INTEGRATION FOR PUBLIC TRANSPORTATION IN URBAN AREA UNDER NATURAL MONOPOLY AND COMPETITION AMONG OPERATORS:
A case study of Yogyakarta, Indonesia

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Abstract: In most cities in developing countries, the drivers operate buses with a daily contract/hire to to the owners. As a consequence, drivers tend to maximise their profit at the expense of passenger's safety. The research aims at investigating measures to avoid such problem by comparing two situations, namely an operation under the current competition regime, and a hypothetical situation where public transport operation is under one operating management, creating a natural monopoly. A mathematical model is developed to represent both systems by optimized the costs for owners, drivers, and passengers. A case study was developed for 4 urban bus routes in Yogyakarta. The result shows that monopoly system applied with the price control may achieve better efficiency under certain conditions. Further research should be directed toward improving public transport operating costs model including cross elasticities of profits.

Keywords: urban public transport, natural monopoly, operation costs, fleet management

1. BACKGROUND

Public transport users require services, which provide comfort and safety with affordable fares and appropriate network coverage. On the other hand, revenue received by the owner and operator must be guaranteed in order to sustain the operation and maintain the business. This condition is essential because many cities has adopted the ideas of running public utilities with limited amount of subsidy. In many cities, particularly in Europe, public transport system runs under government subsidy. This will ensure that the owner and operator receive revenues to ensure its operation with a certain level of services. This situation is unlikely to happen in developing cities because of the lack of financial assistance the city could provide.

In Indonesian cities, such condition is no exception. The option is therefore involving private sector and private bus operators and companies to provide public transport service at the agreed negotiated fare. While the fare is determined by an agreement between public transport operators and the government and then endorsed by the local parliament. Currently there is no service standard that is imposed to the operators and companies. At the current system, the bus driver has a daily contract to pay a fixed sum of money to the owner. It is a common practice. Drivers tend to maximise their profit at the expense of passenger's safety. The number of passengers that can be carried by a particular bus determine the earning of the bus crew, i.e. driver and bus conductor.

More passengers mean more earning for them. This system has made the driver to drive recklessly causing "cream skimming effect" and reducing passenger safety and comfort. Among all players in urban public transport system, it is the drivers and passengers who bear the risk of such operation, leaving owner and government at the safer side.

The aim of the research is to compare two situations, namely a bus operation under the current competition regime, and a hypothetical situation where public transport operation is under one public transport authority, creating a natural monopoly. A mathematical model is developed to represent both systems by estimating the cost functions for owner, driver, operation and maintenance costs and depreciation. An optimisation technique is employed to examine their profitability and business sustainability for a given safety standard. The research use public transport data from Yogyakarta, Indonesia as a case study.

Under the assumption that the market size is constant, it is expected that under natural monopoly, local public transport authority can retain its profitability and reserve an adequate income to the driver while maintaining the speed of the traffic to improve safety and comfort. The profitability of the system is dependent upon the level of system speed, number of fleet and thus the number of driver and the level of acceptable driver income. The research is expected to give an opportunity to mathematically estimate the level of government subsidy if operational risk is to be transfer from private sector to public sector as a representation of public service obligation.

2. THEORETICAL FOUNDATION

2.1. Review of Previous Works

Since the situation described above are common in developing cities, some other works have been done in the area. The works of Morisugi et.al. (1997) and Soehodho (1999) are among the research attempting at examining the cost of producers or consumers. While Morisugi et.al. (1997) focussed their research on the consumer surplus of the bus and taxi users, Soehodho (1999) examine the most appropriate tariff to provide revenue levels ensuring operation below its passenger's capacity.

Other works includes those of Montalbo and Ishida (1997) which tried to model vehicle operating costs by optimaizing the number of labour – total and at the peak hours, the age of vehicles, vehicle-kilometer travelled, driver's salary and energy consumption. The other research of Diaz, et.al. (1997) developed a model for the urban public transport. They identified basic (exogenous) variables and intermediate (endogenous) variables and then develop a delicate model to relate all variables and to produce a total public transport operating costs. An important is the work of Cheser and Harisson (1987). They developed various formula to estimate the costs of public transport operation including the approximation of depreciation value of the vehicles.

