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The modeling of dwelling time of buses at bus stop

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Abstract. This research is aimed to build generic dwelling time modeling for BRT in Indonesia. Dwelling time was counted from the time of the bus entering to leaving the stop, including additional passenger service time. The observations were captured on 172 services period for 6 hours each at 6 heterogeneous bus stop using a video camera. The cameras were mounted inside the bus stop. It was located across stop's gate. This cameras' spot sets to capture the bus and passenger movement time to time. The clustering process used Pearson's correlation to differentiate of several data groups. The groups are global data, passenger by direction and additional data services. The Pearson's correlation value shows best on data that is divided into three categories, which are alighting time, departure time and additional service time. Each category is fitted into several regression models candidates, such as linear, polynomial, power, and logarithmic. A single linear regression model was found valid for representing bus dwelling time for each category. There the dwelling time model is a compound of three categorical model.

1. Background

For non – users, public transportations are poorly - perceived. Therefore, the perception decreases public transportation demand [1]. Especially for Trans Jogja buses, the service quality is the most influential thing for consumer satisfaction [2–6]. Accessibility, the bus stop condition and the lack of punctuality of Trans Jogja cause people to prefer to keep using private vehicles to support their activities. As a consequences, many Trans Jogja users whose goals are not bound by punctuality [7]. Moreover, Trans Jogja users prioritize service quality as the most affected for user satisfaction [2–6]. Most Trans Jogja's user are not on tight schedule [7]. Dwell time is one of the most important factors determining the service quality such as transit capacity and average speed [8].

Some researchers showed that the headway between buses was not close enough [7,9,10]. By using the standard of bus service issued by Ministry of Transportation [11], we can concluded that the Trans Jogja bus service is still beyond the standard. Research showed that bus headway was less than expected [7,9,10]. Furthermore, Trans Jogja's performance indicators are below the standard issued by regulator [11].

Management of dwelling time is considered important to improve service quality. With the availability of this model, it is expected that the operational planning of the bus will be better which



leads to the better quality of the service. Dwelling time model is an important foundation for improving the quality of the bus service. The model helps operators and regulator to have better bus operation planning. The novelty of this paper is the operation condition of service at bus stops in Indonesia is different from the previous studied [12–15].

State of the art of this paper is from the existence of the attendants at bus stops and in buses. Its presence affects the queuing pattern of getting in and out the bus. The dwelling time model which is different from previous research is required. Furthermore, the research question of this study is what kind of model is suitable for predicting the dwelling time at a bus stop. The contribution of this paper is the formulation of the dwelling time model.

2. Literature Review

In calculating the dwelling time, the researcher separated the time of alighting and departing passengers, and other additional characteristic [12,15–19]. The example of this characteristic is low-floor buses [16–18], or buses with two exits [18].

It can be concluded that in general, dwelling time (DT) is a function of the number of incoming passengers (D), boarding (B), bus stop condition (H), bus condition (bus), and operational system (O). The general equation for dwelling time (DT) can be written as

$$DT = f(D, B, H, Bus, O) \quad (1)$$

3. Methodology

One distinct characteristic of Trans Jogja Buses is the attendants. There are at least 3 attendants involved. One is in the bus, and two are in bus stop. The attendants of trans Jogja Bus' duties are : (1) information announcer, (2) driver and passenger assistant, (3) passenger flow controller, (4) record number of passenger, (5) payment facilitator (in bus stop only).

3.1. Hardware

Devices used in this study were related to data collection, processing and reporting. The data were related to the limitations of space, time and object of research. The device used in this study was video cameras to obtain (1) Number of queues at the bus stop (people), (2) The speed of passenger boarding on the bus (person / hour), (3) The speed of passenger alighting from the bus (person / hour).

3.2. Survey Form

Forms were used to record the dwelling times at Trans Jogja bus stop. The main data obtained from this survey are the time of arrival, departure time and additional service each time the bus at the bus stop.

