A STUDY ON THE INTRODUCTION OF BUS RAPID TRANSIT SYSTEM IN ASIAN DEVELOPING CITIES
– A Case Study on Bangkok Metropolitan Administration Project –

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Bus Rapid Transit (BRT) has increasingly become an attractive urban transit alternative in many Asian developing cities due to its cost-effective and flexible implementation. However, it still seems to be difficult to introduce BRT to these cities because almost all of their city structures have been developed under solely a road transport development city plan and weakness of land use control gives rise to many problems, such as urban sprawl, traffic congestion, and air pollution. The purpose of this study was to introduce several strategies to support BRT implementation in Asian developing cities, such as a strategy to appropriately integrate the paratransit system into BRT system as being a feeder along a BRT corridor to supply demand. These proposed strategies were evaluated by applying demand forecasting and emission models to the BRT project plan of Bangkok Metropolitan Administration (BMA) in Thailand. It was demonstrated that the proposed strategies could effectively improve the BRT ridership, traffic conditions, and air pollution emission of the entire system in Bangkok. This study could be further extended to include strategy recommendation if a BRT system were to be introduced to other Asian developing cities.

Key Words: Bus Rapid Transit, Asian developing cities, Ecologically friendly transport, Air pollution emission, Paratransit feeder

1. INTRODUCTION

In many Asian developing cities, transportation development is too rapid and uncontrolled, causing various problems to the environment and human welfare. Many developing cities in Asia therefore have considered a sustainable and ecologically friendly transport mode as one of the most important issues, including low emissions, fewer traffic accidents, and less congestion. Good publicity promoting private mode users to switch to use public modes is one approach to reduce the impact on the ecology since the pollution emission from public modes is much lower than that from private modes per passenger. The usage of cleaner alternative fuels (e.g. Euro and Compressed Natural Gas (CNG)) is another way to lessen the impact as they emit lower air pollution than typical gasoline and diesel engines. It is believed that ecology friendly transportation should be a high-capacity public mode providing advance technology features, and luxurious yet comfortable facilities while having lower emission, moving faster and safer, and most importantly, being attractive to commuters. Moreover, it should be a financially affordable system to developing countries. The Bus Rapid Transit (BRT) is one mode fulfilling these criteria; it is a public mode providing high capacity and consuming cleaner fuels. It also has many comfortable and luxurious facilities with high technology functions for faster and safer travel, including exclusive busway, convenient stations, comfortable articulated buses, and Intelligent Transportation Systems (ITS)(e.g., signal priority system, automatic fare system, Global Positioning System (GPS), bus arrival broadcast information, bus guidance, etc.). Outstandingly, its investment cost is very effective, compared with other transit systems. As proved by an investment cost estimation of Bangkok in 2004, the BRT system cost is approximately 17 and 75 times cheaper than those of Light Rail Transit (LRT) and Subway (36.8[1], 633.9[2] and 2,777.9[3] million baht/km for BRT system, LRT and Subway respectively). The BRT system has proved its efficiency and effectiveness in many cities. For example, Seattle's bus tunnel has reduced surface street bus volumes by 20%. Buses using the tunnel also had 40% fewer accidents than those in mixed-traffic operations. Curitiba uses 30% less fuel per capita for transportation than other major Brazilian cities do. Bogotá's TransMilenio busway had 93% fewer fatalities, and a 40% drop in pollutants during the first 5 months of operation[4]. Moreover, an improvement of life quality of Bogotá's low income people has been observed in the area, being influenced by the TransMilenio system through travel-time and travel-cost savings (16 minutes per trip and US$0.60 per day)[5].

Considering its advantages, the BRT system has become increasingly attractive in many developing cities in Asia, including Jakarta, Bangkok, Hanoi and Manila who currently have started, planned and are considing to operate BRT systems[6]. However, a proper BRT development in these cities specifically involves many regional issues that mainly contribute to the success of BRT implementation. The most successful BRT operating cities have been developed with a well-designed city plan integrating land use strategy with public transit and road networks. Since most Asian developing city structures have been developed under solely a road transport development city plan and weakness of land use control that gives rise to various problems of urban sprawl, traffic congestion, and air pollution, it will be rather difficult to introduce a BRT system under these circumstances. Many studies and guidelines on BRT systems[4,7-11] have been developed and proposed based on successful BRT experiences in various cities. They may not be applied directly, unless proper modifications and enhancements are done accordingly based on specific backgrounds, conditions and characteristics of each Asian developing city. Therefore, further feasibility studies are required before actual BRT implementation can occure.

To make a BRT system possible in Asian developing cities, this work intends to propose supporting strategies for BRT system development. An attempt starts from reviewing existing BRT systems to find out crucial elements contributing to their success, then determining the limiting conditions of Asian developing cities for BRT system implementation, and finally proposing strategies to make the BRT system possible in these cities. Then, the efficiency of proposed strategies is evaluated through a case study of a selected BRT project in Bangkok. However, although this study proposes many strategies to support the BRT system, it mainly focuses on the strategies to supply the demand to the BRT system through proposing concepts and evaluating their efficiency.

