Identifying Characteristics of BRT-Lite System: Learning from Trans Metro Bandung, Indonesia

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Abstract: Trans Metro Bandung (TMB) is a public bus system planned to be a full BRT system, while at present it can be classified as a BRT-lite system. Since TMB did not have a dedicated right-of-way, an elaboration regarding its operational characteristics becomes important. This study aims to evaluate the operational characteristics of TMB in the second corridor. The operational characteristics are explained by travel time variability, passenger waiting time, bus headway, passenger arrival time, location of access and egress, and loading factor. Results of analyses show the impact of operation in mixed traffic and the deviance from basic features of BRT. This study also provides several lessons learned when planning a BRT system in developing cities, especially when applying staging strategy in the implementation.

Keywords: BRT, BRT-lite, TMB, operational characteristics, developing countries.

1. INTRODUCTION

Bus Rapid Transit (BRT) system is well-known as a solution for congestion problem in many urban areas. It is believed that the BRT system is an efficient and effective public transportation that provides alternative ways to solve urban transport problems without costing a huge amount of investment. Since its first development in Curitiba (Brazil) in 1974 until its profile widely known in 1990s (such as in Bogotá and Los Angeles) (Wright, 2004), BRT has emerged as an economically self-reliant mass transit system with significant potential for budget-constrained developing cities (Hossain, 2006). BRT manifests itself in the form of service operated in a dedicated right-of-way that does not fall under a mixed traffic regime. Hensher and Golob (2008) states that it is not valid anymore to claim that only trains have privileged dedicated right-of-way. BRT encompasses service of large bus and trolley bus which operated on the highway with mixed traffic, or separated from general traffic with lane, or operated on a special trajectory (busway) (Arif and Tedjokusumo, 2004). Tann (2009)
indicated seven main features on the BRT: the special lanes, stops, vehicles used, payment systems, the application of intelligent transportation system (ITS), service planning and operation, and trademarks.

Those main features reflect the different characteristics of BRT in different cities as the implementation is adapted to the circumstances and conditions of the city. Wright (2004) states that while the terms of BRT may vary from country to country, the same basic premise should exist, namely a high quality, car-competitive transit service at affordable cost. Furthermore, he argued that the most significant difference between regular bus and BRT systems is the central focus of BRT on customer needs, i.e. speed, comfort, convenience, cost, and safety rather than being focused on a specific technology. More detailed discussions about components, features, and standards of BRT can be found in Wright (2004), Wright and Hook (2007), and the most recent is ITDP (2016).

In practice, there are many variations in the implementation of BRT, which manifests itself in the variation of the services offered. Hensher and Golob (2008) compared 44 BRT systems and found the range of design and service specification that are offered. Hossain (2006) discussed the BRT system in Asian cities in term of planning and collaboration among stakeholders. Currie (2006) describes the major systems operating in Adelaide, Brisbane, and Sydney which shows varying characteristics and performance.

In developing cities, the source of variations in the service levels comes from the stage of BRT implementation as a strategy to overcome the problem of the availability of resources to provide better public transportation service. With the fact that there are variations of the service or system of BRT, especially in the context of Asian cities, supported by different geo-political settings, even under similar circumstances, the condition does not support successful BRT planning initiatives (Hossain, 2006). This wide variety of systems in operation creates in difficulty to define a strict definition of BRT. Meanwhile, Sorg (2011) argued that the definition of BRT implies that a bus system lacking segregated busways is not considered as a BRT, even though it possesses most or all of the other characteristics of a full BRT system. This is labelled as enhanced bus services or BRT lite. The idea of enhanced bus services corresponds to the European approach in providing public buses with high level of service (BHLS), which has been developed mainly in France (Sorg, 2011). This is in line with the concept proposed by Wright and Hook (2007) that distinguished bus systems into informal services, conventional bus services, basic busways, enhanced bus services (sometimes labelled BRT lite), BRT, and full BRT.

In case of Indonesia, BRT system has been tried to be implemented in various cities with various degree of compliance to standard BRT as well as stages of implementation, namely the TransJakarta Busway in Jakarta, the Trans Metro Bandung (TMB) in Bandung, the TransJogja in Yogyakarta, the Trans Metro Pekenbaru in Pekenbaru, the Trans Kawanua in Manado, the Trans Hulontalangi in Gorontalo, and the Trans Pakuan in Bogor. Trans Metro Bandung (TMB) started its operation on September 24th 2009. As a fact, TMB has several drawbacks since it does not have the complete high-level of service of the BRT system. Some of the main problems are the operation of the buses in mixed traffic (ROW-C), limited size of fleet, manual fare collection, and insufficient capable human resources (Bureau of Transportation of Bandung City 2013). The lack of dedicated right-of-way will influence the travel time of buses, where it will also influence the pattern of passenger waiting time. Travel time and waiting time experienced by passengers are important aspects of bus services. These aspects reflect the reliability of the system. Lyons et al. (2007) stated that people expect a stable schedule to wait less for the bus to arrive and with less uncertainties about the travel time.

Another important component of BRT system, according to Levinson et al. (2003), is
station (bus-shelter) besides runways, vehicles, services, route structure, fare collection, and ITS. Contrast to current practice, BRT stations only alight and board passengers at designated stations. These stations are separated by enough distance to minimize stop times while at the same time are close enough to be accessed by most persons in the area (Wright and Hook, 2007). Current passenger behavior that often get on and off from the bus not on the designated bus stop and allowed by the bus drivers is one of the contributing factors that make the service does not reach the level of BRT service quality. According to Vuchic (2007), bus stop affects operation capacity of public transport. To accommodate passenger needs about suitable location of bus stop, thus the determination of the location of the bus stop on specific area is required.

