Relative Efficiency, Technical Progress & Total Factor Productivity of the Transportation Industry within Chinese Reforming Period. Traffic & Transportation. (Hangzhou: Zhejiang University Press vol 1) chapter 1 pp 34-45.
[4] Chen Shuai, Sun You-wang. 2007 Study on the structure optimization problem of comprehensive transportation system in resource scarce society. Technology & Economy in Areas of Communications, 0497-99.
[5] Odeek J. 2000 Assessing the relative and productivity growth of vehicle inspection services: an application of DEA and Malmquist indices. European Journal of Operation Research, 12601-14.
[6] Pan Ying. 2007 Discussion on Development of Comprehensive Transportation System. Hebei Jiaotong Science and Technology, 0310-14.
[7] Xu Yang. 2010 Study on the Integration of Regional Economic Development and Transportation System of Shaanxi Province. Chang’an University.