This paper is organized as follows. The second section determines the conditions that enhance BRT system developments after thorough review of many existing BRT systems. The third section states the limiting conditions of Asian developing cites for development of a BRT system. The fourth section proposes the strategies to make BRT system possible in Asian developing cities. The fifth section illustrates the evaluation process, results, discussion, and the final section presents the conclusion and recommendation.

2. CONDITIONS ENHANCING BRT SYSTEMS DEVELOPMENT

This study has reviewed several existing BRT systems to find out the conditions that make them become successful. The cities famous for BRT systems, such as Bogotá, Curitiba, Seattle, Ottawa, Brisbane and Nagoya have been reviewed. Their conditions contributing to successful BRT system development are summarized below:

2.1 Integrating plan of land use and transportation system

Successful BRT projects are mostly planned under a well-integrated master plan between land use strategy and the transportation system. The direction of the development is towards well specified bus routes along exclusive busways with strong coordination among land use strategy, road network planning, and other public transport systems. For example, Curitiba's master plan has included transit corridors with the urban layout as integrating bus networks that adopt line-haul bus routes along exclusive busways in the development axes penetrating the city center[12]. The busway system was conceived in the early 1970s as an urban planning initiative, aiming to concentrate on population and economic growth along "structural axes" and thus to control urban sprawl. Bogotá is similar to Curitiba; the project was not only designed as a transport scheme but was also part of a comprehensive city upgrading program to improve public space in general, i.e., sidewalks, parks, bikeways, and mixed-traffic streets[13]. Some of the reviewed cases, such as Curitiba and Ottawa, emphasize land use policy to support Transit Oriented Development (TOD) for future growth around major systems to maintain and increase transit ridership.

TOD concepts, such as zoning and other regulatory changes, are applied to promote commercial and residential development within walking distance of the stations. For example, Curitiba has adopted strong land-use controls to effectively guide growth and to encourage mixed-use and high-density development patterns along structural axes that reinforce and encourage the bus system usage.

2.2 Rapid transit operations

According to the reviewed cases, two transit conditions enhancing the BRT system development are as follows:

— High service level: Almost all of the reviewed cases provide headways of less than 5 minutes during peak hours (1.5 minutes in Curitiba)[4], and around 10 minutes during off-peak hours. Feeder services' headways are less than 15-30 minutes, timed to match the main service. The service span basically runs from 5a.m. until midnight (almost 24 hours a day in Ottawa)[14]. This is one important characteristic of BRT service.

— Providing exclusive busway: More than half of the reviewed cases provide exclusive roads for buses. In Nagoya, they constructed the guided busway elevated above the road surface passing the Central Business District (CBD) to avoid traffic congestion[15]. This facility is an obvious physical attraction to passengers. However, it should be noticed that the cities of those systems have been designed, the space for the busway occurred at the initial urban planning stage, so that the bus operation would have no impact on other traffic.

2.3 Entire network perspective

The conditions supporting BRT system development from the entire network system perspective are as follows:

— Good route planning: Many cases design their routes passing through high population areas and incorporate the transfer points to other transit modes such as light or heavy rail to increase mobility within service areas and to increase usage share among various service modes. Most cases are located in suburban areas, or serve the areas between a Central Business District (CBD) and suburban neighborhoods, except Curitiba, Bogotá and Nagoya their network systems inside urban area.

— Providing network feeder: Half of the reviewed cases supply the feeder services to BRT systems. Three different types of feeder services are observed: downtown circulators, neighborhood collector services, and cross-town pick-up services from regional centers to BRT stops/stations. Most feeder services use minibuses with a seating capacity of twenty to thirty persons. In Montreal, a counter-flow BRT (R-BUS)[16] works as a feeder service to Montreal's subway system. This suggests that cross-network transfers among different transit systems may be a promising way to increase ridership and share benefits.

— Proving no competitive local services: Many of the reviewed cases do not provide the local bus services as BRT's competitor. If the riders cannot differentiate between advantages of the BRT and those of buses on local routes, the benefits of BRT may fall short.

2.4 Other conditions

Other conditions supporting BRT system development include:

— ITS application for operation: According to 10 operational BRT sites in the U.S. reviewed by the Federal Transit Administration (FTA)[17], all of them are applying some amount of ITS technologies. The number of ITS technologies being utilized ranges from 3 (Miami) and 10 (Boston) with an average of 5.5. The most popular ITS technologies include vehicle tracking, transit signal priority, electronic fare payment, and traveller information at station/stop. Traffic signal prioritization technologies are utilized as an active transit schedule adherence tool. Transit priority can be used to extend green time allowing behind-schedule buses to get back on schedule. Electronic fare payment is one of the popular technologies in BRT operations, which helps reduce dwell times and increases passenger convenience.

— Marketing strategies: Various marketing strategies are employed in all of the reviewed cases, such as 1) logo or theme representing unique services of BRT, 2) interesting architectural and artistic elements or materials complementing site location, stations, vehicles, and other BRT components harmonizing with the local environment, good examples include Curitiba's transparent cylinder, Brisbane's glass house, and Nagoya's Japanese-style cover and 3) good public relation campaigns, such as design campaigns on station shelters and vehicle appearance, summer camps, traffic conferences, and regular public input processes.

