A STUDY ON BRT APPLICABILITY ON LARGE CITIES IN DEVELOPING COUNTRIES

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ABSTRACT

This paper aims to identify issues on BRT (Bus Rapid Transit)'s introduction to large cities in developing countries, where higher demand must be met by poor funding. Field surveys have been done in Curitiba, Bogotá and Jakarta. Advanced cases such these three cities, Curitiba, Bogotá and Jakarta, are compared based on the framework of performance indicators and design requirements of BRT systems. The authors got clarified that 1) BRT infrastructure is indispensable, 2) operation must be well taken into consideration in order that performance indicators provide acceptable values, 3) information and communication technique must be cost-effective especially as an initial investment, and 4) human resource issues should be highlighted more as it can contribute to most of indicators. It is expected that the urban planning and transportation planning should be discussed with consideration with city's population and activities, road and public transport networks and situation of paratransit. The issues to be solved are the necessity of monitoring the model cases and quantification of index.
Keywords: Bus Rapid Transit, developing countries, performance indicators

1. INTRODUCTION

This paper aims to identify issues on BRT (Bus Rapid Transit)'s introduction to large cities in developing countries, where higher demand must be met by met by poorer funding. BRT systems have been planned or introduced in many cities and more in future. Comprehensive studies must be needed in order that BRT systems show expected levels of their performance.
In the developing world, there are a lot of recent discussions on the introduction of mass transit systems despite of the difficulties in terms of cost and techniques. Because of these reasons, it is not easy for developing cities to introduce the railways or metros. As BRT systems are not inferior to trains in terms of capacity and punctuality, more and more cities in either developed or developing countries, have been introducing the BRT systems.
There are many definitions of BRT. Institute for Transportation and Development Policy (2007) defined the BRT as below.

> Bus Rapid Transit (BRT) is a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service.

Sometimes BRT is described as a bus system with improved vehicles or infrastructures, such as articulated vehicles, segregated busways and stations. In addition to that, however, the advanced operation and management are also very important factors to define a BRT system. In this paper BRT is be defined as: a bus system that is in no way inferior to the other existing mass transit systems by improving the traditional bus service with segregated bus ways, a heavier vehicle fleet, and offering more efficient services with adoption of advanced management and operation system.

2. RECENT TOPICS RELATED WITH BRT

2.1 Summary of existing research

2.1.1 Comparative Studies

There are some researches involved comparisons among several practices of BRT. They tried to compare the systems by using some common data or statistic figures, mainly focus on North American and Latin American cases although there are a few studies covering the worldwide BRT practices also.

As shown in Table1, in an ITDP report there is a comparison of over thirty cities by some quantitative variables, as well as some qualitative variables on infrastructure, operation and management.

Hensher (2008) has summarized not only the quantitative variables such as construction costs and capacity at peak hours but also the qualitative variables such as whether each system has exclusive lanes, integrated network with arterials, and feeder routes or not. Table2 shows Hensher's comparative standards.

Menckhoff (2011) has suggested a set of comparative standards that are categorized into five major categories, as shown in Table3. He has given weighted points to each standard and then summed up the given points as the total achievement.

Table 1 – Comparative standards by ITDP

	Infrastructure	Operation
Quantitative Evaluation	Segregated busways or bus-only roadways	High average commercial speeds(>20km/h)
		Actual peak ridership over 8,000 passengers per hour per direction
Qualitative Evaluation	Special stations and terminals to facilitate transfers	Pre-board fare collection and fare verification
	Overtaking lanes at stations/Provision of express services	At-level boarding and alighting
	Enhanced station environment(i.e. not just a bus shelter)	Fare- and physical-integration between routes and feeder services
	Modal integration at stations	Entry to system restricted to prescribed operators under a reformed business and administrative structure
	Improvements to nearby public space	Competitively-bid and transparent contracts and concessions
	Existence of an integrated "network" of routes and corridors	No need for operational subsidies
		Independently operated and managed fare collection system
		Quality control oversight from an independent entity/agency
		Low-emission vehicle technology(Euro Ⅲ or higher)
		Automated fare collection and fare verification system
		System management through centralized control center, utilizing automatic vehicle location system
		Signal priority or grade separation at intersections
		Distinctive marketing identity for system
		High-quality customer information(e.g. clear maps, signage, real-time information displays)
		Supporting car-restriction measures(e.g. road pricing)

