Research on the Efficiency of Shared Bicycle Enterprises Based on Network DEA

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Abstract. This article uses the Data Envelopment Analysis (DEA) model to evaluate the efficiency of bike-sharing companies with market share in the forefront of the industry. The research in this paper finds that the overall efficiency of the bicycle sharing industry in China is relatively low, and there is greater room for improvement in the two stages of production maintenance and capital operation. At the same time, the bicycle sharing companies have the problems of low efficiency in the capital operation stage of large-scale enterprises and low efficiency in the production and maintenance stage of small-scale enterprises. Regarding this situation, the state can introduce corresponding policies to regulate the shared bicycle market and limit the number and quality of bicycles put by enterprises, thereby indirectly improving the system efficiency in the production and maintenance phase of the industry.

Keywords: Shared Bike Enterprise, Network DEA, Efficiency

1 Introduction

Since the first emergence and development of shared bicycles in 2015, the total number of users has exceeded 300 million, and economic output has exceeded 100 billion. According to estimates by the China Academy of Information and Communication Technology (2018), bike sharing companies will create a total economic output value of 71.4 billion yuan in 2020. However, at the same time, after the industry reshuffle period from 2017 to 2018, about 20 bicycle sharing companies exposed weaknesses in the profit model, and they successively closed down. The leading company, Mobike, was also acquired by Meituan. This has also made investors more cautious, and the government has gradually stopped large-scale subsidies for bicycle-sharing companies, and has strengthened its supervision of the bicycle-sharing industry. Based on the current development status of bicycle sharing, this article abstracts each bicycle sharing company into a system, uses the network DEA to evaluate the efficiency of each bicycle sharing system, and proposes to enterprises to improve system efficiency.

In the evaluation of bicycle sharing systems, scholars at home and abroad have studied from multiple perspectives. Some scholars focus on the brand competitiveness of bicycle sharing, and use brand competitiveness as a criterion for evaluating bicycle sharing systems. Among them, Xu Qing and Li Haiyou (2018) evaluated the competitiveness of bicycle sharing brands based on AHP analytic hierarchy process and fuzzy comprehensive evaluation method. And the coverage of the indicator is only bicycle hardware, usage and brand development. Chen Yanzhen and Wang Hanjun (2018) conducted a comparative study of urban bicycle satisfaction and its

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influencing factors, taking Beijing as an example. After a thorough preliminary survey on the measurement of satisfaction, the ACSI model was used to analyze the satisfaction of various types of bicycles. Debra K et al (2019) proposed a multi-method-based evaluation of free-floating bicycle sharing in college campuses, and provided corresponding suggestions for improvement by analyzing the use of shared bicycles on campus and customer feedback. But its research object is more limited, focusing only on the use of shared bicycles on campus. This article will introduce the network DEA model in the second part and establish an efficiency analysis model for bicycle sharing companies. In the third part, the input-output index selection and related data description of bicycle sharing companies will be explained. Then in the fourth part, the overall efficiency evaluation of the bicycle sharing company and the efficiency evaluation of the two subsystems are performed according to the DEA calculation results. Finally, in the fifth part, this article summarizes the efficiency evaluation of bicycle sharing companies, and gives suggestions for the efficiency improvement of bicycle sharing industry and the efficiency improvement of bicycle sharing enterprises.

2 Network DEA

DEA (data envelopment analysis) was first proposed by A. Charnes et al (1978). Its main principle is to keep the input or output of the decision unit unchanged, and use mathematical planning and statistical data to determine the relatively effective production frontier. Decision units are projected onto the frontiers of production of DEA, and finally their relative effectiveness is evaluated by comparing the extent to which decision units depart from the frontiers of DEA. However, traditional DEA models cannot solve decision-making units with a network structure, so Fare & Grosskopf (1996) proposed a network DEA model. They divided the model into several sub-units and connected them with nodes to examine the role of nodes and the entire system s efficiency.

In the analysis of system efficiency, DEA method is used by many scholars because it has the advantages of being able to handle multiple inputs and multiple outputs, no need to construct production functions to estimate parameters, and relatively fair evaluation of DMU. The DEA method is widely used in evaluation of Bank Profit Efficiency (Glory Hua, Cheng Weihu (2017)), Hospital Performance Evaluation and other fields. Network DEA has the characteristics of decision units suitable for network distribution. It's used in the efficiency evaluation of listed companies in ports, the evaluation of scientific and technological innovation transformation efficiency and the banking system (Xiaoyang Z (2019)), museum evaluation (Antonella B (2018)), China's high-tech industrial efficiency (Linyan Z (2019)) and other multi-stage system efficiency evaluations.

