The optimum bus route selection for sustainable operation (case study: Tangerang bus lane)

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Abstract. The aim of this paper is to select the optimum route option on a bus lane corridor based on operational and economical characteristics. In this research the Tangerang Bus Lane is chosen as a case study. The operational characteristics analyzed are total boarding passenger, total number of bus, bus productivity, bus cost structure and estimated fare. Based on the previous works the operational cost and potential revenue are calculated for both route options, and then an incremental benefit cost ratio analysis is conducted to obtain the most feasible route to operate. The result shows that the alternative route still consistently in providing a better performance compared with the current route.

1. Introduction
The Government of Tangerang City operates a bus lane corridor which connect Poris Plawad Bus Terminal with Kali Deres Bus Terminal in DKI Jakarta. However, based on data recorded by the Tangerang City Transport Agency, the daily ridership is relatively very low compared with other busway systems. In the other hand, there is an alternative location which is more attractive to the potential user for the origin of this service [1], and it has been indicated that this alternative route shows a better operational performance.

Since the operational and maintenance cost are one of the most critical issues in a mass transit system, a right decision on selecting the best route will yield to a very high cost saving, maximum revenue, and low subsidy needed for the for the whole life of the system. Therefore, a further analysis on the operational cost and the potential revenue is an obligatory step to obtain the best route option.

In the following section, the basic theory, research framework, and current situation are described. The last section discusses the optimum route based on financial analysis of operational cost and potential revenue and the final section will be the conclusion of the research.

2. Methods
This section explains the methods used in this research into two subsections namely literature review and research framework.

2.1. Literature review
In the past, planning for public transport was focused on social equity where everybody has to be able to use public transport. This strategy resulted into long public transport routes with many stops,
serving as much as people as possible. Nowadays, public transport routes have to be efficient. The focus of today’s public transport planning is serving mainly areas with high potential of use. Therefore, the estimation of operational cost and potential revenue becomes important aspects in determining an operation route. These aspects are commonly derived from some operational characteristics such as ridership, route length, service frequency, vehicle occupancy, operating speed, and line capacity [2]. While demand estimates are critical to designing the system, planning, operation, and predicting the financial viability of the system. Referring to the previous work [1], the total bus required for service can be calculated using equation (1).

\[
\begin{align*}
n_{op} &= \frac{(2L/V + 60) + R_t}{h} = \frac{2L \times 60}{V \times h} + \frac{R_t}{h} \\
\end{align*}
\]

where,

- \(n_{op}\) = Total number of operating bus
- \(R_t\) = Lay over (or recovery) time (minutes)
- \(L\) = One-way route length (km)
- \(V\) = Average design speed (km/hr)
- \(h\) = Bus headway (minutes)

Number of spares is usually 2 -3 buses or 10 – 20% of number of bus in operation, whichever is greater [3]. Bus productivity is an important parameter for vehicle operational cost calculation. It can be derived from the total number of round trip achieved by each bus during the designated operation hours. Therefore, the total productivity can be expressed in equation (2).

\[
N_{rit} = \frac{T_{op} - T_{spbu}}{T_{rt} + R_t}
\]

where,

- \(N_{rit}\) = Total number of round trip
- \(T_{op}\) = Total time of operation (minute)
- \(T_{spbu}\) = Time for fuelling (minute)

In order to estimate service productivity for the whole system in operation, the distance-travelled by each bus needs to be estimated. There are three categories of distance-travelled, namely effective distance-travelled, empty distance-travelled and total distance-travelled which expressed in equation (3) – (5).

\[
\begin{align*}
Eff_{dis} &= N_{rit} \times 2L \\
Emp_{dis} &= 3\% \times Eff_{dis} \\
Tot_{dis} &= Eff_{dis} + Emp_{dis}
\end{align*}
\]

where,

- \(Eff_{dis}\) = Effective distance travelled (km)
- \(Emp_{dis}\) = Empty distance travelled (km)
- \(Tot_{dis}\) = Total distance travelled (km)

