Evaluation of China Urban Public Transport Efficiency Based on DEA-Malmquist Index Analysis Method

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Abstract

This paper studies on the efficiency changes of urban public transport and its subsystems and the difference between cities in China using samples of China public transport panel data from 36 central cities from 2010 to 2015 based on non-parametric estimation DEA-Malmquist index method. The results show that the average overall efficiency of urban public transport in China from 2010 to 2015 is 0.975, and the downtrend of the M type fluctuates in general. And the comprehensive efficiency of the taxi system is slightly higher than the bus system. And there is no significant difference in the efficiency of public transport between 36 central cities in China. With the rapid development of urbanization, the efficiency of urban public transportation in China needs to be improved. Finally, from the aspects of improving the level of public transport service, optimizing the allocation of resources, and encouraging the development of intelligent transportation, this paper puts forward policy recommendations to improve the efficiency of urban public transport in China.

Keywords

Urban public transport, Public transport, Taxi, Efficiency evaluation, DEA-Malmquist Index.

1. Introduction

City public traffic is an important part of city infrastructure, is the city's economic development artery, and is closely related to the daily life of residents, is the link of social production, circulation and the people's life, has a great effect on the basis of supporting the development of social economy and city construction. With the continuous development of China social economy, the construction of the new urbanization process has been accelerated. And traffic congestion, waste of resources and other issues continue to emerge. Vigorously developing the city public traffic can increase the utilization rate of transport resources, alleviate the city traffic congestion, but also by improving the city living environment to meet people's diverse demand for travel, which become the key to enhance the city's comprehensive competitiveness.

In recent years, China has accelerated the implementation of the priority development strategy of public transport, vigorously carried out the demonstration project of bus city construction, giving full play to the leading role of public transport in urban development. The state of urban public transport has been greatly improved. However there are still problems, such as inefficiency, etc. Under the policy environment of developing public transportation in China, capital, personnel and technology input has been increased, which requires higher public traffic efficiency. Therefore, it is a necessary task to evaluate the public transport efficiency of the major cities in China. The study of public transport efficiency can clearly define the problems existing in the process of public transport development, and provide strong support for the competent departments to formulate support policies pertinent.

From an economic point of view, the efficiency of public transport mainly investigates the best technical efficiency between input and output, which is a contrast relation between the input of the designated public transportation mode and the satisfaction degree of the public traffic demand generated by the input of the public transportation [1]. It mainly investigates whether the existing input resources are redundant, the existing output is insufficient, and whether the input and output elements of the public transport system have reached the optimal allocation. Scholars at home and abroad have carried out more research on the problem of the efficiency of public transportation. But most of the research is aimed at one aspect of the urban public transport system. Liu Yunfeng (2015) uses the DEA-Malmquist index method to evaluate the efficiency of the public transport in Beijing from two aspects of time and system internal [2]. Zhang Yu (2016) adopted the three stage DEA model, considering the factors such as management ineffectiveness and external environmental variables, and evaluated the efficiency of urban public transport from two levels of cost efficiency and service effect [3]. Zhang Peiwen (2016) used the three stage DEA model to make an empirical study on the efficiency of civil aviation transportation enterprises considering the environmental and random factors [4]. Chen L (2017) used the DEA cross efficiency model and studied the efficiency of the bus company by SPSS cluster analysis [5]. Pina, Vicente (2001) used data envelopment analysis, multiple linear regression and cluster analysis to evaluate the efficiency of public transport service provided by public sector and private sector in Spain [6]. Carvalho, Marcius, et al. (2015) used the DEA method to evaluate the public transport efficiency of various cities in Brazil [7]. Daraio, Cinzia, et al. (2015) put the research of economic efficiency into the perspective of transportation planning, studied the problem of local public transport efficiency, and put forward the future research direction in this field [8].

