Improved Method To Determine A Bus Bay Standard Dimensions Using The Queuing Theory

Djoko Sulistiono, Widjonarko Roestam, Amalia Firdaus M

ABSTRACT

Bus bay is a part of a widened road section for loading and unloading bus passengers. Its existence is important in a bus route for reducing or overcoming traffic jam, when the route is not equipped with a bus bay; that is in turn will be a potentially narrowing a route width to cause a traffic jammed. A traffic engineer needs to take into consideration bus frequencies, road function or road classification that yields a proper dimension of a bus bay. This paper will discuss designing a bus bay dimension, in terms of its waiting bus length according with bus arrival rate (bus/hour) using queuing theory. Standards, such as issued by SNI (Indonesian National Standard), Department of Land Transportation-Republic of Indonesia and Septa Bus Stop Design Guide that are applicable for designing a bus bay will be evaluated and compared, then authors proposed a more precise ranges of bus arrival frequencies to get a larger number of waiting buses on a bus bay with its length of waiting bus lane. Result of the study is shown as a relationship between bus arrival rates (bus/hour) with length of waiting bus lane (m) in terms of a linear regression equation $Y = 1.76X + 8.40$. $Y$ is length of waiting bus lane in a bus bay and $X$ is number of arrival bus and the relation has a coefficient correlation ($R^2$) of 0.9878. Hence, it can be concluded that there is a strong relation between bus arrival rates (bus/hour) with the need of waiting bus lane length in a bus bay ($m$). Then, for practical purposes, the equation mentioned above can be used for determining waiting bus lane in a bus bay depending upon bus arrival rates.

INTRODUCTION

Bus bay is part of a widened road section that is for public bus stop (SNI 2838 – 2015) (Badan Standarisasi Nasional, 2015). The main function of the bus bay is to reduce traffic conflicts caused by a bus stopping by on a road side. Besides, it will also increase passenger’s safety and conveniences. Bus bay must be provided by a shelter, that is a structural building for waiting passengers. Stopping bus lane must be paved and length of that lane should be able to accommodate appropriate number of bus depending on its frequencies.

One cause of traffic jam on a road segment is an insufficiency bus bay capacity. It turns that the length of bus bay lane is not suited to as needed length. Several bus bay design standards have been issued, such as SNI-04-1991-03 (Departemen Pekerjaan Umum, 1991). Department of Public Works Republic of Indonesia (Departemen Pekerjaan Umum, et al., 1988) has issued a regulation to determine number of buses on a bus bay based on bus arrival frequencies (bus/hour) with condition that is on a moderate level arrival frequency. On the other hand, Directorate General of Roads – Department of Land Transportation Republic of Indonesia issued a decree (SK No. 271/HK 105/DRJ/96) (Departemen Perhubungan Direktoral Jenderal Perhubungan Darat, 1996) that regulates bus bay lane dimensions based on its bus capacity, number of passengers, as well as embark
and disembark time of bus. Septa Bus Stop Design Guide – 2013 also give a regulation to determine bus bay lane length based on road function or road classification and average bus speed to enter bus bay, but it is not based on arrival frequency.

SNI-2838-2015 (Badan Standarisasi Nasional, 2015) related to bus bay geometrical specification has been issued to standardize shape, dimension and location of bus bay in accordance with nowadays’ needs and trends. However, SNI-2838-2015 ¹ just only regulate length of bus bay for maximum of 2 buses waiting on it. Therefore, Sulistiono et al. (2007) tried to improve that requirement in SK SNI-04-1991-03 (Departemen Pekerjaan Umum, 1991) regarding determining the length of waiting bus lane. The problem can be stated that how to determine the length of bus bay that is fitted to bus arrival frequency. The required length will be discussed in the following matters.