Table 2 - Comparative standards by Hensher

	Infrastructure	Operation
Quantitative Evaluation	Total infrastructure costs per kilometer($US/Km)	Peak ridership(Passenger/hour/direction)
		Average peak headway(Minute)
		Average all day commercial speed(kph)
Qualitative Evaluation	At-level boarding and alighting	No need for operational subsidies(Yes, partial, No)
		Pre-board fare collection and fare verification(Yes, partial, No)
		Modal integration at stations(Yes, partial, No)
		Signal priority or grade separation at intersections(Yes, partial, No)

Table 3 - Comparative standards by Menckhoff

Operation Planning	Pre-board fare collection
	Average peak headway
	Average off-peak headway
	Express service
	Enforcement of right-of-way
	Operation in holidays and midnights
	Operational control to reduce bus bunching
	Multiple routes use same BRT infrastructure
Infrastructure	Physically separated right-of-way
	Physically separated passing lanes at station stops
	Stations set back from intersection
	Stations in center and shared by both directions of service
	Stations occupy former road/median space (not sidewalk space)
Station Design	Articulated buses have 3+ doors and standard buses 2+ very wide doors
	Multiple docking bays and sub-stops, separated by at least half a bus length
	Platform level boarding
Service level and information system for passenger	Branding of vehicles and system
	Safe, wide, weather-protected stations with artwork
	Passenger information at stations and in vehicle
Integration and Access	Bicycle lanes in corridor
	Bicycle sharing systems in BRT corridor
	Improved safe and attractive pedestrian access system and corridor environment
	Secure bicycle parking at station stops

2.1.2 Study on process of introduction and planning method

In this section several studies on the process of BRT introduction and planning methods are introduced. According to the ITDP guideline, the preparation for a BRT project should be carried on with a demand prediction as the first phase. At the second phase, designs of the stations, exclusive bus lanes and the signs for the bus system should be finished.

Reports from the Federal Transit Administration (2009) specified the bus lane, station, fare collection system, bus fleet, and the operation planning and branding as the "Major elements of BRT". It defines the performance realized by those elements as "System Performance" that includes the reduction of travel time, reliability, safety, capacity and accessibility. Furthermore, the profits of the whole bus system made by "System Performance" are named as the "System Benefit" that includes the enhancement of modal share of bus, the improvement of system efficiency, the emerging return on investment and contribution to environment.

The study by Yabe (2006) is among the most integrated studies on planning methods of BRT. Traditional buses have some merits in the terms of cheap construction costs and flexibility of system development, but the punctuality and capacity are inferior to other mass transit systems. Although with all these problems, many can be improved for the BRT systems if bus exclusive lanes and other devices can be installed. As a lot of cities are willing to construct BRT systems at present, more and more cities are discussing the possibility to introduce BRT systems as an alternative to railways or LRTs. In Yabe's study, BRT planning method is discussed in terms of factors for upgrading bus system, relationship among indices for comparison of several BRT systems and influence of BRT on cities.

There are also some other studies about the characteristics of BRT by Dirgahayani (2009), Shrestha (2011), and Sivakumar (2006).

2.2 History of BRT

The word of "Bus Rapid Transit" first appeared in the report published by United States Department of Transportation (1975). This report notes that BRT can be applied to high density cities centres with minimum introduction costs and environmental impacts. The usage of automobile can be controlled and the BRT can be more flexibly improved accompanying the growth of the city. Figure1 shows the year of starting operation of major BRT practices.

