

Cost-Benefit Analysis for the Introduction of a Bus Rapid Transit System in Yangon, Myanmar

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Abstract. This paper analyzes the feasibility of introducing a bus rapid transit (BRT) system and the restructuring of the bus route network to improve the performance of the local bus service in Yangon, Myanmar. First, we summarize the characteristics of the current urban bus service in Yangon. We point out that the point-to-point bus route network results in many overlapping routes along main roads and this leads to serious traffic congestion. Then, we examine the feasibility of two policy options. The first case (Case 1) introduces a new BRT line to the existing bus network; while the second case (Case 2) restructures the bus route network whilst introducing a new BRT line. Five types of BRT fares are considered for each case. To evaluate these policy options, a travel demand forecast system, including the estimation of an origin-destination table and a bus route-choice model, is developed. The results of the evaluation show that Case 1-400, in which a new BRT with a flat fare of 400 Kyats, introduced to the existing bus route network offers the most desirable outcome.

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INTRODUCTION

Yangon is the most important commercial center in Myanmar with about 4.1 million people in an area 598.76 km² (1). There are four main types of transportation available in Yangon: private car, rail, taxi, and bus. The vast majority of urban transportation in Yangon relies on bus transportation. According to Zhang et al. (2), the modal share of bus transportation in Yangon is 84%. This stems from the difficulties associated with car ownership, the low quality of the rail service, and regulation of motorbikes and the para-transit service in the central business district. However, the performance of the bus service including its speed, reliability, capacity, and image is poor in the city. The existing buses run at low speeds, mainly due to poor vehicle performance. The service is not punctual because of serious traffic congestion. The capacity of each vehicle is limited as the majority of buses in Yangon are truck buses. Furthermore, the vehicles are often old and this makes for a poor public transportation image. It is imperative that the quality of the bus service be improved.

This paper analyzes the feasibility of introducing a bus rapid transit system into the bus transportation market and the restructuring of the bus route network to improve the performance of the local bus service in Yangon. The paper is structured as follows. The next section summarizes the characteristics of the bus transportation service in Yangon. Then, section 3 presents the policy options for improving the problems associated with the local bus service. Section 4 shows the methods to be used in the evaluation analysis. This includes a travel demand forecast and a cost-benefit analysis. The evaluation results are discussed in Section 5. Finally, the achievements are summarized and outstanding issues are presented.

URBAN BUS SERVICE IN YANGON

Kato et al. (3) showed that there are the two types of local bus services in Yangon: the bus service provided by bus companies and the bus service controlled by the bus control committees (BCCs). The bus companies are large-scale, private bus operators who own the vehicles, hire the drivers/conductors, and operate the urban bus service in Yangon. Two bus companies now provide services in Yangon: the Golden City Link Co. (GCL) and the Union of Myanmar Economic Holdings Limited (UMEHL). The BCCs are nonprofit organizations controlling small-scale, individual bus owners. Individuals own the buses and lease them to the drivers and conductors. The individual bus owners must belong to one of the BCCs. There are a number of individual bus owners in Yangon.

According to our observations and interviews with local people, the buses can be categorized into six types according to their function, design, and capacity: city bus (air-conditioned); city bus (non-air-conditioned); mini bus; Dyna/Canter; Hilux; and others. Dyna/Canter and Hilux are trucks that have been redesigned for passenger-use by the addition of a roof and seats. They are widely referred to as a “truck bus” by the locals. The majority of buses in operation are truck buses. The vehicles controlled by the BCCs are mainly small-scale buses, including the Mini bus, Dyna/Canter, and Hilux. There are 15 organizations operating or controlling the local bus market in Yangon. In total, 283 routes are operated in the city. TABLE 1 shows the distribution of bus routes in the city across the various organizations. The total number of vehicles in operation on a daily basis is 5,039.

TABLE 1 Organizations operating bus services in Yangon (2008)

| Organization | No. of lines | Daily Average | | |
|-------------------|--------------|-----------------|--------------|----------------|
| | | Running vehicle | Trip | Passenger |
| YDBCC | 127 | 1846 | 16310 | 1993013 |
| Eastern District | 7 | 64 | 324 | 13629 |
| Western District | 42 | 984 | 6133 | 361879 |
| Northern District | 22 | 552 | 3048 | 113800 |
| Southern District | 8 | 504 | 4032 | 362880 |
| YCDC | 1 | 4 | 12 | 1284 |
| Pyi Khaing Phyo | 27 | 233 | 1864 | 167760 |
| Kandayawadi | 3 | 45 | 283 | 22500 |
| Than Myan Thu | 16 | 376 | 1407 | 101871 |
| Parami | 20 | 320 | 3279 | 107470 |
| Shwe Innwa | 3 | 25 | 90 | 27000 |
| Golden Guest 1,2 | 2 | 65 | 350 | 17000 |
| Shwe Myin Pyan | 1 | 12 | 96 | 8640 |
| Myanma Thar | 3 | 4 | 12 | 3000 |
| GEC | 1 | 5 | 20 | 4000 |
| Total | 283 | 5039 | 37260 | 3305726 |

