Performance Evaluation of Bus Network in Yogyakarta, Indonesia Using Macroscopic Simulation Model (VISUM)

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Abstract. The problem of TransJoga as an alternative mode in Yogyakarta is the shortage of resources required for the optimum operation, thus there is a need for constant revision and enhancement of the transit system through performance evaluation. Main objective of this study is to evaluate the performance of TransJogja from the government as the operator and the commuters as the passenger. Evaluation was done based on Origin-Destination matrix travel demand in Yogyakarta. The existing network was modelled with traffic macrosimulation VISUM software. Headway-based assignment procedure was used to model TransJogja passengers travel behaviours. Assignment calibration using TFlowFuzzy was done to produce model that can represent the existing condition the best. The results revealed that network of Trans Jogia has decent coverage and accessibility. However, it has low frequency and low passenger demand, thus effects in very low productivity and line efficiency. There is a long waiting time from and to line 8 (feeder line) with a waiting time up to 19 – 20 minutes in the morning rush hour and 16 -20 minutes in the afternoon rush hour. All line routes have smaller number of average passenger volume than the required number due to low demand or low passenger turnover rate.

1. Introduction

In many developing cities, there is a rapid decline in modal shares of public transport because of the deteriorating quality and lack of alternatives modes, e.g.: walking facility, cycling facility and public transports. This forced many people to shift from using public transport to private vehicle as daily mode of commute [1]. Most of the cities are acknowledging this phenomenon and are trying to tackle this issue by encouraging people to use public transport and non-motorized transport modes. Buses are the major mode of transport alternatives and often the only affordable to the financially low urban area. However, bus service in many places have a very low demand, frequently overstretched system, uncomfortable and unreliable, despite their important role. The reason for this is that there are a very steep rises in both asset and operating cost, as well as lack of resources [2]. Therefore, to ensure the available resources are used effectively and efficiently, there is a need to evaluate the operational performance and the service standard of bus service that being provided to the public.

The city of Yogyakarta, Indonesia has several different modes of public transport, such as: inter-city trains and buses, commuter train and buses, taxis and several traditional transportations which mostly operate for tourism purpose. Trans Jogia is one of the commuter buses and the major alternative mode that was officially introduced by the Department of Transportation, Special Region of Yogyakarta.
However, the operational of TransJogja was worsening in each of the coming operating years. The maintenance of bus fleets and stop points were neglected, resulting in the deteriorating of both the facilities. Thus, there is a need for constant revision and enhancement of the transit system to find weaknesses and potentials. The main objective for this study is to evaluate the performance of TransJogja from both perspective of the government as the operator and the commuters as the passenger. The existing network was modelled with PTV VISUM, a macroscopic simulation software for planning and analysing transportation networks. It provides special feature for public transportation that will help to analyse and evaluate an existing or planned public transport performance and service. PTV VISUM strive to consequently meet the requirements of public transport performance evaluation [3].

2. Bus network performance evaluation
The ultimate purpose of measuring performance is to improve transportation services for costumers [4]. Performance evaluation is largely used in public transport studies and they can have various terms including, “performance measures”, “sustainable transport indicators”, “performance indicators” or “transportation statistic”. Regardless, every agency needs to develop a good set of statistic that are collected consistently, thus it can be suitable for planning and evaluation purposes [1]. It is considered helpful in reporting to the public about the condition of the service. But it also very useful for communicating with the public and help educate the public, government, and legislators regarding the transit merits of making appropriate investment in the system [5]. Performance indicators are specific measurable outcomes used to evaluate progress towards established goals and objectives. It must be carefully selected to avoid misdiagnose or misdirect decision makers that lead to inappropriate results [6]. There are two main indicators: quality of service performance indicators and operational performance indicators.

Some traits belonging to this category of service performance that are likely to be applied to a reasonably well-run bus operator includes, waiting time, walking distance to the bus stops, interchange between routes and services, and journey times. Acceptable level of service will be different from one country to another, and will be greatly affected by income level, the value of place and time, geographic and climatic condition, availability of alternative modes, traditional standards, public attitudes and ethnic characteristics. Even though there is no set of indicator standard that can be universally applied to the quality of bus service in any particular city, however, values have been placed for the standard or indicator by various authorities to provide indications of the quality of service in their cities [2].