**Materials:**

Object study is arterial roads or collector roads that is used by public bus. Based on SK SNI T-04-1991-03 (Departemen Pekerjaan Umum, 1991) related to bus bay (see Figure 1), the total length of bus bay is determined by arrival bus frequency (bus/hour); that consists of entrance, waiting and exit lane.

![Bus Bay Dimensions](source: SK SNI T-04-1991-03)

**Fig. 1:** Bus Bay Dimensions based on entrance (road), waiting bus lane and exits (road)

Table 1: Bus Arrival Frequency and Number of Stopping Bus (n) Relation

<table>
<thead>
<tr>
<th>Bus Arrival Frequency (bus/hour)</th>
<th>(Number of stopping bus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 – 30</td>
<td>1</td>
</tr>
<tr>
<td>30 – 50</td>
<td>2</td>
</tr>
<tr>
<td>&gt; 50</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: SK SNI T-04-1991-03

If there is n bus, therefore the length of waiting lane for bus bay can be determined by n x 14 m. Number of buses waiting on a bus bay that is based on bus arrival frequency can be estimated using Table 1, in which maximum number of waiting bus is just only 3. Thus, SNI-2838-2015 ¹ just only for determining length of bus bay will not be applicable, since it is only valid for maximum number of waiting bus on bus bay is 2 buses. Besides, requirement in SNI-2838-2015 does not include turning radius of entrance and exit lane in bus bay (R₁ and R₂). Sulistiono, et.al. ⁶ tried to reduce range of bus arrival frequency by using queuing theory, so that it will applicable to determine length of bus bay for more precise frequencies with greater than 3 (number of waiting bus).

**Method:**

Queuing theory by Tamin (2003) ⁷, that is used for determining number of waiting bus on a bus bay (n) Is the following:

\[
q = \frac{(\lambda / n)^3}{\mu - (\mu - (\lambda / n))} < 1 \text{ no queu.} \quad (1)
\]

where, q = number of queuing bus

\[\lambda = \text{level of bus arrival (bus/hour)}\]

\[\mu = \text{level of bus service (bus/hour)}\]

n = number of waiting bus
For example, if $\lambda = 30$ (bus/hour) and $\mu = 12$ bus/hour (Service standard – Directorate General Land Transportation is 5 – 10 minutes), then $q = \frac{(30/n)^2}{12-(12-(30/n))} < 1$

$q = \frac{(900/n)^2}{144-(360/n)} < 1 \rightarrow$ yields $n = 4$, and so forth for other arrival rates.

Sulistiono, et. al (2007), based on above method has proposed an improvement the range of the number of stopping bus (n) as shown in Table 2 for determining the length of waiting bus in a bus bay.

**Table 2:** Bus Arrival Rates and Length of waiting bus lane Relation

<table>
<thead>
<tr>
<th>Bus Arrival Rate (Arrivals/hour)</th>
<th>n</th>
<th>Length of waiting bus lane (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>42</td>
</tr>
<tr>
<td>30</td>
<td>4</td>
<td>56</td>
</tr>
<tr>
<td>40</td>
<td>6</td>
<td>84</td>
</tr>
<tr>
<td>50</td>
<td>7</td>
<td>98</td>
</tr>
<tr>
<td>60</td>
<td>8</td>
<td>112</td>
</tr>
</tbody>
</table>

Source: Sulistiono and Widjornarko, 2007

It is shown in Table 2, n and length of waiting bus lane can be determined based on bus arrival rate with an increment of arrival rate of 10. This is the improvement method proposed in using Table 1 to get standard number of waiting bus on a bus bay. Relation between length of waiting bus in a bus bay and the arrival rate can be shown in Figure 2. It is assumed that the relation follows a linear regression.