Referring to the guidelines for bus route design [4], the un-productive (empty passenger) distance travelled is suggested 3% of the total effective daily distance travelled. While for the operational cost component, the guidelines suggested that the components need to be calculated based on actual condition. On the other hand, the potential revenue is determined by the daily ridership represented in equation (6) [1].
\[ R_d = to \times \left[ \left( \left( F_a^p + F_b^p \right) \times T_p \right) + \left( \left( F_a^{op} + F_b^{op} \right) \times T_{op} \right) \right] \quad (6) \]

where,
- \( R_d \) = Daily ridership (pass./day)
- \( F \) = Average maximum flow (pass./hr)
- \( a,b \) = Flow direction
- \( to \) = turnover rate
- \( p \) = Peak
- \( op \) = Off peak
- \( T \) = Operational service time

Referring to TRB [3], turnover rate ranges from 1.2 to 2.0 passengers per bus depending on the route structure and areas served. The financial feasibility of a bus route should be analyzed to achieve a feasible and sustainable operation. Therefore, Benefit-Cost (B/C) ratio method is used to evaluate the feasibility of each route option and then an incremental B/C ratio must be adopted as expressed in equation (7) [5].

\[ \frac{\Delta B}{\Delta C_{(y-x)}} = \frac{Rev_y - Rev_x}{VOC_y - VOC_x} \quad (7) \]

where,
- \( \Delta B \) = Nett benefit (Rupiah)
- \( \Delta C \) = Nett cost (Rupiah)
- \( Rev \) = Revenue (Rupiah)
- \( VOC \) = Vehicle operational cost (Rupiah)
- \( x,y \) = Route option

Since Bus operation is commonly consisted to an operator for a certain period, a financial analysis which considers future forecasting need to be adopted. One approach commonly used is by converting all forecasted value into present situation, called present value method and then continued with BC ratio analysis. The present value calculation can be expressed in equation (8) [5].

\[ V_z(n) = Z_1 + Z_2 \left( \frac{F}{P}, i\%, 1 \right) + Z_3 \left( \frac{F}{P}, i\%, 2 \right) + Z_4 \left( \frac{F}{P}, i\%, 3 \right) + \cdots + Z_n \left( \frac{F}{P}, i\%, n-1 \right) \quad (8) \]

where,
- \( PV \) = Present Value (Rupiah)
- \( z \) = Revenue or Cost (Rupiah)
- \( n \) = Concession period (year)
- \( i \) = Interest rate (percentage)
- \( P,F \) = Present & Future value

2.2. Research framework
The flow of this research consists of two consecutive stages namely demand and service productivity analysis and financial analysis. In the first stage, the potential demand, bus operational characteristics and bus service productivity is analyzed. Then, in the second stage, a benefit-cost ratio analysis based on the estimated bus operational cost and potential revenue is conducted. Adopting results and using similar method from previous work [1], a demand estimation is conducted first on each alternative route. The analysis is based on two main parameters namely total boarding passenger and some estimated operational parameters such as frequency, headway, cycle time and number of bus in operation. The total corridor demand is derived from bus passenger flow obtained from load factor and frequency survey. While for the demand of the proposed service is derived by factoring the corridor
demand with the percentage of potential passenger willing to shift to the proposed service obtained from user opinion/prefere

cnce survey. Since the current bus lane system applies different operational headway, the potential demand should be adjusted with the prevailing headway. Consequently, a new split percentage needs to be derived from the result of preference survey conducted by previous work [1]. Therefore, based on this new split percentage and assuming that the corridor demand does not change significantly, the new potential demand is determined by applying similar procedure as explained in previous paragraph. Meanwhile, the supply analysis requires some operational parameters such as, bus frequency, roundtrip travel time, and number of bus and the operation are estimated based on the required minimum operational headway. Based on the estimated operational parameters, productivity measures such as total number of trips, total distance travelled are determined. In parallel, the operational cost structure is also calculated. Then, by utilizing the estimated demand, and the assumed tariff, the potential revenue is determined. While in the supply side, the total operational cost is also calculated based on the service productivity measures. Finally, by applying incremental benefit cost ratio analysis on the potential revenue and operational cost, the best alternative of route is determined.