3. Research Method

3.1 Study Area and Method
This research is using quantitative approach with descriptive design where it seeks to describe the specific measure as well as overall performance of the whole bus network (TransJogja) in the City of Yogyakarta. The evaluation includes two of the performance indicators which are the quality of service and the operating performance. While the tool that is used to help with the measurements and the evaluation is the macroscopic simulation model PTV VISUM. Indicator standard that is used to measure the quality of the service will be obtained from Technical Guidelines No. SK.687/AJ.206/SRJD/2002 on Public Transport in Urban Area [7], Government Regulation No. 10 of 2002 on Road-based Public Transportation [8] and World Bank Technical Paper, Bus Services: Reducing Costs, Raising Standards [2].

3.2 Research Stages
The study starts with the review of conceptual aspect if the network performance evaluation and the review of the VISUM approach. Then the model construction of TransJogja network includes the process of base origin-destination demand matrix development that is done using the secondary data, the process of construction of road transport network and PuT transport supply as well as the process of assignment of the origin-destination matrix, calibration and finally testing the model result. The result of the model then formed the base network model that represent the existing traffic condition of TransJogja. The evaluation of the quality of service indicator and the performance indicators indicator are then carry out based on the base network model. The flow of the methodology can be seen at the
Result of the performance measurements from the comparison of the model network with indicator standard is used as the base of the suggestion of the improvement strategies.

Figure 1. Study area and flow of the study

3.3 Travel demand data
Travel demand data is obtained from a comprehensive origin-destination survey done by the Government of Special Region of Yogyakarta in 2015. The survey take place in 5 districts with total of 35,133 samples. Results from the survey are information of origin-destination travel journey in Yogyakarta that includes the elasticity of the journey, trend of the journey, mathematic model in relation with the respondent characteristic and visualization of the desire line [9]. Some required changes have been made to develop specific origin-destination matrix for TransJogja. Some changes include shorting 28 inner and outer zones out of the total of 78 zones from 5 districts, calculating demand matrix projection based on Yogyakarta’s population growth rate and calculating demand matrix with percent modal shares of TransJogja in Yogyakarta. This matrix will then be called the PuT-demand matrix during the network simulation process.

3.4 Transport network supply
Transport network supply were obtained from OpenStreetMap (OSM), includes nodes, links, stops, and point of interest. Zones (traffic cells) are the origin and destination of movements (demand), obtained from Database of Global Administrative Areas (GADM). There are total of 28 zones used in the network consists of 24 inner zones and 4 outer zones. There are 17 line routes serving the bus network of TransJogja. Those line routes are divided in three categories which is major circle line (line 1A, 1B, 2A, 2B, 3A and 3B), inner circle line (line 4A, 4B, 5A, 5B, 6A and 6B) as well as feeder line (line 7, 8, 9, 10 and 11). To support the network, there are total of 270 stops, both permanent and portable stops.

3.5 Assignment procedure
By adding the PuT-Demand matrix into the network supply, it satisfied the precondition for running an assignment on the network model [10]. Between the three assignment procedures provided by VISUM, headway-based assignment procedure will be used because it meets the existing condition of TransJogja bus system. It is generally used when the timetable of the period of the analysis is unknown or the timetable is unreliable. After the headway calculation, VISUM will determines routes from origin to destination. To determine a distribution of trips from the possible routes, specific impedance parameter must be used. This distribution process is called route choice in headway-based assignment procedure. Impedance formula used in this process depends on the perceived journey time (PJT) on each of the route alternatives. The final process is route loading which all possible routes found in the route search and route choice are loaded with demand from PuT-demand matrix. This process will result in the
number of trips per origin and its destination. headway-based assignment it is usually assumed that passengers know line headways and times. Which additional information they have, is decisive for their choice behaviour when boarding or transferring.