With these backgrounds, this study aims to evaluate the operational characteristics of BRT-lite system, namely TMB system at the second corridor. An evaluation covers crucial performance of public transit system, namely travel time variability, bus headway, and passenger arrival time. Evaluation of the location of passengers boarding and alighting is also conducted. Lessons learned from this study are also provided and discussed. This kind of analysis provides information regarding how much the deviance of BRT lite system from the full-and-real BRT system. With this information, operator and government can made a better decision when it comes to decide what kind of BRT system they want to implement by considering the consequences.

2. OPERATIONAL PERFORMANCE INDICATORS

2.1 Travel Time Variability

Public transport services in most urban areas face the challenge to improve their reliability (Chen et al., 2009). Reliability improvement makes public transport more attractive and competitive (van Oort, 2011). Reliability covers the uncertainty about the time taken from the beginning to the end of the journey undertaken by passengers (Vincent, 2008). Travel time variability creates uncertainty, where passengers do not know exactly when they will arrive at their destination (Noland and Polak, 2002) or the time required (Pranolo et al., 2012). Congestion, traffic accidents, certain events, bad weather, the number of red lights, and the work area contribute to generating uncertainty, i.e. variability in travel times (FHWA, 2004), including stop times at the shelters and railroad crossings. Nowadays, the public expects a more stable transportation system with less travel time uncertainties (Bell and Iida, 2003). Route selection, the amount of discharge location, and timing intervals between buses are policies that can effectively reduce passenger waiting time and optimize the total travel time (Salek and Machemehl, 1999).

Kieu et al. (2013) divides the travel time variability into three kinds, namely inter-vehicle variability, inter-period variability, and inter-day variability. The measure of travel time variability commonly used is the standard deviation, taken simultaneously with the buffer time index. However, travel time variability can also be shown by the coefficient of variation (Susilawati et al., 2011).

Several studies of time variability have been conducted. Noland and Polak (2002) conducted a study on the travel time variability with a case study in the UK for public transport and in the USA for motor vehicle. The study indicated a need for additional fundamental theoretical research into behavioral issues of travel time variability. The study by Tseng et al. (2004) focuses on the reliability of travel time and scheduling delays and found that the inclusion of both reliability and scheduling attributes would lead to lower estimated
values for both attributes. Study conducted by Yetiskul and Senbil (2012) emphasized travel time variability modelling of BRT with case studies in Ankara, Turkey and found that reorganizing the transit system based on the characteristics of operational regions, highways, time of day, and time of week will produce significant gains in transit reliability. Pranolo et al. (2012) conducted a study on the measurement of travel time and bus buffer time using the boxplot of the TransJakarta system. They show that delays were mainly due to the uncoordinated traffic signal besides the mixed traffic, which overtook the dedicated busway when traffic congestion became unbearable.

Travel time variability has a negative influence on passenger waiting time due to its uncertainty. The problem becomes more complex when there is no real-time bus arrival information. The waiting time is undesirable for the passengers, since it is perceived as unproductive (Salek and Machemehl, 1999). In reducing waiting time or increasing certainty, real-time bus arrival information can be provided to transit passengers. Information about bus arrival time is useful, since passengers can use the waiting time more productively, select another route or alternative mode (Mishalani 2006). Mishalani et al. (2000) studied the value of information to passengers in terms of using the waiting time more effectively. A widely used traditional model employed to express the average passenger waiting time was the half headway model. Many studies have also been conducted to find more representative model (see Salek and Machemehl 1999 or Fan and Machemehl 2002 for more discussion).

From the above discussion, it is clear that studying travel time variability and passenger waiting time as a measure of quality of service is important. Unfortunately, available data of bus system in developing cities to conduct this kind of evaluation are rare, or in many cases, not available.

2.2 Bus Headway

The planning of public transport operating system requires information on the value of headway, capacity, speed, distance, and frequency (Vuchic, 2007). As one indicator of the operating systems of public transport, headway is an important factor for users and operator. Headway is a time interval between two consecutive vehicles that pass a predetermined point on the route of transit for the same purpose (Skinner et al., 2003). This value is determined when it was designed and become a reference number of vehicles that should be operated by the operator at certain times (Rahmah, 2013). Headway will affect the waiting time of passengers, bus travel time, and bus fulfillment time (Hill, 2003). Headway is influenced by unfixed operating schedule, bus passed in non-exclusive special lane, or bus stopped at places other than provided bus shelter (Skinner et al., 2003).

Distribution of time between vehicles is affected by the state of traffic flow. The state of traffic flow can be classified into three, namely high flow, medium flow, and low flow (Zala, 2011). High volume flow is determined when the headway values approaching to the same value (constant) between the vehicles due to the flow of the traffic is very high and close to the congestion. Low volume flow occurs when the value of the headway obtained through a random process because there is no interaction between the two vehicles coming.

In modeling vehicles headway using data from mixed traffic, the lognormal distribution and Weibull distribution can be used to explain the condition. Among several studies, Richter et al. (2009) modelled the distribution of headway of city bus in the city of Ryadh on the back the traffic lights and they found that the gamma distribution can explain the incident.