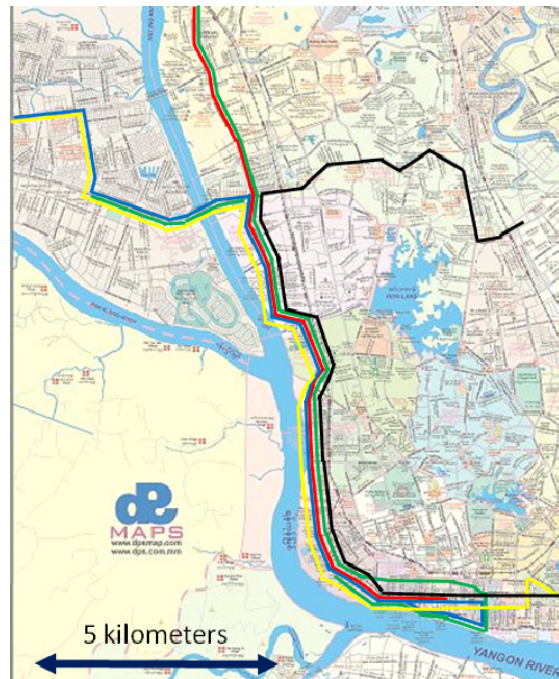


FIGURE 1 Typical bus routes in the south-western part of Yangon City

The total daily number of bus passenger trips is 3,305,726. The size of the organizations ranges from the Yangon Development Bus Control Committee (YDBCC) controlling 2,470 buses to the Shwe Innwa controlling 41 buses.

The majority of bus routes run directly between suburban areas and the central business district, along the main roads. The bus network in Yangon is characterized as a “point-to-point” network. The point-to-point bus network in Yangon results in the overlapping of many bus routes along the major roads connecting the suburban areas with the central business district. An example of the bus routes is shown in FIGURE 1 and the fact that many bus routes overlap along the same road is highlighted. Since a number of buses on various routes run along the same main roads, they increase the traffic flows, particularly at peak hours. This results in serious traffic congestion on the main roads at peak times. Furthermore, the point-to-point network results in excessive competition among bus drivers on the same roads. Although bus services are monitored by the BCC, the monitoring of one particular route is quite independent of the monitoring of another route. Therefore, bus drivers often race against one another to reach the next stop on the route, clearly raising safety issues. It is essential that the performance of bus services in Yangon needs to be improved.

IMPROVEMENT OF BUS NETWORK IN YANGON

Bus rapid transit

As Ernst (4) shows, many developing countries have common characteristics in terms of city structure and urban transportation: high population densities, a significant existing modal share for public bus transportation, and financial constraints providing a strong political impetus to reduce, eliminate, or prevent continuous subsidies for public transit operations. These issues are relevant to Yangon. The bus rapid transit (BRT) has been highlighted recently as a potential solution to these problems. 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 (5). BRT can reduce travel times, attract new riders, and induce transit-oriented development. It can be more cost-effective and provide greater operating flexibility than rail transit (6). The BRT system will typically cost four to 20 times less than a light rail transit (LRT) system and 10 to 100 times less than a metro system (7). Knowledge of the success of BRT throughout the world, along with the low cost and staged development possibilities has made BRT popular in developing countries (8).

Design of bus rapid transit in Yangon

We examine the feasibility of introducing a bus rapid transit (BRT) system in Yangon City. It is assumed that a new BRT line is introduced on one of the roads connecting Insein Garden and Kyone Gyi Road, as shown in FIGURE 2. The total length of the BRT line is 15.6 kilometers. The roads include the main road, which has six lanes. It is assumed that two lanes are converted to lanes exclusively for use by the BRT service. This enables the BRT vehicles to run faster than other buses because no other vehicles hamper the operation of the BRT. It is also assumed that new BRT vehicles with a higher capacity than city buses will be introduced. To simplify the fare transaction, a fixed fare system will be introduced. The service frequency is assumed to be almost the same as that for existing city-bus services.

The assumed details of the BRT design are as follows:

- Average speed: 28 km/h including the running time between stops and time spent at bus stops.
- BRT stops/terminals: six BRT stops including Insein Garden, Thamine Junction, Butar Yone, Hlaing Zay, Halpin, and Kyone Gyi.
- BRT capacity: a BRT vehicle has the capacity for 120 passengers.
- Fare system: a fixed-fare system.
- Service frequency: 20 services per hour (peak).
- BRT operator: a single bus company.
- Investment: stops/terminals, exclusive lanes, pedestrian access, parking facilities, etc.

Restructuring of the bus network

The bus route network must be restructured to solve the problems caused by the point-to-point network. As Vuchic (9) shows, bus services are improved if the trunk is upgraded to an independent rail or BRT service. In particular, a network that includes a trunk line with feeders can increase passenger numbers. It should be noted that services on separate rows, attractive stops, and steady headway are required to attract passengers because a network that includes a trunk line with feeders requires passengers to transfer at terminals. Then, we examine the impact of restructuring the bus network in Yangon. The case studies compare two options: BRT introduction without restructuring the bus network, and BRT introduction in conjunction with restructuring the bus network.

METHOD OF ANALYSIS

The cost-benefit analysis is applied to examining the feasibility of the BRT introduction. First, we forecast the demand for bus travel. The bus route demand is estimated with a bus-route choice model, after the bus-use origin-destination matrix is estimated. Next, the operating cost of the bus operators is estimated based on the cost data collected in our survey. Then, the cost of introducing the BRT is calculated on the basis of the experience of