On the basis of the existing literatures, considering the characteristics of the development of public transport, using DEA-Malmquist index analysis method, to Chinese 36 central city bus and taxi panel data as the sample, study efficiency change and the city of Chinese city public transportation system and differences between changes, and objectively reflect the efficiency of city public transportation. This study helps to clarify the problems existing in the development of public transport and provide theoretical support for the implementation of the priority development strategy of public transport.

2. Construction of Efficiency Evaluation Model

2.1 Research Method.

According to the characteristics of urban public transportation data, this paper selects the Malmquist index method based on DEA method to evaluate the efficiency of urban public transportation [9]. The basic idea of DEA method is to solve the production frontier of every decision unit by linear programming, and uses distance function to describe the distance from each object to the frontier to evaluate the efficiency of input and output. Malmquist index is a common method of using panel data to measure the total factor productivity changes of decision units based on DEA method. The DEA-Malmquist index method is applicable to the evaluation of the total factor productivity of multiple evaluation objects and multi-input and multi-output.

The Malmquist index can be expressed as

$$\begin{aligned} & M_0\left(x_t, y_t, x_{t+1}, y_{t+1}\right) \\ & =\left[\frac{D_0^{t+1}\left(x_{t+1}, y_{t+1}\right)}{D_0^{t+1}\left(x_t, y_t\right)}\right]\times\left[\frac{D_0^{t}\left(x_{t+1}, y_{t+1}\right)}{D_0^{t}\left(x_t, y_t\right)}\right]^{\frac{1}{2}} \\ & =\frac{D_0^{t+1}\left(x_{t+1}, y_{t+1}\right)}{D_0^{t}\left(x_t, y_t\right)}\times\left[\frac{D_0^{t}\left(x_{t+1}, y_{t+1}\right)}{D_0^{t+1}\left(x_{t+1}, y_{t+1}\right)}\right]\times\left[\frac{D_0^{t}\left(x_t, y_t\right)}{D_0^{t+1}\left(x_t, y_t\right)}\right]^{\frac{1}{2}} \\ & =TC\times TEC \end{aligned} \tag{1}$$

Where M is the Malmquist index, t denotes the measured time, x represents the input value of the evaluation object and y indicates the output value of the evaluation object. D^t and D^{t+1} denote the distance function in t period and t+1 period respectively. If M>1, the efficiency of the period from the t to the t+1 is increasing. Conversely, if M<1, the efficiency of the period from the T to the t+1 is reduced. If M=1, it shows that the efficiency is constant.

The Malmquist index uses the distance function to decompose the total factor productivity index (TFP) into the technical creation index (TC) and the technical efficiency change index (TEC). At the same time, the technology efficiency change index (TEC) is decomposed into pure technical efficiency change index (PEC) and scale efficiency change index (SEC). The technological creation index (TC) is the index of the growth effect, which reflects the movement of the enterprises from the t to the t+1 in the production frontier. It mainly examines the technology whether it is progressing or stagnating or declining. The technical efficiency change index (TEC) is an index that reflects the level effect, which reflects the proximity of the enterprise and the production frontier from the t to the t+1 period. It mainly examines whether technical efficiency is improving. The pure technical efficiency change index (PEC) is the efficiency level of the organization in the short term without the scale factor. It reflects the pure technical efficiency changes from the t to the t+1 period, and mainly examines the use of technology. The scale efficiency change index (SEC) is a measure of whether the decision unit is in the most suitable scale. It reflects the scale efficiency changes from the t to the t+1 period. It mainly examines the best level of profit or business performance.

2.2 Variables Selection.

Urban public transport system is formed by a variety of public transport modes, including public transport, taxi, subway and other interrelated modes of transportation [10]. The opening time of some urban rail transit is short, and some cities are not open for the time being. The analysis of urban public transport index by reference to urban traffic [11]. In this paper, the availability of data is considered, and only two subsystems of bus and taxi selection are evaluated. Considering the characteristics of the development of public transport, on the basis of a comprehensive, scientific and operable principle, we select the bus staff, taxi practitioners, bus number, the number of taxis, bus routes and road area length as input indexes, and select passenger transport, taxi passenger traffic, bus and taxi mileage as output indexes. Table 1 lists input-output indexes and their significance.

