STUDY OF HETEROGENEOUS TRAFFIC CHARACTERISTIC MODEL ON ARTERIAL ROADS BASED ON DRIVER BEHAVIOUR (CASE STUDY: DRIVER BEHAVIOUR IN MAKASSAR)

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ABSTRACT

Microscopic analysis was required to predict driver behavior accurately. The directly observed driver behavior was maintaining lateral gap and longitudinal gap. The present study was aimed to analyze the distribution pattern of lateral gap and time headway of motorcycles and light vehicles in heterogeneous traffic in Makassar City. This study used tracking data from traffic record survey in the arterial road of road A.P. Petta Rani type 9 lane 2 directions for 11 hours to determine the effects of type, speed, lateral position and traffic flow. Data extraction showed that lateral gap between adjacent vehicles significantly varied depending on several traffic conditions, i.e. subject vehicle speed, speed and type of adjacent vehicle, and road width. It was found that different lateral gap managed by vehicles which moved at the same speed could be modeled by normal distribution. Similarly, lognormal distribution could be used to model gap managed by vehicles moving at certain speed with respect to the speed of one of adjacent vehicles. The result of statistical test analysis showed that the distributions of time headway of passenger vehicles in the period of an hour didn’t vary. Visually, there was a trend of headway following exponential distribution pattern. The study results provide a good expectation to proceed in order to test the suitability of the numerical distribution model, so that it can be used in the development of a traffic simulation micro model in follow-up studies.
1. INTRODUCTION

Road user behavior is a dominant factor causing various traffic problems in many places. There are important distinctions in analyzing driver behavior in a traffic flow: overt driver behavior and covert driver behavior. Only overt behaviors can be directly observed and recorded in certain conditions. Covert behavior isn’t revealed by direct observation and conclusion will be obtained from external behavior. Covert behaviors are cognition, emotion, attitude or habit. Behavior in maintaining lateral gap of every driver is influenced by various factors, including speed of subject vehicle, speed and type of adjacent vehicle, and road width.

In heterogeneous traffic, when traffic volume is quite high, most two-wheeled vehicles try to use small gaps in traffic flow and move at speed close to their free speed. Gap acceptance is a significant factor in determining road capacity considering all drivers can predict safe gap based on their preference for maneuver, whether to overtake, change lane, or follow a vehicle in front of them. There are two approaches to measure longitudinal gap, i.e. gaps based on distance and time. However, this study used time approach since it’s very difficult to measure the correct gap in the approach based on distance. Moreover, most gap acceptance in previous studies adopted the approach based on time which is defined as time headway.

The majority of traffic flow (over 70%) consists of two-wheeled vehicles. The behaviors of two-wheeled vehicle drivers in this condition are very complex because two-wheeled vehicles move very dynamically both laterally, depending on the size and gap, and longitudinally. Headway or time headway is a micro traffic indicator or characteristic which is very useful in analysis and planning of urban transportation, especially in traffic planning (May, 1990). For example, headway is used in planning traffic light signal, estimating traffic volume to evaluate road capacity, and assessing traffic performance. The purpose of this study was to analyze the lateral gap of vehicles moving side by side and distribution pattern of time headway of vehicles moving one after the other. Several past studies focus on analysis of lateral and longitudinal gaps in heterogeneous traffic.

Pal and Mallikarjuna (2010) study the relation between lateral gap and area occupancy and compare longitudinal gap of vehicles moving one after the other with the speed and lateral position of the vehicles. Lateral gap is used to assess effective width of dominant vehicle and determine cell width of heterogeneous traffic flow. Mallikarjuna and Rao (2011) perform a comprehensive study to model heterogeneous flow and limit the importance of lateral and longitudinal gaps in it. They also provide mathematic equation for the relation between lateral gap and area occupancy for various vehicle types. Mallikarjuna et al. (2013) study the relation between lateral gap an speed and produce average lateral gap for vehicle based on vehicle speed.

Considering the importance of headway, several theoretical approaches by statistical distribution approaches based on several empiric researches in developed countries have produced a standard of value and headway distribution model (Miller, 1961; Shalter, 1974; May, 1990; Luttinen, 1996; Sadheghenni, 2002) which can be used for planning and analysis.
of transportation in general. This behavior is the opposite of traffic condition in developing countries which isn’t orderly in road lane, such as in India (Arashan, 2002). In terms of heterogeneous traffic characteristic in Makassar, there are only a study on traffic speed distribution (Zakaria et al., 2011; Sulistianingsih et al., 2012), a study on headway distribution of passenger vehicles in heterogeneous traffic in Makassar City by Azikin (2014).