2.2. Exploiting Natural Monopoly to Improve Bus Operation Efficiency

While the trend worldwide operation are directed toward promoting privatization and price/service competition, the expected improvements failed to appear in developing country's urban public transport services. This has been due to the overall structure of the industry. In a perfectly market mechanism the consumers are gaining a benefit from price reduction since operators ared pushed to reduce their profit up to the consumers marginal benefit, e.g. willingness to pay. Therefore an equilibrium between the passenger demand and costs of production is set to equal. Such situation is unlikely to happen because the market often does not operate in perfect mechanism. There are usually several operators and owner trying to maximise their profit and no service standard is imposed. Licenses are granted to operators without an obligation to comply with services determined by users. So the price "negotiation" does not really happen.

It is the main reason why many local government/authority opt for a price control. The problem for such option is that it tends to widen the willingness to pay of the consumer and the overall services offered by operators. It was almost always the case that the operators/companies are reluctant to increase efficiency my providing the most direct routes since they will at increase operators/owners revenue although they provide less operating costs. The term operator and owner often mean two different business entities. Owner is the one who own the license and sub-let the bus to the operator which is the driver and his bus crew. Owner tries to maximize profit by exploting the driver and the driver try to maximize profit by exploiting the passenger.

Many studies, especially in developing cities, concluded that public transport market is an unchallenging market, creating a natural monopoly. An alternative for solving such dillema is by providing a monopoly with price control, which Dominick (1993) describes with the following concept.

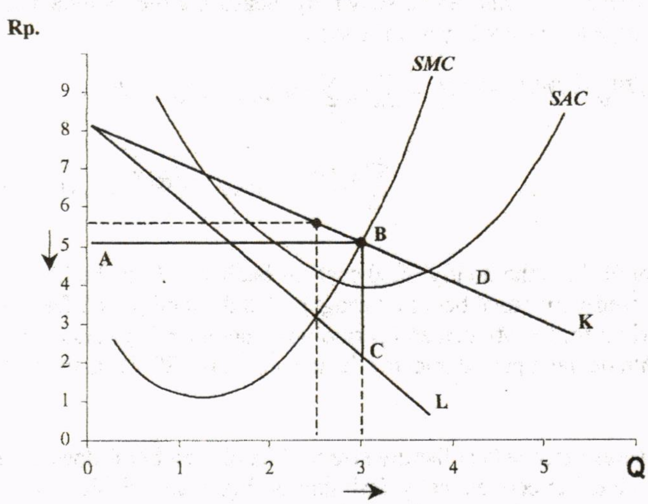

Figure 1. Concept of Natural Monopoly with Price Control
(source: Adopted from Dominick, 1993, pp. 253)

Dominick (1993) argued that in the monopolistic condition, the commercial firms like public transport companies want to maximize their profit by setting marginal cost (SMC) equal to the marginal revenue (MR=L). It means that the companies have the market power to keep the otput below the competitive level and the output is too small compared with the user's willingness to pay (MB=K). In other words, cost of production is less than user's willingness to pay. When the government set the price to a certain price level, e.g. price control, the monopolists are forced to increase its production up to the level when the costs of production will be equal to the willingness to pay (K) at the level of B.

Other way to force market equilibrium is by imposing lump-sum tax to the consumer average costs (SAC) to reach point where the commercial firms gain its maximum profit (until the point where vertical dashed-line crosses demand curve or K). Lump-sum tax will not change the marginal costs so that when the SAC curve is changed, the SMC curve will not be altered.

Wohl and Hendrikson (1984) stated that "the problem of peak loads or intretempora; demand fluctuations complicate investment, pricing and efficiency planning enourmously but are of great importance". This is ranged from the situation where the peak-load is the to the complex peak-load situation. In the case of public transportation, the situation is even more complicated because there are different operators and companies with different facility size serving similar routes or corridor. In situations in which facility sizes are discrte, one needs to calculate the total net benefits for each possible facility size and then choose the facility with the largest non-negative net benefits. In situations of perfect divisibility the same principle exists, although the method of identifying the best facility is more difficult due to the large number of alternative. Further Wohl and Hendrickson stated that "under certain circumstances a planner may simply follow the procedure continously expanding the facility size until the long run incremental total net benefit due to the expansion is zero....". This can be shown by measuring the incremental benefits from the change in facility size, e.g, from x to y as follows:

$$\Delta TNB_{xy} = TNB_y - TNB_x = \sum_{h=1}^{r} k_h \sum_{q=q_{hx}}^{q_{h,y}} [mb_{h(q)} - 24(F_y - F_x)$$
$$- \sum_{h=1}^{r} k_h [SRVC_{y(q_{h,y})} - SRVC_{x(q_{h,x})}] \quad \text{................(1)}$$

