Journal of Theoretical and Applied Information Technology
28th February 2013. Vol. 48 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

EVALUATION METHODOLOGY OF BUS RAPID TRANSIT (BRT) OPERATION

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ABSTRACT

In the paper, the indicator system and evaluation methodology of BRT operation was established according to the characters of BRT development in China. These indicators include six aspects: infrastructure, transport capacity, service level, economic results, safety and emergency management, and energy saving & emission reduction. The pilot study was implemented in Jinan city. The results of pilot study show: the presented evaluation methodology of BRT operation agrees with the system designing standards and therefore is operational.

Keywords: *Bus Rapid Transit (BRT), Evaluation methodology, Operation, Indicator system*

1. INTRODUCTION

Thirteen of all Chinese major cities have launched their Bus Rapid Transit (BRT) system by the end of 2010, making the number of the BRT buses 2,943 and the total length of the bus routes 514 kilometers. The key issues concerning the BRT system include system capacity, the comparison between the BRT system and the conventional forms of mass transit, and the comparisons within different BRT systems. To draw conclusions it is necessary to conduct studies on the BRT system by developing an evaluation system that is equipped with comprehensive indicators and methodology.

Chinese scholars started to pay attention to the evaluation indicator system of the operation of the BRT system at the beginning of the 20th century. Lin Jing [1] developed an indicator system that focuses on the technical factors, the economic and social impacts of the BRT system. Jiaqing Wu and Zheng Lin [2] developed their indicator that is based on the present and future of the BRT system close to the Southern Central Axis Area in Beijing. The indicator examines the service level of the BRT system as well as the benefits it may generate to the operation companies and the community. Haixia Wang, Rui Song, Ming Li [3] developed the BRT evaluation indicator system and its Hierarchical structure to examine the infrastructure, service level, economic results of the BRT system, and its relationship with the urban development. Their study outcomes also include a rating standard for each indicator of the evaluation indicator system. Mingming Chen and Huimin Niu [4] developed the evaluation indicator system and the related methodology to make comparison of BRT systems of different forms and time, and between the BRT system and other forms of mass transit. Hanying Deng and Chaohong Guo [5] separated the most effective BRT approach by recording and analyzing the features of the BRT system. Shengxue Zhu [6] described the functions and impacts of the BRT system from the angles of infrastructure investment, service level, and the overall benefits by using multiple individual factors as the indicators. They also built an indicator system to determine the development of the BRT system by using layer analysis. The post-BRT evaluation system developed by Yan Zhang [7] includes post-process evaluation, post-economic and post-social impacts evaluation, post-sustainability evaluation, and the overall post-evaluation.

The evaluation indicator system of the BRT system has drawn considerable attention in China, but there is still a lack of research in some aspects of the indicator. The missing of a comprehensive evaluation indicator system may compromise the BRT system's operation status. The existing evaluation systems, developed based mainly on overseas experience, pays little attention to the operation status of the BRT system, which is of crucial importance in China. The evaluation systems that currently are being applied also have difficulties in meeting the expectations of the government, customers, operation companies, and the employees.

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2. THE DEVELOPMENT OF THE EVALUATION INDICATOR SYSTEM

2.1 Guidelines

The evaluation indicator system of the operation of the BRT system should be comprehensive, integrated, systematic, and scientific, and is of objectiveness, functionality, and equality, and is able to provide guidance to the evaluation and can be compared with other indicators as well.

2.2 Basic Functions

The basic functions of the evaluation indicator system of the operation of the BRT system include to ensure a scientific evaluation on the planning, operation, and the service level of the urban BRT system; to improve the safety, convenience, mobility, comfort, and reliability of the urban BRT system, to examine the carrying out of the strategies and policies concerning the prioritizing of the public transport, and to provide suggestions for the state and local governmental departments to issue laws and regulations for the BRT system.

2.3 Structure Designing

The evaluation indicator system of the operation of the BRT system has three categories, thirteen aspects, and twenty-five individual indicators. The structure of the indicator is as the Fig.1.

