

# The relationship of volume and headway on heterogen traffic conditions in Makassar City

*by Sakti Adji Adisasmitha Unhas*

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## The relationship of volume and headway on heterogen traffic conditions in Makassar City

H Halim<sup>1</sup>, S A Adisasmita<sup>2</sup>, M I Ramli<sup>2</sup> S H Aly<sup>2</sup>

<sup>1</sup>) Doctoral Program Civil Engineering, Universitas Hasanuddin, Makassar, Indonesia

<sup>2</sup>) Department of Civil Engineering, Universitas Hasanuddin, Makassar, Indonesia

E-mail: hasmar29@gmail.com

**Abstract.** The purpose of this study was to examine the relationship between vehicle distance (gap) formed by the vehicle volume. For this reason, in this study, there were 16 (sixteen) roads that were used as objects of research. To get the values from the gap variable, the VISSIM software is used in the data processing. In the use of this software calibration and validation are done by trial and error to produce simulation results that can replicate the actual traffic conditions. The results of this study indicate that statistically from the coefficient of determination and F test conducted concluded that there is a significant relationship between vehicle volume and gap.

### 1. Introduction

Transportation problems are problems that are always faced by developing countries such as Indonesia, both in the field of urban transportation and inter-city transportation (rural transportation). The creation of a transportation system that guarantees the movement of people, vehicles or goods in a smooth, safe, fast, inexpensive, convenient and environmentally appropriate way is a development goal in various sectors. Often with rapid economic growth, Makassar City has experienced growth and development in the past decade. This development can be seen with the many public facilities from malls, hotels, business centers, and offices. It is also supported by the availability of transportation infrastructures such as international ports and airports.

This development has an impact on the increasingly crowded activities of the urban population which causes an increase in the number of motorized vehicles to support the movement of the population in the city of Makassar. However, the growth of the city has a negative impact, namely the imbalance between the growth of vehicles and the growth of transportation infrastructure. Road growth in Makassar City only grew by 0.8% - 2% per year while vehicle growth reached 15% - 16% annually. This causes congestion on several roads. This is further aggravated by Makassar City's prevailing traffic conditions which are heterogeneous traffic [1].

In some previous studies revealed the existence of a fundamental relationship between volume (flow) with speed (speed) and density (density) [2,3]. The relationship is used as a guide to determine the mathematical value of the road capacity for ideal conditions and can be used as a basis for the implementation of traffic management that is more appropriate. The relationship between speed and traffic volume can be stated that if the traffic flow on a road segment increases then the rate on the road segment will decrease [4].

An increase in traffic volume will cause changes in traffic behavior. This behavior change is commonly called Aggressive Driving. Traffic violations such as speed limit violations, vehicle lanes are



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not safe, violating traffic signs, distance to other vehicles that are too close (gap and lateral), do not give cents when switching lanes, and how to drive a disruptive, maneuvering zig-zag in overtaking a vehicle is a characterization in driving aggression behavior. One study shows that there is a relationship between speed and time between vehicle arrivals (time headway) especially in heterogeneous traffic flows [5-7]. And other studies reveal that headway is the main parameter to determine a minimum safe gap (gap) in urban roads [8].

On the other hand, heterogeneous traffic conditions are a condition where mixing modes of transport occur in various compositions of various sizes, maneuvers, static and dynamic control characteristics in the same space and time. In this pattern, fast-moving vehicles such as passenger cars, trucks, buses and motorbikes will be found sharing space with slow-moving non-motorized vehicles including bicycles, rickshaws, carts, etc. Heterogeneous traffic patterns can also be seen in the use of road lanes. In this pattern, the vehicle does not follow a regular traffic flow pattern following the available markers. From the description of this study, the relationship between traffic volume and microscopic conditions, especially the gap variable, is the distance between vehicles in the longitudinal direction of Makassar City traffic conditions that are heterogeneous.

## 2. Literature review

### 2.1. Characteristics of traffic flow

Transportation is defined as an activity that transports or removes cargo or goods from one place to another. The movement of goods and people will provide more significant benefits and usability [9]. This benefit can be achieved if transportation offers fast, cheap and timely services, provides a sense of security or is free from the possibility of accidents and a sense of protection against damage to goods during the trip, providing a high mobility, which in turn reduces the level of disparity between regions.

