Characteristics of Traffic in a Highly Congested Motorway in Urban Area in Jakarta-Indonesia

Fergyanto E. Gunawan

Abstract—**In the city of Jakarta in Indonesia, the traffic jam occurs almost every day on various locations across the city. The city that surrounded by some satellite cities, by itself, has about 10 million populations, but the greater Jakarta has more than 20 million populations in total. A large number of people commute in and out Jakarta every day and it leads to a severe traffic jam. Therefore, the Indonesia government has set the problem as an urgent and important national research topic. It is clear that optimizing the existing motorways in Jakarta is one of the possible solutions because building new motorways are prohibited by the dense Jakarta population. Within this conviction, we are developing a framework where the Jakarta traffic can be studied comprehensively within a reasonable cost. Unfortunately, the existing framework on the basis of the microsimulation cannot be directly used for the Jakarta traffic conditions. In this paper, we present the unique feature of the Jakarta traffic, and evaluate the existing car-following models that suitable for the Jakarta traffic.**

Index Terms—**Microsimulation, GHR model, optimal velocity model, IDM model, fundamental diagram**

I. Introduction

The traffic in Jakarta---one of the world's largest cities with more than 20 million population (The population is 24 million as per national census of 2000 according to Indonesia government as cited by Wikipedia [1]) and rising, the biggest city by a wide margin in Southeast Asia [2]…has become extremely bad where the traffic jam practically occurs on the daily basis on various locations across the city. The Indonesia Ministry of Economic Coordination asserted that on each travel, the inhabitants of the greater Jakarta spend about 60 percent of their traveling time in the traffic jam, and only about 40 percent are for actual travel [3]. The traffic jam adversely affects various sectors of the nation including economic, health, and other sectors. In the economic sector, for an example, the traffic jam cost the country, in 2009, by an amount of 5.5 Trillion rupiah or about 600 Million USD at the exchange rate of 9,000 rupiah/USD. The number is about 3--6 percent of Jakarta gross domestic income in the same year according to the head of Indonesia Transportation Society (MTI) [3]. The transportation cost has reached approximately 30 percent of regular incomes [4]. Furthermore, the Ministry stated that the average speed of a vehicle drops to ±20 km/h from ±26 km/h in 2002, or drops by a factor of 25 percent during the last seven years. According to Jakarta Traffic Management Center, the number of the private cars increased by 4 percent to 2,115,786 vehicles since 2009 within a year. During the same duration, the public vehicles increased by 1.5 percent to 859,692 vehicles, and the motor vehicles significantly increased by 11.1 percent to 7,516,536 vehicles [3]. From 2002 to 2007, the number of the motor vehicles has increased by a factor of three [5]. The huge number of vehicles has regularly brought down the Jakarta traffic particularly during the rush-hour.

The conditions of the traffic, we discuss in this research, are similar to that in [6] for some aspects but different for some other aspects. The first similarity is that the both traffics have dominant two-wheeled vehicles and many motorways do not have vehicular lane. The second similarity can be found on the state of the vehicle where one can hardly determine whether a vehicle is in a car-following state or in a lane-changing state. We should note that those states were the basic assumptions underlying many existing developments in the microscopic simulations [7--12] where a traffic lane is an important basic unit, and a vehicle are mostly moving along a well-defined lane.

Although there are many similarities, but the present traffic conditions are different from those in [6] on few aspects. The first is the volume of the current traffic is significantly higher. The other is many drivers do not understand or appreciate traffic regulations, and the authority do not strictly enforce the existing regulations. For an example: in the Jakarta traffic, we can easily find a two-wheeled vehicle crosses an intersection when the traffic signal ahead of them turned red. The fact that the driving license can easily be obtained without a rigorous assessment from the authority also contributes to the complexity of the traffic.