All of the above conditions advantageously influence higher riderships to the BRT routes. Consequently, BRT systems could have a positive cost recovery ratio, resulting in less subsidy or none at all from the government.

3. LIMITATIONS OF ASIAN DEVELOPING CITIES TO INTRODUCE A BRT SYSTEM

Most Asian developing cities have been developed under city plans based only land transport development and with a weakness of land use control which have caused many problems, including urban sprawl, severe traffic congestion, and air/noise pollution, etc. These problems subsequently become obstructions to BRT system implementation. Mainly, the limiting conditions to system implementation in these cities are as follows.

3.1 Insufficient demand for BRT system

Urban sprawl is often one characteristic of fast growing cities in Asian developing countries. With a lack of effective planning and land use control, the urban sprawl in these cities has grown continuously and uncontrollably for a long period. For instance, a previous study[18] discovered that evidently, the urban sprawl of Bangkok has grown more rapidly and continuously than Tokyo during the period of 1965-1985, which is a result of low population density spreading over the entire city. As a result, the corridor with high demand for supporting BRT development is much more difficult to be identified.

3.2 Difficulties in operation of BRT system

With poor initial city planning, the city plans did not incorporate transit systems into the urban street network, resulting in difficulties during the attempt of obtaining exclusive lane integration. Many roads are narrow or have only a few existing lanes. Moreover, they are critically congested, especially during peak hours. Thus, it really requires a good plan to establish the busway for BRT system, especially in constructing the busway on existing road surfaces. In some cases, an elevated busway along the critical congested sections may be needed. The installation of the Transit Signal Priority system at intersections is also another issue requiring a good system design. In case where a BRT corridor is designed to pass a major intersection with high traffic volumes, a Transit Signal Priority system would be designed to give priority to the bus, and to simultaneously minimize negative impacts to traffic from other approaches, especially from cross-street traffic. At intersections with small delay, this signal priority system may not be necessary. However, for successful BRT system implementation, detailed planning of the BRT functional operation and its impacts on other traffic are necessary. One potentially good tool to achieve this is a micro-simulation modelling application, an interesting topic for further research.

3.3 Insufficiency of introduction of BRT system to the public

In most Asian developing cites, the BRT system is considered an innovative transit system. According to the field interview, people in Bangkok still do not understand clearly the concepts and features of the BRT system; they are unable to differentiate between BRT system and conventional bus systems. Hence, the BRT system still seems unattractive to the majority, especially since its development requires turning an existing lane into an exclusive bus lane, some people (particularly, ones with private vehicles) have negative attitudes for the fact that it may cause more congestion along the BRT corridor.

Comparing between Asian developing cities and the cities with successful BRT operation, the factors that might decelerate their BRT development are; 1) Land use patterns: most Asian developing cities possesses urban sprawl, resulting in low population density spreading over an entire city area; 2) Existing city road networks: there is no space available for further transit line development and there is critical traffic congestion. The BRT system alone is inadequate and almost impossible to implement successfully; appropriate strategies to support BRT system development are necessary.

4. STRATEGIC PLANS TOWARDS BRT SYSTEM IMPLEMENTATION IN ASIAN DEVELOPING CITIES

Developing cities in Asia have recently realized the importance of land use control, by starting to enforce the land use regulation, allocation, and land use development policy (TOD, for example). However, it is rather difficult to be applied to cities where their urban structures have already been settled for a long period; Reallocation of land use activities on some parts of the corridor could be costly and take a lot of time. Rather than applying only the concept of land use control[19], this study instead proposes potential strategies that adopt advantages of the unique characteristics of Asian developing cities, and additional strategies that alleviate the limiting conditions of these cities to successful BRT implementation/development.

4.1 Providing good organizing feeder and parking facilities

The paratransit is a flexible and widely used transportation mode in Asian developing cities. Several types of paratransit in this region include Jeepny in Manila; Bemo, Opelet, and Mikroket in Jakarta; Hired Motorcycle, Song Thaew, and Siro Lek in Bangkok. The paratransit usually provides a service along local streets that connect residential areas to main streets with public transit services. This paratransit can penetrate through local streets that often are too narrow and long to fit larger public modes, e.g., bus. However, existing paratransit systems are not well established and organized for easy incorporation with the transits. Therefore, this study proposed to apply the paratransit as being a feeder of BRT with a well integrated design plan. Its route services demands from urban sprawl to the stations along BRT corridors. The integrating of BRT and paratransit, such as facilities and fare system integration would be established. A well-designed BRT with paratransit feeder integration would yield significant impact in terms of getting people out of their cars and onto public transit. Feeder connections would not only increase BRT capacity, but also improve the accessibility of communities around BRT stations. Figure 1 demonstrates the system integration design of BRT and paratransit feeder. At BRT station, the small-size Terminal & Parking facilities are provided. The terminal for paratransit system would be established there as a starting point of route service among small connectors. In addition, long-term parking lots would be provided for small vehicles, e.g., motorcycles and bicycles. The temporary parking area would be provided for temporary parking vehicles, e.g. taxi, to pick up/drop off the BRT passengers. At the end of the BRT corridor/high demand service stations, Park & Ride (P&R) facilities would be provided for private car users to park their cars and transfer to BRT system for access to the CBD.