In the evaluation of bicycle sharing system, Zhang Yuelei et al. (2018) used the C^2R model in DEA method to evaluate the competitiveness of bicycle sharing brands. However, the model used is relatively simple, and the efficiency of the bicycle sharing system is still treated as a "black box", without further research on its internal production operations and capital operations. The chain network DEA structure used in this paper is shown in Figure 1. The entire model can be considered as a system composed of a series of subsystems.

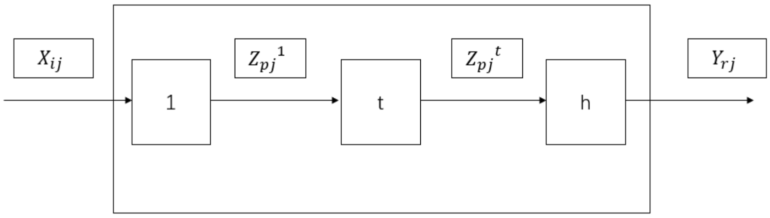

Fig. 1. Chained Network System Schema

Suppose that the system consists of a series of h subsystems, where $X_{ij}$and Y_{ij} are the input and output vectors of the entire system, where$Z_{pj}{}^{t}$ is the p-th intermediate output of the j decision unit at the t stage . Let v_i and u_r be the input and output factor weights respectively. The weight of the p intermediate output in the t stage is $w_p{}^{t}$. There are n decision-making units. The efficiency evaluation model is as follows:

$$max \sum_{r=1}^{s} u_r\, Y_{rk}$$

$$s.t. \sum_{i=1}^{m} v_i\, x_{ik} = 1$$

$$\sum_{r=1}^{q} w_p{}^{t}\, Z_{pj}{}^{t} - \sum_{r=1}^{q} w_p{}^{t-1}\, Z_{pj}{}^{t-1} \leq 0$$

$$\sum_{i=1}^{s} u_r Y_{rj} - \sum_{p=1}^{q} w_p{}^{h-1}\, Z_{pj}{}^{h-1} \leq 0$$

$$v_i, u_r, w_p{}^{t} \geq \varepsilon$$

$$j = 1 \dots n\ , r = 1 \dots s, i = 1 \dots m, p = 1 \dots q, t = 2 \dots h-1 \tag{1}$$

According to this model, the optimal solutions for the weights of inputs, outputs, and intermediate factors can be obtained: $u_r{}^{*}$, $v_i{}^{*}$, $w_p{}^{t*}$, and based on these optimal solutions, decisions can be obtained Efficiency of each subsystem of unit k:

$$E_k{}^{1} = \sum_{p=1}^{q} w_p{}^{1*}\, Z_{pk}{}^{1} / \sum_{i=1}^{m} v_i{}^{*}\, x_{ik}$$

$$E_k{}^{t} = \sum_{p=1}^{q} w_p{}^{t*}\, Z_{pk}{}^{t} / \sum_{p=1}^{q} w_p{}^{(t-1)*}\, Z_{pk}{}^{t-1}$$

$$E_k{}^{h} = \sum_{r=1}^{s} u_r{}^{*}\, Y_{rk} / \sum_{p=1}^{q} w_p{}^{(h-1)*}\, Z_{pk}{}^{h-1} \tag{2}$$

Using formula (2), the efficiency of each subsystem in the system can be obtained. At the same time, it can be seen from formula (2) that the efficiency of the subsystem has a great impact on the overall efficiency of the system. Optimization of efficiency, the overall efficiency of the system will be higher.

3 Indicator selection and bike sharing company data description

In terms of bicycle sharing companies, this article selects the top six bicycle sharing companies in 2018 as the decision-making unit (DMU). The company name and market share information are shown in Table 1. The specific structure of the bicycle sharing system is shown in Figure 2.

In the production and maintenance part, the company invests a certain amount of money in bicycle purchase, deployment and maintenance of bicycles, and attracts customers to use bicycles through good production and maintenance, thus gaining word of mouth, which is specifically reflected in the market share and active penetration of bicycles.