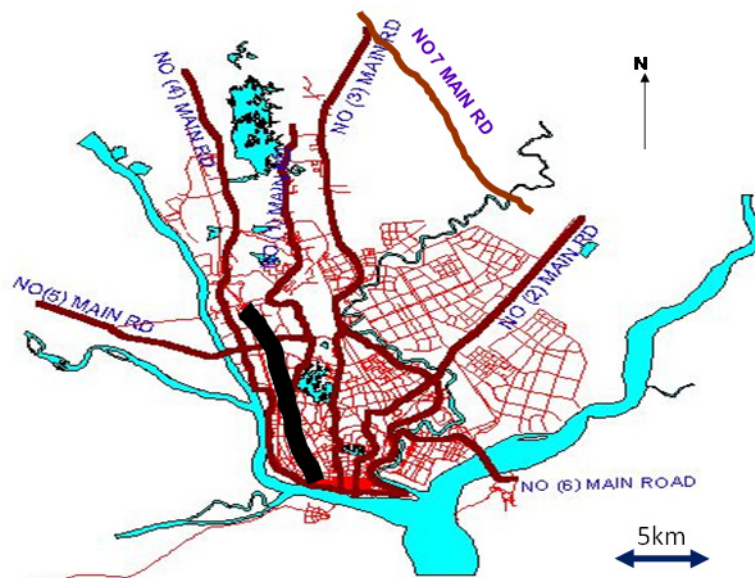


FIGURE 2 BRT routes examined in the study: denoted by the thick line on No.4 Main Road

other countries. Finally, the cost-benefit analysis is conducted.

Travel demand analysis

Zoning system

First, we define the 29 zones in the target area on the basis of township boundaries. Since the boundaries of some townships are much larger than in other zones, they are divided into two or more zones based on the road network. Then, the nodes in each zone are defined and are mainly located at major intersections in the corresponding zone. The defined zones are shown in FIGURE 3. Then, the bus transport network is defined in the target area on the basis of the above zones. Once the 29 zones are defined, the 29 nodes are connected by a bus transport network. The 42 links in the simplified network are defined based on the real road network in the target area.

Preparation of travel data in the network

First, the journey time of each link is defined on the basis of link length. Although the travel speed varies among links, we assume that the average travel speed during the morning is 20 km/hour in any link. This speed is estimated using the data collected from the bus travel survey. Next, we prepare data on the transfer time at each link. The transfer time is defined as the time it takes to walk from the place where a bus passenger gets off one bus to the place where the passenger boards the next bus. On the basis of the surveyor's observations, we estimate that the transfer time is 5 minutes at any stop.

Data collection for bus-use travel demand and operator's cost structure

First, the research team conducted local interview surveys from September 15 to 23, 2008 and November 9 to 21, 2008, relating to local bus operations in Yangon. We prepared an interview sheet for the survey. The interview sheet requested the bus operators answer questions about the current situation, including basic information about the organization, labor system, buses, operating facilities, routes, service frequency, fuel, travel time, and cost. Two bus companies, four bus control committees, 22 individual bus owners, and local bus authorities were interviewed. The details of the survey are shown in Kato et al. (10).

Next, we conducted two types of local survey into urban bus-user's behavior. One was an Origin-Destination (OD) survey, which collected data on sample-based individual origins and destinations in Yangon City. The other was a bus travel survey, which collected data on sample-based route-choice in Yangon. The data collected in the OD survey will be aggregated to estimate the zone-based OD travel patterns, whereas the data collected in the bus travel survey will be used to estimate a discrete bus route-choice model. The OD survey was implemented from November 9 to 21, 2008, with the bus travel survey conducted from November 14 to 19, 2008.

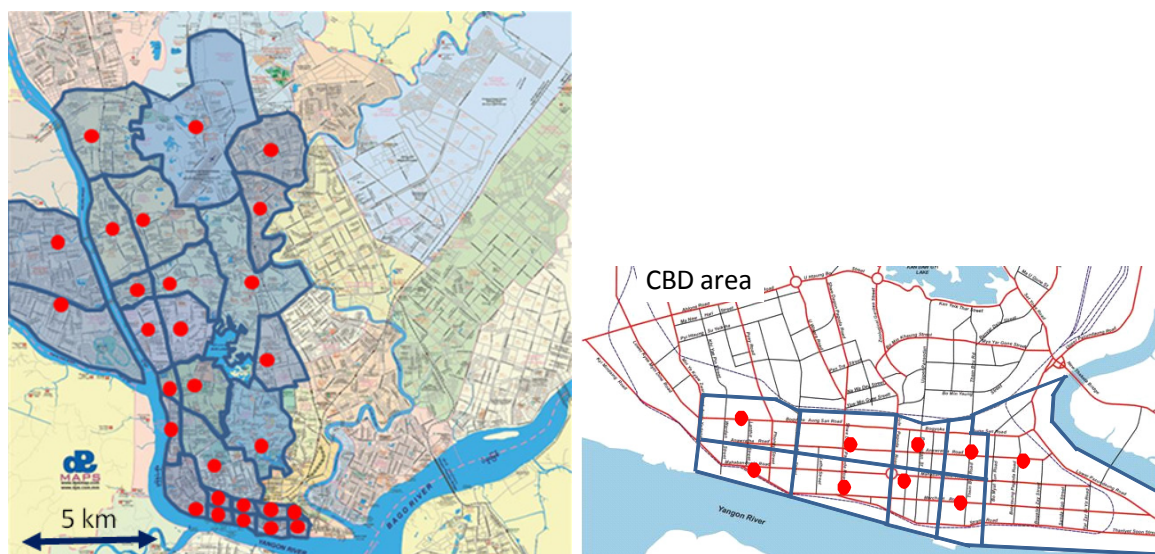


FIGURE 3 Zoning system used in the analysis

Finally, data from 2,524 individuals was collected in the OD survey and from 2,372 individuals in the bus travel survey. Further detail of these surveys is shown in Kato et al. (10).