This report is a part of our project in establishing a computational model for the urban traffic in Jakarta, Indonesia. The computational model has to be established to leverage our study in optimizing the motorways in the area. Unfortunately, majority of the existing micro-simulation models are tailored to model the condition of traffic in advanced countries. Only three out of the 32 major micro-simulation models have the option to take into account the two-wheeled vehicles [13]. By considering the uniqueness of the present traffic and limitation of the existing models, a new micro-simulation model has to be established or the existing model should be extended to take into account realities found in the Jakarta urban traffic. As the first step in our project, we report the nature of the traffic in the urban area of Jakarta, Indonesia in this paper.

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II. Characteristics of Urban Traffic in Jakarta, Indonesia

This section provides quantitative and qualitative descriptions of a typical urban motorway in Jakarta, Indonesia. The quantitative descriptions provided in here were obtained by performing measurement on the traffic flow for some days. Meanwhile, the qualitative descriptions were obtained by observing the same traffic.

A. *The Site*

Typical characteristics of the urban motorways in Jakarta can be observed in Kemanggisan Raya street (see Fig. 1), which is a highly congested motorway particularly during the rush hours. The street is under the West Jakarta administration, but it is not far from the Central Jakarta where the central business district is located. Following the Kemanggisan Raya street to the north, one would arrive on one of big hubs in the region called Slipi where an arterial road intersecting with some collector roads in a rather complex fashion.

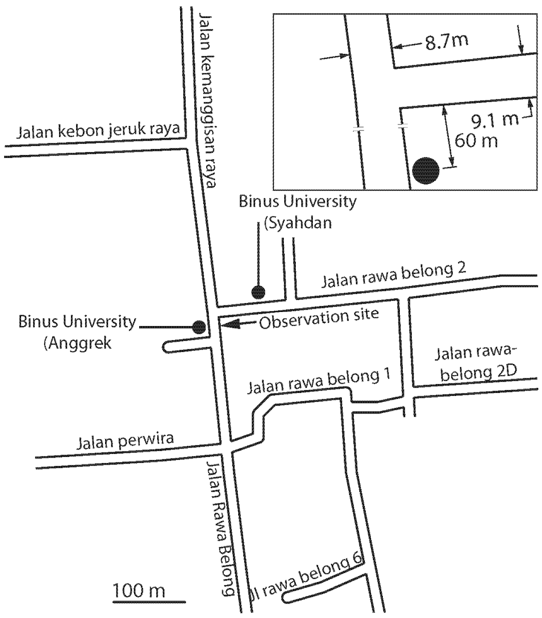

Fig. 1. The observation site. The inset shows the size of the streets

Traffic jam often occurs due to the high traffic density and the transaction of vehicles in the T-junction near the measurement site is rather slow. This is mainly attributed to the fact that the junction does not have any traffic light; hence, conflicts between vehicle movements are often unavoidable. However, the system is able to self-regulate for a modest traffic density to maintain a continuous flow of the traffic.

The Kemanggisan Raya street has a width about 8.7 m around the T-junction area as shown in the inset of Fig. 1. This narrow street is a two-way street. The Rawa Belong 2 street that connected to the Kemanggisan Raya street is also a two-way street. The traffic is mainly moving along the Kemanggisan Raya street. The amount of traffic that turns to the Rawa Belong 2 street from the Kemanggisan Raya street is usually small according to separate observations. Although the volume is small, but since the transaction of vehicle in the T-junction is inefficient but self-regulating, within a short amount of time, the large volume of traffic along the Kemanggisan Raya street may quickly be piling up.

B. *Methodology*

We observed the traffic flow crossing the observation site, see Fig. 1, for every five-minute interval where in each interval, the number of vehicles was counted for a duration of four minutes, and one minute was used to register the data.

The recorded data involved the traffic to the north, in the direction of Kemanggisan, and the south, in the direction of Rawa Belong, of the site. For each direction, the data of the two-wheeled vehicle were separated from those of the four-wheeled vehicle. The observations were performed on Dec. 6, 8, 13, and 16 of 2010 at 7:00 to 9:00 local time and at 17:00 to 19:00 local time. Usually, the traffic gets heavy during those durations.