Table 1 Input-output Indexes and Their Significance

	Index	Variable	Unit	Index Meaning
Input	X_1	Bus workers	/	State of human resources investment in the industry
	X_2	Taxi workers	/	
	X_3	Bus number	/	Vehicle allocation in public transportation
	X_4	Taxi number	/	
	X_5	Bus line length	km	Development of urban bus lines
	X_6	Road area	million square meters	Urban public transport infrastructure
Output	Y_1	Bus passenger traffic volume	million	Urban public transport capacity
	Y_2	Taxi passenger volume	million	
	Y_3	Bus operation mileage	million kilometers	Output status of urban public transport
	Y_4	Taxi mileage	million kilometers	

2.3 Data Sources.

The data of urban public transport panel in 36 central cities of China from 2010 to 2015 is selected as sample data. These cities can reflect the overall level of the development of public transport in China, and can also reflect the national difference. The data from the statistical yearbook, "China Transportation Statistics Yearbook" and "China City Statistical Yearbook".

3. Result Verification and Analysis

3.1 Time Trend Analysis.

Based on the DEA evaluation method and DEAP2.1 software, we calculate the urban public transport efficiency and the decomposition index from 2010 to 2015. The specific results are shown in Table 2.

Table 2 Total Factor Productivity of Urban Public Transport in China and Its Decomposition Index

Time	TEC	TC	PEC	SEC	TFP
2010-2011	0.941	1.040	0.966	0.974	0.979
2011-2012	1.059	0.946	1.028	1.031	1.002
2012-2013	0.953	1.008	1.018	0.937	0.961
2013-2014	0.992	0.983	0.957	1.036	0.975
2014-2015	1.005	0.954	1.012	0.994	0.959
Average	0.989	0.986	0.996	0.994	0.975

From table 2, the overall efficiency of urban public transport in China has shown a trend of overall stability and a slight decline from 2010 to 2015. The average public transport efficiency is 0.975 and less than 1, which indicates that the total factor productivity index has a negative growth trend, and the urban public transport efficiency has decreased. According to the decomposition of the total factor productivity index, we can see that the index of technical efficiency change of public transportation and the changing index of technology are less than 1. This shows that China's popularization and application of new technologies for public transport is insufficient at this stage. The index of technological creation change is greater than the index of technical efficiency change. When new technology is applied and promoted, there will be lagging effect on the improvement of technical efficiency. According to the decomposition of the technical efficiency index, the average value of the pure technical efficiency index is 0.996, the average of the scale efficiency is 0.994, and the two are less than 1. So it is the reduction in the efficiency of public transport by the reduction of pure technical efficiency and the reduction of scale efficiency. According to table 2, we draw the trend map of total factor productivity and decomposition index of 36 central cities from 2010 to 2015, and analyze the time trend of total factor productivity change (see Figure 1). As can be seen from Figure 1, the overall efficiency of urban public transport in China is generally stable, showing a downward trend of M type fluctuation. The change trend of comprehensive efficiency is basically consistent with the trend of technical efficiency, which is lagging behind the efficiency of technological creation. The overall efficiency of urban public transport in China is more than 1 between 2011 and 2012, and the other years are less than 1. This shows that the comprehensive efficiency of urban public transport needs to be improved, and the input of related personnel, vehicles and roads of urban public transport has not yet played the greatest potential.