Estimation of the origin-destination table

We estimate the OD table for bus users. As no data regarding the OD table was available, the data was estimated using socio-demographic data and the OD survey originally conducted by our study team.

Estimation of zone-based trip production

First, we prepared zone-based socio-demographic data, including data on the population by gender and the number of households. This statistical data was collected from the Government. Unfortunately, data on zone-based number of employees was not available. Second, we estimated the sample-based worker's rate and the sample-based modal share of bus use by commuters. According to the data collected in the OD survey, the total number of people in households to which the respondents belong is 10,457, of which the total number of workers was 6,095. Thus, workers account for 58 percent of each household. Next, according to the data collected in the OD survey, the total number of household commuters using buses was 5,172. Thus, the average modal share of bus use among workers was 0.845. Third, we estimated the sample-based working rate in days. The average commuting rate was 5.99 days. Then, we estimated the population distribution in some townships given that two or more zones are sometimes included in a township. We simply assumed that population density is constant in a township. This means the zonal population is in proportion to the zonal area in the corresponding township.

Finally, we calculated the trip production from each zone using the following formula:

$$TP_{i|t} = \sum_g PO_t^g \cdot WK \cdot BS \cdot WR^g \cdot PD_{i|t} \quad (1)$$

where $TP_{i|t}$: the number of trips generated from zone i in township t ; PO_t^g : population of township t by gender in township g ; WK : average worker's rate in the household; BS : average modal share of bus use among workers; WR^g : working rate by gender g ; and $PD_{i|t}$: the zonal population rate of zone i belonging to township t .

Estimation of OD table

We estimate the OD matrix on the basis of the estimated trip production. First, we estimate the sample-based proportion of trips from an origin to a destination for each zone. Then, we simply multiply the sample-based proportion of trips by the zone-based trip production. This is summarized as follows:

$$T_{od} = r_{od} \cdot TP_o \quad (2)$$

where T_{od} denotes the number of trips from origin zone o to destination zone d ; r_{od} , the sample-based proportion of trips from origin zone o to destination zone d ; and TP_o , the number of trips generated from zone o . The OD matrix shows the daily demand from one zone to another. Note that the OD matrix only includes commuters who use buses. We assume that this OD matrix is constant during the project period.

Bus route demand forecast

We use a bus route choice model for forecasting bus route demand. The route choice model of bus users in Yangon was estimated by Kato et al (10). This model outputs the probability of choosing the bus route for a given OD pair. The explanatory variables in the model are travel time, travel cost, and the type of bus vehicle. Our analysis uses the estimated multinomial logit (MNL) model. The probability of choosing the r th route is chosen from zone o to d for individual n is derived as follows:

$$p_{od,r}^n = \frac{\exp(V_{od,r}^n)}{\sum_{r' \in R_{od}^n} \exp(V_{od,r'}^n)} \quad (3)$$

where $p_{od,r}^n$ denotes the probability of choosing the r th route to move from zone o to d for individual n , and $V_{od,r}^n$ is the universal component of the indirect utility of an individual n when the r th route is chosen from zone o to d . Kato (10) proposed the following estimated utility function:

$$V_{od,r}^n = -0.0547TT_{od,r}^n - 0.0054TC_{od,r}^n + 0.5899BT_{od,r}^n \quad (4)$$

where $TT_{od,r}^n$ denotes the total travel time for the r th route chosen to move from zone o to d for individual n ; $TC_{od,r}^n$, the total travel cost; and $BT_{od,r}^n$, the dummy for bus type. The total travel time includes the in-vehicle riding time, waiting time at the stops, transfer time at the stops, and the access/egress time to and from the stops. The dummy for bus type is defined as 1 if the bus is a city bus, and 0 if it is not.

If the total volume of traffic flow from zone o to d is given as T_{od} , the expected volume of traffic flow when the r th route is chosen to transfer from zone o to d $t_{od,r}$ is expressed as follows:

$$\begin{aligned} E[t_{od,r}] &= T_{od} \cdot p_{od,r} \\ &= T_{od} \cdot \frac{\exp(V_{od,r})}{\sum_{r' \in R_{od}} \exp(V_{od,r'})} \end{aligned} \quad (5)$$

where $p_{od,r}$ denotes the probability of choosing the r th route to move from zone o to d . Note we assume a representative individual for each OD pair in the above aggregation process.

Evaluation of the policy options

The policy options were evaluated considering the demand for the BRT, the profit for the BRT operators, the users' benefit, the supplier's benefit, the social benefits, and a cost-benefit analysis. To calculate the operating costs for the BRT and the bus operators, we used the results from the cost structure analysis shown by Kato (10). The cost functions incorporating the vehicle km and the fleet size are used for calculating the operating cost. Kato (10) proposed the following cost functions:

$$OC_{bc} = 47.5VKM + 3504400 \quad (6)$$

$$OC_{cb} = 165.6VKM + 35335.1NV \quad (7)$$

$$OC_{tb} = 136.4VKM + 7478.9NV \quad (8)$$

where OC_{bc} denotes the operating cost of a bus company (Kyats/day); OC_{cb} , the operating cost to an individual bus operator owning a city-bus (Kyats/day); OC_{tb} , the operating cost to an individual bus operator owning a truck-bus (Kyats/day); VKM , vehicle kilometers; and NV is the fleet size.

The revenue from the bus and BRT operations is simply assumed to stem from the fares paid by bus passengers. The fleet size on each route is also calculated based on the assumption that the bus operators will adjust their fleet size to satisfy demand. Assumptions regarding the types of vehicles used are assumed on the basis of the current situation. Then, the supplier benefits are defined as the total profit for all bus operators in the market.