The basic concept of transportation, which is interrelated with the implementation of transportation and travel patterns in urban areas that are influenced by the center of the activity. It can be summarized that the city transportation system is controlled by several factors, humans as road users, goods needed by humans, vehicles used as means, roads as infrastructure, and management of city transportation. The interaction of the four factors, namely the driver, vehicle, road, and environment into a traffic system will get a characteristic traffic flow. This characteristic is needed as a reference in traffic planning. The characteristics of traffic flow are influenced by 2 (two) parameters, namely the parameters of macroscopic traffic flow and microscopic traffic flow parameters [10].

- Macroscopic parameters, which characterize the flow of traffic as a unit (system), to obtain an operational picture of the whole system. Example: Volume, speed, density. Volume, velocity, and density are macroscopic measures in which traffic in a given time interval is represented by a single value of each that forms the flow of traffic as a whole.
- Microscopic parameters, which characterize the behavior of each vehicle in the traffic flow that affects each other. Example: headway, spacing, occupancy, gap, and clearance.

### 2.2. Traffic volume

Volume is the most critical variable in traffic engineering. Traffic volume is a calculation process that relates to the number of movements of a vehicle's time union at the location of a particular location. The number of movements calculated can include one mode or a group of modes of transportation. The period for data retrieval depends on the destination, the consequences and the level of accuracy required will determine the frequency, time and distribution of traffic flow.

Vehicle movements that occur consist of various types and based on the correction factor of a Passenger Car Unit (PCU) vehicle. Traffic volume aims to determine the value of the relative importance of a route, fluctuations in traffic flow, current distribution and the tendency of traffic on a road system. The average traffic volume is the average number of vehicles calculated according to a specific time unit, which can be said daily as average daily traffic volume (LHR) or annual average daily traffic volume (LHRT) [11].

The traffic volume current equation can be seen in the following equation:

$$Q = n/t \quad (1)$$

Where:

Q: Traffic Volume (vehicles/hours, SMP/hours)

n: Number of Vehicles (Vehicles)

t: Time interval (hours)

### 2.3. Headway, spacing, gap dan clearance

The interaction between vehicles in a road creates space and time that overall has a relationship with the parameters macroscopically. Flow, density, and density are three variables that can be used to express traffic performance. In addition to these parameters, other parameters are needed which microscopically affect traffic flow. One of the most critical microscopic parameters is the distance between or headway. The headway is the time interval between the front of a vehicle and the front of the vehicle behind it at an observation point. Headways can be stated in time or the distance. Headway which is indicated in time is called time headway, while what is stated in the distance is called head headway or distance headway [12].

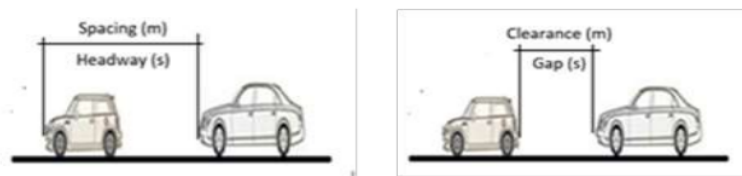
- Time Headway

Is the time taken between one vehicle and the next vehicle to go through a certain point? The average time between vehicles =  $1 / \text{volume}$  between vehicles.

- Space Headway

Is the distance between the front of one vehicle and the vehicle in front of the next vehicle. The average distance between vehicles =  $1 / \text{density}$ .

The availability of space between vehicles in traffic flow is essential. The available space will give the driver a sense of security. In the availability parameter, this space is known as gap and clearance. The gap is the space between the back of the vehicle and the front of the next vehicle in units of time. While Clearance is the space between the rear of the vehicle with the front of the following vehicle in the distance. In addition to feeling safe, the availability of this space will be used as a gap in the process of copying a vehicle. So that we need the acceptance of an adequate gap. In general, the process of receiving a gap in the process of overtaking a vehicle where a driver who wants to pass will estimate the space needed and estimate the availability of sufficient space for the vehicle. Based on the comparison between the space required and available, they decide to start overtaking or delay it. Illustrations of Headway, Spacing, Gap, and Clearance can be described as follows:



**Figure 1.** Illustration of headway, spacing, gap, and clearance.

### 2.4. Traffic simulation using VISSIM

The traffic simulation model can be divided into three categories, namely macroscopic (section-by-section) transportation network simulation, mesoscopic (simulation model that combines macroscopic and microscopic properties) and microscopic (simulating the movement of individual vehicles in traffic flow) [13]. Microscopic simulation or commonly referred to as microsimulation is intended as any simulated transportation and pedestrian mode that can represent itself individually, so it is necessary to consider all the parameters that affect the simulation. Transportation system modeling and simulation

are increasingly in demand because of its ease in the process of changing various scenarios while still looking at the potential that can be implemented in the field. VISSIM is included in the microscopic category of software that has the advantage of being able to model various types of vehicles including motorcycles and non-motorized vehicles.

Vissim software is Vissim is software from PTV from Germany. Vissim itself is an abbreviation of Verkehr in Städten Simulations Modell which means a city traffic simulation model. Vissim can analyze traffic and displacement with modeling constraints such as path geometry, vehicle composition, traffic signals, stop lines, driver behavior and others, so that it becomes a useful tool for evaluating various alternatives based on transportation engineering as decision-making steps which is more effective and efficient in a planning activity including simulations in model development [14].

### 3. Methodology

#### 3.1. Location and Data Collection

The location of the study was conducted on 16 (sixteen) roads that reflected arterial and collector road sections in Makassar City. From this road section, secondary data is collected as well as primary data in the form of traffic volume, vehicle speed and free-flow speed, geometric conditions of the road, type and composition of the vehicle.

#### 3.2. Traffic Simulation

One of the essential things in the behavior of motorists which is related to consistency in maintaining the distance between vehicles. The process of preparing a vehicle requires a safe distance between vehicles both longitudinal distance and lateral distance. For this reason, how a driver puts his vehicle as safe as possible against other vehicles when overtaking a vehicle. Measuring the process of preparing a vehicle is difficult, so simulation is needed that approaches the real conditions in the field to get the desired variables. One of the software related to traffic simulation is Vissim software. The steps in making traffic simulation using the vissim software are as follows:

- Data collection  
The secondary data used is in the form of aerial photographs taken from Google Earth to facilitate the depiction/creation of the road network on VISSIM. While the primary data collected is in the form of inventory / geometric road data that is done manually using the walking measure, the traffic flow volume data is calculated using the traffic counting method in the afternoon peak hours at 06:00 to 22:00 by classifying the type of vehicle into 11 kinds. The speed data for each type of vehicle is calculated using the journey speed method. The types of vehicles used in this study were Motorbikes, Private Cars, Public Transportation, Pick Up, Small Buses, Large Buses, Open 2as Trucks, 2 Axles Closed Trucks, 3 Axles Trucks, Joint Trucks, Trailers.
- Stages of simulation modeling  
In conducting microscopic simulations using VISSIM, several parameters need to be determined and inputted so that the simulation model can run.
- Calibration and validation  
VISSIM calibration is a process informing the appropriate parameter values so that the model can replicate traffic to conditions as close as possible. The calibration process can be carried out based on the observed area driver behavior. The method used is trial and error by referring to previous studies regarding calibration and validation using VISSIM. Validation on VISSIM is the process of testing the truth from calibration by comparing the results of observations and simulation results. The validation process is carried out based on the amount of traffic flow volume and queue length. The method used is to use the basic Chi-squared formula in the form of a statistical formula Geoffrey E. Havers (GEH). GEH is a modified statistical formula of Chi-squared by combining the difference between relative and absolute values. The following GEH formula has specific provisions of the error value generated as in Table 1 [15].

$$GEH = \frac{(q_{\text{simulated}} - q_{\text{observed}})^2}{\sqrt{0,5 \times (q_{\text{simulated}} + q_{\text{observed}})}} \tag{2}$$

Where:

$q$  = Traffic volume data (vehicles/hours)

**Table 1.** Conclusions from calculation results statistical formulas Geoffrey E. Havers.

GEH < 5.0	be accepted
5.0 ≤ GEH ≤ 10.0	Warning: possible error model or bad data
GEH > 10.0	rejected

#### 4. Result and analysis

##### 4.1. Geometric conditions of roads and types of vehicles

The geometric condition of the road is the most important thing in planning and evaluating road performance. There are several variables from the road geometric that will be used for further analysis, namely road length, track width and the number of lanes and lanes. This data and several other variables that will be simulated into the VISSIM software to get the value of the gap/headway.