3.3. Video

Video camera sets, and video processing software were used. The hardware was installed on a bus stop to capture images of passenger behavior when getting off the bus and boarding on the bus. Data from the video during the stop as illustrated on Figure 1 is summarized as data on arrival, departure and other service times. Calculation of service time at the bus stop (dwelling time) started when the bus door opened for passengers to alight from the bus until it is closed, at the bus stop.



Figure 1. The Screen Shoot of the Survey Video

3.4. Regression Model

Regression method was used to develop a bus service time model at the dwelling time. The model developed in this study consisted of a linear regression model. The adjusted R^2 was used to validate of the linear regression model. In addition to validation using the R^2 value, graphic observation with scatter plot was used to see the correlation between variables.

A scatter plot diagram is a summary view of all relationships between variables in the model. The model has several independent variables. Therefore, it required different scatter plots presented as a scatter plot matrix. Each scatter plot in a matrix also has the most appropriate linear and non-linear curves. There are six candidate models available in Libre Office Calc software. Candidate models are linear, logarithmic, exponential, power, polynomial and moving averages. The model with the greatest correlation value was chosen out of the various candidate models. Correlation values are presented together on the diagram. This correlation value shows the validity of the relationship between variables in the model.

3.5. Validation of Distribution and Regression Models

The distribution and regression models had to be tested for their goodness of fit. The tests included *chi-square* test, Pearson correlation test, and graphic observation. The following is an explanation of the tests. *Chi-square* test and graphic observation were used to validate distribution and regression models. Pearson correlation test was only used to validate regression models from this study.

4. Data Summary

Data for modeling dwelling time at the bus stop were obtained from video recordings of passengers arriving & leaving, at 6 stops, 6 hours between 07.00-18.00 WIB, for 7 days, for 172 times the bus stopped at the bus stop. A summary of survey data is presented in Table 1 and Table 2.

Table 1. Summary of Number of Passengers

Alightin	Number of	Boardin	Number of	Total	Number of
<i>Min.</i>	0	<i>Min.</i>	0	<i>Min.</i>	0
<i>1st Qu.</i>	0	<i>1st Qu.</i>	1	<i>1st Qu.</i>	2
<i>Median</i>	1	<i>Median</i>	2	<i>Median</i>	4
<i>Mean</i>	1,635	<i>Mean</i>	3,412	<i>Mean</i>	5,047
<i>3rd Qu.</i>	2	<i>3rd Qu.</i>	5	<i>3rd Qu.</i>	7
<i>Max.</i>	10	<i>Max.</i>	20	<i>Max.</i>	22

Source: survey results

Table 2. Summary of Passenger Service Time

Alightin	Time	Boardin	Time	Etc	Time	Total	Time
<i>Min.</i>	0	<i>Min.</i>	0	<i>Min.</i>	0	<i>Min.</i>	0
<i>1st Qu.</i>	0	<i>1st Qu.</i>	1	<i>1st Qu.</i>	5	<i>1st Qu.</i>	7
<i>Median</i>	1	<i>Median</i>	2	<i>Median</i>	6	<i>Median</i>	12
<i>Mean</i>	2,194	<i>Mean</i>	4,788	<i>Mean</i>	6,635	<i>Mean</i>	13.25
<i>3rd Qu.</i>	3	<i>3rd Qu.</i>	7	<i>3rd Qu.</i>	7.75	<i>3rd Qu.</i>	18
<i>Max.</i>	14	<i>Max.</i>	28	<i>Max.</i>	35	<i>Max.</i>	42

Source: survey results

The survey results on Table 1 showed that the maximum stop time at the bus stop is below the maximum value standard issued by the Ministry of Transportation. The duration of bus stop time is under 45 seconds at peak time, and 60 seconds at non – peak.

Based on Figure 2, the data can be divided into alighting, departure and other service times. The regression pattern that matches the correlation is linear regression. Figure 2 also shows the correlation of determination (R^2 and R^2 adj) related to the regression. The linear regression equation model for passenger service time at stop (y) in second with x is the number of passengers.