1.1. Concept of Lateral Gap
Analysis of microscopic characteristics, such as individual vehicle characteristics in terms of headway and lateral gap is a useful variable in describing heterogeneous traffic conditions. Heterogeneous traffic in a lane causes undisciplined lane use, leading to discomfort for drivers or road users due to small vehicles between large vehicles or causing lateral gap. Lateral gap managed by different vehicle types can influence speed and longitudinal gap. In collecting and calculating lateral gap data, vehicle size must be noted, i.e. length and width, as well as distance between adjacent vehicles in the observed lane for various vehicle types.

Based on preliminary study in several streets, it was found that the lateral clearance between adjacent vehicles varied significantly depending on several traffic conditions. Speed of subject vehicle, speed and type of adjacent vehicle, and road width are found to significantly affect lateral gap. Likewise, lateral gap managed by vehicles moving at the same speed can be modeled with normal distribution. Similarly, normal log distribution can be used in modeling gap managed by vehicles in certain speed in relation with the speed of one of the adjacent vehicles.

![Figure 1](image)

**Figure 1** Behavior of the first vehicle and the second vehicle in maintaining or managing lateral and longitudinal gaps

Lateral gap data was measured by position of adjacent vehicles, i.e. two-wheeled vehicles (MC-MC), light vehicles (LV-LV) and combination of two-wheeled vehicle and light vehicle (MC – LV). In heterogeneous traffic where the number of two-wheeled vehicles (MC) is significantly higher than the number of light vehicles, lateral position of the longitudinal of each vehicle type in a lane is strongly affected.

1.2. Concept of Traffic Headway
The theory of microscopic traffic describes vehicle movements in a lane in a road or road section. Vehicle movement in the lane can be visualized as a distance-time diagram shown in Figure 2.
A theoretical approach of model of vehicles moving one after the other can give clearer definition on the characteristics of vehicle headway. For example, vehicle-$j$ position at certain time $\omega$ is expressed as $x_j(\omega)$. Time required by a vehicle to pass observation ($x$). If vehicle-$j$ speed is assumed to be constant during headway, then vehicle-$j$ headway during $\omega$ is:

$$t_j(\omega) = \frac{x_{j-1}(\omega) - x_j(\omega)}{\dot{x}_j(\omega)}$$  \hspace{1cm} (1)

The numerator of the distance of vehicle-$j$ during $\omega$, and point represents difference in time. The equation provides the basis for the relation between time headway, distance headway, and model of vehicles moving one after the other. Based on illustration and equation derivation above, time headway or just headway is the time difference between vehicles moving one after the other past a certain point in a (Salter, R.J., 1974). In detail, time headway consists of two types of time, i.e. occupancy time and time gap. Occupancy time is the length of time vehicle physically passes an observation point. Time gap is time difference when the rear of the front vehicle passes an observation and the front of the following vehicle passes the same point (May, A.D., 1990).

2. DATA COLLECTION AND ANALYSIS METHODS

This study recorded traffic in one of the arterial roads in Makassar City, specifically in Jl. A. P Petta Rani which is a type type 9 lane 2 directions arterial road with median. Dense traffic during peak morning, noon, and afternoon hours causes disorderly traffic behavior in using the lane. Traffic was recorded at 07.00 – 18.00 Wita for seven days from Monday to Sunday to get peak traffic hours. The survey used video recorder which can record traffic situation from certain height. The recorder was put in pedestrian bridge on that streat and could visualize traffic condition along certain road segment.

Figure 3 Data collection location in Jalan A.P. Petta Rani
Based on the tabulation of record of distance between vehicles and passing time, the lateral gap between vehicles moving side by side and time headway of two wheeled vehicle moving one after the other were determined. The statistical parameters of the data of lateral gap and time headway, including average indicator, standard deviation, maximum value, minimum value, modus, and median, were analyzed. Based on statistical indicator value, simulation was performed to determine the interval of lateral gap and time headway classification and period of a distribution analysis to get satisfactory distribution.

The final part of the analysis of the lateral and headway gap distribution in this study is to conduct statistical tests to see and assess the extent of variance and mean differences between headway distributions over a period of time in an hour. Statistical tests used the F-test method for testing variance and t-test for mean difference test.