**Table 2.** Road geometric conditions.

Roads	Road Length (km)	Road width (m)	Road type
Jl. Perintis Kemerdekaan	11197	27.80	6/2D
Jl. Urip Sumoharjo	4506	24.00	6/2D
Jl. A. P. Pettarani	4373	38.10	6/2D
Jl. Rajawali	0.840	13.00	2/1UD
Jl. Gagak	0.300	10.00	2/1UD
Jl. Abdullah Daeng Sirua	3727	8.00	2/2UD
Jl. Antang Raya	1500	6.80	2/2UD
Jl. Daeng Tata	1637	7.10	2/2UD
Jl. Jend. Sudirman	1339	19.50	4/2UD
Jl. Arif Rate	0.320	17.60	4/2D
Jl. Haji Bau	0.620	15.80	4/1UD
Jl. Sam Ratulangi	2067	16.50	4/2UD
Jl. Veteran Selatan	1878	22.60	4/2D
Jl. Veteran Utara	2641	22.60	4/2D
Jl. Hertasning	1544	20.12	4/2D
Jl. Boulevard	1670	29.40	6/2D

From observations on roads that are used as research objects, each has a geometric condition that is different from each other. Several geometric variables will be used for further analysis. From the measurement results from the road segment, it is known that each of them has 8 (eight) types that have a divided and undivided road type. While the road that has the most extended road length is Perintis Kemerdekaan Street with a distance of 11,197 km while the shortest road segment is on Jalan Gagak with a distance of only 0.3 km. As a Primary Road for AP Road. Pettarani, Jalan Perintis Kemerdekaan,

and Jalan Urip Sumiharjo have a reasonably large road width of 38.1 m, 24 m and 27.8 m. For a review of the number of lanes, there are 4 (four) roads that have six lanes, and there are seven roads with four lanes and the remaining two lanes with five lanes. As for geometric conditions as illustrated in table 2.

4.2. Volume and Traffic Simulation

Based on the survey that has been carried out, the average volume of vehicles from the three road sections shows that Jalan AP. Pettarani has the highest vehicle volume compared to others. On this road, the average volume reaches 7,744 vehicles/hour. While the smallest volume occurs at Jalan Haji Bau which has an average volume of 1,604 vehicle/hour. Of the thirteen of these road sections based on the characteristics of traffic flow and geometric road characteristics simulated using VISSIM software. The calibration process is carried out by forming the appropriate parameter values so that the model can replicate traffic to conditions as close as possible. The calibration process can be carried out based on the observed area driver behavior. The method used is trial and error by referring to previous studies regarding calibration and validation using VISSIM.

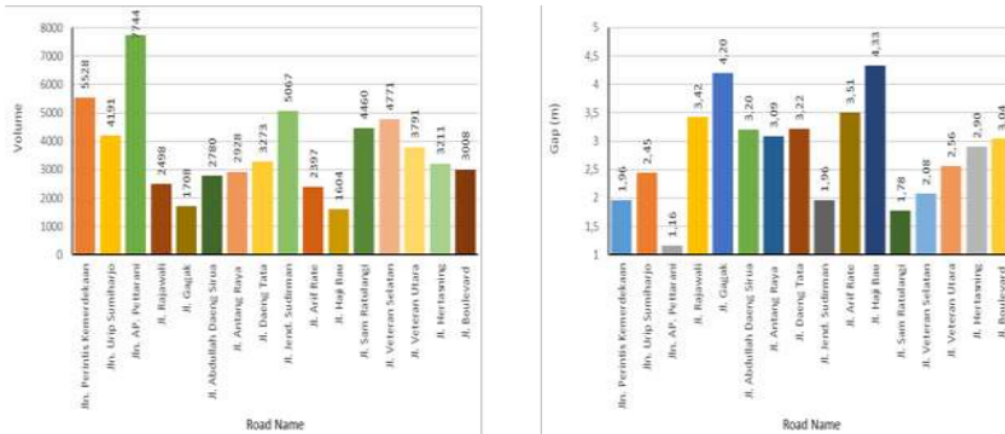


Figure 2. Average volume and gap of each road segment.