2.3 Passenger Arrival Time
The service level of bus system such as TMB is influenced by two factors: the frequency of buses arrival and passenger arrival rate. Arrival time between the user is identified as the time difference between two consecutive passenger comes at a service facility (Sugito and Mukid, 2011). The time difference between two passengers can be written as shown in equation 1 (Mazaya et al., 2012).

\[ \Delta t_n = t_n - t_{n-1} \]  

where:
\( \Delta t_n \) : Difference of Passenger Arrival Time (minute)
\( t_n \) : Passenger Arrival Time at n
\( t_{n-1} \) : Passenger Arrival Time at (n-1)

Braendli and Mueller (2006) said that the estimated time of passenger’s arrival is very important for two main reasons. First, the time of arrival affects the waiting time. Second, the arrival time affect the stability of the transport network. The presence of large variation in the arrival time causes instability of bus arrival because of the time delay of the vehicle.

There are two models of passenger arrival time, namely passenger who does not know the schedule of the bus and passenger who knows the schedule of the next transport (Braendli and Mueller, 2006). There are also two patterns of arrival, namely passenger arrival comes one at a time, and a batch of passengers coming at a time (batch arrival) (Utami, 2009). Passenger arrival time, passenger waiting time, and the buses headway are three important aspects in determining the quality of public transport services (Braendli and Mueller, 2006).

2.4 Bus Stop

Bus stop is the location where the bus dropping-off and -on passengers in several areas (Kittelston, 2003). Bus stop facility plays an important role as an attraction for the passengers to use public transport (TRB, 2003). Good accessibility, such as the availability of a special lane of wheelchairs and the elderly, will affect the attractiveness of the passenger (Kittelston, 2003). A stopping place should be accessible with a distance of about 400 meters or within 5 minutes walking at a speed of 4.5 km per hour (Tyler, 2002). Passenger’s distance in accessing stopping place is known as the catchment area (TCC, 2010). Recommendations of the distance according to the TCC (2010) are:

1. High-frequency corridor (<10 minutes between buses at peak): 400-500 m
2. Medium frequency corridor (10-30 minutes between buses at peak): 300-400 m
3. Low frequency corridor (> 30 minutes between buses at peak): 200-300 m

Quality of stopping place will affect the distribution of passengers in each of the stops. The distribution was subsequently affecting the bus loading factor. Loading factor is the ratio between the numbers of passengers with the capacity offered (Vuchic, 2007). Bandung Department of Transportation (2002) states that the minimum loading factor to operate a public transport was 70%. SPM TransJakarta regulated 0.75 persons / room as the standard loading factor.

3. LOCATION AND MATERIAL

3.1 Trans Metro Bandung

The focus of the study is the second corridor of TMB. Trans Metro Bandung (TMB) was operated in the City of Bandung, the capital city of West Java Province, where located around
150 km from the Jakarta, the capital city of Indonesia. TMB started its operation on September 24, 2009. The Ministry of Transportation granted ten unit of medium buses with air-conditioned to DAMRI as the operator of TMB (NTMC Korlantas, 2012). This system was implemented as a part of the effort of the Ministry of Transportation in improving the public transportation services in Bandung. TMB was a joint project between the Government of Bandung and Perum II DAMRI Bandung, with a sharing system (Metrotvnews 2009). In the beginning, TMB have a single corridor only, namely Cibiru – Cibeureum, where the bus was operated without exclusive lane and no priority given when reaching the intersection, with a total length of 23 kilometers and 14 stops for the round trips. The permanent shelter was started after two years in operation (Pikiran Rakyat 2011). In the first week of its operation, each bus traveled in average of 47 trips per bus or 204 km and served 27.686 passengers of general public and 28.870 students (NTMC Korlantas, 2012).

The second corridor, as a continuation of the cooperation between The City Government of Bandung and the Ministry of Transportation, was in service from 10 December 2012 to serve passenger from Cicaheum to Cibereum with a 12 km-length and 19 shelters in both directions (Dinas Perhubungan Kota Bandung, 2013) (Figure 1). The Ministry of Transportation granted ten units of buses for this second corridors, where 12.800 passengers have been transported from 10 December until 27 December 2012 (Gandapurnama, 2012). Until today, the TMB system has not enjoyed an exclusive lane or even priority at intersection yet. The construction of permanent shelter is still in a protracted process. However, in practice the passengers of TMB can get-in-or-off the bus anywhere as they wish and the fare is collected manually before passengers entering the bus (Dinas Perhubungan Kota Bandung, 2013).

These facts imply that TMB system does not comply with standard features of BRT system, i.e. full-BRT system. Thus, it is difficult to categorized TMB into one specific group as defined by Wright and Hook (2007). It is argued that current practice will put the quality of TMB below the quality of general BRT system in the world.

Moreover, in the case of Indonesia, the implementation of BRT systems was completed in several stages, with the initial stage was on the provision of buses, bus-stops, ticketing system, and corridor determination. The provision of exclusive right-of-way was considered in the later stages. This is also the case for Trans Metro Bandung (TMB). Up to 2014, Bandung has been operating two corridors, namely Corridor I (Cibiru-Cibeureum) and Corridor II (Cicaheum-Cibeureum). More corridors are in the pipeline for future implementation (Bureau of Transportation of Bandung City, 2013).