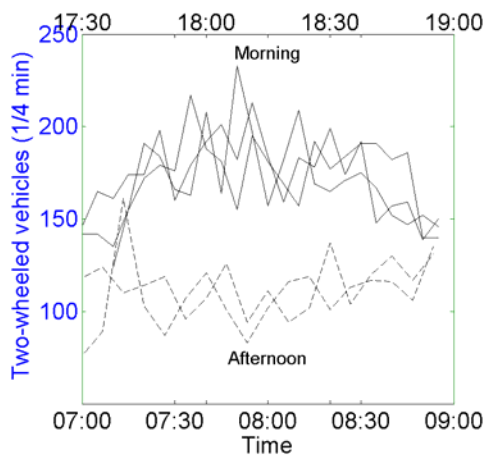

Fig. 2. The traffic flow of the two-wheeled vehicles to the north.

C. *The Traffic Flow Data*

The measured traffic flow data are presented in Figs. 2--5 for the traffic in the both directions and the both types of vehicles. The data clearly indicate that the volume of the two-wheeled vehicles is significantly higher than that of the four-wheeled vehicles. During the morning time, for example, the volume of the two-wheeled vehicles is about five times bigger than the volume of the four-wheeled vehicles as can be seen in Fig. 2 and Fig. 4. We speculate that the peaks of two-wheeled vehicles volume that consistently occur before 08:00 are tightly related with the office hour that mainly started at 09:00.

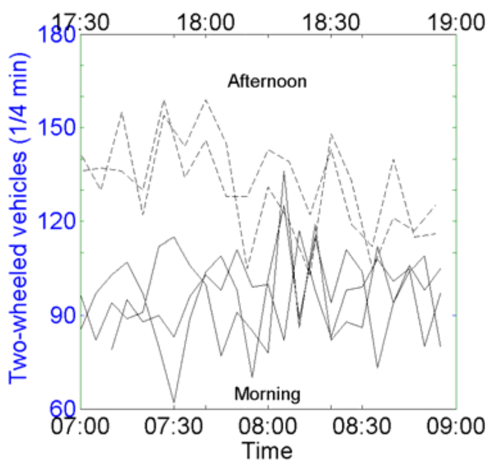

Fig. 3. The traffic flow of the two-wheeled vehicles to the south.

By comparing Fig. 2 to Fig. 3, we conclude that the traffic in the north direction is high in the morning time and in the south direction is high in the afternoon time. In the morning time, the volume of the two-wheeled vehicles to the north direction is twice as much as that to the south direction.

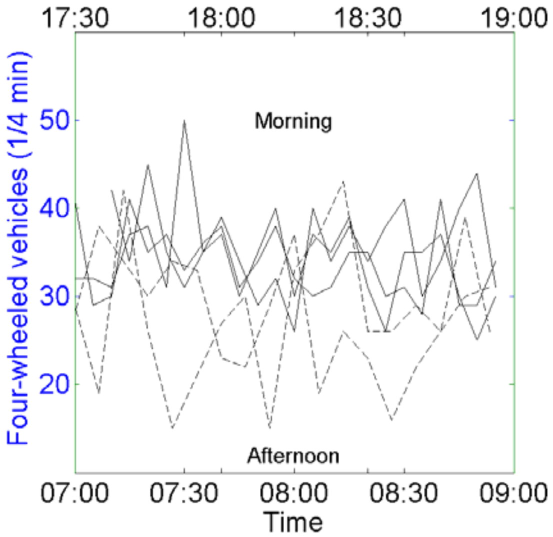

Fig. 4. The traffic flow of the four-wheeled vehicles to the north.

Meanwhile, the volume of the four-wheeled vehicles is about the same for those vehicles to the north and those to the south as well as those in the morning time and those in the afternoon time.

