Empirical Analysis of Heterogeneous Traffic Flow

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Abstract: Traffic flow in many developing countries is strongly mixed comprising vehicle types, such as motorcycles, cars, (mini) buses, and trucks; furthermore, traffic flow typically exhibits free inter-lane exchanges. This phenomenon causes a complex vehicle interaction, rendering most existing traffic flow modeling approaches insufficient and requiring a new approach. New approaches to the heterogeneous non-lane-based flow have been proposed but empirical verification has been lacking. To bridge this gap, this paper presents some preliminary analyses on a data set collected from a number of road sections in the city of Surabaya, Indonesia. Video data is used to capture aspects of vehicle interaction. Using the porous flow approach, we investigate aspects related to the pore size-density distributions and class-specific critical pore sizes.

Key words: *Heterogeneous Traffic Flow, Vehicle Interaction, Porous Flow Modeling, Pore Size and Density.*

1. INTRODUCTION

Typical traffic flow condition in Surabaya are characterized by a mix of motorcycle (62.2%), private car (30%), and other mostly (mini) buses (7.8%). This mix uses the entire road space with non-lane-based discipline (Lasmini, 2012). Current congestion is increasing mostly caused by a strong increase in motorcycle use (increase 6.25% per year) (Widyastuti, H., Bird, R. N., 2004). The complexity of heterogeneous traffic flow derives from the individual behavior of each of the vehicle types which distinguishes the combined flow behavior from a homogeneous flow.

Academic research addressing the problem, has focused on applying multi-lane multi-class phase-space density (MLMC PSD) modeling to capture the interactions between fast and slower moving vehicles by considering an immediate lane change with probability π (Hoogendoorn, S.P., P.H.L. Bovy, 1999), they consider a continuum model that indicates a planning with macro level which distinguishes between different users with a certain fraction of the traffic lane reserved for priority vehicles (Daganzo et al, 1997).

The other considerations on heterogeneous flow explained traffic flow characteristics in Asian countries. By heterogeneous flow observation at the highway with an undivided two-lane two-way road, it is a systematic attempt to understand the heterogeneous traffic flow parameters which can provide a basic understanding of the behavior of vehicle flows (Sharma et al 2010). By conducting the formation mechanism of non-motorized vehicle (nm-vehicle) illegal lane-changing behavior (NILB) and number of simulation series, it is revealed that the proposed model can be used to figure out the travel characteristic of mixed traffic flow in

most Chinese cities, complex traffic problems such as traffic breakdown, moving synchronized flow pattern (MSP) and moving jam (Hu, X., et al, 2012). These approaches cannot be applied to figure out the complexity and the unique nature of heterogeneous traffic flow.

Previous research on heterogonous traffic flow has focused less on understanding the interaction between vehicles in the case of no lane discipline. Density measurement is insufficient due to depend only on headway. This should be defined by a porous medium. A relation needs to be established between the microscopic behavior and the macro performance of the flow. The porous flow approach conceptualizes such relationship. The micro behavior needs to be analyzed by figuring out the equilibrium speed density relationship that explicitly assesses the pore space distribution (Nair et al, 2012).

Developing heterogeneous traffic flow modeling using headway to measure the density and approaching a porous medium has been conducted in the previous research on heterogeneous traffic flow with non-based lane traffic. The literature is almost silent on the detail of verification of the proposed model with an empirical observation. Consequently, this research is expected to figure out the interaction of each vehicle with the investigation of traffic data and the pore space distribution formation for different vehicle mixes, to test the usefulness of specific lane for motorcycle and public transport based on their behaviors, and to determine various critical pore sizes for each class. This paper is specifically to process the observation video data and to interpret the video images, and to produce the pore size distribution of each vehicle type.

Making a better understand on the driver behavior and against this background, the specific purposes of this paper is to answer questions related to how the traffic observations can refine the model with the real estimated parameters, and verify the difference of motorcycle behavior when interacts with the other vehicles.

The result of this research is expected to assist practical users in understanding the driver behavior in various vehicle classes (between small vehicles, small and big vehicles, big vehicles), assessing the relationship of this behavior with the transport policy undertaken, and estimating the parameters required in developing proposed approach for further analysis.

This paper is organized as follows: section 2 explains heterogeneous traffic flow modeling and highlights the challenge of the present research. Section 3 analyses driver behavior based on an interpretation of video data (Surabaya City), a preliminary investigation is made into parameter estimation for the proposed model. Section 4 discusses the specific finding from pore space distribution, motor cycle behavior due to the relevant policy undertaken. Finally, the last section is conclusion and further recommendation.