Table 1. Share bike market share of the top six enterprises

Share bike brands	Market share
Mobike	56%
Ofo	29%
Hello	9%
Bluegogo（Green Orange）	3%
Youon	1%
Kuqi	1%

In the capital operation stage, the company uses the results of the previous stage to conduct capital operations, and the final capital operation capacity is expressed as the company's operating income.

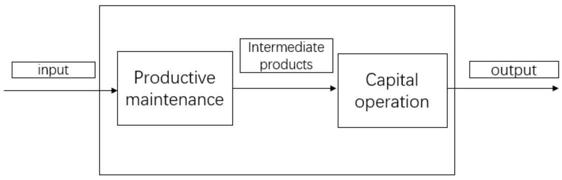

Fig. 2. Shared bike system schematics

The corresponding data of the three types of indicators are shown in Table 2 through the inquiries in the above three research reports and the official websites of each brand enterprise.

Table 2. Summary table of data for each shared bicycle enterprise

	Input indicators		Intermediate indicators		Output indicator
Brand	Total number of bikes put on the market	Bike quality score	Market share	Active penetration	Operating income
Ofo	1000	65.9	29	0.226	10
Mobike	500	72.2	56	0.231	15
Hello	350	75.5	9	0.171	12
B&G	200	73.9	3	0.008	6.7
Youon	150	69.2	1	0.005	8.45
Kuqi	100	70.1	1	0.002	1.2

4 System Efficiency Evaluation of Bicycle Sharing Enterprises

After integrating the data in Table 2, the calculation was performed using MaxDEA8. The models used for the calculation were output-oriented variable returns to scale (VRS) BCC model and output-oriented variable returns to scale CCR model. The calculation results are shown in Tables 3 and 4.

4.1 System efficiency analysis

In order to comprehensively analyze the efficiency of the system, this paper obtains three types of efficiency indicators through operations: comprehensive technical efficiency (VRSTE), pure technical efficiency (PTE), and scale efficiency (SCALE).

Table 3. The efficiency of each shared bicycle enterprise

Brand	VRSTE	PTE	SCALE
Mobike	1.000	1.000	1.000
Youon	1.000	1.000	1.000
Hello	0.954	0.984	0.970
Ofo	0.730	1.000	0.730
B&G	0.688	0.713	0.965
Kuqi	0.213	1.000	0.213
Industry Average	0.764	0.950	0.813

As can be seen from Table 3, as far as the industry efficiency values reflected by the top six bike-sharing companies are concerned, the overall system of the bike-sharing industry is not very effective, which indicates that there are more management and resource allocation problems within the bike-sharing system, making The resources invested by various enterprises have not been able to obtain corresponding outputs. Combining the status quo, the reason these two bike-sharing companies can achieve system effectiveness is that Mobike was acquired by Didi in 2018 and was included in Didi's transportation network plan, while Youon went public at the end of 2017. Stock market capital The influx of Youon expanded Youon's company size and improved the scale efficiency of Youon, thereby driving the overall system efficiency of Youon to improve. The second echelon of efficiency value is Hello Bike, ofo and B&G Bike. Among them, the efficiency indicators of Hello bicycles are close to 1. Hello bicycles are mainly launched in second- and third-tier cities, avoiding fierce competition in first-tier cities. As a result, their input has received better feedback. Ofo's pure technical efficiency is 1, but its scale efficiency is low. The main reason for this is that ofo's expansion is too fast. As of 2019, ofo has launched more than 10 million bicycles worldwide. With the extremely expanded market and user scale, the internal organizational structure of ofo has become more complex, but its internal management and organizational structure has not changed. In the fierce market competition, the system is inefficient, and it gradually leaves the first echelon.

4.2 Comprehensive technical efficiency analysis of two subsystems

We divide the bicycle sharing system into two subsystems in series-production maintenance and capital operation system. The comprehensive technical efficiency of each subsystem is shown in Table 4.

Table 4. Integrated Technical Efficiency of Subsystem from different enterprises

Brand	Production maintenance	Capital operations
Hello	1.000	0.158
Mobike	1.000	0.038
Ofo	1.000	0.041
B&G	0.134	0.496
Kuqi	0.089	0.355
Youon	0.071	1.000

The relationship between the efficiency of the production and maintenance system and the efficiency of the capital operation system of the bicycle sharing company is shown in Figure 3. It can be seen that the efficiency of the production and maintenance system is higher, and the efficiency of the capital operation of the larger enterprises is generally lower.