### 3.2 Data Collection

The collection of data and information for this study was done by collecting primary and secondary data. Some information of this study can also be obtained in Ramadhan and Joewono (2014), Rahmadiensyah and Joewono (2014), Ramdhana and Joewono, (2014), and Oktano and Joewono (2014). Operational data of TMB was collected from 14 December to 20 December 2013 at operation hours of TMB from 06:30 until 15:30. This observation time of 06.30 was selected as the first bus operation in the morning, while 15.30 was selected as the time of the last bus dispatched. Observations employed camera recorder to record the bus headway and passenger arrival time. Meanwhile, sports tracker application utilizing a GPS system, which was installed on a smartphone, was utilized to record time and location of buses. The smartphone was brought by the surveyors during the survey. This application recorded data of bus travel, namely average speed, distance, duration, route, and provides diagrams of speed and altitude. Based on this information, the terminal time, running time,
stop time, and dwelling time can be calculated and in the further stage to obtain the total cycle time.

Data collected shown a contradiction fact between the published and actual bus frequency. The published data shown a frequency of 6 trips per day with ten units of bus, while the actual frequency was 4 to 5 trips per day on weekdays and 3 trips per day on weekends. In this study, the survey only observed 3 trips per day for the weekends and weekdays. This study traced the actual bus route even when the bus drivers sometimes changed their route to avoid congestion during the service.

Figure 1 Route of the second corridor of TMB (Google Maps, 2013)

In this study, four location of bus stop was selected to record headway and passenger arrival time, namely stops at Jl. Cicadas Cicaheum - Bank BCA, intersection of Jl. Jakarta - Persib Stadium, Kosambi - Postal Giro, and Jl. Alun Alun Asia Africa - Bank Panin. Two locations of bus stops for collecting passenger waiting time were Persib Stadium and Postal Giro. In recording the real position of bus stops, surveyors were assigned on-board bringing the My Tracks application operated through Smartphone to record location and number of passenger boarding and alighting at any point, both official or not. The surveyors recorded the stopping places coordinate in global axis as the equipment was connected to the system of Global Positioning System (GPS). Location coordinates was further inputted into the ArcGIS software and digitized to define the location of stops.

4. DATA ANALYSIS

4.1 Analysis of Travel Time Variability

In this study, travel time was measured as a total time for a bus to travel from the origin terminal and return to the origin terminal. It includes the total duration of the bus when cruising the road (running time), dwell time (time for passengers to access and egress the bus), and the time when the bus reaching destination terminal (time for changing driver, waiting for
the next trips, cleaning, and so on). Figure 2 up to Figure 4 display the bus trajectories for one-week trips, which were categorized into morning trip (1st), noon trip (2nd), and evening trip (3rd). The longest travel time in the morning trip was 2 hours 46 minutes and the shortest was 2 hours 7 minutes, where the one-week’s average was 2 hours 21 minutes. In noon trips, the range of travel time was between 2 hours 31 minutes and 3 hours 13 minutes with an average of 2 hours 50 minutes. For evening trips, the travel time ranged from 2 hours 45 minutes to 3 hours 35 minutes with an average of 3 hours. The relatively higher travel time at noon and evening indicated that traffic was heavier at noon and evening than in the morning. The travel time variability was calculated using equation (2) as proposed by Kieu et al. (2013).

\[
T_{TV} = \sqrt{\frac{\sum_{i=1}^{D}(T_i - \bar{T})^2}{T}}
\]

where

\[T_TV\] : travel time variability (percent),
\[D\] : number of observed trips per day,
\[T_i\] : travel time (hour), and
\[\bar{T}\] : average travel time (hour).

The values of Travel Time Variability (TTV) for each day are presented in Table 1 for buses operated on the designated (initial) route as well as on the alternative route. Sometimes the drivers informally shift to an alternative route at noon and evening as a way to escape from congestion. In official scheduling, this alternative route was not recognized. Driver decision to change to the alternative route affected the observations on Monday and Tuesday. It is found that Thursday had the highest variability. TTV is also calculated for weekdays and weekends as appears in Table 2. The analysis shows that the variability on weekdays is higher
than on the weekend for designated and alternated routes. It is also found that the variability is higher on designated route than alternated route. This is reasonable as the bus drivers changed the route to avoid congestion on the initial route. This decision seems to improve the reliability of the bus schedule.

**Table 1** Values of travel time variability per day

<table>
<thead>
<tr>
<th>Day</th>
<th>1st Trip (T)</th>
<th>2nd Trip (T)</th>
<th>3rd Trip (T)</th>
<th>$\sum (T_i - \bar{T})$</th>
<th>TTV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>2.769</td>
<td>2.888*</td>
<td>2.893*</td>
<td>2.769 (2.890*)</td>
<td>0 (0.00001*)</td>
</tr>
<tr>
<td>Tuesday</td>
<td>2.331</td>
<td>3.230*</td>
<td>2.983*</td>
<td>2.331 (3.106*)</td>
<td>0 (0.030*)</td>
</tr>
<tr>
<td>Wednesday</td>
<td>2.385</td>
<td>2.525</td>
<td>2.800</td>
<td>2.570</td>
<td>0.089</td>
</tr>
<tr>
<td>Thursday</td>
<td>2.122</td>
<td>3.007</td>
<td>3.030</td>
<td>2.720</td>
<td>0.536</td>
</tr>
<tr>
<td>Friday</td>
<td>2.279</td>
<td>2.536</td>
<td>2.756</td>
<td>2.524</td>
<td>0.114</td>
</tr>
<tr>
<td>Saturday</td>
<td>2.397</td>
<td>2.879</td>
<td>3.593*</td>
<td>2.638 (3.593*)</td>
<td>0.116 (0*)</td>
</tr>
<tr>
<td>Sunday</td>
<td>2.185</td>
<td>2.789</td>
<td>3.031</td>
<td>2.668</td>
<td>0.380</td>
</tr>
<tr>
<td>Average</td>
<td>2.603</td>
<td></td>
<td></td>
<td>0.052</td>
<td></td>
</tr>
</tbody>
</table>