The user benefit is calculated on the basis of consumer surplus theory. The consumer surplus of the representative bus user from zone o to d is formulated as:

$$CS_{od} = \frac{1}{\kappa_c} \ln \sum_{r' \in R_{od}^n} \exp(V_{od,r'}) \quad (9)$$

where κ_c is the coefficient for the travel cost in the utility function of the bus route-choice model (Williams, 11). Then, the user benefit is calculated as:

$$UB = \sum_{od} T_{od} \cdot (CS_{od}^1 - CS_{od}^0) = \frac{1}{\kappa_c} \left(\sum_{od} T_{od} \cdot \ln \sum_{r \in R_{od}^1} \exp(V_{od,r}^1) - \sum_{od} T_{od} \cdot \ln \sum_{r \in R_{od}^0} \exp(V_{od,r}^0) \right) \quad (10)$$

where CS_{od}^1 is the consumer surplus for the representative bus users travelling from zone o to d in policy option 1, and CS_{od}^0 is the consumer surplus in the do-nothing option.

The social benefit is defined as the sum of the user's benefit and the supplier's benefit. The cost-benefit analysis is applied on the basis of the social benefit and the investment cost. The lifetime of the project is assumed to be 15 years. The social discount rate is assumed to be 20 percent.

CASE STUDIES

Study cases

We examined two cases regarding policy options on the bus route network. The first case (Case 1) introduces a new BRT line on the existing bus network. This means that the existing bus routes remain even after the introduction of the new BRT line. The BRT operator must compete with the existing bus operators in Case 1. The second case (Case 2) restructures the bus route network whilst introducing the new BRT line. It is assumed that the bus routes are restructured into a trunk-and-feeder network. The feeder routes are categorized into five blocks, namely A, B, C, D, and E, based on their location. In Case 2, the BRT line adopts the role of the trunk line connecting the major bus terminals, while the feeder bus lines run between the bus stops and the bus terminals. The BRT operator can run a monopolistic business connecting the major bus terminals. Case 0 is defined as the do-nothing case. Evaluations were made by comparing Case 1 or Case 2 with Case 0. The bus route networks assumed in each case are depicted in FIGURE 4.

The following five levels of BRT fares were examined in each case: 300, 400, 500, 600, and 700 Kyats. It was assumed that the bus services provided by the existing bus operators in Case 1 have the same fare system and service frequency as the existing system. In Case 2, the fare system adopted was a distance-based system, but this was not adopted for the BRT line. The service frequency of the restructured feeder routes was defined based on expected demand.

Results of case studies

The evaluation results for the case studies are shown in TABLE 2, which include (i) the operational vehicles, annual revenue, annual cost and annual profit of non-BRT operators and the BRT operator, and (ii) the annual supplier's benefit, annual user's benefit, annual social benefit and total social benefit over 15 years.

First, the existing bus operators lose some revenue in Case 1. This is mainly because many bus passengers shift from the existing bus routes to the new BRT line. Revenue increases as the BRT fare increases simply because bus passengers choose the cheaper bus route. The number of operational buses and the operating costs are also reduced in Case 1. Consequently, existing bus operators do not experience a serious profit impact in Case 1.

Second, feeder operators earn more revenue in Case 2 than in Case 0. This is because bus passengers are forced to use the feeder services twice, for access and egress to/from the BRT terminals. As the fare system is distance-based with the initial fare for feeder service, the passengers must pay the initial fare twice. On the other hand, the feeder operators can also reduce their operating costs in Case 2. This reflects the reduction in vehicle kilometers because the feeder routes are shorter than the existing bus routes. Consequently, the feeder bus operators can earn a positive net profit in Case 2.

Third, in Case 1, the BRT operator earns the most when the BRT fare is set at 400 Kyats. If the fare is too low, revenue decreases although passenger numbers increase. If the fare is set at too high a level, revenue is adversely affected by declining passenger numbers. Operating costs are lower as the BRT fare increases because demand for the BRT decreases accordingly.

Fourth, in Case 2, the BRT operator earns positive net revenues when the BRT fare is set at 300, 400 or 500. This is because BRT passenger numbers are higher in Case 2 than in Case 1. In Case 2, the bus passengers have to use the BRT as no other bus routes connecting the suburb area with the central business district exist. Operating costs fall as the BRT fare rises. Consequently, the BRT operator earns positive net profits when the BRT fare is 300, 400 or 500.

Fifth, the supplier's benefit is positive in all cases. The case in which the supplier's benefit is highest is Case 2-300. However, the user's benefit is only positive in Cases 1-300 and 1-400. The user's benefit in Cases 1-500, 1-600, and 1-700 is negative because the BRT fare is expensive for bus users. The user's benefit in Case 2 is negative first because the journey time increases due to increased transfers, secondly because bus passengers have to pay more because of these multiple transfers, and thirdly, because the BRT fare is expensive for passengers.