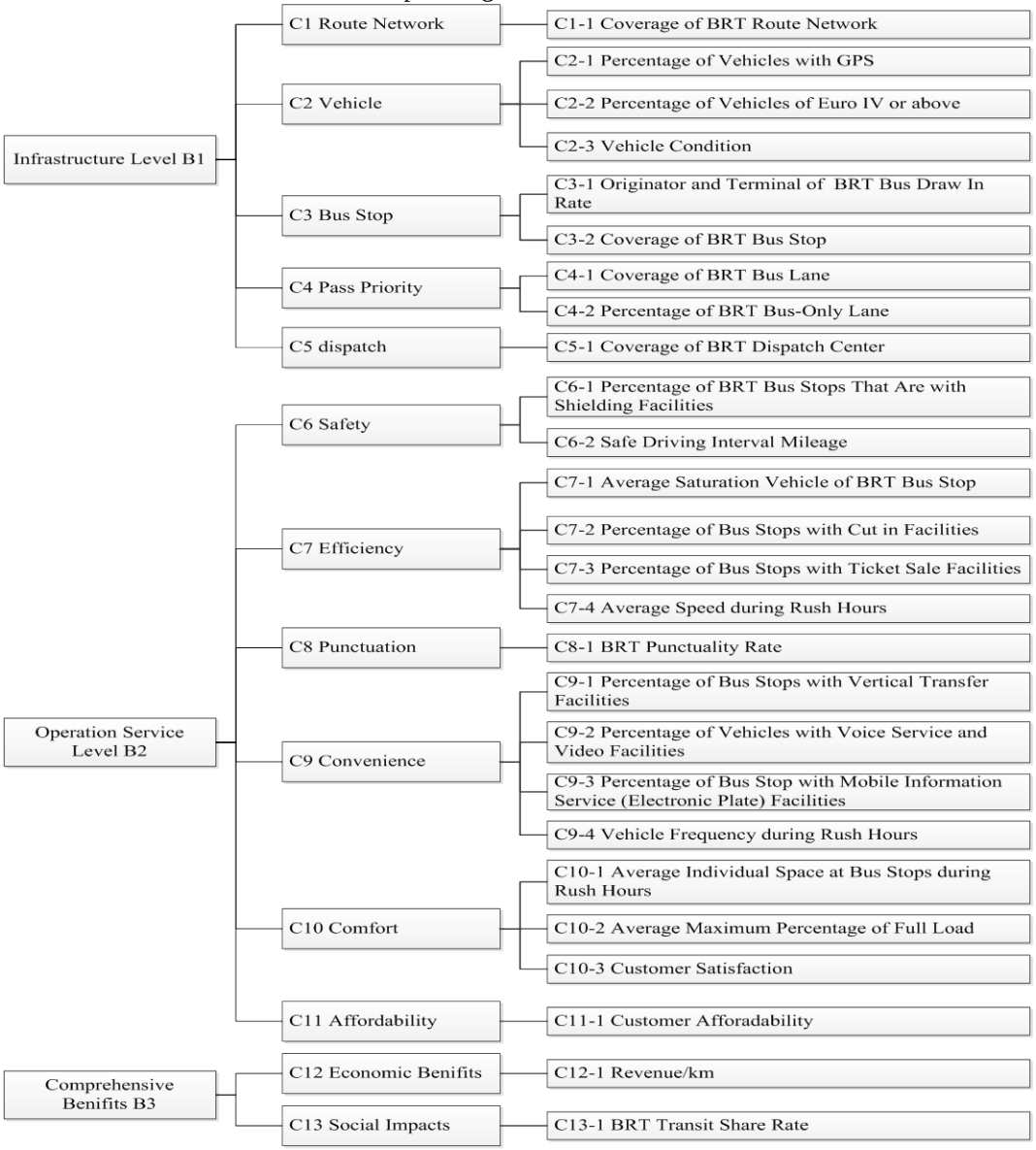

Fig1.The Evaluation Indicator System Of The Operation Of The BRT System

Journal of Theoretical and Applied Information Technology
28th February 2013. Vol. 48 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

3. METHODOLOGY AND MODEL

Taking the features of the Chinese BRT system into consideration, the study uses the gray clustering analysis as the tool of analysis. The steps are as the following:

1) Calculating the whitening matrix $\{d_{ij}\}$;

2) Calculating the eigenvalue λ_{jk};

3) Transforming the indicators;

4) The non-dimension process;

5) Calculating the gray whitening function $f_{jk}(d_{ij})$

6) Calculating the weight of every indicator in each category.

The following formula can be used to calculate the weight of the gray cluster:

$$W_i = \frac{S_{ij}\sqrt{S_{ij}}}{\sum_{i=1}^{n} S_{ij}\sqrt{S_{ij}}} \qquad (1)$$

In the formula, W_i stands for the weight of the evaluation factor i in level j.

S_{ij} stands for the average value of the evaluation factor i in every level of the categorizing standard.

7) Calculating the cluster coefficient η_i^j;

$$\eta_i^j = \sum_{i=1}^{n} w_i f_j^k(x) \qquad (2)$$

In the formula, η_i^j stands for the cluster coefficient of evaluation point i on evaluation level j; if the value of the indicator of the evaluation point i falls into category j, $f_j^k(x)$ stands for the function value of indicator's whitening function k.

8) Building cluster vector $\sigma(i)$;

$$\sigma(i) = (\sigma_{i1}, \sigma_{i2}, ..., \sigma_{ik}) \qquad (3)$$

9) A cluster is the level of development of the BRT system in urban areas.