2.   TRAFFIC FLOW MODEL FOR HETEROGENEOUS TRAFFIC

Traffic flow theories describe the interactions between vehicles, drivers and infrastructures in a precise mathematical way which has been pioneered by a study which Bruce D. Greenshields conducted in the 1930s. This research produced the relation between spacing and velocity that is called as the fundamental relation or fundamental diagram (Greenshields, 1934). In 1955, continuity of this subject has been started by Lighthill and Whitham who has developed the first dynamic traffic flow model to a number of vehicle classes. In that case, a separate fundamental diagram describes each class behavior. A conservation law was used to describe the LWR model which assumed that flow q is related to density k. The fundamental diagram was known by the equilibrium relation $Q_e(k)$. The formulation that provides a partial

differential equation for a freeway without an access or exit ramps which is explained as follows:

$$\frac{\partial k(x,t)}{\partial t} + \frac{dQ_e(k)}{dk} \cdot \frac{\partial k(x,t)}{\partial x} = 0$$

(1)

Heterogeneous traffic with non-based lane condition has been explained by vehicular headway pattern analysis. It has been found that the exponential and log normal distribution describes the heterogonous traffic flow on two-lane two-way national highways in Bangladesh (Hossain, D. M., Igbal, G.A., 1999). By comprehensive review of study on non-lane based traffic, the unique characteristics of traffic composition, driver behavior, roadway geometry, maneuverability, and vehicular interactions were presented in models study of heterogeneous traffic flow (Khan, Maini, 2000). According to Marwah, and Singh (2000), the simulation results during analysis of service level has demonstrated the capability of model to simulate urban heterogeneous traffic flow condition. The result was found that the classification of service level for urban heterogeneous traffic condition was categorized into four groups (LOS I, II, III, and IV) for Kanpur roads, India using a two-lane one way traffic.

Replication of heterogeneous traffic flow on roads where vehicles move without lane discipline was based on the headway distribution and speeds of the different categories of vehicles. This represents the vehicles position on the road surface, and updating their positions using a coordinate system with respect to an origin. The model has been used to evaluate traffic management measures like segregation of vehicles on major urban roads, provision of exclusive lanes for buses/bicycles, banning of certain categories of vehicles from selected stretches of roads, etc (Arasan, V. T., and Koshy, R. Z., 2005). This research was continued by quantifying the vehicular interactions in heterogeneous traffic in terms of PCU, using micro-simulation technique, and considering the effect of road width and traffic volume on PCU values of vehicles (Krishnamurthy, K., Arasan, V.T., 2012). By development of a model through object oriented programming (OOP) approach to simulate heterogeneous traffic on urban roads in India, the research revealed that this approach was satisfactory to replicate the field condition based on headway distribution and speeds of different types of vehicles (Venkatesan et al,2008).

Nair et al (2011 a,b, 2012) have developed on heterogeneous traffic model based on non lane-based traffic flow. The model uses the concept of pores that is indicated as the areas between vehicles and between vehicles and the roadside. The other approach on heterogeneous traffic flow under the non-lane-based conditions was considered on the model of vehicular time gap by approaching two distributions, namely Generalized Pareto (GP) and Generalized Extreme Value (GEV) with better tail modeling properties (Dubey et al,2012).

In order to evaluate heterogeneous traffic flow characteristics and to determine the appropriate estimation of traffic flow parameters, several empirical analyses have been used. The empirical analysis has been tested in macro level which related to lane-changing characteristics on uncongested multilane freeways particularly in the interrelations between the traffic conditions and the frequency (and fraction) of vehicles changing lanes by using a time-elapsed video recorder. From limited observation, it is revealed that the distribution of headways and speed, and density ratios between neighboring lanes are principal factors affecting the lane-changing behavior (Chang, Kao, 1991). The non-homogeneous traffic has been considered by modification of density method to measure the PCU values for accurate capacity, safety, and operational analysis of highways carrying non-homogeneous traffic. The density data is collected by videotape observations at Indian traffic condition (Tiwari et al, 2007).

Related to heterogeneous traffic flow model explained earlier, the empirical analysis is based on the porous flow approach due to consider the traffic stream at microscopic level and indentify as a porous medium which illustrates the heterogeneous traffic flow in developing country particularly in Indonesia. To understand this traffic condition, this paper considers applying the porous flow model with observation of traffic data in freeway, and assessing the behavior of motorcycle with the availability of specific lane prepared for motorcycle and public transport.