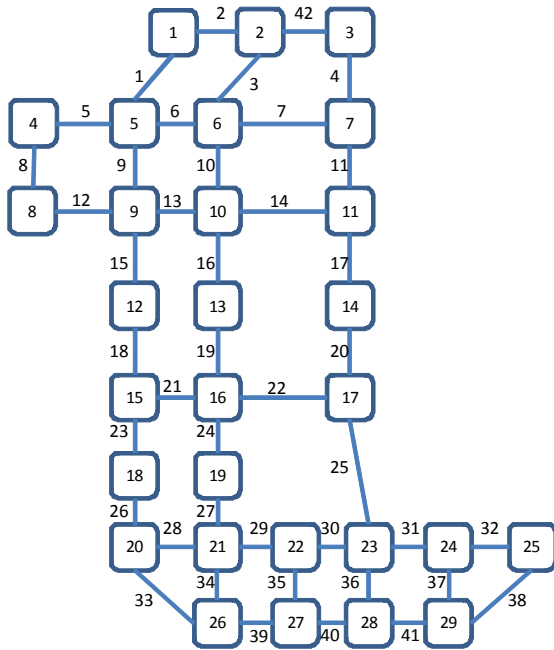


FIGURE 4a Simplified bus network

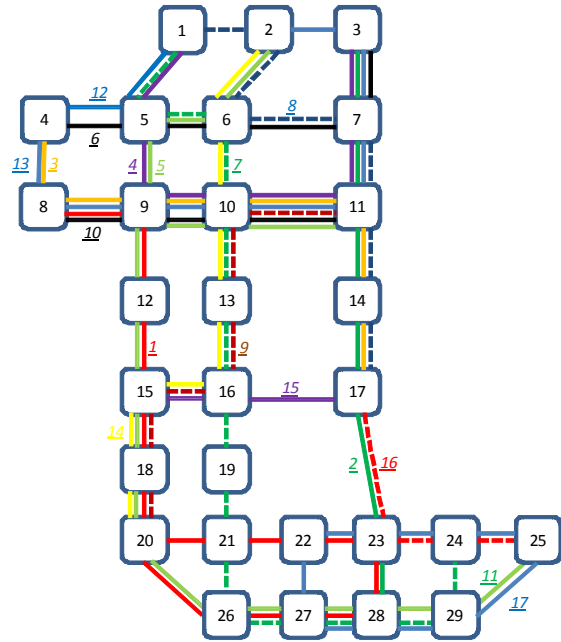


FIGURE 4b Bus route network (Case 0)

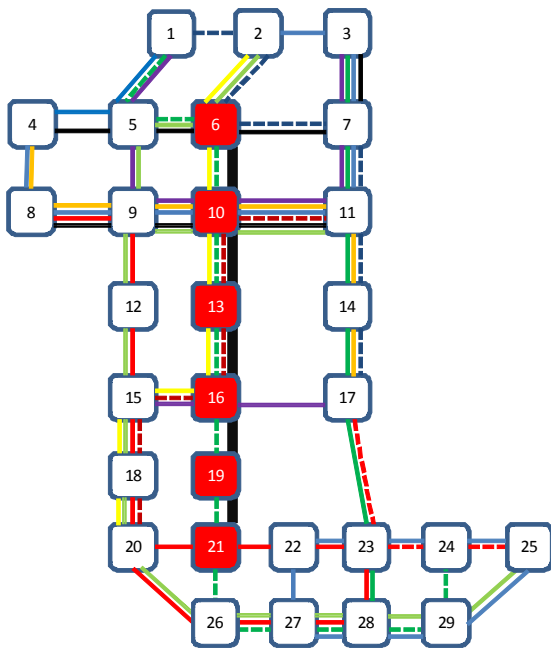


FIGURE 4c. Bus route network (Case 1)

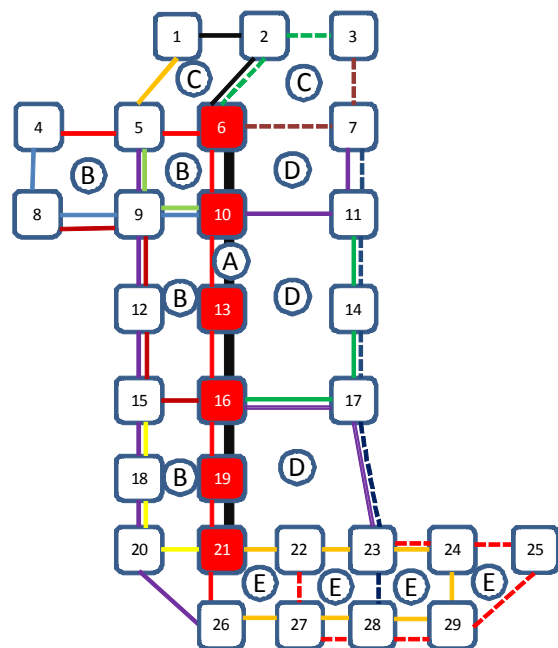


FIGURE 4d. Bus route network (Case 2)

Sixth, interestingly, the social benefit is positive in all cases. Case 2-300 offers the highest social benefit; followed by Case 1-300 and then Case 1-400.

Cost-benefit analysis

The investment cost assumed is based on previous experiences when the BRT was introduced to other low-income countries. We use the cost data from the experience of introducing the BRT system in Bogota (12). According to Hook (13), the cost per kilometer was US\$ 6.9 million in Bogota. This includes the costs for the studies and designs, exclusive routes, general traffic, public space, stations, pedestrian terminals, parking, properties, network services, maintenance and so on. Note that the cost of BRT introduction in other cities was