**Fig. 2:** Graph of Arrival Rates and the Length of waiting bus Lane Relation

Sulistiono, et al (2007), has evaluated the turning radius of entrance and exits ($R_1$ and $R_2$). The turning radius $R_1 = 18$ m at speed 20 km/hr meets the requirement of the standard, while the turning radius $R_2 = 12$ m at the same speed needs additional length of 0.8 m to fulfill the same requirement standard. The length of exits/entrance based on SNI-04-1991-03 (Departemen Pekerjaan Umum, 1991) is 17 m, when it is calculated using equation: $L_t = V x \frac{W}{3}$ (Dept. of Public Works, 1988) at the speed 20 km/hr is 20 m. Therefore, it should be an additional length of 3 m the length of exits/entrance of a bus bay when using SNI-04-1991-03.

**Discussion:**

Determination of the length of waiting bus in a bus bay using Queuing Theory can reduce the range of bus arrival rates (see Table 2), so that it can be able to improve the requirement standard in SK-SNI T-04-1991-03.
For bus arrival rate of 30 bus/hour based on requirement of SK-SNI T-04-1991-03, it needs only 1 stopping bus (n=1), while using Queuing Theory it yields n=4. This result, in turn, will reduce the impact of narrowing in the road, since the length of waiting bus lane has been sufficient, as seen in Figure 2. Linear regression between the arrival bus rate (x) with the length of waiting bus lane (y) is $Y = 1.76X + 8.4$ with $R^2 = 0.9878$. This equation can be used as an alternative method in determining waiting bus lane length in relation with a more precise bus arrival rate increment. The need of additional turning radius $R_2$ of 0.8 m and exits/entrance lane of 3 m will potentially improve the safety of exit and/or entry bus.

Nowadays, Indonesia Government tries to overcome traffic jammed occurred, especially in big cities, by increasing number of public mass transportation using trains or buses. For example, Jakarta city as a capital city currently (2017) uses public transport only 15 percent of total mode of transportation and it will be increased at least 50 percent within the next two years (2019). In line with reducing number of private transportation especially private cars, there will be a lot of bus bays built in roads within bus routes. Therefore, the equation discussed can be used as an alternative method determining waiting bus bay lane with a more precise increment number bus arrival rates compared to the requirement using the SNI-04-1991-03.

**Conclusions:**

Based on the above discussions, it can be concluded as the following:

1. The length of waiting bus lane in a bus bay can be determined based on bus arrival frequency using Queuing theory. The higher bus arrival frequency, the bigger number of stopping bus (n) and it will enlarge the length of waiting bus lane in a bus bay. The relation between bus arrival rate ($x$) and the length of waiting bus lane ($y$) is $Y = 1.76X + 8.4$ with $R^2 = 0.9878$.

2. The turning radius $R_1$ determined using SKSNI T-04-1991-03 Standard at bus speed of $V=20$ km/hour, is 18 m; which is defined by RSSNI T-14-2004 yields $R_1$ is just 12.8 m for fulfilling a convenient and safe turning radius. Therefore, $R_1$ can be sufficiently determined using SKSNI T-1991-03 Standard. However, the turning radius $R_2$ determined using SKSNI T-04-1991-03 Standard only yields 12 m. Hence, it is needed an additional radius of 0.8 m to fulfill a convenient and safe turning radius.

3. The length of exit or entrance lane, considered as a taper, will needs a minimum of taper length ($L_t\text{ min}$) of 20 m, based on the Geometry Standard of City Roads (1988)$^{3)}$. However, it just needs only 17 m, based on SKSNI T-04-1991-03 standard$^{2)}$. Therefore, it will need an additional length of 3 m for considering the convenient and safety of the passengers during the bus exits and entries a bus bay.

4. To use the equation proposed in point (1) in designing a bus bay dimension, there will be an adjustment to the yielded dimensions. The minimum turning radius $R_{min}$ should be at least 12.8 m and the minimum of taper length ($L_t\text{ min}$) should be at least of 20 m.

**REFERENCES**


Sulistiono, Djoko and Widjonarko, 2007.*Study of Bus Bay Requirements in City Bus Route*, Seminar Nasional Teknik Sipil FTSP-ITS.