3. STUDY SITE AND DATA COLLECTION

The study area is selected at the main roads of Surabaya City which locates from the south to the center of city as illustrated in Figure 1. To figure the availability of exclusive lane effects on the traffic distribution, two cross-sections as national road which is with and without exclusive lane for motor cycle and bus were selected from the main freeways as gateway roads to the city center of Surabaya City. Administratively, Surabaya City as the capital city of East Java Province comprises 31 sub districts as can be seen in Figure 1. The total area of Surabaya is approximately 326.81 km² within the altitude 3-6 m from mean sea level. This city has a population more than 2.79 million and high density more than 10,000 persons per km^2 in 2006 (City Plan of Surabaya City, 2007).

This section describes the data collection and processing for this research. The step procedure is to set up the overall requirements of data to apply the porous flow approach. The detail of each step is explained as follows: traffic flow survey, video stabilizer, and data processing.

3.1. Traffic Flow Survey

The interaction between vehicle data on the cross-section of the national road was collected from two locations using a video recorder. Since the comparison of the driver behavior between the national road with and without exclusive lane for motorcycle and public transport is one of the research objectives. Representatives of this case, Darmo Raya Street and Ahmad Yani Street with and without this lane respectively were selected due to high proportion of motorcycle and public transport in the traffic flow. The location of these roads is shown in Figure 1. The selective locations are chosen based on such criteria as follows huge number of private vehicles (motorcycle and car) in the traffic flow, the purpose for not adjacent to the intersection, bus stop, and gasoline station etc is to avoid crossing and unusual behavior for each vehicle.

Data was collected by observation made with traffic sensors such as video recording and traffic counting. Two ways are done to investigate traffic data, since the video recording needs enough space to illustrate traffic condition at whole lanes for each direction. Video recording should be set up at the position of high building adjacent with the road areas having height approximately twice of the lane width and the shooting angel about 45 up to 60 degree that captures movement of overall vehicles at the specific time period such as during 10-30 minutes in the peak hour morning and evening, and also normal condition at noon.

The purpose of video recording is expected to figure out the interaction between each vehicle particularly at the national roads. This recording was done in order to investigate the interaction of each vehicle in the low speed (left lane) and high speed (right lane), and the influence of the motorcycle and bus lane presence to the other vehicles. In this study, the major attention on driving behavior of passengers' vehicles consists of motor cycle, car,

paratransit, and bus. The video recording will be extracted to the sequences of images of paths and trajectories of vehicles. Furthermore, robust method is used to stabilize the images (Knoppers et al, 2012). From the measurement of bounding box of the valid pixels in the last stabilized image, the result of stabilization of a series of images (trajectory) includes 20 variables of each image for each object. The trajectory data of individual image that informs occupancy area (length and width) for each vehicle consists of the center of gravity X-coordinate in meter, Y-coordinate in meter and time (second) from the certain reference point. In this paper, these values will be used to calculate pore space, density, and average space speed of each object.

The other way is that traffic counting was done to detect number of each vehicle types and its speed. The data were presented in each class values for a period time, for instance, every 5 minutes during peak hour (06.00-08.00 a.m. and 16.00-18.00 p.m.) and normal condition (11.00 a.m.-13.00 p.m.) on weekday. The observation was done on Monday to Thursday in the second week of September 2012. During traffic counting and speed observation, a surveyor notes vehicle type of motorcycle (MC), non-motorized vehicles such as bike, and pedicab, and paratransit ("Angkot"), the other observes bus, truck, and car. The spot speed inspection was conducted at the same time with traffic counting done at cross-section. Each cross-section is assigned one or two persons to investigate and measure spot speed for each vehicle type passing the certain distance with speed gun radar.