Table 1.Standards Of The Evaluation Levels

Number	Indicator	Unit	Level			
			A	B	C	D
1	B1	10,000 km/time	›150	100~150	50~100	‹50
2	B2	min	‹20	20~30	30~40	›40
3	B3	km/h	›40	30~40	20~30	‹20
4	B4	%	›95	85~95	50~85	‹50
5	B5	%	‹22	22~40	40~60	›60
6	B6	min	‹3	3~5	5~10	›10
7	B7	min	‹8	8~15	15~20	›20
8	B8	min	‹3	3~5	5~8	›8
9	B9	%	‹50	50~60	60~85	›85
10	B10	%	‹40	40~50	50~60	›60
11	B11	Yuan	‹1.5	1.5~2	2~3	›3

A—outstanding, B—good, C—acceptable, D—poor

4. PILOT STUDY

The study uses the BRT1 system in the city of Jinan as the case example to examine the indicator of the evaluation indicators of the BRT operation status. The indicator of the evaluation of the service level of the BRT system is divided into four levels—A (outstanding), B (good), C (acceptable), D (poor).A—outstanding, B—good, C—acceptable, D—poor.

An effective evaluation on the service level of the BRT1 system in the city of Jinan can be conducted by applying the gray clustering analysis to the actual values the indicators of the BRT1 system.

Table 2.Actual Values Of The Evaluation Indicators Of The Jinan BRT1 System

Evaluation indicator	Actual values	Evaluation indicator	Actual values
B1	490	B7	13
B2	32	B8	7
B3	21.5	B9	75
B4	90	B10	35
B5	38	B11	1
B6	8		

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

1) The whitening matrix is as the following: D={490,30,21.5,90,38,8,13,7,75,35,1}

2) The results of non-dimension are as the Table 3.

3) Calculating all whitening functions, the results are listed in Table 4.

4) Calculating the weight of the indicators (see Table 5 for results)

5) Calculating the cluster coefficient of the indicators at four levels.

σ_{11} =0.2446, σ_{12} =0.2517, σ_{13} =0.2860, σ_{14} =0.1207

Cluster vectors: $\sigma(i)=\{0.2446,0.2517,0.2860,0.1207\}$

6)The maximum cluster coefficient of cluster vector $\sigma(i)$ is 0.2860, meaning that the service level of the BRT1 system in Jinan is medium in needing of improvement.

The pilot study in Jinan shows that the evaluation indicator is adaptable and functional, and can be published as the indicator of the evaluation indicators of the BRT operation status.

Table 3.The Dimensionless Indicators And Levels

Indicator	Indicator Value	Level							
		A	B			C			D
			Low	Medium	High	Low	Medium	High	
B1	0.98	›0.3	0.2	0.25	0.3	0.1	0.15	0.2	‹0.1
B2	0.8	‹0.5	0.5	0.63	0.75	0.75	0.88	1	›1
B3	0.538	›1	0.75	0.88	1	0.5	0.63	0.75	‹0.5
B4	0.947	›1	0.89	0.95	0	0.53	0.71	0.89	‹0.53
B5	0.633	‹0.37	0.37	0.52	0.67	0.67	0.83	1	›1
B6	0.8	‹0.3	0.3	0.4	0.5	0.5	0.75	1	›1
B7	0.65	‹0.4	0.4	0.58	0.75	0.75	0.88	1	›1
B8	0.876	‹0.38	0.38	0.51	0.63	0.63	0.81	1	›1
B9	0.882	‹0.59	0.59	0.65	0.71	0.71	0.85	1	›1
B10	0.583	‹0.67	0.67	0.75	0.83	0.83	0.92	1	›1
B11	0.333	‹0.5	0.5	0.63	0.75	0.75	0.88	1	›1

Table 4.The Values Of All Indicator's Whitening Functions

Level	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
A	1	0	0	0	0	0	0	0	0	1	1
B	0	0	0	0.95	0.8768	0	0.5882	0	0	0	0
C	0	0.3846	0.3077	0	0	0.8	0	0.6579	0.7867	0	0
D	0	0	0.6923	0	0	0.2	0	0.3421	0.2133	0	0

Table 5.The Standard Weight Of Indicators

Level	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
A	0.0499	0.0832	0.1664	0.1664	0.0616	0.0499	0.0666	0.0632	0.0982	0.1115	0.0832
B	0.037	0.0933	0.1304	0.1407	0.077	0.0592	0.0859	0.0756	0.0963	0.1111	0.0933
C	0.0184	0.1078	0.0772	0.087	0.1017	0.0919	0.1078	0.0993	0.1042	0.1128	0.0919
D	0.011	0.1095	0.0548	0.058	0.1095	0.1095	0.1095	0.1095	0.1095	0.1095	0.1095

A—outstanding, B—good, C—acceptable, D—poor

The pilot study in Jinan shows that the evaluation indicator is adaptable and functional and can be published as the indicator of the evaluation indicators of the BRT operation status.

CONCLUSIONS

This paper puts forward a new method to evaluate the bus rapid transit (BRT) operation, and shows the accuracy and feasibility of the evaluation methodology, provides reference and technical

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

support for urban public transport network in our country at the same time. It has great importance improving travel efficiency of residents and the service level of bus rapid transit (BRT).

ACKNOWLEDGEMENT

The study is funded by the Western Traffic Construction Projects of the Ministry of Transport (2011-318-221-1210) and Volvo Research and Educational Foundations. The author would like to extend the gratitude to the Energy Foundation and Jinan Urban Sustainable Transport Research Center, whose support was crucial to the completing of the study.

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