TNB is the total net benefit, F_x is the hourly fixed cost for facility *x*, F_y is the hourly fixed cost for facility *y*, $mb_h(q)$ is the hourly marginal benefit during the *h*th demand period for a flow of *q* and $q_{h,x}$ is the hourly equilibrium for the *h*th demand period with facility *x*. The same applies for facility *y*. In the equation, the *h*th demand period inlcudes k_h hours of flow. SRVC is the short run variable costs.

The approach above insures that the best facility size will be chosen but it does not guarantee that the chosen facility will be either economically desirable or financially viable. To be economically feasible, the facility must have total benefits larger than total costs; that is:

$$= \sum_{h=1}^{r} k_h \sum_{q=1}^{q_{h,x}} [mb_{h(q)} - srmc_{x(q)}] \geq 24Fx \quad \text{.....................................(2)}$$

In some cases a financial constraint may be imposed so that total payment might be required to exceed costs as follows:

$$\sum_{h=1}^{r} k_h[q_{h,x}p(q_{h,x}) - SRVC_{x(q_{h,x})})] \geq 24Fx \qquad (3a)$$

Or

$$\sum_{h=1}^{r} k_h q_{h,x}[p(q_{h,x}) - sravc_{x(q_{h,x})})] \geq 24Fx \qquad (3b)$$

Where *srmc* is the short run marginal costs and *sravc* is the short run average costs.

2.3. Public Transport Cost Structure

Public transport cost structure is complicated since it involves the direct interaction between the public transport demand and supply. From the economic point of view, the public transport costs include passenger's costs and operator's/owner's costs. Passenger's cost consists of public transport fare and cost of time is formulated below:

$$TC_{pnp} = JP \times \{TV \times [\frac{1}{2} H(1 + C^2) + \frac{ATL}{V})] + Fr\} \qquad (4)$$

Where

TC_{pnp}	:	Total passenger costs
JP	:	Number of passengers
TV	:	Value of Time
H	:	Headway
C	:	Headway coefficient of variation Koefisien variasi dari headway
ATL	:	Average Trip length
V	:	Averege travel speed
Fr	:	Fare

If the frequency offered in a route is not constant, than the above formula can be rewritten as follows:

$$TC_{pnp} = \sum_{i=1}^{n} TC_{pnp_i} \qquad (5)$$

with i is the service variability in a route.

The estimation of operator/owner's cost for the whole service period is a sum of the costs of peak and costs of non-peak time as formulated below:

$$TC_{operator} = TC_{peak} + TC_{non-peak} \quad \text{.......................................(6)}$$

with TC_{peak} is the total peak hour costs and $TC_{non-peak}$ represents non-peak total costs

$$TC_{peak} = BN_{peak}\{\frac{PB}{\eta} + KMT[f(L) + f(T) + f(O) + f(R) + f(MT) + f(FC)\} \quad \text{............(7a)}$$

$$TC_{non-peak} = BN_{non-peak}\{\frac{PB}{\eta} + KMT[f(L) + f(T) + f(O) + f(R) + f(MT)\} \quad \text{............(7b)}$$

BN represents the number of bus operated, KMT is the kilimeters travelled, L is the amount of lubricants, T is tire use, O is the fuel use, R is retribution costs (a common charge in Indonesia for the use of public facility), MT is the maintenance costs and FC is a fixed cost associated with the vehicle ownership, e.g. license plate number, vehicle tests, insurance, salary of administration staffs, interests and depreciation.

The firm's revenue will be defined as a function of its demand. In a pure competition, the revenue will be represented by the costs of production.

Depreciation value is estimated following Chesher and Harisson (1987); that is:

$$V(t) = \exp^{(-0.147t)} * VP \quad \text{..(8)}$$

with $V(t)$ is the value of vehicle at the year-t and VP represents the price of new vehicle.