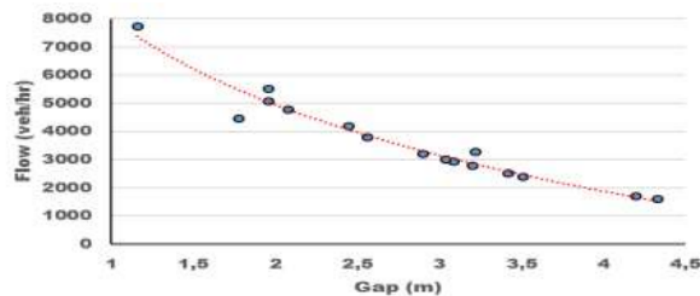
4.3. The relationship between volume and gap

Based on the calculation of the gap as presented earlier in figure 2. Furthermore, data related to traffic volume as the dependent variable and microscopic characteristics data in the form of the gap (longitudinal distance) as the independent variable. To determine the pattern, a curve matching test approach is used. Compatibility of curve models with observational data by calculating the coefficient of determination (R2). The curve with the highest R2 value indicates that the curve has the best suitability for the observation data compared to other curves. The results of the full curve matching test calculation are described in table 3 below.

Table 3. Value Match curve model to gap.

Models	Parameters					
	R <sup>2</sup>	F	Sig.	Constants	□ <sub>1</sub>	□ <sub>2</sub>
Linear	0.902	129.030	0.000	8482.585	-1711.154	-
Logarithm	0.956	301.651	0.000	8034.019	-4442.778	-
Inverse	0.935	200.535	0.000	-145.875	9591.071	-
Square	0.949	120.401	0.000	11302.106	-3930.010	396.418
Power	0.927	176.838	0.000	10625.687	-1.166	-
Exponential	0.968	424.682	0.000	12762.047	-0.472	-

From table 3 above shows that the results of the calculation of the gap parameter curve show the model of the relationship with the Logarithm function can be used to predict the effect of the independent variable (X) on the dependent variable (Y). This is based because the Logarithm function has the highest R2 value compared to other functions. These results indicate that the relationship between traffic volume and distance between vehicles (gap) has an inverse relationship. The higher the volume that occurs, the smaller the distance between vehicles (gap). Likewise, the lower the traffic volume, the higher the distance between vehicles. The relationship between traffic volume and distance between vehicles (gap) as illustrated in the following figure 3.



**Figure 3.** The relationship between volume and gap.

Thus, the suitability of the model used is the equation formed for the relationship between volume and gap is:  $Y = -4.443 \ln(x) + 8.034$ , coefficient of determination  $R^2 = 0.9556$ . The statistical test related to the hypothesis made for the logarithmic model using the ANOVA test is:  $H_0 =$  Gap variables cannot predict traffic volume  $H_1 =$  Gap variables can predict traffic volume.

The interpretation of the logarithm model is known that Fcount is 301.651 with the degree of freedom with a significance level of 0.000 for gap parameters with the degrees of freedom  $Df1 = 1$  and  $Df2 = 15$ , so the Ftable value is known to be 4.54. By comparing Fcount and Ftable, if  $Fcount > Ftable$ , then  $H_0$  is rejected as well as vice versa if  $Fcount < Ftable$ , then  $H_0$  is accepted. From the results of the analysis, it is known that Fcount is greater than Ftable, so it can be said that  $H_0$  is received or the gap variable can predict traffic volume. Likewise, by comparing the probability value (p-value), if the p-value is  $< 0.05$ , then  $H_0$  is rejected, and if the p-value  $> 0.05$ , then  $H_0$  is accepted. Because of the probability value  $< 0.05$ , it can be concluded that the regression model with logarithm function can be used to predict traffic volume.

## 5. Conclusions

Makassar City is one of the cities that has a high growth rate of vehicles that reach 16% per year. This has an impact on the increase in traffic volume which in turn will form the distance between one vehicle and another which is very narrow. The distance between the vehicle or gap constructed shows the pattern of traffic volume that occurs. This is evidenced by the significant relationship between traffic volume and the gap. Mathematically the model forms the logarithm equation  $Y = -4.443 \ln(x) + 8.034$  with a coefficient of determination of 0.9556. Likewise, the ANOVA test shows that the F test result of 301.651 is more significant than Ftable. Thus, it can be said that regression models with logarithmic functions can be used to predict traffic volume.

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