3. RESULTS AND DISCUSSION

3.1. Gap Lateral Parameters

The distribution of the lateral gap of heterogeneous traffic vehicles and the behavior of maintaining the gap between vehicles in varying traffic conditions is an important variable that must be measured and analyzed from a path or path without any separation between paths in a road lane. The lateral gap is measured from the side of the vehicle closest to the other vehicle if there is more than one vehicle beside the subject vehicle. Similarly, track or lane correction and vehicle dimensions (length and width) are inputs in the calculation of lateral gap data. Here the average dimensions of vehicles based on the following types of vehicles:

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Average dimensions (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>length</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Passenger vehicle</td>
<td>4.2</td>
</tr>
<tr>
<td>Cars</td>
<td>4.7</td>
</tr>
<tr>
<td>motorcycle</td>
<td>1.8</td>
</tr>
<tr>
<td>Truck</td>
<td>7.5</td>
</tr>
<tr>
<td>Bus</td>
<td>10.3</td>
</tr>
</tbody>
</table>

An analysis is performed on the lateral gap by using a statistical test (one-way ANOVA) to ensure that the lateral gap values are dependent on the pair of vehicles moving side by side. The analysis revealed that the gap is indeed dependent on the pair of vehicles moving side by side.
Table 2 Statistical parameters of lateral gaps for different combinations of vehicle pairs

<table>
<thead>
<tr>
<th>Street Name</th>
<th>Vehicle Pairs</th>
<th>Mean (m)</th>
<th>Std. Deviasi (m)</th>
<th>Min (m)</th>
<th>Max (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.P. Petta Rani</td>
<td>MC - MC</td>
<td>0.94</td>
<td>0.50</td>
<td>0.22</td>
<td>2.45</td>
</tr>
<tr>
<td></td>
<td>LV - LV</td>
<td>1.64</td>
<td>0.81</td>
<td>0.40</td>
<td>3.50</td>
</tr>
<tr>
<td></td>
<td>MC - LV</td>
<td>0.99</td>
<td>0.40</td>
<td>0.25</td>
<td>1.93</td>
</tr>
</tbody>
</table>

3.2. Lateral Gap Distributions

Based on the results of data analysis on the lateral gap distribution of each pair of vehicles, it is found that the traffic volume and vehicle type composition is an important factor affecting the lateral distribution of vehicles. When the volume of traffic is relatively high, the separation of two-wheeled vehicles and light vehicles is very small and is affected by the type and size of the vehicle. Whereas in conditions of free flow or relatively low traffic volume, the utilization of road space has a uniform trend and the lateral distribution of the vehicle is not affected by the type and size of the vehicle.

The lateral gap data of the vehicle pair is done by advanced analysis to find the frequency distribution function by using SPSS program. It was found that the lateral gap of different vehicle pair types had different distribution patterns. This proves that the behavior of maintaining the lateral gap depends not only on the subject vehicle type but also the combination of front and subject vehicles.

Figure 4 Distribution of the lateral gap of an average pair of vehicles

Figure 4 shows the magnitude of the lateral gap frequency distribution of each pair of vehicles in the range of 0.25 m to 2.75 m. The largest number of vehicle frequencies is in the range of lateral gap 0.75 - 1.00 m. This shows the three types of pairs of vehicles have a predominant tendency to keep their vehicle's distance to reach the desired speed at a lateral gap distance of 0.75 to 1.00 m. The same analysis was also carried out for lateral gap variations with adjacent vehicle velocities, for different vehicle combinations, also performed and having similar trends.
Figure 5 Trend relationship between speed and average lateral gap of vehicle pairs

Figure 5 shows with an increase in the speed of adjacent vehicles, where the subject vehicle is moving at a certain speed, between the lateral between two vehicles increases. In the case of the lateral gap MC-MC pair there is a significant variation in lateral development and the variation is a non-linear trend pattern. Based on the results of the analysis that was built with the same speed with the changes that occur within.

3.3. Headway Statistics Parameters

The initial step of analyzing tabular headway data determined from the extraction process of vehicle arrival recording through an observation point is to determine the values of headway statistical parameters for each time period of 5 minutes, 10 minutes and 15 minutes. The result of determination of statistical values of headway of motorcycle and passenger vehicle passing on A.P Petta Rani street for a period of 15 minutes, especially for the period of 07:00 - 08:00, is presented in Tables 3 and 4. In this case, the 15 minute period is the optimal time period of the simulation result against a satisfactory headway distribution form as explained in the next sub-section.