TABLE 2 Evaluation results of policy options

| <i>Non-BRT</i> | BRT fare | Operational vehicles | Annual revenue | Annual cost | Annual profit |
|----------------|----------|----------------------|--------------------|--------------------|----------------------------|
| | Kyats | Vehicles | Million Kyats/year | Million Kyats/year | Million Kyats/year |
| Case 0 | n.a. | 4626.3 | 103784.7 | 84639.4 | 19145.2 |
| Case 1-300 | 300 | 4207.8 | 96446.2 | 76982.6 | 19463.6 |
| Case 1-400 | 400 | 4275.0 | 97553.3 | 78212.8 | 19340.4 |
| Case 1-500 | 500 | 4386.9 | 99433.9 | 80260.1 | 19173.8 |
| Case 1-600 | 600 | 4467.1 | 100809.4 | 81726.7 | 19082.7 |
| Case 1-700 | 700 | 4520.8 | 101743.6 | 82709.2 | 19034.4 |
| Case 2-300 | 300 | 4074.1 | 113700.4 | 74536.3 | 39164.1 |
| Case 2-400 | 400 | 4224.2 | 116529.9 | 77284.1 | 39245.8 |
| Case 2-500 | 500 | 4343.5 | 118813.4 | 79466.3 | 39347.0 |
| Case 2-600 | 600 | 4430.6 | 120500.6 | 81059.5 | 39441.1 |
| Case 2-700 | 700 | 4489.7 | 121653.7 | 82140.4 | 39513.3 |
| <i>BRT</i> | BRT fare | Operational vehicles | Revenue | Cost | Profit |
| | Kyats | Vehicles | Million Kyats/year | Million Kyats/year | Million Kyats/year |
| Case 0 | n.a. | n.a. | n.a. | n.a. | n.a. |
| Case 1-300 | 300 | 93.7 | 39351.0 | 3016.2 | 36334.8 |
| Case 1-400 | 400 | 77.2 | 43867.2 | 2652.4 | 41214.8 |
| Case 1-500 | 500 | 52.9 | 37318.0 | 2538.4 | 34779.6 |
| Case 1-600 | 600 | 34.4 | 30064.3 | 2245.9 | 27818.4 |
| Case 1-700 | 700 | 22.6 | 23756.1 | 2133.8 | 21622.4 |
| Case 2-300 | 300 | 119.0 | 48225.6 | 3049.9 | 45175.7 |
| Case 2-400 | 400 | 84.6 | 45506.4 | 2722.7 | 42783.7 |
| Case 2-500 | 500 | 57.7 | 38929.8 | 2466.7 | 36463.2 |
| Case 2-600 | 600 | 38.2 | 31458.8 | 2281.8 | 29177.0 |
| Case 2-700 | 700 | 25.1 | 24858.4 | 2157.0 | 22701.3 |
| <i>Benefit</i> | BRT fare | Supplier's benefit | User's benefit | Social benefit | Social benefit in 15 years |
| | Kyats | Million Kyats/year | Million Kyats/year | Million Kyats/year | Million Kyats |
| Case 0 | n.a. | n.a. | n.a. | n.a. | n.a. |
| Case 1-300 | 300 | 36653.3 | 13998.3 | 50651.6 | 299719.0 |
| Case 1-400 | 400 | 41409.9 | 4643.4 | 46053.3 | 272850.0 |
| Case 1-500 | 500 | 34808.2 | -1892.1 | 32916.1 | 196083.0 |
| Case 1-600 | 600 | 27756.0 | -6329.1 | 21426.9 | 128945.0 |
| Case 1-700 | 700 | 21511.7 | -9313.3 | 12198.4 | 75018.3 |
| Case 2-300 | 300 | 65194.6 | -9202.3 | 55992.3 | 330928.0 |
| Case 2-400 | 400 | 62884.4 | -18951.1 | 43933.2 | 260461.0 |
| Case 2-500 | 500 | 56665.1 | -25816.3 | 30848.8 | 184002.0 |
| Case 2-600 | 600 | 49472.9 | -30504.4 | 18968.5 | 114579.0 |
| Case 2-700 | 700 | 43069.4 | -33665.7 | 9403.7 | 58687.7 |

cheaper than in Bogota. For example, the cost per kilometer of introducing BRT systems was US\$ 2.5 million in Curitiba, US\$ 1.2 million in Quito (Eco-Via Line) and US\$ 0.5 million in Taipei. However, the reasons why the cost in those cities was so cheap should be carefully examined. The results of the cost-benefit analysis are summarized in FIGURE 5. The cost-benefit ratio is more than one in Cases 1-300, 1-400, 1-500 and Cases 2-300, 2-400, and 2-500. The highest cost-benefit ratio is 1.479 in Case 1-300.

Discussions

First, the cost-benefit analysis shows that Cases 1-300, 1-400, 1-500, and Cases 2-300, 2-400, and 2-500 have cost-benefit ratios of more than one. This means that they are viable from the viewpoint of the socio-economic efficiency of the investment.

Second, TABLE 2 shows that the social benefit is positive in all cases. Case 2-300 offers the highest social benefit, followed by Case 1-300 and then Case 1-400. Case 2-300 offers the highest supplier's benefit although it imposes a negative user's benefit, mainly because of network restructuring. Although Case 2-300 is viable from the viewpoint of social benefits, it may be unacceptable from the user's viewpoint. Case 1-300 and