3.6 Model calibration
Assignment is mainly used to determine the passenger volume in each line routes and calculate passenger specific PuT skims. To make sure that the simulation model can represent the actual existing traffic condition, verification of the result needs to be done. It is carried out by comparing observed data (count value) of passenger trips with the data result from the assignment process. Verification process is done using GEH statistic (Geoffrey E, 1970s). The use of GEH as an acceptance criterion for travel demand forecasting models is recognized in the UK Highways Agency's Design Manual for Roads and Bridges, the Wisconsin microscopic simulation modelling guidelines, the Transport for London Traffic Modelling Guidelines and other references. According to DMRB, 85% of the volumes in a traffic model should have a GEH value of less than 5.0. GEHs in the range of 5.0 to 10.0 may needs further investigation.

4. Result and discussion
4.1 Quality of service indicators
4.1.1 Walking distance
Using one of the display calculation features in VISUM called Stop Catchment Area, circles with constant radius of 500 m were drawn around each stop to graphically display the coverage of TransJogja network. As seen from the figure 2, there are quite large gaps between stops at the west and south part of the network. This means those area is insufficiently accessible by the service of TransJogia. Large gaps between stops creates inconvenient for passenger as it increases the walking times. This indication measures that the improvement strategy should aim toward making this area of the network more accessible.

![Figure 2. Stop Catchment area of TransJogja network model](image)

4.1.2 Stop point fitness
This indicator show how big is the potency or capability of stop point serving passenger across the network. There are two analysis done using the display calculation feature in VISUM called 2D display. This feature can display graphically which stops are passenger mainly choose for boarding and transferring. The evaluation shows important stops for passenger along their journey; thus, improvement can be implemented if there are any detected deficiencies.
From Figure 3 and Table 1, we can see that there are three stops with more than 250 passenger board at their origin area. This means these stops will be their first stop points along their journey. These stops are Bus Stop Prambanan, TPB Pasty 1 and Park and Ride Gamping. However, TPB Pasty 1 is classified as a portable stop, which is built as temporary stops before the construction of permanent stops.

Evaluation for passenger transfers show two most used stop point for passengers to transfers directly in the stop. From figure 4, two stops namely Bus Stop Ngabean and Bus Stop KHA Dahlan have the highest volume of passenger transfers, respectively 100 passenger and 62 passengers. Thus, it is necessary to evaluate in detail about passenger’s connecting journey and waiting time at those stop points.
4.1.3 Transfer waiting time
Stop point Ngabean is observed further following its role as the stop interchange in the TransJogja network. The evaluation set at the morning peak hour from 6:00 am to 7:00 am and afternoon from 3:00 pm to 4:00 pm. Through this feature expected transfer waiting time can be seen clearly for each connecting line. At the stop point Ngabean, majority of passenger are transferring between line 6a, 6b, 8 and 11 to line 9 and 3B in the morning peak. While in the afternoon peak, majority of passengers are transferring from line 3A and 9 to line 6A, 6B, 8 and 11.

Table 2. Passenger transferring direct (> 50 passengers)

| Stop area number | Code | Bus Stop Name       | PassTransDir (pas.) |
|------------------|------|---------------------|---------------------|
| 195              | H    | Bus Stop Ngabean    | 100                 |
| 156              | H    | Bus Stop KHA Dahlan 2 | 62                  |

Table 3. Connecting journey and transfer wait time (morning peak)

| From Name | Time of arrival | To Name | Time of departure | Transfer wait time | LOS       |
|-----------|-----------------|---------|------------------|--------------------|-----------|
| Line 8    | 6:16 AM         | Line 3B | 6:35 AM          | 19 min 20s         | Very Bad  |
| Line 8    | 6:16 AM         | Line 9  | 6:36 AM          | 20 min 22s         | Very Bad  |
| Line 6A   | 6:25 AM         | Line 3B | 6:35 AM          | 9 min 56s          | Regular   |
| Line 6A   | 6:25 AM         | Line 9  | 6:36 AM          | 10 min 58s         | Regular   |
| Line 6B   | 6:25 AM         | Line 3B | 6:35 AM          | 9 min 56s          | Regular   |
| Line 6B   | 6:25 AM         | Line 9  | 6:36 AM          | 10 min 58s         | Regular   |
| Line 11   | 6:35 AM         | Line 3B | 6:35 AM          | 2 min              | Good      |
| Line 11   | 6:35 AM         | Line 9  | 6:36 AM          | 3 min 2 s          | Good      |
Figure 6. Transfers display of regular service (afternoon peak)