*calculated based on changed route by drivers from the designated (initial) route to avoid congestion

**Table 2** Travel time variability for weekdays and weekends

<table>
<thead>
<tr>
<th>Day</th>
<th>Initial Route</th>
<th>Alternated Route</th>
<th>Initial Route</th>
<th>Alternated Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>0.186</td>
<td>-0.108</td>
<td>0.012</td>
<td>-</td>
</tr>
<tr>
<td>Tuesday</td>
<td>-0.252</td>
<td>0.063</td>
<td>0.108</td>
<td>-</td>
</tr>
<tr>
<td>Wednesday</td>
<td>-0.012</td>
<td>0.000</td>
<td>0.012</td>
<td>-</td>
</tr>
<tr>
<td>Thursday</td>
<td>0.137</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Friday</td>
<td>-0.059</td>
<td>0.003</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Saturday</td>
<td>-</td>
<td>-</td>
<td>-0.015</td>
<td>0.0002</td>
</tr>
<tr>
<td>Sunday</td>
<td>-</td>
<td>-</td>
<td>-0.015</td>
<td>0.0002</td>
</tr>
<tr>
<td>TTV</td>
<td>0.051</td>
<td>0.019</td>
<td>0.003</td>
<td>0</td>
</tr>
</tbody>
</table>

4.2 Analysis of the Component of Travel Time

Travel time is also calculated according to its components, namely terminal time ($t_t$), stop time including dwelling time ($t_d$), and running time ($t_r$). Table 3 shows the value of each component for each day.

Drivers' decision to take alternative route (changed route) is certainly with a good reason: avoiding congestion on the actual route. Therefore, t-test was used to compare the two routes. The result of Levene test (p-value = 0.630) indicates that equal variance can be assumed. Analysis shows that there is a significant difference in the average travel time between these two routes, where the alternated route has significantly shorter average travel time (Table 4).

**Table 3** Components of travel time per day

<table>
<thead>
<tr>
<th>Day</th>
<th>First Trip (hour)</th>
<th>Second Trip (hour)</th>
<th>Third Trip (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>0.667</td>
<td>0.480</td>
<td>1.622</td>
</tr>
<tr>
<td>Tuesday</td>
<td>0.667</td>
<td>0.283</td>
<td>1.381</td>
</tr>
<tr>
<td>Wednesday</td>
<td>0.667</td>
<td>0.362</td>
<td>1.357</td>
</tr>
<tr>
<td>Thursday</td>
<td>0.667</td>
<td>0.192</td>
<td>1.264</td>
</tr>
<tr>
<td>Friday</td>
<td>0.667</td>
<td>0.276</td>
<td>1.336</td>
</tr>
<tr>
<td>Saturday</td>
<td>0.667</td>
<td>0.291</td>
<td>1.440</td>
</tr>
<tr>
<td>Sunday</td>
<td>0.667</td>
<td>0.348</td>
<td>1.170</td>
</tr>
</tbody>
</table>

*The results are calculated using the Levene test to compare the two routes (p-value = 0.630), which indicates that the variances are equal.*
An analysis is also performed to compare travel time of weekends and weekdays for both the initial and alternated route. The analysis result with equal variances indicates that the average travel time between weekends and weekdays is not significantly different for bus traveling in designated route. On the contrary, the result shows that there is significant difference between weekdays and weekends for buses operated on alternated route \((p=0.045)\). The difference exist because the bus passed the central market of Pasar Kosambi when they took the alternated route. This area is more congested on weekend due to more traffic activity.

Furthermore, an analysis of variance is employed to compare the average value of travel time among trips (morning, noon, and evening trips) for bus traveling only on fixed routes. The result of one-way ANOVA shows that there is a significant difference between the various trips \((F = 11.548; \text{df}1 = 2; \text{df}2 = 13; p = 0.001)\). Using the Student-Newman-Keuls (SNK) test \((\alpha = 5\%)\), it is found that the morning trip has significantly less travel time than noon and evening trips. However, the difference between noon and evening trips is not significant.

It is generally accepted that Monday, as the beginning of the week, is usually associated with heavy traffic jam. This is also the reason why drivers of TMB are more likely to shift the route to avoid congestion. The decision to shift the route certainly depends on the traffic and, may be in less degree, whether or not some passengers in the bus are affected by the change of the route. The decision may be beneficial for most passengers in the bus as all of them want to reach their destination as soon as possible. However, it should be kept in mind that there is a possibility to skip some customers waiting for the bus at the bus stops along the original route. With the decision to change the route, it will deplete the reputation and reliability of people in using TMB. This can be a dilemma and the management of TMB should seriously consider about this.

### 4.3 Analysis of Passenger Waiting Time

Observation to obtain PWT was conducted from 07.00 to 14.00 for a week (Monday to Sunday) at two bus stops. From the observation, the waiting time of 435 passengers were collected. The reported waiting time is the time experienced by passengers when they arrive at the bus stop until the time they get on the bus. Descriptive statistics of passenger waiting time is provided in Table 5. The average for the whole week is 12.56 minutes, while the average per day ranges from 8.020 up to 18.492 minutes.