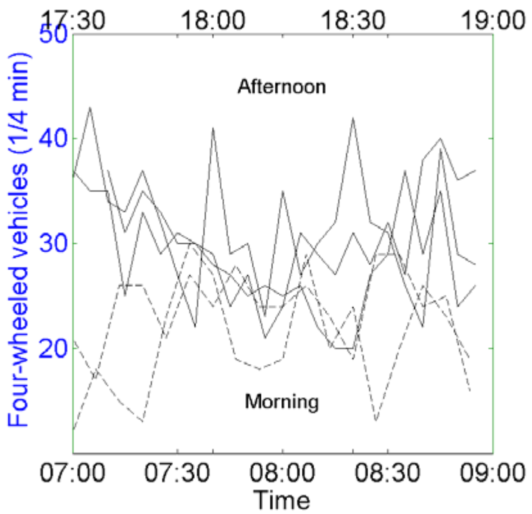

Fig. 5. The traffic flow of the four-wheeled vehicles to the north.

D. The Traffic Behaviors

We observed that the state of movement of the four-wheeled vehicles was mainly in the car-following state. The size of the street, evidently, has enforced the four-wheeled vehicles to move in such way. This driving behavior leads to a relatively constant traffic volume as clearly indicated in Fig. 4 and Fig. 5.

A unique feature that differentiates the Jakarta traffic to the traffic in many countries is the minibus (see Fig. 6). The minibus is an important public transportation system and it exists widely across the country.

Fig. 6. A minibus: a widely used public transportation system

The traffic behavior of the minibus is also unique. The vehicle may suddenly stop anywhere, although it initially moves in a platoon, to pick or to drop passenger. It seems the vehicle may accelerate following the follow-the-leader model because the density of the traffic; however, it may decelerate according the model, but it may also stop instantly. The vehicle has strong tendency to not engage in the car-following interaction because its driver mainly focuses on picking up and dropping off the passenger. When the minibus stops, it tends to fully block the four-wheeled vehicle behind it, but the two-wheeled vehicles are free to move. Because the minibus exists dominantly, and has rather different behavior in comparison to that of the private four-wheeled vehicles, then one needs to take into account its unique feature in order to accurately model the dynamics of the Jakarta traffic.

The two-wheeled vehicles were rarely in the follow-the-leader state in the traditional sense. It may involve in such interaction when the distance between them is reasonably large, for an example, about five meter. However, a two-wheeled may stay behind a leader by slightly shift its position to the right or to the left of the leader. But when the leader slows down, the follower will likely overtake it, if possible, instead of slowing down. The latter case happens quite often. Another dominant driving behavior of the two-wheeled vehicle is to drive aggressively and to constantly change its lateral position in order to find an empty space ahead. The high fluctuation of the volume of the two-wheeled vehicles (see Fig. 2 and Fig. 3) seems to strongly be related with this driving behavior.

III. Review of Traffic Models

The previous section has clearly shown that the four-wheeled vehicles, except the minibus, on the Kemanggisan Raya street tend to move in the car-following state. We briefly discuss, in this section, three models of the microscopic car-following models particularly from aspects of numerical implementation and models similarities. We limit our discussion to the LandM model (or Gazis-Herman-Rothery (GHR) model or the General Motor nonlinear model) [14,15], the optimal velocity model with delay [16--19], and the intelligent driven model (IDM) [20]. Those models, respectively, are written as:

$$an(t) = \alpha \frac{v_n^m(t) \cdot [v_{n+1}(t-t_d) - v_n(t-t_d)]}{[x_{n+1}(t-t_d) - x_n(t-t_d)]^l} \quad (1)$$

$$\tau a_n(t) + v_n(t) = V(\Delta x_n(t-t_d)) \quad (2)$$

$$a_n(t) = a_{\max}\left[1 - \left(\frac{v_n(t)}{v_0}\right)\delta - \left(\frac{s^*(t)}{s_n(t)}\right)^2\right] \quad (3)$$

where a_n, v_n, and x_n, respectively, are the acceleration, velocity, and position of the n-th vehicle following the (n+1)-th vehicle. The τ is the velocity relaxation time and t_d is the driver delay.