Table 3 Statistical parameters of motorcycle headway A.P. Pettarani

<table>
<thead>
<tr>
<th>Statistical parameters</th>
<th>Parameter values of observed headway time period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>07.00 – 07.15</td>
</tr>
<tr>
<td>Max</td>
<td>5.76</td>
</tr>
<tr>
<td>Min</td>
<td>0.05</td>
</tr>
<tr>
<td>Mean</td>
<td>0.85</td>
</tr>
<tr>
<td>Std deviasi</td>
<td>0.71</td>
</tr>
<tr>
<td>Modus</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Table 3 shows explains that the maximum value occurring for all four time periods of 15 minutes for an hour is up to 8 seconds occurring in the period 07.45 - 08.00. Minimum headway value is 0.05 seconds that occurs in the time period 07.00 - 07.15 and 07.45 - 08.00. The average value per 15 minutes in one hour shows in the headway value range of 0.85 - 1.20 seconds. The standard score of the headway deviation for the four time periods is in the range of 0.71 - 1.14 seconds and the mode parameters are in the range of 5.71 - 7.95 seconds.
Table 4 Statistical parameters of light vehicle headway A.P. Petta Rani

<table>
<thead>
<tr>
<th>Statistical parameters</th>
<th>Parameter values of observed headway time period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>07.00 – 07.15</td>
</tr>
<tr>
<td>Max</td>
<td>9.37</td>
</tr>
<tr>
<td>Min</td>
<td>0.82</td>
</tr>
<tr>
<td>Mean</td>
<td>2.64</td>
</tr>
<tr>
<td>Std deviation</td>
<td>1.38</td>
</tr>
<tr>
<td>Modus</td>
<td>1.51</td>
</tr>
</tbody>
</table>

Table 4 explains that the maximum value occurring for all four time periods of 15 minutes during one hour is 14.12 seconds which occurs in the period 07.30 - 07.45. Minimum headway value is 0.78 seconds which occurs in the time period 07.45 - 08.00. The average value per 15 minutes in one hour shows in the headway value range of 2.64 - 2.93 seconds. The standard score of the headway deviations for the four time periods is in the range of 1.38 - 1.92 seconds and the mode parameters are in the range of 1.49 to 1.93 seconds.

3.4. Headway Distribution Simulation

In order to find and determine the class interval of headway data classification so as to obtain a satisfactory distribution form visually and in accordance with the theory of forms of headway distribution (generally in the form of negative distribution of exponential or logarithmic), the simulation of searching values of satisfactory class interval. In this case it simulates the headway data into various headway class intervals and varies the time period of headway analysis. The simulated time period of headway analysis is each per-5 minutes, per-10 minutes, per-15 minutes, and per-30 minutes. The simulation results show that the optimum headway interval value in pairs with the time period of analyzing the headway distribution form is 1.0 seconds and the period per-15 minutes. The forms of headway distribution at optimum class intervals and 15-minute time periods at 07:00 - 08:00 are presented visually in Figure 3 which is accompanied by a manually created distribution trend line.

Figures 5 through 7 show that visually the passenger vehicle headway distribution with a class interval of 0.25 - 0.50 seconds and a time period of 15 minutes tends to have a certain pattern of a form of statistical data distribution. This allows for further analysis of the suitability of the headway distribution model.

Figure 5 Distribution of headway vehicle pair (MC - MC) A.P. Petta Rani
The follow-up analysis conducted in this study was to examine the similarities and differences between the forms of headway distribution per-15 minutes over a period of 1 hour. From the test results found that between the three forms of headway distribution within the time period of 07:00 - 08:00 there is no difference in the level of variance. The same thing for the average value of headway distributions obtained headway distribution in a period of 15 minutes in an hour, especially at 07:00 - 08:00 is to have the same pattern of distribution both variance and average.

4. CONCLUSION
The frequency distribution of the vehicle's lateral gap is in the range of 0.25 m to 2.75 m, where the largest vehicle frequency is in the range of the lateral gap of 0.75 to 1.00 m. Along with the increased speed of adjacent vehicles, the lateral gap between the two vehicles also increases. In the case of lateral gaps MC-MC pairs obtained significant variations of the lateral gap following a non-linear trend pattern.

The result of statistical test analysis showed that the distributions of time headway of passenger vehicles in the period of an hour didn’t vary. Visually, there was a trend of headway following exponential distribution pattern.

The study results provide a good expectation to proceed in order to test the suitability of the numerical distribution model, so that it can be used in the development of a traffic simulation micro model in follow-up studies.
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