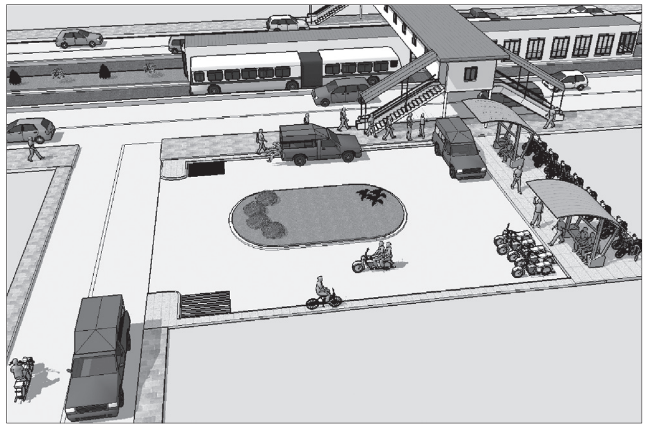


Fig. 1 Paratransit system feeding to BRT system by serving passengers from local streets to BRT stations

The entire integration system of applying proposed strategies (paratransit feeder and P&R facility) with high density land use allocation along BRT corridor is demonstrated in Figure 2. It is apparent from the figure that BRT plays an important role as the rapid mass transit feeder, serving passengers from suburban residential areas to the business area in the CBD. An alignment of BRT corridor is established to connect the CBD and the satellite city in a suburban area. At the CBD side, it connects to the network of mass rapid transit service in the CBD. Along the

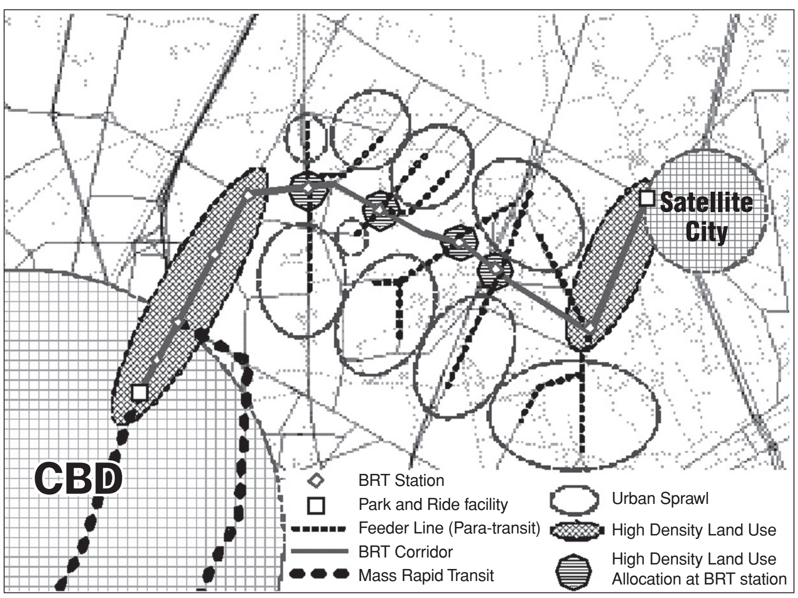


Fig. 2 BRT integrating with paratransit feeder, high density land use allocation and P&R facility at the end of/along the BRT corridor

BRT corridor, sections with low density land use activities and urban sprawl would require the application of strategies to supply higher demand at BRT stations and along the corridor. These include paratransit feeder and high density land use allocation that modifies land use regulation to promote commercial and residential development within walking distance and to establish cut-through paths linking cul-de-sacs, so bicyclists and pedestrians may have direct access to stations for integrating and promoting Non-Motorized Transportation (NMT)[20] with BRT. The P&R facilities would be provided at the end of the BRT corridor for private-car users to park their vehicles and transfer to BRT system.

4.2 Decreasing number of local buses parallel/adjacent to BRT corridor

In urban networks of Asian developing cities, their roads are mostly congested, especially during peak hours. In establishing a cost-effective busway for the BRT, one lane of existing road being planned for BRT corridor would generally be dedicated for an exclusive bus lane. As a result, the decrease of existing road capacity would cause more congestion along/adjacent to the BRT corridor. Moreover, the operation events of existing local bus routes, such as stopping at the bus stop, would cause more interruption to the flow of mixed traffic. However, it is impractical to remove all existing local bus routes along the BRT corridor, as the BRT service would most-likely have a "skip stop" type of design to help make the BRT travel time more competitive with auto travel. As such, the BRT bus-stop spacing would be too sparse to serve the dual purposes of BRT service and local bus service. Therefore, this study proposes that any existing local bus routes along/adjacent to the BRT corridor would remain unchanged without functioning as a BRT competitor. However, to attract more BRT riders and to improve the traffic condition along the BRT corridor, the frequency of existing local bus services should be decreased.

4.3 Introduction of an advanced signal priority system

An introduction of advanced signal priority system to the BRT operation is an approach to enhance the performance and reliability of a BRT system and to reduce the impacts of BRT operation on other traffic. A good signal control design with an advance bus detection system could give priority to the bus approaching the intersection without delay. It could also minimize the increased delay of other traffic in all approaches due to bus priority operation.