3. RESULTS OF THE ANALYSIS

3.1. Brief Description of Yogyakarta and Its Urban Bus System

Yogyakarta, a city with around 475,000 inhabitants has developed into an urban area with population of around 1,000,000, living in places beyond the city's administrative boundaries. With 32.50 km2 of area, its population density is ranging from 7,327 person/km2 to 27,373 person/km2, creating a dense city. In the suburban area, the density remains low with approximately 5,000 person/km2. The city has also 238,249-km road network covering approximately 5% of the city area. It means that the road is relatively narrow with low capacity. It should be pointed out that the attempt to widen the road is unlikely to happen due to high building density along its roads. The urban area of yogyakarta is an agglomeration of the city of yogyakarta and two nearby regencies, bantul and sleman.

With around 50 universities and colleges, yogyakarta is certainly a magnet for students around the country, demonstrated by a number (69.744 students) and high percentage (15%) of university/college students to the city population. It also attracts foreign students to stay for educational purposes. The tremendous increase in the use of motorcycle and public buses in recent years are the powerful reflection on how much is the influence of yogyakarta as an education-city.

Yogyakarta public transport system is a combination of 30 – 40 pax urban buses operating individually (owned by both public and private companies), taxis, rickshaw and horse drawn cart. Recent study has demonstrated that in some routes the bus system operates in the over-supply environment creating energy inefficient operation, neck-to-neck competition resulting in high traffic violation and a danger of severe accidents. The condition is worsened with the fact that buses are 10-20 years old and inadequately maintained. At the moment the urban bus system has approximately 500 buses and 17 routes producing more than 1 billion vehicle-km annually.

In this research, 4 routes were selected as case studies. Route 2, 3, 4 and 7 were chosen to represent the characteristics of Yogyakarta urban bus system.

3.2. Optimization principles and assumptions

In principle, the research undertook exercise to compare two situations. First situation is the current practice, where the operator or driver attempts to maximise its profit by cream skimming passengers and they pay a fixed amount of vehicle rent to the owner. Second situation occurs when the operator or driver receives a fixed salary and the owner receives revenue from passengers. With the later situation, a monopoly with price control, the risk of bus operation will be transferred from driver to the owner. In such operation practice, it is expected that crean skimming effect will not happen as the driver now has no incentive to pick up as many passengers as possible. This will then encourage them to drive according to the service standard required, e.g. boad and alighting at the bus stop, follow the timetable.

Basically, optimization procedure will attempt to maximize profits and minimize/reduce costs. In both situations, there are several requirements:

a. owner costs of monopolistic operation ≤ owners costs of current system
b. operator/driver's salary ≥ current earnings
c. passenger costs at monopolistic system ≤ passenger costs of current system

The above requirements ensure that the proposed system – a monopoly with price control, is attractive enough for the public transport firms, drivers and passenger to shift to the new system, otherwise they will not participate in such new public transport management.

There are several assumptions associated with the characteristics of bus system and therefore these assumption are inherent in the intepretation of the results:

a. The demand and the number passenger of a particular route or corridor does not change from one day to another. This means that at the current system, if one driver earns more than what he/she normally earns, than the other drivers operating at the similar routes of corridor will suffer from reduced earnings.

b. There is a reservoir labor supply for bus drivers. This assumption implies that if the driver can not accept the proposed salary (in the case of a proposed system), the driver's replacement will not require additional costs.
c. In order to obtain higher efficiency of the proposed system, the management is allowed to rationalize the number of fleet but must maintain the current bus network. This assumption is necessary since the study did not carry a specific survey to assess the network efficiency.

Beside the above assumptions, there are other technical assumptions such as: non-peak passengers is assumed as 30% of peak passengers, the driver's salary at the proposed system is determined as the average earnings of monthly earnings. Such assumption can be refined if new data are available. For the purpose of simplicity the study assumes that all passengers have similar travel time value. The value of time was estimated from the average salary of employees.

3.3. Operational Characteristics

For the purpose of analysis, the survey was conducted to obtain several basic statistics and information about the system characteristics.