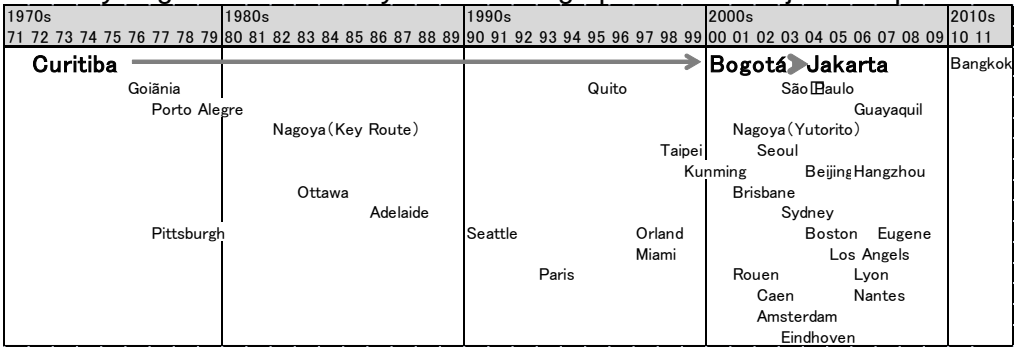

Figure1 shows the year of starting operation of major BRT cities.

As shown in Figure1, the earliest BRT practice is in Curitiba, Brazil had been taking an initiative in deciding the city's master plan that included bus system as an important element of the city. Based on the master plan, BRT in Curitiba finally started its operation in 1974. After Curitiba, several other Brazilian cities opened their own BRT systems one by one. Lately, some cities in Mexico, Colombia, Peru and Ecuador also introduced the BRTs. Especially, the BRT system in Bogotá, the capital of Colombia, has been designed by themselves on the basis of the Curitiba BRT but with some of their own ideas. This Bogotá BRT system was then named Transmilenio and became operational in 1999. Transmilenio boasts of a very high level of performance with higher speed, capacity and outer presence. As Figure2 shows, the number of BRT systems has been dramatically increased from 1999 to 2003 right after the start of the Bogotá practice of Transmilenio, which is regarded as a new milestone for the BRT systems globally.

Transjakarta in Jakarta city, Indonesia, is a follower of Transmilenio. It was a non-profit organization, called as ITDP, which opened a local brunch in Jakarta just to help developing a new BRT system in the city. Under the ITDP Indonesia's suggestion, the Transmilenio experience had been fully utilized.

On the other hand, buses in North America, including United States and Canada, Australia, and European countries have been evolving in their own ways. Runcorn, one of the British new towns, is famous for the busway system that was installed in accordance with the new town development. Essen in Germany is the first city to own guided bus system, which can be regarded as one of the BRT systems. In recent years, more and more Indian and Chinese cities have been showing interest on constructing BRT. According to a report by EMBARQ, thirteen Chinese cities and four Indian cities have already installed BRT systems. Some African and Middle Eastern cities like Dar es Salaam and Amman are also discussing the introduction of exclusive bus lanes and pre-boarding fare collection systems. The first Japanese arterial bus system started to operate in Nagoya in 1982. In Seoul the bus system has been completely reorganized in 2004 and now operates many centre-located exclusive bus lanes. Seoul municipality admits the reference to the Curitiba bus system. There are also about ten Southeast Asian cities, including Vientiane and Khon Kaen, which are trying to introduce new BRT systems. BRT system is expected to play a more and more important role because the construction of BRT is easier and cheaper than that of railways.