4.4 Promoting BRT system to the public

A marketing strategy would be conducted to the public using various types of advertising distribution to introduce the concepts, advantages among other modes, and contributions of BRT system. Brochures, websites, advertisements, etc. can be published and distributed to the public, with an attractive logo and theme specially designed to represent the uniqueness of the BRT system appealing to travellers. One effective media to introduce the comprehensive concepts, features, and advantages of BRT system to the public is video clip generated by the simulation program. Once operated, the BRT system still requires continuous updating and repackaging of market strategies to ensure its continued consumption.

5. EVALUATION OF PROPOSED STRATEGIES

To evaluate proposed strategies, they are generally applied to a case study of selected BRT projects in Asian developing cities. Comparison between BRT projects with and without proposed strategies is made. The performance of each case is evaluated by measuring the impact on traffic conditions, representing as network performance, and measuring impact of air pollution, and the volume of air pollution emissions (NO, CO, and PM) of the entire network. The selected project for this study is phase 1 of the BRT project planned by BMA[21], consisting of two BRT corridors, North and South routes. They plan to establish a busway on the road surface by taking lanes from existing roads. The study area covers Bangkok Metropolitan Region and its vicinity provinces. The personal trip and model parameters are provided by the Bangkok Metropolitan Region - Extended City Model (BMR-ECM) in the project of Transport Data and Model Center 3 (TDMC3), Office of Transport and Traffic Policy and Planning (OTP)[22]. The model year is the year 2011 when the BRT project as well as the extension of blue line subway is expected to be operated. The BRT corridors, Rapid Mass Transit line, and road network in this study are illustrated in Figure 3.

5.1 Model methodology

This study has applied the demand forecasting model, the System for Traffic Demand Analysis (STRADA 3), and emission model, Japan Environmental Agency's model or JEA model, to evaluate the proposed strategies with the trip and model parameters from BMR-ECM model of TDMC3. The behavior of travellers riding the BRT system has been observed through a Stated Preference (SP) questionnaire survey in order to develop

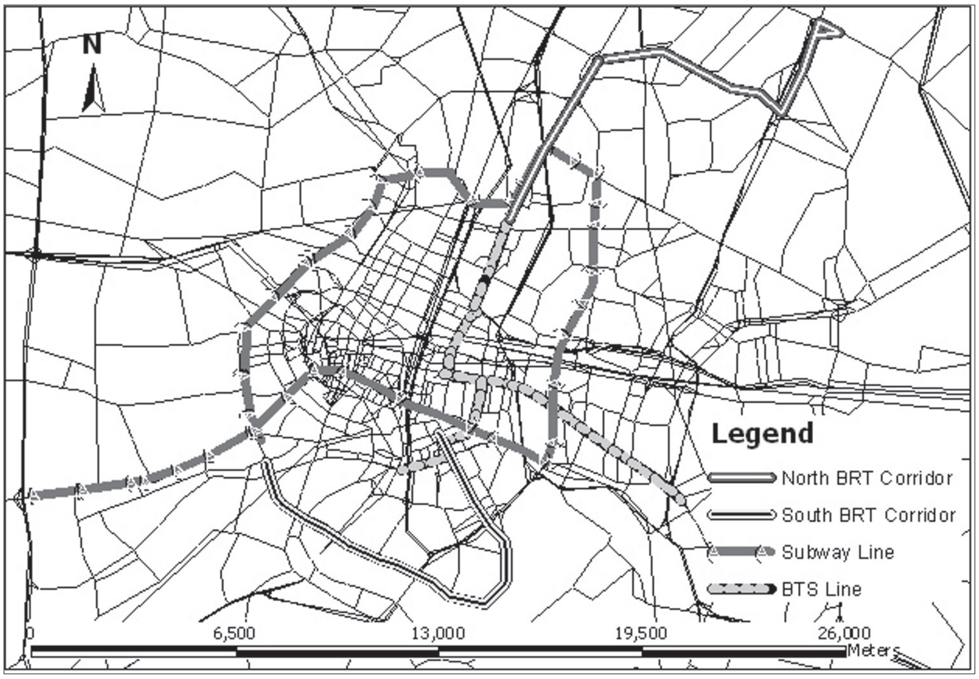


Fig. 3 BRT corridors, Mass Rapid Transit lines and road network in Bangkok Metropolitan Region and its vicinity provinces

mode choice model for future conditions. The model flowchart is illustrated in Figure 4. According to the flowchart, the personal trip distribution matrices categorized by household vehicle ownership and travel purpose are the input matrices of the mode split. Basically, the traffic assignment is modelled separately into road network and transit route assignments. However, since the existing normal bus transit route operates in a mixed traffic road network, these two models are therefore necessary to exchange the parameters with each other. The transit assignment needs the bus travel speed resulting from highway assignment as an input parameter of level of service of a normal bus. Vice versa, the highway assignment requires normal bus volume for initial assignment given by transit assignment. An output from the demand forecasting model is then used as an input parameter of the emission model to estimate emission volume of the entire network.