Table 1. Characteristics of bus crew (drivers and fare collector/bus conductor)

Route	Respondents	Working hours	Respondents at working hours	Daily crew (drivers and fare collectors) earnings (rupiah)			Preferred daily salary, total crew (drivers and fare collectors), (rupiah)			
				Min	Max	Average	50,000-70,000	70,000-80,000	80,000-90,000	90,000-100,000
2	20	10-11 11-12 12-13	3 9 8	50,000	75,000	60,250	2	11	4	4
3	14	10-11 11-12 12-13	1 10 3	50,000	80,000	60,357	6	8	0	0
4	20	10-11 11-12 12-13	1 14 5	65,000	120,000	90,375	4	10	4	1
7	23	10-11 11-12 12-13	0 12 11	50,000	80,000	65,978	4	7	0	4

Chi-square test using $\alpha = 0.05$ shows that $H_{table\ (16.9190)} > H_{calc\ (12.37)}$, and therefore can be concluded that average preferred earning is indifferent. The Kruskal Wallis test on current driver and crews earnings show that the daily earnings for operating route 2, 3, and 7 are indifferent (Kruskal Wallis Test - $H_{table\ (7.815)} > H_{calc\ (5.35)}$). Earnings for route 4 is relatively higher than the other.Statistical tests show that there are difference in driver and crews earning for different routes. This is also difficult to maintain if a standard of service is to be imposed. At the current system, drivers not only tend to compete against each other at the similar routes, but also wants drive their buses the most profitable routes.

Table 2 below shows the result of passenger characteristics at routes 2, 3, 4 and 7. Value of time is estimated by a estimating of average salary of the employee in Yogyakarta. No differentiation is made to distinguish various market segment, e.g. employee, student, self-employed, no employment.

Table 2. Passenger Characteristics at different routes

No	Route	No of respondents interviewed	Expected waiting time (min)	No of respondents fall under waiting time	Average trip length (km)	Value of time (rupiah/menit)
1	2	69	<5 5-10 11-15 15<	48 20 1 0	4.12	32.6
2	3	54	<5 5-10 11-15 15<	11 37 6 0	3.35	32.6
3	4	53	<5 5-10 11-15 15<	44 8 11 0	5.41	32.6
4	7	56	<5 5-10 11-15 15<	24 31 1 0	5.39	32.6

Source: survey and analysis

Travel speed and the number of total and operating fleet of buses obtained from a 3-days survey are presented in the Table 3. below.

Table 3. Average speed and number of buses in operation

Route	Speed (km/hour)	Number of buses				
		Total fleet	Fleet in operation during the survey period			Average
			1	2	3	
2	18.02	85	69	100	85	85
3	14.11	24	24	24	23	24
4	16.85	102	67	65	61	65
7	16.34	109	62	85	69	79

3.4. Comparison between Current and Monopoly Systems

a. Fleet size

The optimization process has produced a number of results. The number of buses is one essential result since it reflect the efficiency of the current fleet. It is the principles of the proposed system to rationalized the bus fleet in response with the demand as pointed out in Section 2 above. The public transport suply is differentiated between peak and non-peak time. It was assumed that there is no network change, so that the trip length for each route remains constant. The study examined various profit level (8%, 10%, 15% and20%), and for the purpose of comparison only 10% profit level is presented. The profit level is an important decision for fleet size because it is a result of a combination of fare level (average – public and student fare), proportion of sudent's fare and the number of passenger. The result of analysis can be seen in the following table.

Table 4. Comparison of fleet size

Route	Current System	Proposed System At fare level of Rp.					Off-peak headway	Speed	Daily pax
		390	*420*	*450*	*480*	*510*	(min)	(kph)	Person
2	71	50	54	59	63	71	4	18	29,055
3	16	5	6	7	7	8	15	18	3,986
4	65	38	41	43	46	50	4	18	25,126
7	82	37	40	44	47	51	4	18	23,851

The above table demonstrates that the number of vehicle is reduced substantially, especially for route 3 where at the current level of fare, the service is unprofitable. By maintaining similar or better passenger service (reflected in the off-peak heardway), the operator should operate not more that 8 buses or 50% of the current bus system. Similar situation occurs for other routes. From the calculation, one can also see that the increase of profit level will reduce the fleet size while maintaining the similar level of off-peak headway and bus travel speed.

b. Passenger costs

At the certain profit level and various fare level, the analysis is also able to produce the passenger costs for different routes as shown in the below table.