3. Result and Discussion

Tangerang bus lane corridor has two route options and basically, both routes share the corridor more than half of its total length and there is only slight difference in term of route length. The one-way route length of route A, connecting Poris Plawad Terminal and Kali Deres Terminal, is about 10.8 km, and the alternative route (or Route B), connecting Cikokol Terminal and Kali Deres Terminal is, about 11.6 km. The observed average speed along the corridor are 21.2 km/hr (peak morning) and 26.1 km/hr 14 (peak evening). Referring to previous work [1], the assumed parameters of the proposed service is shown in table 1.

Table 1. Assumed parameter.

| Parameter                  | Peak Hour  | Off-Peak Hour |
|----------------------------|------------|---------------|
| Average Design Speed       | 17 km/hr   | 20 km/hr      |
| Bus Capacity               | 85 (seats & standing) | 85 (seats & standing) |
| Service Time Window        | 6 hrs      | 11 hrs        |
| Fueling Time               | 15 minutes | 15 minutes    |
| Lay over time              | 10 minutes | 10 minutes    |
| Seat Turnover rate         | 1.3        | 1.3           |

Adopting equation (6) and (8), the required minimum headway [6], the route length as explained previously, and the design speed shown in table 1, the adjusted bus frequency and roundtrip travel time are calculated as shown in table 2. While, by applying the equation (1) as in section 2, assumed parameters as in table 1, and the adjusted headway as in table 2, the number of bus in operation can be determined as in table 2.

Table 2. Estimated operational parameters.

| Parameters                  | Route A  | Route B  |
|-----------------------------|----------|----------|
| Adjusted Headway (minutes)  | 7.5      | 7.5      |
| Adjusted Bus Frequency      | 8        | 8        |
| Roundtrip travel time (minutes) | 86  | 86  |
| # of Bus in operation (bus) | 11       | 12       |

Taking the assumed parameter as shown in table 1, the estimated operational parameters as shown in table 2, and equation (2) to equation (5) as described in section 2, the service productivity can be calculated as summarized in table 3. Referring to the actual cost for each component obtained from
various resources the operational cost in term of bus-km for each alternative route is shown on table 4. By multiplying the service productivity in table 3 and bus operational cost per km in table 4, the total operational cost for each alternative route can be calculated as shown in table 5.

**Table 3.** Bus service productivity.

| Service Productivity | Route A | Route B |
|----------------------|---------|---------|
| Total service (Cycle) length (km) | 21.5 | 23.1 |
| Number of trip (peak-hour) | 5 | 4 |
| Number of trip (off-peak) | 9 | 9 |
| Distance-travelled (peak-km/day) | 107.7 | 92.5 |
| Distance-travelled (off peak-km/day) | 193.9 | 208.1 |
| Total Effective distance-travelled (km/day) | 301.6 | 300.6 |
| Empty distance travelled (km/day) | 9.0 | 9.0 |
| Daily Total distance-travelled (km) | 310.6 | 309.6 |
| Monthly distance-travelled (km) | 9,319.3 | 9,288.2 |
| Annual distance-travelled (km) | 113,385.2 | 113,007.3 |

**Table 4.** Operational cost per bus-km (in rupiah).

| Cost Component | Route A | Route B |
|----------------|---------|---------|
| Bus Investment | 705.6 | 707.9 |
| Air Conditioning (AC) | 107.1 | 107.5 |
| Crew | 1,046 | 1,049.5 |
| Vehicle License & Operational Permit | 24.9 | 25.0 |
| AC maintenance | 21.4 | 21.5 |
| Management | 904.5 | 907.5 |
| Fuel Consumption | 1,500 | 1,500 |
| Tires | 116.7 | 116.7 |
| Minor Maintenance | 58.9 | 58.9 |
| Major Maintenance | 97.5 | 97.5 |
| General Checking | 11.7 | 11.7 |
| Fuel consumption for AC | 450 | 450 |
| Non-productive fuel Consumption | 17.6 | 17.0 |
| Mechanic | 82.6 | 82.8 |
| **Total Cost** | 5,144.8 | 5,153.1 |