In general, this dwelling time is the time needed to prepare the first passenger to alight, the time between the last passenger boarding into the bus until the bus departs, and or the other time such as time for coordination between the attendant on the bus and the attendant at the bus stop. The equation is the one that has the largest R^2 value and the smallest p value.

5. Results and Discussion

5.1 Result

The model of bus service time at the bus stop (Dwelling Time) is formulated using this following equation:

$$\begin{aligned}
 \text{Alighting passenger service model} & \quad y_2 = 1.5 x_2 + (-0.26) \\
 \text{Boarding passenger service model} & \quad y_3 = 1.47 x_3 + (-0.22) \\
 \text{Additional service model} & \quad y_4 = 0.089 x_1 + 6.187
 \end{aligned}$$

Description of the Equation:

- y_2 : Alighting passenger service time (seconds)
- y_3 : Boarding passenger service time (seconds)
- y_4 : other service times (ungrouped) (seconds)
- x_2 : number of alighting passengers (people)
- x_3 : number of boarding passengers (people)

The equation was formulated on the condition that passengers were assisted by the attendants of Trans Jogja bus at each bus stop and in the bus. The model accommodated the diversity that existed in passenger service time at the bus stop, namely the service of alighting and boarding passenger, and other services. Other service times are used for coordination between the attendants on the bus and at the bus stop, although there are no passengers arriving or leaving. From the results of the survey, the maximum stop time at the bus stop is below the maximum value standard issued by Ministry of Transportation.

5.2. Discussion

The survey results showed that the maximum stop time at the bus stop does not exceed the standard of the Ministry of Transportation. The duration of alighting passenger service is less than 45

seconds at peak time, and 60 seconds at non – peak time.

The bus passenger service model at the bus stop follows the linear regression equation. The variations in the dwelling time is the time to serve the alighting and boarding passengers, and other service time. The grouping of these variations is in line with previous studies that separates the time of alighting and boarding of passengers [12,15–19].

This dwelling time model has a good Pearson correlation validity value (R^2). In this dwelling time model, R^2 of alighting passengers is 0.86, and R^2 of boarding passengers is 0.9. Both models have a *p-value* of <0.001 . The R^2 values show that other variables such as days, routes, sitting or standing passengers, payment methods do not seem to have much effect. There are specific things of the Trans Jogja Bus operation that must be considered, as follows:

1. Use of high-floor buses, capacity 22 seats, 19 standing passengers,
2. Two attendants are available, at fixed stops and in the buses,
3. The payment system is located at the bus stop, separated from the bus and can use human assistance.
4. Electronic payments on buses do not affect the queue, because passengers can make payments after boarding in the bus, and the bus runs,
5. There is no operational variation in bus services other than the portable stop.

With the proposed operational conditions as above, the produced model can be used with the similar operational conditions. This study is limited to the Trans Jogja Bus with the existing operational plan. Also limited to three variations, namely alighting and boarding passenger service time, and other services. Changes to the operational system may have an influence on service time at the bus stop.

6. Conclusion

The passenger dwelling time model at the bus stop is fit to the single linear regression model. The dwelling time model that is suitable for Trans Jogja Bus is the accumulation of the alighting passenger service process, the boarding passenger service time, and additional service times. The dwelling time model formulated in this study is representative of the Trans Jogja Bus which is a pilot bus of Bus Rapid Transportation (BRT). As a BRT pilot, the Trans Jogja Bus has specific characteristics such as a high floor, the bus is assisted by the attendant at the bus stop and in the bus, a door for the passengers to alight and depart. This condition was not found in the previous study regarding the dwelling time.

7. Suggestion

There are generalizable results of this study, which is the dwelling time model at the bus stop. However, these models must be calibrated to other locations to get more general models.

The service model at the existing dwelling time complies with the standards of the Ministry of Transportation [11]. However, there is still space for improvement by extending the calculation of bus service time from entering to leaving the bus stop. The service time is calculated since the deceleration, stopping to serve, accelerating to reach its free flow speed. The calculation of suggested service time complies with the standards in the United States [8], which also better reflects the overall service at the bus stop.

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