

The Comprehensive Evaluation of BRT System Based on Introduced Examples in Major Cities of China

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Abstract : In recent year, in the major cities of China, in order to improve the problems caused by motorization, the countermeasure to develop Bus Rapid Transit system as the central of public transit has been implementing. This paper aims to propose the evaluation method, based on the internal and external effects and their relationship obtained by analyzing the actual data of four major cities. As a result, some typical individual factors were selected and both internal and external effects were evaluated based on their factors. In addition, an idea of the comprehensive effects by integrating internal and external effects was proposed.

Keywords: BRT, Internal and external effect, Comprehensive effect, China

1. INTRODUCETION

With the rapid development of urbanization and motorization in China, traffic congestion and environmental pollution is becoming worse and worse. In order to improve the present situation and construct the traffic system with sustainable development, the integration of transportation should be placed in an important strategic position, and giving priority to the development of public transportation should be considered as a major policy. Therefore, the introduction of BRT system in Chinese major cities are very prevailing at present. However, the effects of the introduction of BRT systems are not tested adequately. This paper considers all the factors in internal and external systems, sets the index of evaluation based on the definition of “transportation integration” and chooses 4 typical cities as research objects to analyze their effects quantitatively and qualitatively. The previous research (Li and Hino 2011-1, 2 2012-1) results are: for internal effects, the convenience of transportation is improved; for external effects, the development of new economic zone is promoted and the basic facilities of environment are improved.

In this paper, BRT No. 1 in 4 typical cities is chosen as research objects. Their introducing conditions are cleared out and the relationship between internal and external effects is analyzed. Based on the relation, an idea that internal and external effects are integrated to be evaluated is put forward.

2. BASIC INDICATOR OF BRT SYSTEM EVALUATION

Before exploring the method of evaluating BRT introducing effects, it is necessary to specify the relation between internal and external effects. Because the introducing conditions of BRT system are different, they need to be cleared up firstly, which is very important, especially for the analysis of the relation between internal and external effects based on BRT system and the function of rail traffic (Li and Hino 2012-2).

2.1 BRT Introduced Conditions in Object Cities

Although the population and GDP scale of each object city are different, their traffic conditions are similar, such as more and more traffic congestion due to urbanization and motorization, lower and lower service level and sharing rate of public transportation and so on. However, each city has its particular condition. For Beijing and Guangzhou, the opening of Olympic Games and Asian Games made traffic needs increase greatly. As a touring city, Hangzhou improved its traffic service for tourists. Xiamen's development is limited by its space as an island city.

Since the present development of rail traffic and the function of BRT system in each object city are different, the quality and quantity of introducing effects also vary. Owing to it, whether there is rail traffic or not was taken into consideration in the research on the introducing conditions of BRT system in previous research as shown in Ttable1 (Li and Hino 2011-1).

Table1.Comparison of BRT introduced conditions of object cities

City	Introducing Traffic Conditions	Necessity	Role and position of BRT	
BeiJing	1.Increased urbanization	Correspond to the increasing traffic demand	Have rail traffic	1.Befor subway has been introduced, BRT is arterial traffic 2.After subway has been introduced, BRT complement the traffic need of subway
GuangZhou	2.Increased motorization			1.In the section without subway, BRT is arterial traffic 2.After introduced subway in the section BRT share the transport capacity of subway (Length is longer than subway)
HangZhou	3.Low public transport share rate	Correspond to tourists' traffic needs	No rail traffic	1.In the section without subway BRT is arterial traffic 2.Willbe converted into railway
XiaMen	4.Traffic congestion worsened	The development of New District		

2.2 Re-allocation of Road Space for BRT

As to the setup of BRT-only lane, Beijing and Guangzhou expanded roads to ensure it; Xiamen constructed viaducts for it; Hangzhou marked out 2 lanes from its 6 lanes for BRT-only lane considering its high density of downtown development, nevertheless, which makes road capacity insufficient and makes the cars on roads more crowded.

2.3 Internal and External Effects according to Introducing Conditions of BRT Systems

This paper divides the introducing factors for effects of BRT systems in 4 object cities into 9 categories, and analyzes the relation between internal and external effects through grouping these effects as shown in Table2.