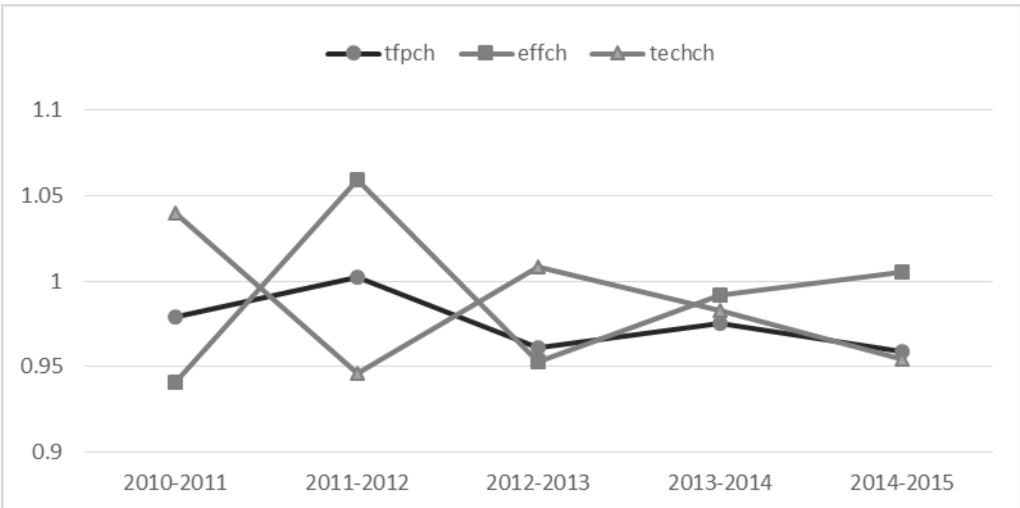

Fig. 1 Total Factor Productivity and Its Decomposition Index Trend Map of Urban Public Transport in China

3.2 Analysis of the Subsystem of Public Transportation.

In order to clearly show the transport efficiency of urban public transport subsystem, this paper calculates the total factor productivity and its decomposition index of two modes of transportation in China from 2010 to 2015. The specific results are shown in Table 3.

Table 3 Total Factor Productivity and Its Decomposition Index Table for Public Transportation and Taxis

Time		TEC	TC	PEC	SEC	TFP
2010-2011	Bus	1.024	1.009	0.964	1.062	1.033
	Taxi	0.975	1.027	1.034	0.942	1.001
2011-2012	Bus	1.02	0.965	1.005	1.015	0.984
	Taxi	1.041	0.982	1.053	0.989	1.022
2012-2013	Bus	0.974	1.015	0.997	0.977	0.989
	Taxi	0.963	1.014	1.018	0.945	0.976
2013-2014	Bus	0.982	0.982	0.958	1.025	0.964
	Taxi	1.009	0.979	0.967	1.043	0.988
2014-2015	Bus	0.975	0.981	0.987	0.987	0.956
	Taxi	0.919	1.053	1.006	0.914	0.968
Average	Bus	0.995	0.99	0.982	1.013	0.985
	Taxi	0.981	1.011	1.015	0.966	0.991

As shown in Table 3, the comprehensive efficiency of the bus system is 0.985, and the comprehensive efficiency of the taxi system is 0.991. This shows that the proportion of the input index of the bus system and the taxi system is basically equal, and the comprehensive efficiency is not quite different. Comparatively speaking, the comprehensive efficiency of the taxi system is slightly higher than that of the bus system, which is mainly due to the higher technical and technical efficiency of taxis.