5.2 Scenario establishment

Regardless of various strategies proposed for BRT system development, the three most essential issues regarding transit demand supply to be evaluated are decrease of parallel and adjacent local buses, high density land use allocation, and paratransit feeder in areas along the BRT corridor. Based on existing plans of the BRT study project, this study further upgrades it as follows. The frequency of local bus services along and adjacent to BRT corridors is decreased in order to alleviate traffic congestion and supply more demand to the BRT system. Areas along two BRT corridors with low demands are enhanced through relocating high density land use activities and establishing paratransit system feeders along BRT corridors. Four scenario settings with various combinations of proposed strategies are summarized in Table 1.

5.3 Results and discussion

The operational performances from the demand forecasting model of each scenario, including total travel distance, total travel time, and average speed, resulted from the demand forecasting model are shown in Table 2. Table 3 shows the results of emission volumes (NOx, CO and PM) in each of the scenarios. The contour plots showing emission reduction of each pollution type, comparing scenarios 2, 3 and 4 to scenario 1, an existing condition, are illustrated in Figure 5.

From the operation performance results, it reveals that scenario 1, a typical BRT implementation without the proposed strategies, yields the lowest operation performance. After implementing scenario 2 (i.e., an integrated BRT system with two proposed strategies of a decrease in the number of local buses and high density land use allocation in the areas of BRT corridors) and

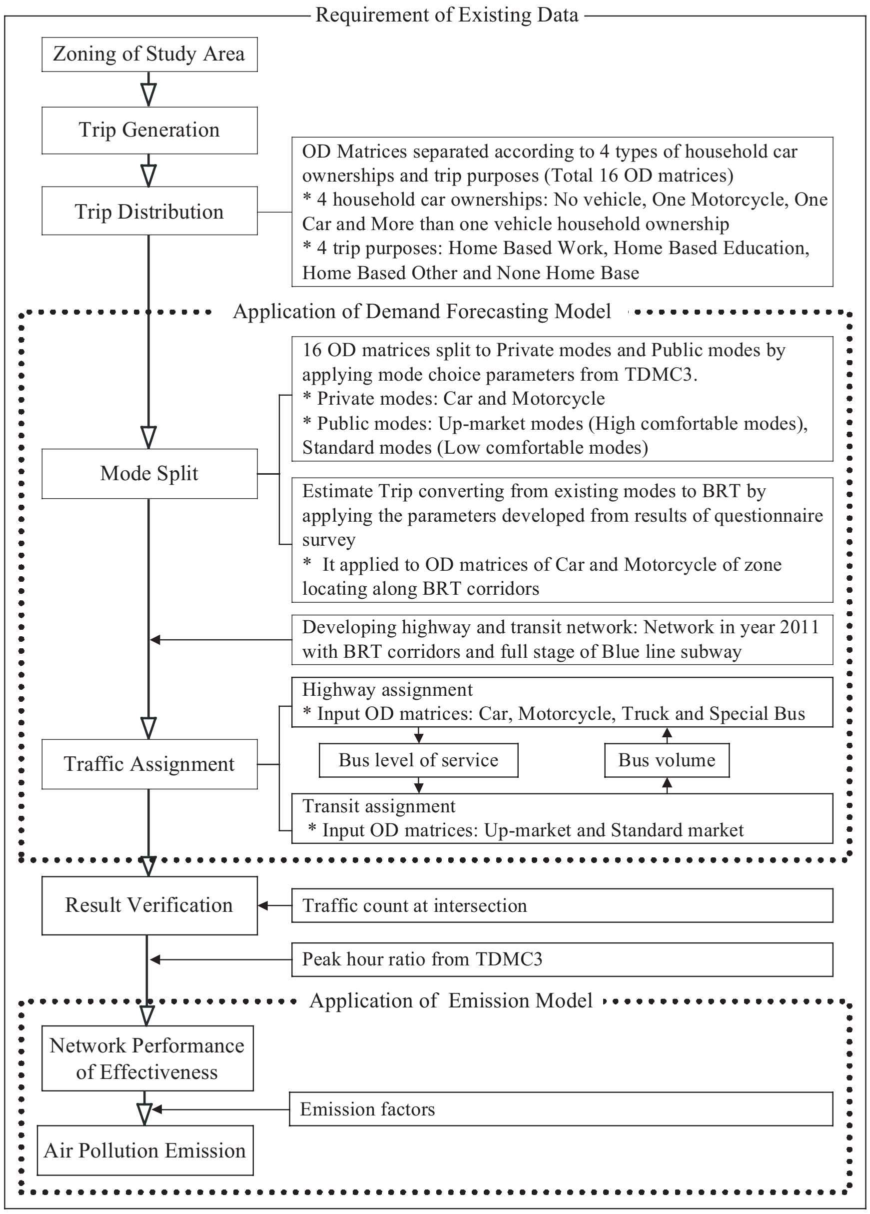


Fig. 4 Model flowchart

scenario 3 (i.e., an integrated BRT system with two proposed strategies of a decrease in the number of local buses and a paratransit feeder in the areas of BRT corridors), their network system performances are improved. Nevertheless, after implementing scenario 4, an integrated BRT system with all three proposed strategies, the network system gives the highest performances. These results are reasonable since a decrease in the number of local buses in areas of BRT corridors is expected to improve traffic conditions in areas of the BRT corridor while some local bus users are attracted to switch to use the BRT system.