<table>
<thead>
<tr>
<th>Day</th>
<th>Median</th>
<th>Mean</th>
<th>Max</th>
<th>Min</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>4.583</td>
<td>8.558</td>
<td>44.283</td>
<td>0.067</td>
<td>9.358</td>
</tr>
<tr>
<td>Tuesday</td>
<td>8.442</td>
<td>9.644</td>
<td>37.667</td>
<td>0.167</td>
<td>9.454</td>
</tr>
<tr>
<td>Wednesday</td>
<td>6.575</td>
<td>8.020</td>
<td>40.567</td>
<td>0.633</td>
<td>6.945</td>
</tr>
<tr>
<td>Thursday</td>
<td>14.692</td>
<td>14.408</td>
<td>34.150</td>
<td>0.533</td>
<td>8.565</td>
</tr>
<tr>
<td>Friday</td>
<td>7.183</td>
<td>13.609</td>
<td>49.317</td>
<td>0.417</td>
<td>12.792</td>
</tr>
<tr>
<td>Saturday</td>
<td>12.967</td>
<td>18.492</td>
<td>66.200</td>
<td>0.050</td>
<td>16.107</td>
</tr>
<tr>
<td>Sunday</td>
<td>11.233</td>
<td>15.172</td>
<td>77.933</td>
<td>1.733</td>
<td>17.095</td>
</tr>
</tbody>
</table>
The median of waiting time on Thursday is the highest within weekdays as the consequence of the highest travel time variability on this day. Interestingly, the maximum waiting time on Thursday is the lowest (34.15 minutes) as shown in Table 5. The median and mean of waiting time for Saturday and Sunday are relatively higher compared to any other days in weekdays (exception is for Thursday), where mainly due to the numbers of bus trip are less than on weekday. Therefore, weekday and weekend waiting time should not be statistically compared.

Analysis using Anderson-Darling test (Ang and Tang, 2007) shows that the suitable probability distribution for passenger waiting time is the exponential distribution (p-value = 0.640). The probability density function (PDF) for passenger waiting time is explained by equation 3.

\[
f(x) = 0.07908e^{-0.07908x}
\]  
(3)

When the analysis is conducted by dividing headway into several groups, different distribution functions can be found. Weibull probability density function is found as fit with the data. Figure 5 explains the density function for three groups of bus headways, i.e. less than 20 minutes, 20-40 minutes, and more than 40 minutes.

At present, there is no dedicated standard for the service quality of TMB. In Jakarta, the maximum waiting time of TransJakarta Busway is regulated as high as 7 minutes at peak hour and 15 minutes at non-peak hour (the Governor of DKI Jakarta, 2014). This standard is similar with the standard of road based mass transportation regulated by the Ministry of Transportation, Republic of Indonesia (2012). For headway, maximum values of 15 minutes for peak-period and 30 minutes for non-peak period are regulated as the minimum service standard for urban transport services (Ministry of Transportation, 2013).

Based on the results of analyses, it can be concluded that the passenger waiting time of TMB system can be classified as not acceptable when it is compared to those three available standards. Current waiting time distribution shows a large variation and implies a large deviation from the standard. When the waiting time is separated into three classifications according to the length of headway, the waiting time seems to be longer.

\[
f(x) = 1.1437 \cdot 8.4322x^{1.4722}e^{-1.1437x^{0.4322}}
a. \text{Bus headway less than 20 minutes}
\]

\[
f(x) = 1.1548 \cdot 11.932x^{1.932}e^{-1.1548x^{11.932}}
b. \text{Bus headway 20-40 minutes}
\]
4.4 Relations between Passenger Waiting Time and Travel Time Variability

This study revealed the real condition and performance of TMB. It shows that even though the government and operator provided with high quality buses, the bus performance is highly influenced by traffic conditions. TMB experienced variability in travel time from day to day in a week, while the bus also experiences diversion from the planned route to avoid congestion. Lack of dedicated right-of-way significantly influenced the travel time variability. Consequently, it influenced the passenger waiting time as well.

The relationship between the passenger waiting time and bus travel time variability was estimated by developing a simple linear regression as presented in equation 4. Pair data of the passenger waiting time (PWT) and travel time variability (TTV) from each day were analyzed. From the model, the TTV significantly influenced the PWT at 10% significant level. The result indicated that TTV could explain 50% of the variability of passenger waiting time. Higher variability makes passengers wait longer.

\[
\ln(PWT) = 2.142 + 4.29 \times \text{TTV}
\]

\(t=11.79\) \(t=2.22\)

\[F = 4.94; \ p\text{-value} = 0.077; \ R^2 = 49.69\%; \ R^2 \text{(adj)} = 39.63\%\)

4.5 Analysis of Headway and Passenger Arrival Time

There were six vehicles operated during the survey period with the frequency of three trips per day which resulted 68 headway data per day. Table 6 shows the average headway for each day. Based on one week observation, it is found that the average is 27 minutes, the median 25 minutes, and standard deviation 12 minutes.

<table>
<thead>
<tr>
<th>Days</th>
<th>Bus headway (min.)</th>
<th>Passenger arrival time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>7.00</td>
<td>58.00</td>
</tr>
<tr>
<td>Tuesday</td>
<td>4.00</td>
<td>67.00</td>
</tr>
<tr>
<td>Wednesday</td>
<td>10.00</td>
<td>50.00</td>
</tr>
<tr>
<td>Thursday</td>
<td>10.00</td>
<td>47.00</td>
</tr>
<tr>
<td>Friday</td>
<td>11.00</td>
<td>49.00</td>
</tr>
<tr>
<td>Saturday</td>
<td>4.00</td>
<td>59.00</td>
</tr>
<tr>
<td>Sunday</td>
<td>11.00</td>
<td>47.00</td>
</tr>
</tbody>
</table>
Analysis based on Anderson–Darling test found that the \( p\)-values for normal distribution, lognormal, and Weibull are equal to 0.005, 0.005 and 0.010, respectively. Goodness of fit test results \( p\)-value as much as 0.092 for gamma distribution and it is greater than 5%. It can be concluded that gamma distribution fits the data.