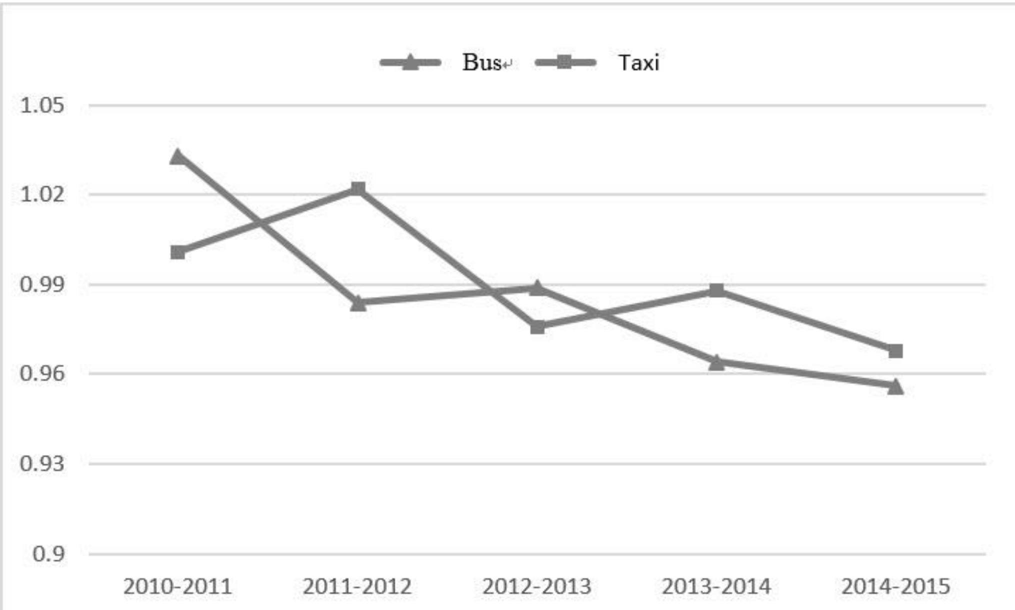

Fig. 2 Total Factor Productivity Line Chart for Buses and Taxis

The total factor productivity (TFP) chart of the two subsystems of bus and taxis of Figure 2 can be more intuitively shown that the comprehensive efficiency of the taxi system is slightly higher than that of the bus system. This shows that in the central cities of China, the comprehensive efficiency of the taxi system is high and occupies an important position in people's daily travel.

3.3 Analysis of Urban Differences.

In order to compare the efficiency of public transport in cities with different economic development levels, the paper calculates the urban public transport efficiency and the decomposition index of 36 central cities in China from 2010 to 2015. The results of the calculation are shown in Table 4.

Table 4 Total Factor Productivity and the Mean Value of Decomposition Index in Each City

City	TEC	TC	PEC	SEC	TFP
Beijing	0.942	1.003	1	0.942	0.945
Tianjin	0.97	0.972	0.995	0.976	0.943
Shijiazhuang	0.983	0.989	0.99	0.993	0.972
Taiyuan	1.002	0.992	1.018	0.984	0.994
Hohhot	0.97	0.973	0.973	0.997	0.944
Shenyang	0.993	0.972	1.007	0.986	0.966
Changchun	0.981	0.94	1	0.981	0.922
Harbin	0.999	1.008	1	0.999	1.008
Shanghai	0.995	0.996	1	0.995	0.991
Nanjing	0.968	1.005	0.995	0.973	0.973
Hangzhou	0.985	0.969	0.979	1.006	0.955
Hefei	0.989	0.995	1.026	0.964	0.984
Fuzhou	1.001	0.968	1.001	1	0.969
Nanchang	0.984	0.99	0.987	0.998	0.974
Ji'nan	0.96	0.993	0.948	1.012	0.953
Zhengzhou	0.985	0.981	0.99	0.995	0.966
Wuhan	0.98	0.961	0.999	0.981	0.942
Changsha	0.995	0.976	1.004	0.991	0.971
Guangzhou	0.999	0.985	1	0.999	0.984
Nanning	0.951	0.986	0.962	0.988	0.938
Haikou	1.006	1.022	1	1.006	1.028
Chongqing	0.999	0.989	1	0.999	0.989
Chengdu	1.02	0.99	1.02	1	1.01
Guiyang	0.999	0.957	1	0.999	0.956
Kunming	0.941	0.996	0.952	0.989	0.937
Lhasa	1.013	1.019	1	1.013	1.032
Xi'an	1.007	0.969	0.999	1.008	0.975
Lanzhou	1.006	1.004	1.007	0.999	1.01
Xining	1	0.994	1	1	0.994
Yinchuan	1.009	0.982	1.004	1.004	0.991
Urumqi	0.992	1.004	1	0.992	0.997
Dalian	1.003	0.979	1	1.003	0.982
Qingdao	0.997	0.996	1	0.997	0.993
Ningbo	0.98	0.977	0.983	0.996	0.958
Shenzhen	1.021	0.97	1.01	1.01	0.99
Xiamen	1	0.986	1	1	0.986
Average	0.989	0.986	0.996	0.994	0.975