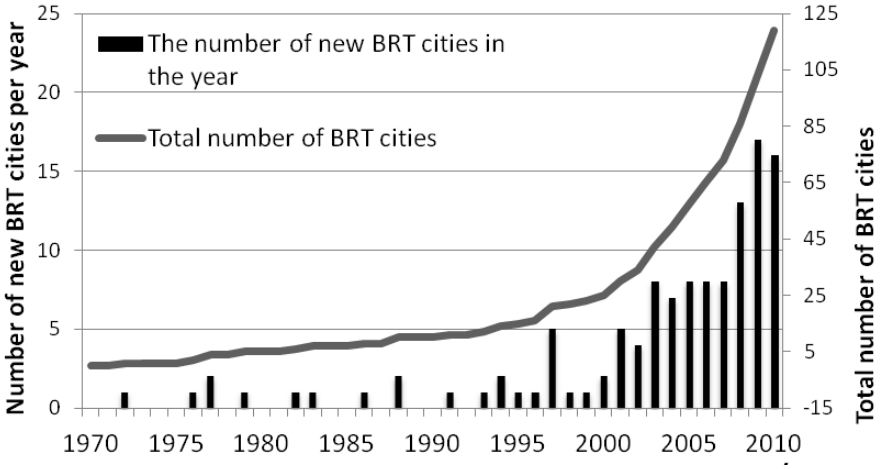

Figure 2 - The number of new BRT cities in the year/Total number of ḂRT

3. COMPARATIVE ANALYSIS OF CASE CITIES

In this section a comparison analysis is carried on in order to clarify the special issues associated with large and middle sized developing cities when installing BRT systems. RIT systems in Curitiba, Transmilenio in Bogotá, and Transjakarta in Jakarta are included as the case study cities. As mentioned previously, Curitiba is the global pioneer of BRT. RIT is a very good practice of bus system and is well coordinated with the urban planning. Bogotá has a huge scale bus system, which has influenced many other Latin American cities. Jakarta has learned a lot from Transmilenio and owns the largest network of exclusive bus lanes in the world. Several papers defined BRT as the bus system with bus exclusive lanes, pre-fare collection system, and no gap between the bus floors and the platform. Curitiba's exclusive bus lanes started in 1974 followed by the introduction of pre-boarding fare collection system featuring the unique tube-shaped bus stations in 1991. It has given a strong impact to the other cities. Bogotá tried to improve the service level of their bus system by using information and communication technologies. As a result, Bogotá's Transmilenio has successfully improved the aspects of capacity, travel time, safety and efficiency. Today a lot of BRT cities are following the systems of Curitiba, Bogotá and Jakarta. In this sense the current issues of BRT are always more or less connected with the experiences in these three cities.

The field surveys of this study have been focused on these three cities. The scheme of the field survey is shown in Table4.

Table 4 - Outline of the field survey

	Curitiba, Brazil	Bogotá, Colombia	Jakarta, Indonesia
Features	World's first BRT Bus with development	High performance Information technology	Asian longest network
Date of survey	8/31/2011-9/24	9/10/2011-9/12	12/10/2011-12/14
Population	1.85 million	7.36 million	9.59 million
Area	435 Km2	352 Km2	660 Km2
GDP per capita	US$ 10,816	US$ 5,967	US$ 3,005
The year of operation start	1974	1999	2004
Length of busways	64.6 kilometer	84 kilometer	123 kilometer
Number of vehicle	1915	519	524
Average passenger per day	350,000	812,000	360,000

Source: http://www.embarq.org/, http://www.transmilenio.gov.co

The view about evaluation indicators for bus operation and bus system design requirement is shown as below, based on the field surveys and the existing researches. The evaluation indicators for bus operation are categorized into four groups, 1) Speed and punctuality, 2) Safety, 3) Capacity, and 4) Efficiency. In this case "Efficiency" means the percentage of capacity per total cost of operation. Therefore it will become more efficient with lager capacity by cheaper cost. A. design requirement, B. infrastructure, C. capacity and D. system operation help the evaluation indicators to work well. Table5 shows the relationship between BRT design requirements and the evaluation indicators for bus performance. Shaded cells are the factors that are especially well-related. Though information technology may influence either infrastructure or most of performance levels of bus system, it is categorized as one of the factors in infrastructure in this table.