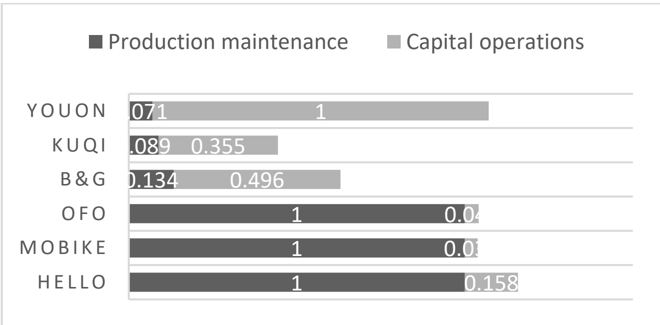

Fig. 3. Efficiency schematics of the Shared bike enterprise subsystem

It can be seen from Figure 3 that the comprehensive technology efficiency of Hello, Mobike and ofo is relatively high during the production and maintenance stage, indicating that these three companies have a strong ability to invest in vehicles to occupy the market and retain users, but in contrast to their capital operation stage, three companies generally lack the ability to quickly turn market share into revenue, especially Mobike and ofo. The two leading companies in the bicycle sharing industry together account for nearly three-quarters of the market share in the bicycle sharing industry, but their operating income cannot account for the same share of revenue in the bicycle sharing industry.

5 Conclusion

This article uses network DEA to analyze the various bicycle sharing companies, and the preliminary conclusions are as follows:

According to the calculation of the average system efficiency of the industry in Table 4, it can be known that the current efficiency of the bicycle sharing industry is low, only 0.764, and there is room for improvement in the two sub-phases of production maintenance and capital operation. The overall low efficiency of the industry will also have an impact on society. The low efficiency of production and maintenance in the industry will cause manufacturers to increase the number of bicycles in order to increase market share, cause bicycles to accumulate, and affect traffic smoothness and appearance. Regarding the status quo of the industry, the state can introduce corresponding policies to regulate the shared bicycle market and limit the number and quality of bicycles invested by enterprises.

Large-scale enterprises with high current market share, such as Mobike, ofo, etc., should focus on improving their monetization capabilities. They can alleviate cost-end pressure by reasonably increasing prices overall. At the same time, it is necessary to dig deeper into the value of data and traffic to strengthen self-hematopoiesis. The shared bicycle scene has the advantages of high crowd coverage, high usage frequency, and user location and preference information. Shared bicycles can bring traffic synergy value to their respective ecosystems through the shared bicycle platform, thereby leveraging synergistic values to enhance monetization capabilities.

References

[1] Xu Qing, Li Haiyou. Research on the Competitiveness of Shared Bicycle Brand——Based on AHP Analytic Hierarchy Process and Fuzzy Comprehensive Evaluation [J] ,Market Weekly, 2018 ,07: 58-59.

[2] Chen Yanzhen, Wang Hanjun. Comparative Study on City Bicycle Satisfaction and Its Influencing Factors——Taking the Sixth District of Beijing as an Example [J] ,Economic Issues, 2018 (05): 105-112.

[3] Debra K, John O. S, Katie B, Jason E. Evaluation of free-floating bike-share on a university campus using a multi-method approach[J],Preventive Medicine Reports,2019,16:100981.

[4] A. Charnes, W.W. Cooper, E. Rhodes. Measuring the efficiency of decision making units[J],European Journal of Operational Research, 1978,2(6):429-444.

[5] Rolf F,Shawna G. Network DEA[J],Socio-Economic Planning Sciences,2000,34(1):35-49.

[6] Glory Hua, Cheng Weihu.Research on Profit Efficiency of Listed Banks Based on Data Envelopment Analysis [J] ,Mathematical Statistics and Management, 2017,36 (06): 1069-1079.

[7] Xiaoyang Z, Zhongwen X, Jian C, Liming Y, Shouyang W, Benjamin L. Efficiency evaluation for banking systems under uncertainty: A multi-period three-stage DEA model[J],Omega,2019,85:68-82.

[8] Antonella B, Francesco C, Stefania F.How well is the museum performing? A joint use of DEA and BSC to measure the performance of museums[J],Omega,2018,81:67-84.