Table2. The introducing factors for effects of object cities' BRT system

	A	B	C	D	E	F	G
	Integrated Normal Bus Rate (%)	Feeder Bus	Transport capacity (10 ⁴ /y)	C/ public transpot Capacity (%)	Speed	Punctuality Rate	Speed Of Cars
BeiJing	31.8	×	9490	2	46.9	60	41
GuangZhou	35.8	×	26988	10	84	UK ↑	22
HangZhou	11.4	5	1606	2.1	96.2	90	-30
XiaMen	40	19	7400	12	100	80	13
	H		I				
	Satisfaction Rate(%)		Improved Transfer				
BeiJing	80		Transfer station is colse to subway;cross road by underpass and overpass.				
GuangZhou	66		Transfer is free between with normal bus.				
HangZhou	96		Transfer is free between 5 feeder bus lines at 8 stations.				
XiaMen	80		Transfer is very close and very cheap between 19 feeder bus lines.				

In this table, the factor G(cars' speeding) as an effect after introducing BRT system can relieve environmental pollution but is opposite to the effect of giving priority to the development of BRT system and lowers the effect of maintaining traffic system balanced. Thus, restraining car's development is essential for realizing the priority of public traffic. Apart from this, the speed of BRT systems in the other cities except Xiamen is still lower than social cars' and social cars in Hangzhou speed down, which will definitely deteriorate environmental pollution.

The factor H(Satisfaction) in high punctuality, short using time and travel information supplement is thought highly and helps to improve public traffic image and people's knowledge of giving priority to the development of public traffic, which can be considered as external effects.

Based on the effects above, 3 basic indexes in internal effects and 4 basic indexes in external effects are selected out, as shown in Table3.

In the meantime, their interrelations are gained as Figure 1, which can be thought that the effect after introduction influences internal effect, and internal effect influences external effect.

Table3. Internal effects and external effects corresponded with individual effects

Effects of combination	Internal effect	
A,C,H	1.The operating effects of enterprises	
B,C,D	2.The satisfaction of traffic needs	
E,F	3.The improvement of traffic convenience	a) The improvement of speed and punctuality rate.
B,I		b) The improvement of transfer.
Effects of combination	External effect	
A,B,C,D,E,F,G	1.The reduction of Environment pollution	
C,D,E,F	2.The decrease of social cost	
B,C,D	3.The improvement of the share rate of public transportation	
The imporvement of traffic convenience and the position of BRT	4.The promotion of new economic zones	a)The increase of houseing price . b)The increase of population and employment.