Table 5 - Relationship between BRT design standard and performance level

		Travel time	Safety	Capacity	Efficiency
Infrastructure	Segregated busways	■		■	
	Stations	■	■	■	
	Vehicles			■	
	Information technology				■
Planning/ Management	Operation of timetables	■		■	■
	Operation of stations			■	■
	Network with corridor and feeder routes			■	
Management	Contract management and operation				■
	Salary system		■		■
	Vehicle management	■			■
	Training for staffs		■		■
Other	Traffic management	■	■		■
	Automobile control			■	■
	Land use			■	■

3.1 Current situation and issues of RIT, Curitiba

Curitiba's RIT is introduced as a bus system featuring arterial routes integrated with circular and feeder routes that are connected with each other in the terminals, exclusive lanes and articulated or bi-articulated vehicles. The operating companies take their roles under a management organization, URBS. They have contracts about the drivers' salary and the time schedule. RIT has also bus priority signals and parking management in the city centre in order to discourage the car usage. Constructions of condominiums are allowed along the arterial bus routes only.

In spite of all these efforts, our case study and interviews show that the situation in Curitiba has been changing completely back from 2004. At some tube bus stops, there are long queues during the peak hours possibly due to the lack of cares about the design of the tubes and the usage. Moreover, the chronic situation of management for operation, the operating companies have never tried to make efforts to serve better. The Brazilian federal government's promoting policy of purchase and use of cars has worsened the road congestion by less priority of traffic signals dedicated to the buses. Condominiums along the bus ways have become so popular that their prices keep raising with more rich people with cars move and live there. The other problems about the utilization of platforms, the management of the operating companies, training of the staffs, traffic management, and regulations of car usage are also becoming more serious.

3.2 Current situation and issues of Transmilenio, Bogotá

Transmilenio can be characterized as a system utilizing information and communication technologies for faster and more punctual operation with higher capacity. They have constructed segregated busways, passing lanes, stations capable of six buses per direction, vehicles with standard, express services, management for platform usage, and connection with feeder routes. They consider the training of staffs, especially drivers so important that they are connecting the driver's performance with the salary system. Thanks to the cooperation with traffic management, buses can have a priority and keep fast speed even on the crowded roads. After the price of gasoline rose, the government started to regulate the number of cars which can enter the city central by their number plates. In this sense a car regulation policy is still working. However, there is no policy for transit oriented development in Bogotá though this BRT system attracts a large scale development along the BRT corridors. Transmilenio is safe and can save travel time, therefore more and more citizens use it year by year. Now the main concern is to reduce the congestion level of Transmilenio.

3.3 Current situation and issues of Transjakarta, Jakarta

Transjakarta started its operation only after three years of planning. Moreover its network has extended to more than 170 kilometre just within seven years. It is a great bus system with a segregated busway network and its management setup between operating and managing companies. However the stations cannot meet the demands. Furthermore, bus vehicles with only one door on one side cause longer dwelling time at stations. The managing company doesn't make any contracts with the operating companies in term of service levels so they cannot manage the operation and usage of stations properly. The operation remains unchanged as in the other developing cities, where each driver usually drives a same vehicle every day, which leads to inefficient operations. There is a regulation on cars, they are allowed to enter the city centre only when more than three passengers are riding. But it is not working well. It is also clear that problems exist in the station and fleet usage, contracts with operating companies, and the traffic management as well.

3.4 Evaluation Analysis

Each case is evaluated based on the aspects of BRT design shown at the left side of Table 5. The result of the evaluation is summarized into Table6.

3.4.1 Infrastructure

All the cases introduced physically segregated busways. The exclusive bus stations have been introduced in all cases. Current situation in Curitiba looks insufficient to the level of demand. Some facilities in Jakarta also look insufficient. Therefore, these two cases are evaluated as not enough. Curitiba and Bogotá introduced articulated and bi-articulated buses, while Jakarta never introduced those buses, which does not meet the demand. BRT in Bogotá is equipped with information and communication technology.

3.4.2 Planning

Bogotá introduced efficient scheduling such as through services across the corridors. Jakarta also introduced the similar system but with some confusion. Operation of stations in Curitiba is not appropriate with some confusion. On the other hand, that in Bogotá works well. Some stations in Jakarta have some confusion. Coordination between trunk and feeder routes is applied in Curitiba and Bogotá.