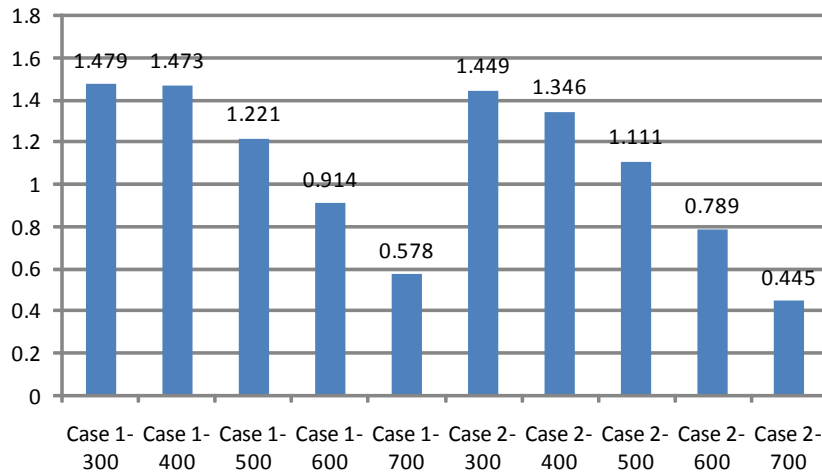


FIGURE 5 Cost-benefit ratios for each case

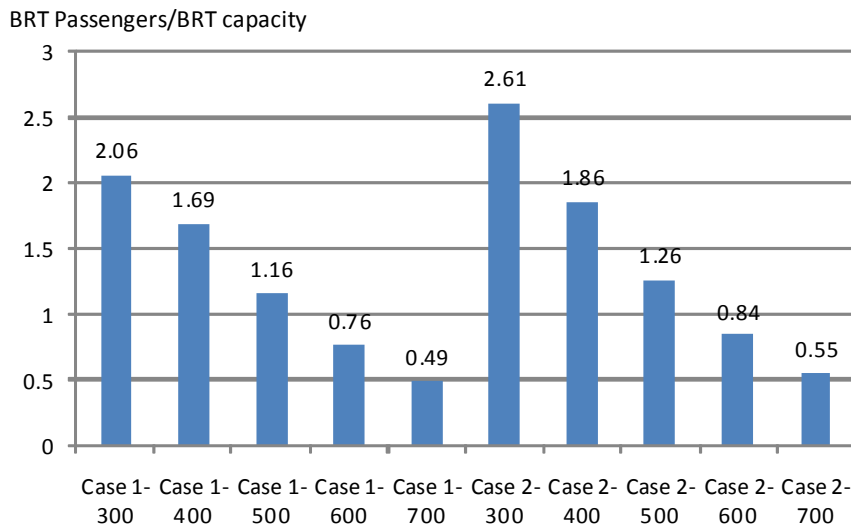


FIGURE 6 Load factors for BRT vehicles in each case

1-400 offer positive benefits from both the supplier’s and users’ viewpoints. Moreover, the existing bus operators make some profit gains in Case 1-300 and Case 1-400, making both acceptable to them.

Third, a technical problem should be pointed out. FIGURE 6 shows the average load factors for BRT vehicles in these cases. This shows that the capacity of BRT vehicles does not satisfy BRT demand in Cases 1-300, 1-400, 1-500 or Cases 2-300, 2-400, and 2-500. However, if passengers are permitted to stand in vehicles, the maximum load factor could be 1.5 to 2. Note that the average number of passengers per vehicle in Curitiba’s BRT is 275, although only 57 seats are provided (Evans, 14). This means that the Curitiba BRT carries a large number of standing passengers. Since many passengers have to stand in the existing bus services in Yangon, this may be acceptable. If standing passengers are acceptable, Cases 1-400, 1-500 and Cases 2-400 and 2-500 might also be feasible.

Consequently, it is concluded that Case 1-400 is the most viable. The cost-benefit ratio passes the social-economic viability test. The supplier’s benefit is positive. The net profit for existing operators is also positive. The load factor for BRT vehicles is quite high, but physically feasible if standing passengers are permitted. The user’s benefit is also positive.

CONCLUSIONS

This paper analyzes the feasibility of introducing the BRT system and restructuring the bus route network to improve the performance of the local bus service in Yangon, Myanmar. First, we summarize the characteristics of the current urban bus service in Yangon. We point out that the point-to-point bus route network causes many overlapping routes along the main roads and this leads to serious traffic congestion. Then, we examine the

feasibility of two policy options. The first case (Case 1) introduces a new BRT line to the existing bus network while the second case (Case 2) restructures the bus route network in addition to introducing the new BRT line. Five types of BRT fare are considered for each case. To evaluate these policy options, a travel demand forecast system, including the estimation of origin-destination table and the bus route-choice model, was developed. The results of the evaluation show that Case 1-400 in which the new BRT with a flat fare of 400 Kyats is introduced to the existing bus route network is the most viable and beneficial option.

Topics for further research are set out as follows. First, the method for evaluating the policy option should be improved. For example, the bus route-choice model used in our paper does not explicitly incorporate in-vehicle congestion or traffic congestion. The in-vehicle congestion may seriously influence the route choice made by bus passengers. The introduction of an exclusive lane reduces road capacity for other traffic and this causes traffic congestion in other lanes. It is important to consider these factors when evaluating the real impact of introducing a BRT system. Second, it is important to examine the social impact and environmental aspects of BRT introduction. For example, the impact of introducing the BRT on the participation of low income people in social activities must be investigated. The contribution made by a BRT system to the local and global environment should be also evaluated. Third, it is critical to examine the engineering feasibility of introducing a BRT system. For example, traffic control at intersections along the exclusive lane must be carefully examined to avoid traffic accidents. The design of the BRT stops/terminal, including the facilities for quick boarding and exits, should be investigated. It is also necessary to consider the introduction of advanced technology into the BRT service such as a smart card system, the provision of passenger information, and a computer-based schedule control system. Financial issues are also important. Although the paper does not explicitly assume the organization operating the BRT, it may be necessary to introduce financial support for the BRT start-up. Finally, consensus-building must be considered. The participation of citizens, the private sector and the public sectors is likely to be critical when promoting the introduction of BRT.

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