Table 1 Scenarios settings of the BRT system development

Scenarios	Decreasing Number of Local Bus Parallel and Adjacent to BRT Corridors	High Land Use Density Allocation along BRT Corridors	Paratransit System Feeder along BRT Corridors
1	-	-	-
2	○	○	-
3	○	-	○
4	○	○	○

Table 2 Performance of effectiveness of each scenario

Performance of Effectiveness	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total Travel Distance (vehicle-km)	248,138,431	247,161,681	247,169,337	246,422,508
Total Travel Time (vehicle-hr)	16,281,079	16,205,979	16,208,142	16,053,110
Average Speed (km/h)	15.2	15.3	15.3	15.4

Table 3 Emission volume from transport sector

Air pollution	Emission Volume (kg/day)		
	NOx	CO	PM
Scenario 1	293,770	1,012,925	12,419
Scenario 2	292,579	1,009,873	12,364
Scenario 3	292,627	1,010,061	12,366
Scenario 4	292,554	1,008,833	12,358
Scenario 1 - Scenario 2	1,191	3,052	55
Scenario 1 - Scenario 3	1,143	2,864	53
Scenario 1 - Scenario 4	1,216	4,092	61

The application of high density land use allocation could increase trip generation, as well as the number of choices for riders along BRT corridors. The application of paratransit system feeder along BRT corridors could increase BRT users by improving accessibility and service area extension of BRT system.

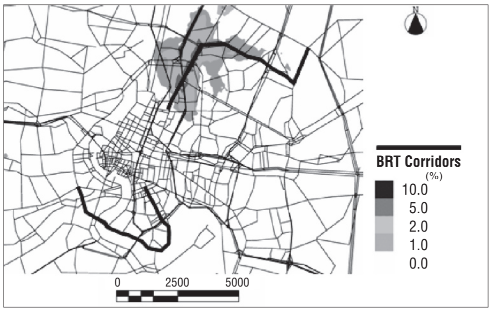
According to the resultant air pollution emissions of the entire network, it reveals that the improvement is correlated to the road network performance. After implementing scenarios 2, 3, and 4, the network systems release a lower amount of emission volumes than scenario 1, especially scenario 4 releases the lowest volumes of emission. These improvements could be explained as a decrease in the number of local buses in areas of BRT corridors that could directly reduce the emission from the reduced vehicles. The application of high density land use allocation along BRT corridors increases and attracts more BRT travellers; BRT system consumes cleaner fuel, thus emitting lower air pollution than ordinary buses and private cars. With a paratransit system feeder that increases accessibility and extends the service area of the BRT system, the private car and ordinary bus users are attracted to switch to the BRT system, resulting in a decrease of emissions from private cars and ordinary buses.

From the contour plots of emission reduction comparing the four scenarios, the volumes of emission reduction are obviously decreased over the areas of the BRT corridor due to decreasing number of local buses and private modes.

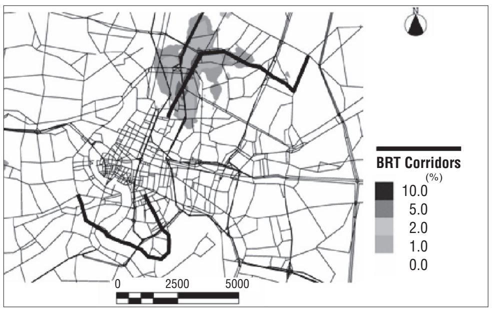
From the results of this study, it implies that all proposed strategies, scenarios 2, 3 and 4, do improve the BRT performance. The proposed strategy of paratransit feeder, Scenario 3, has an efficiency to improve network performance similar to the high land use density allocation, Scenario 2. As integration of all strategies, Scenario 4, it achieves the greatest improvement.

6. CONCLUSIONS AND RECOMMENDATIONS

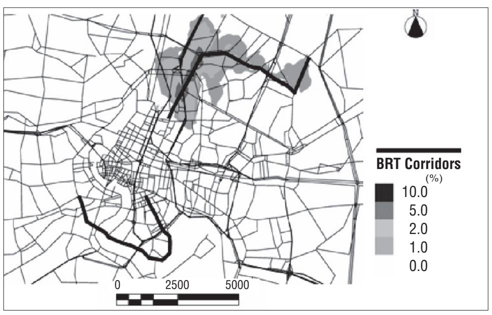
This study proposes several strategies for successful BRT system implementation in Asian developing cities, by first determining crucial elements contributing to existing BRT systems successes. It then identifies the limiting conditions of Asian developing cities for BRT development. The main difference is that most Asian developing city structures have been solely developed under a road transport city plan and weakness of land use control that gives rise to various problems of poor urban development patterns, low density urban sprawls, haul line and space deficiency to establish transit corridors, and traffic congestion. These findings have motivated several strategies to address the limitation and to enhance the development of BRT system in these cities. This study mainly focused on the strategies for supply demand to BRT system through formally proposing their concepts and later evaluating their performances. Rather than general strategies for Transit Demand Management (High density land use allocation, park and ride facilities, etc.), two strategies of well-integrated paratransit as a feeder to the BRT and a decrease in the number of local buses in the areas of BRT corridors are proposed. The evaluation reveals that paratransit system feeder and other strategies proposed could enhance the BRT system's performance by improving traffic network conditions and