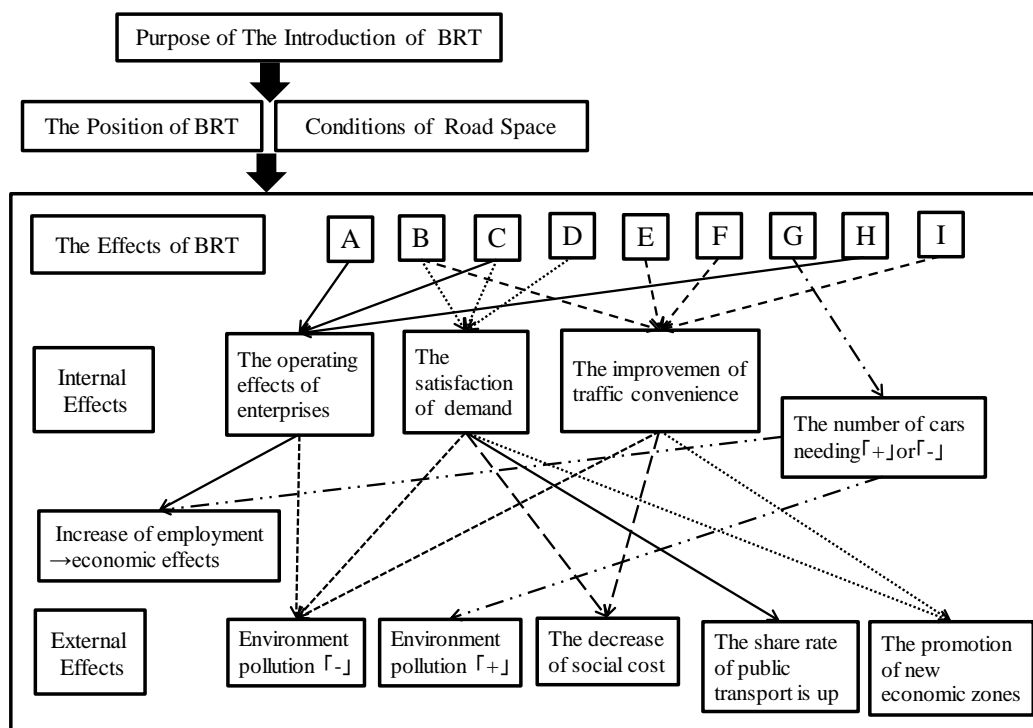


Figure1. Relationship extended from internal effects to external effects

3. THE RELATION BETWEEN INTERNAL AND EXTERANL EFFECTS

3. Internal Effects

3.1.1 Enterprises' operating effect

The effects after the introducing BRT system including the integration rate of bus lines along BRT line (A), the annual transporting capacity of BRT system (C), and the satisfaction rate of

BRT users (H) can influence enterprises' operating effects. In other words, because the number of travelling buses and walking distance is reduced due to the integration of bus lines, operating cost also decreases. In addition, large travelling capacity brought by high full-load rate can increase enterprises' operating profits. Take the data of Guangzhou BRT system as an example to test out the result. We can see that 9.2 million Yuan loss is cut annually although this enterprise influenced by fare policy is still in deficit, as shown in Table4 (Zhu *et al.*, 2011).

Table4. The operating effects of test calculation example of Guangzhou BRT

Enterprises' operating effects	Cost (yuan/km)	Income (yuan/km)	Travelled distance (km/day)	Operating effects (yuan/year)×10 ⁴	Promotion effect (yuan/year)×10 ⁴
2009year	7.4	6.5	389693	-12801	9246
2010year	8.1	7.8	324652	-3555	

Increasing passengers is the basis to raise profits. Through improving the convenience of BRT system, people's traffic modes shifts from bicycle, car and taxis to BRT system. It is reported that the number of users shifting from these traffic modes to BRT system amounts to 20, 000 every day (Zhu *et al.*, 2011). Furthermore, such a shift can not only increase BRT profits but also make a contribution to relieve environmental loads and rationalize traffic modal split.

BRT systems in 4 object cities all enjoyed high satisfaction because of fast speed, high punctuality, waiting information supplement and improved station environment. Such a high satisfaction contributes greatly to the evaluation of operating effects, as shown in the relation between effects and satisfaction of Figure2.

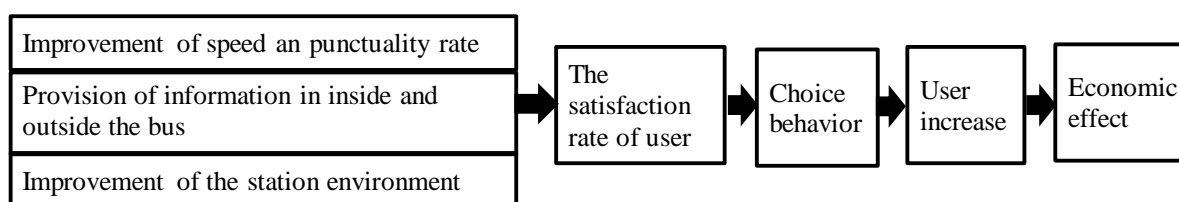


Figure2. Relation between the operating effects and the satisfaction rate of user

3.1.2 The satisfaction of traffic needs

The satisfaction of traffic needs is evaluated by synthesizing the feeder buses of BRT system (B), the annual transporting capacity (C) and its proportion in the transporting capacity of public transportation (D). However, the setting of feeder buses varies according to different introducing conditions and functions (the relation with rail traffic) of BRT system. For an example, in Beijing and Guangzhou, the traffic needs of BRT line is almost consistent with its

transporting capacity, while in Hangzhou and Xiamen, because BRT system plays the same role with rail traffic, in order to expand the BRT using scope, setting feeder buses is necessary.

As evaluation indexes of BRT transporting capacity, the increase of effect (C) and (D) figures leads to the decline of service level in Figure3. Therefore, it is necessary to determine the upper limit of transporting capacity (full-load rate) to evaluate and ensure service level. Since the crowding inside buses in rush hours influences BRT system effects greatly, the transporting capacity in rush hours is taken as object and the standard value 80% of Chinese city traffic departments is determined as the upper limit. With the trade-off relation between full-load rate and operating effect, it is necessary to set a proper scope. In other words, if the situation of over demands is improved, determining the lower limit is essential.