\[
f(x) = \begin{cases} 
\frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha - 1} e^\left(-\frac{x}{\beta}\right), & \text{for } x \geq 0 \\
0, & \text{for } x \leq 0 
\end{cases}
\]

\(
\Gamma(4.83) = \int_{0}^{\infty} x^{4.83} e^{-x} dx \quad \mu = \alpha \beta = 27.00 \quad \sigma = \sqrt{\alpha \beta^2} = 12.00
\)

with: \( \alpha = 4.83; \beta = 5.53; x = \) headway (minute)

This study also employed data of passenger arrival time and number of passengers at the bus stops: Stadion Persib and Kantor Pos Kosambi. For this analysis, data of the time between passenger arrival were grouped into five minutes interval. Descriptive statistics of the time between passengers arrival are provided in Table 6. The result of analysis found that Weibull distribution (AD=10.20) is fit with data with \( p\)-value = 0.08. The Weibull distribution function is presented in Figure 6 with an average (\( \mu \)) as much as 1.75 minutes.

\[f(x) = 1.152x^{2.6} e^{-1.152x}\]

\(x=\) arrival time (minute)

Figure 6. PDF of passengers’ arrival time

4.6 Analysis of Locations of Access and Egress

The habit of the TMB’s passenger in making access and egress outside the designated bus stop creates an impact of scattering location of passengers’ access and egress along the corridors. This scattered location of passengers’ position are collected by employing data recorder. Data of location are combined into a hypothetical service area (catchment area), which is 200 m, 400 m, and 500 m where the center is the official designated bus stop location. Based on this catchment area, it can also be determined the preferred location of bus stop. The preferred location is selected by setting the center location of passenger concentration when they access and egress in each catchment area. This new procedure result a proposed bus stop location. These two procedures result different number of bus stops location. It is found a proposed bus stop location as much as 47 for the catchment area of 200 m, 18 stops for 400 m, and 16 stops for 500 m (Table 7).

Figure 7 up to Figure 9 show the entire passenger locations for access and egress for the three catchment area. Catchment area is shown with a green circle in the picture. Using data about the real location of passenger stops, both at designated or alternative, the quality of
stops is analyzed. The analysis is performed by evaluating the area that not been served or uncovered (blank-spot) as well as the locations that was served by more than one catchment area (overlap). The distances of blank-spot and overlap are obtained by measuring the distance that is not covered by any catchment area. Figure 10 shows the illustration of the determination of blank-spot and overlap distances between two adjacent catchment areas. The analyses are conducted for the two trips.

![Figure 7. Locations of passengers’ access and egress for 200 m catchment area](image)

![Figure 8. Locations of passengers’ access and egress for 400 m catchment area](image)

![Figure 9. Locations of passengers’ access and egress for 500 m catchment area](image)

Descriptive statistics of the data stops, blankspot, and overlap for each catchment area are shown in Table 7. Comparison analyses between the two trips direction are performed using t-test as appear in Table 9, where the results of homogeneity test are provided in Table 8. Analyses show that there are no significant difference between the two trips direction for both the distance of blank-spot and overlap for the catchment area of 400 and 500m. Difference result is found for catchment area of 200m in the distance of blank-spot and overlap. It can be easily understood that wider catchment area will reduce the variability of passengers’ location in making their access and egress.
Analysis is continued by calculating the blank-spot and overlap distance for the proposed
location. Contrast with previous analyses, where the previous relied on the designated location of bus stop while the proposed bus stop location relied on the center of concentration of the selected location by passengers. The proposed location of bus stops are selected by selecting the location of bus stop based on the catchment area. Result of analyses are provided in Table 10. It can be concluded that the proposed bus stop location performs better in reducing variability, since there are no significant difference between the distance of blankspot and overlap in the two bus directions.

<table>
<thead>
<tr>
<th>Area</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Catchment Area of 200 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blankspot</td>
<td>-0.825</td>
<td>18.000</td>
<td>0.420</td>
<td>-14.707</td>
<td>17.836</td>
</tr>
<tr>
<td>Overlap</td>
<td>-0.6470</td>
<td>35.0000</td>
<td>0.522</td>
<td>-13.486</td>
<td>20.843</td>
</tr>
<tr>
<td>The Catchment Area of 400 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blankspot</td>
<td>-0.012</td>
<td>5.000</td>
<td>0.213</td>
<td>-111.670</td>
<td>78.339</td>
</tr>
<tr>
<td>Overlap</td>
<td>0.694</td>
<td>29.0000</td>
<td>0.493</td>
<td>40.606</td>
<td>58.500</td>
</tr>
<tr>
<td>The Catchment Area of 500 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blankspot</td>
<td>-1.122</td>
<td>3.000</td>
<td>0.309</td>
<td>-109.683</td>
<td>89.721</td>
</tr>
<tr>
<td>Overlap</td>
<td>-1.298</td>
<td>19.0000</td>
<td>0.210</td>
<td>-110.567</td>
<td>85.164</td>
</tr>
</tbody>
</table>

4.7 Factor Loading

The calculation of the factor loading is performed using the published headway (25 minutes) and vehicle capacity (79 space). Using data for the whole week, it can be calculated the average of loading factor for the three catchment areas. The average loading factors for 200m, 400m, and 500m are 0.88, 0.89, and 0.90 person / space.