In the GHR model of (1), the constants α, m, and l are the model parameters, and investigations on the constants were well summarized in [21]. In (2), $V(\Delta x_n)$ is an optimal velocity function, which in general, is expressed as [19]

$$V(\Delta x_n) = v_0\left[\tanh\left(\frac{\Delta x_n - D}{b} - C_1\right) + C_2\right]$$

where v_0 is the desired velocity, $\Delta x_n = x_{n+1} - x_n$, b is the length scale, D is the vehicle length, C_1 and C_2 are constants. In the last model, (3), $a_{\max}$ is the maximum acceleration, s_n is the gap between vehicles, δ is the acceleration exponent, and s^* is the desired minimum gap, which is defined by:

$$s^* = s_0 + s_1\sqrt{-} + T_n v_n + \frac{v_n \Delta v_n}{2\sqrt{a_{\max} a_{\min}}}. \quad (4)$$

In (4), s_0, s_1, and T_n specify the headway in space and in time. The $a_{\min}$ specifies the minimum deceleration.

Each of those models has their own limitations, but first, we should note that those governing dynamics are only for vehicles in a platoon. Model (1) only applicable when the vehicle is not far from its leader or in the car-following state; meanwhile, (2) and (3) are also applicable when the vehicle is in the free-flow state. Those three models are no-collision model. Model (3) does not take into account the driver delay, which is a crucial feature in the traffic dynamics at the microscopic level. The existing velocity function, for the model (2), tends to produce an extremely high and unacceptable acceleration. It is physically understandable that the vehicle acceleration is not symmetric with respect to the vehicle deceleration. Hence, in implementing (1), one needs to evaluate whether the vehicle accelerating or decelerating, and employs different values of m and l. Such evaluation is not necessary for (2) and (3). Therefore, (2) and (3) are more simple to be implemented in a microsimulation framework. In the model (3), one should specify the acceleration $a_{\max}$ separately from the deceleration $a_{\min}$, and the deceleration term will automatically dominate (3) when the follower approaching the lead vehicle. Therefore, it is easier to implement (3) for general vehicle dynamics. When their parameters are adjusted properly, those three models can produce quite similar responses.

Regarding the connection of the model to the macroscopic traffic flow, [14] has shown that (1) leads to various variations of the fundamental traffic flow diagrams by adjusting the model parameters m and l. In addition, [22] has shown that (2) leads to a fundamental diagram resembling the traffic dynamic in a Japanese highway where the free flow traffic was clearly separated from the congested traffic. The GHR model also produces a similar fundamental diagram when one sets m to zero and l to a small number. Finally, [20] demonstrated that (3) could produce the latter fundamental diagram particularly when the acceleration exponent δ is large; theoretically, when it approaches ∞; however, [20] found that for Germany highway traffic, $\delta = 4$ is more acceptable. The three models are not only able to produce similar responses, but they can also produce similar traffic flow diagrams. Therefore, we conclude that the vehicles dynamics given by three models are essentially similar from microscopic point of view as well as macroscopic point of view.

IV. Conclusions

We have presented the features of the traffic in a motorway in the urban area in Jakarta, Indonesia. The traffic is mainly governed by private four-wheeled vehicles, minibus vehicles, and two-wheeled vehicles where the volume of the latter vehicles is significantly higher than the two previous vehicle-types. It also has been identified that the private four-wheeled vehicles tends to move following the car-following model; the minibus vehicles may also involve in the car-following interaction but it tends to move independently. Because of those facts, modelling Jakarta motorways in urban area requires large attention being paid to the two-wheeled vehicles and the minibus vehicles.

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