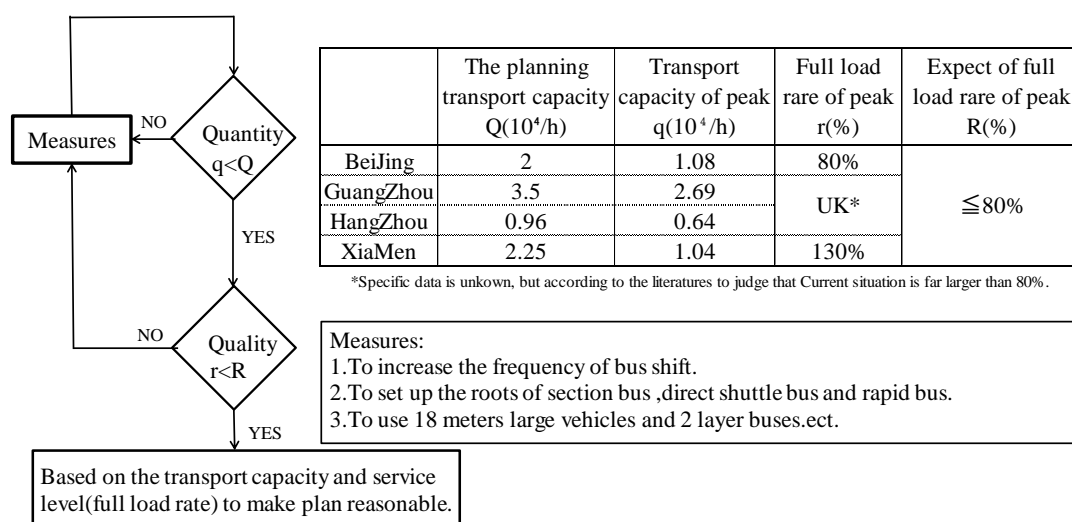


Figure3. Improvement method of demand sufficiency based on evaluation indexes

3.1.3 The improvement of traffic convenience

The indexes of traffic convenience include feeder bus of BRT system, the improvement of speed, the rise of punctuality rate, and the improvement of transfer. Speed and punctuality are major indexes to evaluate service level. From Table3, it is seen that each object city improved a lot. The setting of feeder buses makes great contribution to expanding BRT using range and improving traffic convenience. It is reported that in Xiamen a lot of feeder buses connect to BRT system, thus to expand its using range to 2~3 kilometers along BRT line (Li *et al.*, 2010).

As to transfer, viaducts and underground passages are built to realize short distance transfer to feeder bus, common bus or subway. In addition to this, free transfer policy is applied to improve convenience.

3.2 External Effects

3.2.1 The reduction of environment burden

As indicated in Figure1, the internal effects brought by the introduction of BRT system is related to the improvement of public transportation usage, which can promote the city development along BRT line, scatter population and be expected to better the atmosphere quality and environment. Nevertheless city development may lead to population concentration and the increase of car using.

The effect of reducing environmental burden is considered as external effect. Its producing process and the relation between internal and external effects are cleared out in Table 5. In this table, it is intended to show the relation that the effect of BRT introduction affects internal effect and internal effect affects external effect.

Table5. Relation between internal and external effect from environment pollution

Individual Effect	Internal Effects	External Effect (The reduction of Environment pollution)
A: Integrated Normal Bus Rate	The operating effects of enterprises	Because the bus number and travelled distance are reduced, the exhaust decreases, too. → The reduction Environment pollution
B: Feeder Bus	The satisfaction of the demand The improvement of traffic convenience	Because of introduced feeder buses and improved transfer → Convenience improvement
C: Transport Capacity of BRT	The operating effects of enterprises The satisfaction of the demand	→ Transport volume increase → The operating effects of enterprises → The share rate of public transport is up- → Reasonable management of the demand
D: C/ Transport Capacity of public transport	The satisfaction of the demand	
E: Speed	The improvement of traffic convenience	Improved speed → The exhaust decreases
F: Punctuality Rate		The improvement of traffic convenience → Car using are reduced → The exhaust decreases
I: Improved Transfer	For using of BRT it is opposite effect	Rised speed of car → The exhaust decreases Restraint of increasing car using → To keep the exhaust decreasing
G: Speed Of Cars Rised	The improvement of traffic convenience	

In this table, the rise of car speed can reduce exhaust gas and the improvement of travelling environment brings out the increase of car usage. Therefore, in order to reduce environmental burden, strengthening the policy of giving priority to the development of public transportation (restrain car using) is very important. In recent years, the air pollution caused by PM 2.5 in Chinese major cities is mainly due to more and more exhaust gas given off in traffic jams. To relieve this problem, public transportation represented by BRT system should be improved and car usage should be restrained.