Table 4. Connecting journey and transfer wait time (afternoon peak)

| From Name | Time of arrival | To Name | Time of departure | Transfer wait time | LOS |
|-----------|----------------|---------|------------------|-------------------|-----|
| Line 9    | 3:06 PM        | Line 11 | 3:18 PM          | 12 min 13s        | Bad |
| Line 9    | 3:06 PM        | Line 6A | 3:23 PM          | 17 min 3s         | Bad |
| Line 9    | 3:06 PM        | Line 6B | 3:23 PM          | 17 min 3s         | Bad |
| Line 9    | 3:06 PM        | Line 8  | 3:26 PM          | 20 min 23s        | Very Bad |
| Line 3B   | 3:10 PM        | Line 11 | 3:18 PM          | 8 min 10s         | Regular |
| Line 3B   | 3:10 PM        | Line 6A | 3:23 PM          | 13 min            | Bad |
| Line 3B   | 3:10 PM        | Line 6B | 3:23 PM          | 13 min            | Bad |
| Line 3B   | 3:10 PM        | Line 8  | 3:26 PM          | 16 min 20s        | Bad |

Total circle in the transfers display of regular service is having the division of 1 hour with sub-division of 15 minutes. The bars of transfer flow show that some of the connections have unacceptable waiting time (> 19 min) which fall under the ‘very bad’ LOS level. It is mostly happened in connecting journey to and from line 8 both in morning and afternoon peak. This indicates that the improvement on the service of line 8 is necessary to better serve the transferring passenger at stop point Ngabean.

4.1.4 Journey time

Using isochrones calculation, journey time was calculated based on the parameter journey time. Figure 15 and 16 display the isochrones of journey time in the morning and afternoon peak hour. Gadjah Mada University (UGM) was chosen as the destination place in the morning and origin location on the afternoon because it is renowned as the centre of activity in the City of Yogyakarta. Departure/arrival extension is the time following the specified time period within which connections must start or need to reach their destinations. Limiting the maximum number of transfers to active vehicle journey will influence the calculation of the connection search process. Impedance for the number of transfers is multiplied by the factor of 10 to also influence the calculation of the connection search.
As shown from figure 7, the south-west part of the network is still lack of accessibility of TransJogja for travel activities to and from Gadjah Mada University. Improvement of the service to the south-west part of the network will be necessary in the future. About 47% stop points across the network have travel journey to UGM in about 10 to 20 minutes in the morning peak. While 40% stop points have travel journey from UGM in about 10 to 20 minutes in the afternoon peak.

5. Conclusions
This descriptive analysis of the performance evaluation of bus network in the City of Yogyakarta was presented to find potential and deficiencies in existing bus network of TransJogja. Some conclusions obtained from the study are:

a. TransJogja bus network in Yogyakarta is lack in network coverage at the south-west part of the city and there are locations with long gaps between stop points.

b. Long waiting time from and to line 8 (feeder line) with waiting time up to 19–20 minutes in the morning rush hour and 16–20 minutes in the afternoon rush hour (LOS: very bad).

c. About 40% - 47% locations in the network can reach Gadjah Mada University in under 20 minutes using TransJogja.

Overall, the network of TransJogja have a decent coverage and accessibility, but have low frequency and low passenger demand, thus effects in a very low productivity and line efficiency. Options for improvements alternatives includes the restoration of important bus stop and expansion of network, shifting and re-scheduling of bus journey and the big scale program of bus system reform programs are suggested to be implemented in order to support the development of a better TransJogja network.
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