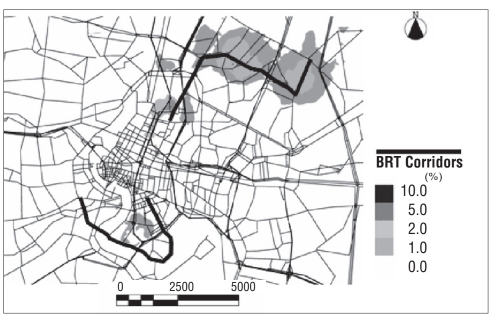
(A) Emission reduction of NOx (Scenario 1 - Scenario 2)



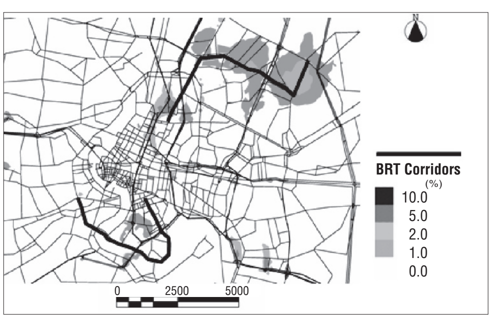
(B) Emission reduction of NOx (Scenario 1 - Scenario 3)



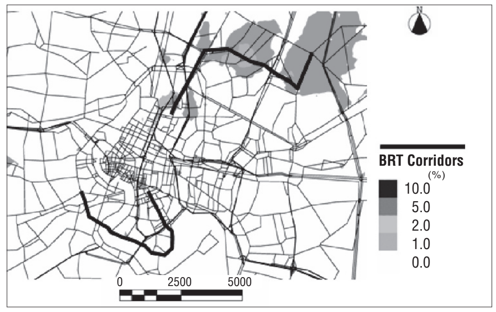
(C) Emission reduction of NOx (Scenario 1 - Scenario 4)



(D) Emission reduction of CO (Scenario 1 - Scenario 2)

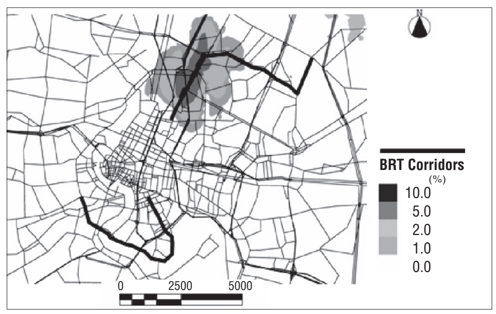


(E) Emission reduction of CO (Scenario 1 - Scenario 3)

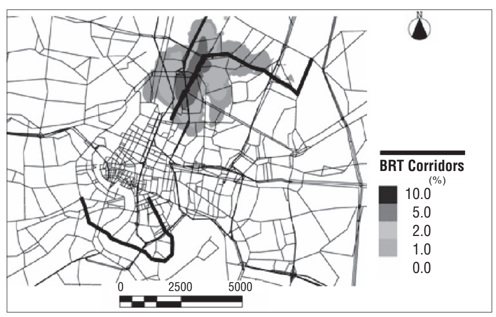


(F) Emission reduction of CO (Scenario 1 - Scenario 4)

(G) Emission reduction of PM (Scenario 1 - Scenario 2)



(H) Emission reduction of PM (Scenario 1 - Scenario 3)



(I) Emission reduction of PM (Scenario 1 - Scenario 4)

Fig. 5 Contour of emission reduction of each air pollutant

air pollution emissions. Therefore, this study would be further extended to include strategy recommendations to enhance the sustainable development of BRT in Asian developing cities.

Other issues should either be considered carefully for BRT development in Asian developing cities, or should be future works including: 1) Physical road constraint: the road spaces for busway construction should be carefully taken into consideration. The previous feasibility study of BRT system implementation in Hanoi concluded that the BRT system is not feasible due to a limitation in existing road space; 2) Institutional disagreements among authorities concerning BRT operation: the BRT project in Thailand appears to have an unclear problem between the BRT project planning authority and other concerned authorities since the local bus authorities along BRT corridors prefer not to reroute their services; 3) Negative impacts of BRT operation: in Thailand's BRT project, the traffic police authority is reluctant to donate existing lanes for exclusive bus lane construction since they are afraid that it will cause even more critical traffic congestion than the current situation. It is suggested that a further feasibility study at the micro level is necessary to evaluate the BRT system operation impact to other traffic; 4) Including more indicators for evaluation of performance of proposed strategies: the evaluation analysis of proposed strategies should expand to include more indicators such as economic indicators, e.g. Benefit over Cost ratio; 5) Long-term planning: in the future, the full stage plan of mass transit system network in these developing cities will be completed, it means that the network of mass transit system will cover the entire city (in this study, mass transit network of cased study covering only some parts of CBD). Consequently, the travel behavior of mass transit users, including BRT users would be changed from this study. Therefore, further studies of BRT development in full stage of entire network system should be conducted.

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