**Table 5.** Total operational cost.

| Cost | Route A | Route B |
|------|---------|---------|
| Daily Operational Cost (Rp/bus) | 1,598,198.5 | 1,595,452.1 |
| Daily Operational Cost (Rp/route) | 15,068.729.0 | 16,322,702.7 |
| Annual Operational Cost (Rp/route) | 5,500,086,094.6 | 5,957,786,501.8 |

Since the system is operated as a bus lane, the potential user obtained from the opinion survey, is about 29% of the existing public transport user along the corridor. By modifying the estimated demand from the previous work [1] and applying equation (6) in section 2, the total estimated boarding for route A is 12,279 pax/day and for route B is 12,734 pax/day. Therefore, potential revenue for both route with assumption that the flat fare is IDR 3,500/trip can be estimated. The estimated potential revenue for both route is indicated in table 6.
Table 6. Total potential revenue.

| Cost               | Route A       | Route B       |
|--------------------|---------------|---------------|
| Daily Revenue (Rp) | 42,976,500    | 44,569,000    |
| Annual Revenue (Rp)| 15,686,422,500| 16,267,685,000|

As shown in table 5 the operational cost for route B is higher, but in contrary its potential revenue as shown in table 6 is higher than of route A. This situation resulted to a further analysis for selecting the best route option by utilizing an incremental benefit-cost ratio analysis for the base year operation.

In this research, the benefit is simply taken from the potential revenue and the cost is from the estimated operational cost. Therefore, by applying equation (7) as in section 2, the B/C ratio for Route A and Route B are 2.9 and 2.7 respectively. While the incremental B/C ratio for these two Route is 1.3.

Taking a look solely from each B/C ratio value, seems that route A has a better performance, but having compared the B/C ratio value for both alternatives where the route A is taken as the reference, the route B finally shows better result. This is due to the difference of their potential revenue, while their operational cost is only slightly differed. Therefore, based on this analysis the result is confirmed with the results of previous work [1] which compares the performance indicator for each alternative route.

A further financial analysis by taking into account the assumed concession period (i.e. 7 yrs.), a consistency of previous analysis and sustainability of the operation of Route B could be checked. Therefore, for this purpose, assumptions are made for the following; annual passenger growth is assumed 3% [7]. Operational Cost is assumed increased 5% annually based on the ideal inflation rate.

Since there is no data for the elasticity of price to the demand, the fare is kept maintained as the basic year. In this analysis all forecasted value will be converted to the present value (PV), so by applying equation (8) as in section 2, the result is shown in table 7. Using similar approach as in the base year analysis, the B/C ratio for Route A and Route B are 2.13 and 2.07 respectively. While the incremental B/C ratio for these two Route is 1.2.

Table 7. Present Value Analysis

| PV Benefit (Rp) | PV Cost (Rp) |
|-----------------|--------------|
| Route A         | Route B      | Route A       | Route B       |
| 76,367,779,299  | 79,197,597,654| 35,823,527,766| 38,252,741,396|

Based on the calculated B/C ratio, the results of financial analysis with 7 (seven) years concession period and some assumptions, the analysis indicates a consistence results with that of base year and furthermore a sustainable operation seems can be achieved.

4. Conclusion
The analysis consistently shows, as compared to previous work result, that the route B potentially provides a better performance. It is strongly recommended that, in complementary with the current operation, the Government of Tangerang City operates a bus lane from Cikokol to Kali Deres (i.e. Route B).

References
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