From table 4, from 2010 to 2015, there was no significant difference in the comprehensive efficiency of public transport between the 36 central cities in China. Among them, Harbin, Haikou, Chengdu, Lhasa, Lanzhou and other cities have high public transport efficiency, all of which are more than 1. Cities such as Beijing, Harbin, Nanjing, Haikou, Lhasa, Lanzhou and Urumqi are more efficient in technological creation. Hangzhou, Fuzhou, Ji'nan, Haikou, Chengdu, Lhasa, Xi'an, Xining, Yinchuan, Dalian, Shenzhen, Xiamen and other cities are more efficient in scale. Cities such as Taiyuan, Shenyang, Hefei, Fuzhou, Changsha, Chengdu, Lanzhou, Yinchuan and Shenzhen have high technical efficiency. Changchun, Kunming, Nanning and other cities have low comprehensive public transport efficiency, both less than 0.94. Changchun has hampered public transport efficiency mainly because of technological creation, and Kunming and Nanning, mainly due to pure technical efficiency, have hindered the promotion of public transport efficiency.

4. Conclusion and Proposition

In this paper, the DEA-Malmquist index method is applied to analyze the change of public transport and sub system efficiency and the difference between cities in 2010 Central Cities of China from 2010 to 2015. The main conclusions are the following points.

First, the average overall efficiency of urban public transport in China from 2010 to 2015 was 0.975, which showed a downtrend of M type fluctuation in general. The change trend of comprehensive efficiency is basically consistent with the trend of technical efficiency, which is lagging behind the efficiency of technological creation. The scale of urban public transport in China is expanding. However, the transportation resources have not been fully utilized, and have not yet reached the optimal scale. The scale effect has not yet been achieved, and the efficiency of urban public transport has yet to be improved.

Second, the comprehensive efficiency of the bus system is 0.985, and the comprehensive efficiency of the taxi system is 0.991. The comprehensive efficiency of the taxi system is slightly higher than the bus system, which is mainly due to the higher technical and technical efficiency of the taxi.

Third, the difference in public transport efficiency between the 36 central cities of China is not significant. Among them, Harbin, Haikou, Chengdu, Lhasa, Lanzhou and other cities have high public transport efficiency. Changchun, Kunming, Nanning and other cities have low public transport efficiency.

In view of the above conclusions, in order to improve the comprehensive efficiency of urban public transport in China, the following suggestions are put forward.

First, urban public transport is an important social public welfare undertaking. To improve the efficiency of urban public transport, we must constantly improve the level of public transport services, adjust the fare structure, optimize operation scheduling and management level, and increase the attractiveness of public transport. In recent years, along with the car, ride, bike sharing appear new things, which have a certain impact on the efficiency of city public transportation. Only by optimizing the travel structure, urban public transportation can build a modern urban public transport system to meet the needs of economic and social development and public travel.

Second, China's urban public transport infrastructure investment and labor input still have greater space. We should constantly optimize the efficiency of resource allocation. At the same time, we must focus on the application and innovation of new technology and new equipment. We should continue to increase investment in technology, introduce advanced technology, increase investment in the purchase and upgrading of large capacity public transport facilities, and increase the proportion of public transport trips.

Third, in the era of Internet, to improve the efficiency of urban public transport, we must promote the application of information technology in urban public transport operation management, service supervision and industry management. We should encourage the development of intelligent transportation, and focus on the construction of public travel information service system, vehicle operation and dispatching management system, safety monitoring system and emergency disposal system.

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