3.2.2 The cutting down of social cost

In previous research (Li and Hino, 2012-1, 2), take the number of BRT users, the shortened time and per capita GDP as indexes to calculate the social cost cut down. BRT users' travel costs also reduce because of the rise of car speed. Add these two figures, we can get the effect that social cost is cut down, as shown in Table6.

The convenience of BRT system shortens people's travelling time and the policy of free transfer reduces BRT users' travelling cost. It is reported that the travelling costs of BRT users in Guangzhou reduce 540 million Yuan every year (Pan and Jian, 2011). Just as the description in 3.1.1, it is estimated that enterprises' operating effect is improved after the introduction of BRT system. Owing to it, we can expect the effect that government's subsidy will be reduced.

To sum up, it can be proved that it is possible to reduce social cost because of the expansion of traffic needs and the improvement of convenience.

Table6. Relation between internal and external effect from social cost

Internal Effects	External Effects (The decrease of social cost)
The satisfaction of traffic needs → The large transport capacity	For users of BRT: $\text{Transport Capacity} \times \text{Shortened Time} \times \text{Time value} = \text{The decrease of social cost}$
Speed Of Cars Rised	For users of Cars: $\text{Transport Capacity} \times \text{Shortened Time} \times \text{Time value} = \text{The decrease of social cost}$
The imporvement of traffic convenience → free transfer	For users of BRT the fare expenditure has been decreased
The operating effects of enterprises →The large transporting capacity	Because of decreased deficit of enterprise, the amount of government subsidy can be reduced

3.2.3 The promotion of new economic zone development

The satisfaction of traffic needs and the improvement of traffic convenience promote the development of the areas along BRT line. For example, the previous research shows that the introduction of BRT is inclined to make residential price, population and employment go up, as shown in Table7 (Li and Hino, 2012-2).

Residential price is influenced not only by improved traffic convenience but also by many other factors such as residence types, the distance to downtown and BRT stations, having other traffic modes or not. As a result, it is not so easy to indicate the influence of BRT introduction by using the specialized indexes. On the other hand, in Xiamen, after introducing BRT system, residential area and real estate transaction amount both increased. Such effects are almost caused by the effect of improved traffic convenience brought by BRT introduction

as shown in Table8 (Li and Hino, 2012-2). Besides it, with the economic development in new economic zone, the residential price along BRT line went up, and the population and employment also increased.

Moreover, the increase of population because of improved traffic convenience promotes new residential needs, outskirts development and improvement of infrastructure facilities. It is a typical example of TOD (Transport Oriented Development) policy, as shown in Figure4.

Table7. Comparison of influence on development by introduced BRT and subway

	Data's period	Regions along BRT No.1 Line	Regions along Subway	Growth rate of average price	Increase of population(10 ⁴)	Increase of employment(10 ⁴)
BeiJing	2004—2007	48%	60%	70%	2.7→15.6	1.6→10
GuangZhou	2010—2011	10%	25%	20%	—	—
HangZhou	2006—2010	100%	×	105%	20→45	—
XiaMen	2008—2011	77%	×	13%	31→58	9.4→16.3

Table8. Influence on development by introduced BRT in Xiamen

	Population (10 ⁴)	Employment (10 ⁴)	Housing Price (yuan/m ²)	Sold Area (10 ⁴ ·m ²)	Total Transaction Amount of Real estate (10 ⁹ ·yuan)
Before introduction(2008)	31.2	9.4	6500	42.7*	17.98
After introduction(2011)	58.1	16.3	11500	71.7	20.1
Growth rate(%/y)	23%/y	19.8	20	70.3	3.7