Figure 11 shows the variation of loading factors for each day in one week. It can be seen that the factor loading for each day is above the specified minimum level according to the Ministry of Transportation, namely 0.70 people / space. When it is compared with the standard of TransJakarta (0.75 persons / space), again TMB has higher loading factor. Figure 11 also shows the loading factors for the two directions. It shows that the loading factors for the two directions seems as varied among days, while analysis shows that there is no significant difference between weekdays and weekends (t = 0.245; df = 19; p-value = 0.809).

4.8. Lesson Learned

From the experience of Trans Metro Bandung as one example of BRT-lite system, several things can be highlighted as lessons learned for other stakeholders who have plans to implement the BRT system or to upgrade one. The first is the selection of activity when BRT
will be implemented in several stages. The result from TMB shows that providing high quality bus as the first step in implementing BRT systems may not be the right strategy if it is not supported by the provision of dedicated right-of-way. The study showed that the lack of dedicated right-of-way influence the duration of passenger waiting time, not just the length of travel time and its variability. In some cases, when the traffic conditions are worse, bus drivers could make an initiative to shift to another less congested route to avoid being trapped in congestion on the actual route. This action may cause customers waiting for the bus on the skipped route left without service. A strong and may also be a political will from the local government to seriously support the success of BRT implementation can be shown by providing an exclusive lane for this bus service. Thus, providing infrastructure in the form of exclusive right-of-way seems as more important than the bus itself.

Based on the results of this study, the second lesson learned is related with the requirement to build successful BRT system. Even though the general features of BRT is well understood, the local context should be carefully considered. Especially in developing cities, selection of activity in preparing the implementation of the full BRT system can differ from practices in developed cities, since the availability and capability of resources are different. This is in line with Sorg’s statement (2011) that local performance requirements have to guide the planning process in each case, instead of defining an optimally performing BRT system in a general way. Thus, the standard of success of BRT cannot be generalized between staging implementation and one-stage implementation. The reason is provided by Sorg (2011), namely that the judgment of success of BRT system is influenced by underlying expectations and the comparison to formerly existing public transport systems.

Third, the improvement strategy of an existing BRT system will vary according to the current class of the BRT system. It is argued there is no standard way to improve the system. Some recommendations in improving the system have been proposed by Hidalgo and Carrigan (2010). Understanding of the capability of government and operators, as well as the needs of customers is obviously imperative. By way of this example, the provision of dedicated lanes, which will improve the reliability, seems to have higher importance than the provision of high quality buses. Certainly, the decision should be supported with the provision of facilities for people in using TMB as a way to attract public to use the system. This supporting facility will vary from place to place according to the local capability and intended level of BRT system.

Fourth, the BRT system is not just a bus system with specific features. BRT system implies a real public transportation with high quality and standard. It means there is a requirement to change the habit of operator as well as the users to follow the standards. As a way of example, the practice of access and egress in very flexible way along the corridor cannot be tolerated. The activity of access and egress should be completed in dedicated bus stop. This very basic features require the change of habit of users, operators, drivers, as well as regulators. To have a high mobility means to restrict the accessibility. To have a higher reliability of travel time and headway, then dedicated bus stop is a must. A change of behavior should be also considered by providing learning process for all stakeholders involved.

5. CONCLUSIONS

This study elaborates the operational characteristics of Trans Metro Bandung, where it was planned as a BRT system. The focus is on the bus’s travel time variability and passenger waiting time. Since TMB at present is operated under mixed traffic regime, the impact on
travel time variability and waiting time become significant. Analysis results show that travel times vary among days as well as between weekdays and weekends. Variation was not influenced by road traffic only, but also by diversion from the planned route. This study also found the positive association of travel time variability with passenger waiting time.

Analyses also found the statistical distribution of bus headway as well as the passengers’ arrival time. This distribution provides information regarding the impact of the implementation of bus under mixed traffic. Low coordination between the distribution of headway and passenger arrival time seems as having positive influence in increasing the low reliability of TMB system.

As a matter of fact, current passenger can easily get in or get off from the bus in very flexible way. They can decide the location of stop they want. It absolutely in contrary with the very basic feature of BRT. This practice results a distributed concentration of passenger, where ideally it should be concentrated in specific location, e.g. location of activities. This study shows that the designated bus stops are unmatched with the need of users. Analysis shows that consideration of the concentration of people’s location in proposing bus stop location will reduce the variability.

Thus, from the experience of TMB, several lessons learned can be noted. The provision of dedicated lanes seems to be the most important thing in implementing the BRT system, while the other elements can be provided at the next stages. Provision of dedicated lanes is expected to improve the reliability of the bus system as a way to attract people to use this bus system. In improving and evaluating the BRT system, the local context and conditions should be carefully investigated. The understanding will provide a fair judgment about the success, since the success of the implementation of BRT system should be judged in line with the particular class of BRT. Furthermore, to ensure the success of the implementation of real public transport then a behavioral changes should also be considered and introduced. To have a high quality and capacity of public transport system, it is required to have a suitable behavioral in using public transport, e.g. dedicated location of access and egress, access to bus stop, or waiting location or transfer. The success of BRT implementation seems as not require an infrastructure development only but also the change of behavioral of all related stakeholders.

In having an integrated and holistic view for BRT development, there are many other aspects can be considered to upgrade the current system to a full system for further study. One of the important studies is the inclusion of demand features, such as spatial and temporal distribution of the ridership.

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