Table 4. The difference in passenger costs between current and proposed system at 10% profit level, in %

Route	Fare	Speed (km/hour)				
		18	19	20	21	22
2	390	0.22	-2.41	-4.76	-8.72	-8.72
	420	0.13	-2.60	-4.84	-8.76	-8.67
	450	-0.18	-2.56	-4.70	-8.56	-8.56
	480	-0.20	-2.71	-4.75	-8.31	-8.31
	510	-0.34	-2.61	-4.68	-8.24	-8.24
3	390	3.55	2.88	-0.88	-3.33	-4.87
	420	1.72	-0.12	-3.43	-4.01	-5.86
	450	1.27	-0.53	-4.03	-4.49	-5.83
	480	0.12	-2.33	-3.34	-6.17	-7.15
	510	-0.69	-2.49	-4.44	-6.35	-7.55
4	390	-4.70	-7.49	-10.03	-12.31	-14.45
	420	-4.85	-7.48	-10.00	-12.21	-14.21
	450	-4.76	-7.41	-9.76	-12.09	-12.02
	480	-4.81	-7.31	-9.70	-11.97	-13.69
	510	-4.71	-7.21	-9.63	-11.68	-13.51
7	390	-3.94	-6.85	-9.39	-11.67	-13.52
	420	-4.10	-6.81	-9.25	-11.58	-13.39
	450	-4.09	-6.85	-9.23	-11.36	-13.23
	480	-4.20	-6.86	-9.18	-11.25	-9.40
	510	-4.14	-6.76	-8.96	-10.99	-12.84

At route 2 and 3, passenger costs will be increased at fare level between 390 – 420 kph and travel speed of 18 kph. However as the travel speed increases, passenger costs gradually decreased showing the increased benefit to the passenger due to the reduced travel time. In other word, the fare increase is off-setted by reduced travel time although not at the same rate for different speed. In fact, a maximum reduction is unique for a combination of fare and speed. A natural monopoly system applied for route 2 for instance, at the speed of 19 kph, a fare increase will also increase the passenger's benefit whereas at the speed of 21 and 22 kph, the system produces opposite results.

As a consequence, it is very essential to identify the combination of fare and speed at which tha best or the maximum benefit that can be enjoyed by the public transport users. It can also be seen that a marginal speed change produce a substantial difference. It can therefore be concluded that that the user benefit is sensitive to speed changes.

c. Profitability of the proposed system

The important indicator for the success of the proposed system is the profitability. The private sector or public transport owners will only participate in such a system only when it can be demonstrated that the operation is financially feasible and the proposed system generate more revenue to them. The study has calculated the difference of costs to operate two situations and compare them to see how much each operator will benefit. The calculation is based upon 10% profit level and 5% profit over a capital investment. The result is shown below.

Tabel 5 Difference in the costs of operation between current and proposed system, in %

Route	Cost Components	Year 1-4 (%)	Year 5-10 (%)	Route	Cost components	Year 1-4 (%)	Year 5-10 (%)
2	a. fixed costs	9.18	15.69	3	a. fixed costs	66.67	66.67
	b. crew costs	18.82	18.82		b. crew costs	66.67	66.67
	c. variable costs	33.81	33.81		c. variable costs	51.64	51.54
4	a. fixed costs	6.64	21.54	7	a. fixed costs	2.05	6.64
	b. crew costs	21.54	21.54		b. crew costs	34.18	34.18
	c. variable costs	31.39	31.39		c. variable costs	40.30	40.30

Table 5 identifies that the biggest difference is measured for route 3 where the reduction of fleet size is also the highest. A significant variable cost saving is also enjoyed for route 7 due to the reduction of frequency offered by current system.

This information is therefore very useful in determining the plan for action for route specific and for a particular cost component.

4. CONCLUSIONS AND REMARKS FOR FUTURE WORKS

The research has demonstrated that the current system which rely heavily on the competition among drivers yields inefficient operation. An exploitation of the nature of public transport as a public utility can be seen as an alternative. A natural monopoly system with price control can be utilized to promote public transport efficiency since it has a robust theoretical foundation and can be proven to yield a satisfactory result with empirical data.

The research has also provided a foundation for wider implementation of the natural monopoly principle to other routes. This will be a firm base toward the integration of service standard and operation management. Such integration will and can be developed organizationally in the form of public transport authority. However, prior to implement such measure, there are several other works and researches need to be carried out. It is important for example that in order to implement the proposed system, some regulatory measures of boarding and alighting discpline must be enforced. Other works include the impacts of demand elasticity to the supply of buses, the investigation on the improved efficiency of the network as well the impacts of the integration with other forms of public transport.

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