* is a data of 2010

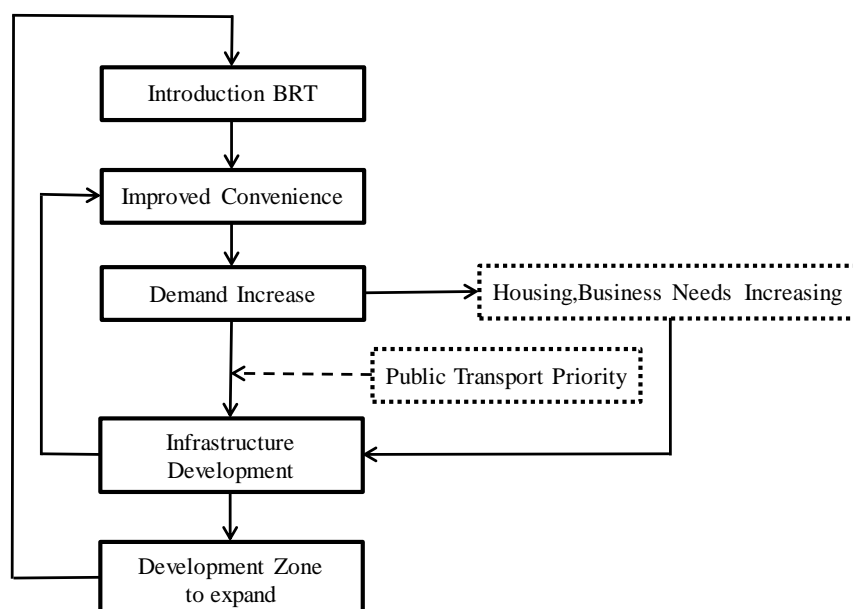


Figure4. Circulation of the effect by introduced BRT as an example of ODT

4. COMPREHENSIVE EVALUATION ON BRT SYSTEM INCLUDING INTERNAL AND EXTERNAL EFFECTS

The research so far explains the relation between internal and external effects by examples. The relation between them is qualified temporarily. Actually they are interrelated so that it is significant to integrate them. But the first and important trouble to do that is to set the same criteria for these different indexes.

The evaluation on the effects of BRT introduction based on these effect indexes is applied to 2 different types of evaluation: (1) the evaluation comparing with rail traffic program; (2) the evaluation comparing BRT introduction alternatives.

In terms of (1), on the condition that the major public transportation is programmed by comparing BRT program with the subway lines in similar cities, the advantages and disadvantages of the planned system may be found out. In this type of comparison, all kinds of benefits and costs (B/C) are compared to judge either subway or BRT system has better introducing effects. Thus it is essential to convert the value of indexes with different units to the value which can be measured by currency, or set the same criteria to standardize the value of indexes with different units. Nevertheless, considering the properties of various indexes are different, it is not easy to set the same criteria. For example, calculate the percentage of each index of subway and BRT system and, add weighted sum to get the total sum, and then we can get the effect of B/C of the planned BRT. When doing this, to determine the importance of each index accurately is very important to not only realize the evaluation of the alternatives, but also propose the factor, which reflect the policy of program.

As to (2), the introducing effects vary according to the functions of BRT system to subway. For example, we can think that Beijing BRT system strengthens subway's transporting capacity, and in Guangzhou, BRT has the access function to subway. According to it, the evaluation target should be divided into two types: judging the rationality of every plan based on the function of BRT system (2-A); evaluating the advantages and disadvantages of alternatives of BRT programming, for example, in case of introducing BRT system to the existing rail system like subway (2-B).

5. CONCLUSION

This paper aims to put forward the method to evaluate the effects brought by BRT introduction, under presupposing its purpose, building conditions and function in traffic system. Based on the analyses of actual data, various effects of BRT system introduced to 4 object cities according to introducing conditions were divided into 2 types, such as, internal effects and external effects. And the method to integrate inner and outer effects was brought

up, based on some basic indexes and their qualified relation.

To consider the social cost like the fairness of tax and environmental pollution, analyzing the relation between internal and external effects and modeling them must be important. They are also essential and significant subjects for effective introduction of BRT as the suitable public transport system. In addition, the evaluation method mentioned in this paper was discussed from the perspective of practical application to formulate the transport system corresponded to an economic and proper policy of sustainable development, by the comparison with rail transit program, and also to propose the BRT programming so as to maximize its introducing effect. Under such circumstances, it is significant to point out these differences and predict them, because introducing effects are different according to the alternatives of BRT programs, as well as the existence of rail transit.

In order to further develop this application, more data collection and more deepened analyses of object cities must be essential. Furthermore, the idea and model of comprehensive evaluation with appropriate weights for major indexes, which are also other important subject, should be essential in the near future.

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