3.4.3 Management

Contract between operators and managing organization in Curitiba does not look working properly. Driver dispatching system in Jakarta is not flexible, which affects inefficiency of bus terminal operation. Vehicle dispatching system in Bogotá works well, while deadheading system in Jakarta is so poor that the system has become inefficient. Driver's quality in Curitiba has become worse due to lack of training and monitoring system. Transjakarta does not have training system either.

3.4.4 Others

Curitiba recently stopped bus priority control system. In Jakarta several intersections are operated manually with less priority on BRT. Curitiba currently stopped the strong restriction of parking facility construction in the central area. The federal government in Brazil has promoted car purchasing and gasoline consumption, which results in heavy traffic congestion in Curitiba. High occupancy vehicle restriction is introduced only partly in Jakarta. Suburban shopping centres have been constructed recently without considering transit oriented perspective. No specific strategy on land use has been applied in Jakarta.

Table 6 - Evaluation for BRT

Note: ○:satisfactory △:partly or not enough ×:nothing considered		Former Curitiba	Current Curitiba	Bogota	Jakarta	Travel time	Safety	Capacity	Efficiency
Infrastructure	Segregated busways	○	○	○	○				
	Stations	○	△	○	△				
	Vehicles	○	○	○	×				
	Information technology			○					
Planning/ Operation	Operation of timetables			○	△				
	Operation of stations		×	○	△				
	Network with corridor and feeder routes	○	○	○					
Management	Contract management and operation	○	×	○	○				
	Salary system	○	○	○	×				
	Vehicle management			○	×				
	Training for staffs		×	○	×				
Other	Traffic management	○	×	○	△				
	Automobile control	○	×	○	△				
	Land use	○	△	○					

3.5 Summary

A summary of the field studies is shown in table6 by modifying Table5 with the situation of Curitiba, Bogotá and Jakarta. This table shows the relationship between the existing BRT cities and their bus performances. According to the result of the analysis in the Table6, it is clear that Bogotá and the earlier Curitiba have better infrastructure for a bus system. However, as mentioned before, the current Curitiba and Jakarta have problems in travel time and capacity due to the lack of caring about the infrastructure. Bogotá best the other practices on time scheduling, fleet and driver's management, to which Curitiba and Jakarta made little effort so far. It is why the Bogotá system can be operated efficiently with larger capacity. The clear contract between operating and managing companies brings to the system more efficiency and safety. The information technologies shown in table6 within the infrastructure may influence the whole bus system. The conclusions can be summarized as; 1) Infrastructure should be designed carefully; segregated busways and stations must become a necessity for the BRT operations. It also influences the safety and travel time. 2) The effects of operation should be concerned; not only fulfilled infrastructure but also better operation are necessary for a BRT to operate efficiently. 3) Thinking about the utilization of information technology; operation with information technology can be very cost effective, it worth the installation even if the initial investment is not cheap. 4) Staff education is also important; training for crew, drivers and conductors, can influence the bus system's travel cost, safety and cost effectiveness.

4. CONCLUSION

This study aims to clear the special issues associating with the introduction of BRT systems in large and middle sized cities in the developing countries. Field surveys have been done in Curitiba, Bogotá and Jakarta because these cities are comparable to each other. Based on the field surveys, comparison analyses have been done with a performance analysis. As the results, design of infrastructure including the usage of information technology, ideas for operation, and training for staffs would make a BRT system more efficient. It is expected that the urban planning and transportation planning should also be discussed, considering the city's population and activities, road and public transport networks, and its situation of paratransit. The issues remain to be solved are the necessity of monitoring the model cases and the quantification of the indices. As shown in Curitiba, the practical situation is always changing; it is why a consecutive monitoring is necessary. When the initial evaluation is done, the discussion about the alternatives with quantitative indices becomes important. It is expected that the quantifications can be considered in the future.

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