Ahmad Yani and Darmo Raya Streets corridors as national highway have several business and trading areas from south sides to the city center of Surabaya City. The cross-sections are divided eight-lane two-way road with an overall carriageway width of 12 meters and paved shoulders 1.5 meters in each direction. At this area, as many activities take place, the traffic volume is higher than the other places. The number traffic flow passing the carriageway is approximately 1,970 vehicles/hour (motorcycles) and 1,450 vehicles/hour (private cars). The average speed was investigated up to 46 km/h with speed limit 60 km/h for motorcycle, and 47 km/h with car speed limit 80 km/h respectively.
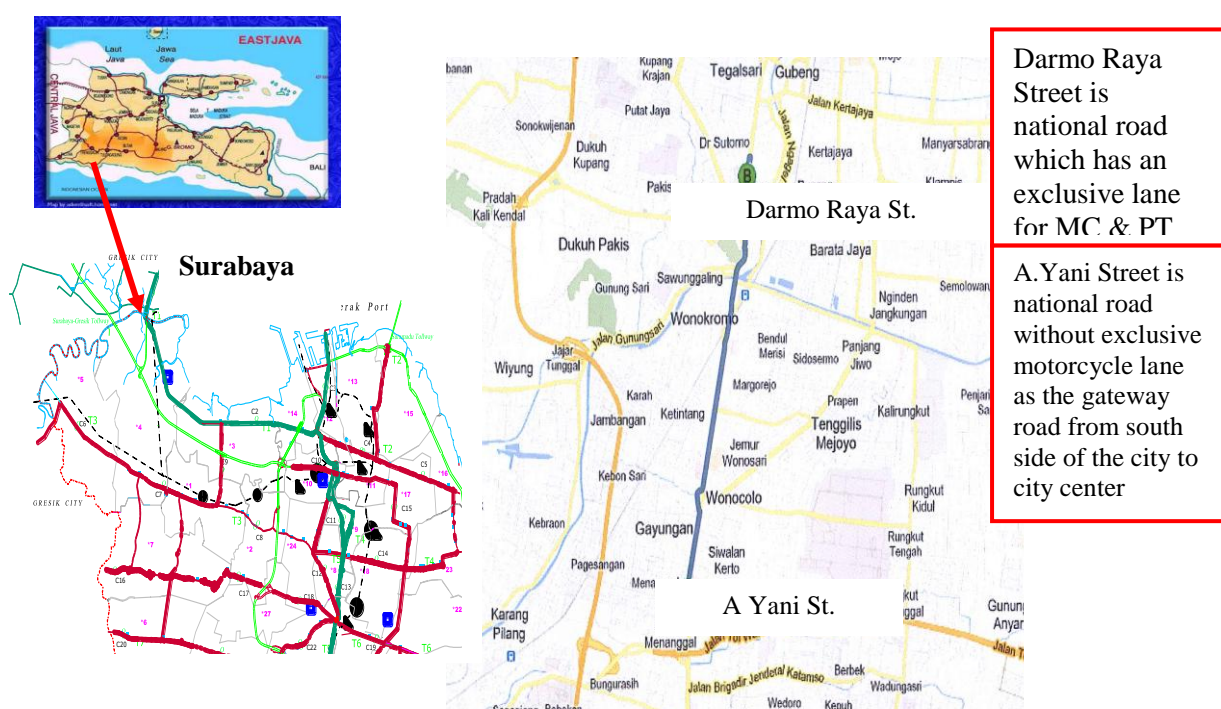

Figure 1. Study area case, Surabaya City, East Java Province, Indonesia

3.2. Video Stabilizer

Understanding the traffic flow for heterogeneous traffic is recorded by video which needs to be stabilized during certain time recording for each object as illustrated on Figure 2. For stabilization system for each image to be measured the position of each object in certain time, it needs several steps consisting of choosing pixel value, lens correction, turning the search range of six parameters (Δx, Δy, K, Δz, ω, φ), wedge transform, selecting the output area, size and rectification, and selecting an area of interest images, restarting the system and parallel processing, single image transformation function, and automatic switching to a new image (Knoppers et al, 2011). The position (X,Y,t) in the image from the reference image as inform the center of gravity X-coordinate in meter, Y-coordinate in meter and time (second) is needed to analyze the position of each object which is used in analyzing pore space and density ranges where occurred for each object (each vehicle).

Figure 2 the output of wedge transformation

In processing data from video stabilization, the video recording data for example 5 minutes produced approximately 6000 images as a result of this analysis. The composition of the traffic is grouped into four classes, named type 1 to type 4 for motorcycle, car, minibus, and bus respectively. This classification is used to measure pore space and density. The detail for each type of vehicle is indicated on Table 1.

Table 1 Vehicle classes and their sizes

class	Type	Vehicle included	Average dimensions a_v (m^2)
1	Motorcycle (MC)	Scooter, Motorbike Mopeds	0.76x2.145
2	Car	Car, Jeep, Van	2.1x5.8
3	Paratransit	Minibus as public transport	2.1x5.8
4	Bus	Bus	2.5x12

3.3. Data Processing

Pore space (r_p) is specified as the areas between vehicles and between vehicles and the roadside. The main result of stabilization process of video recording used in this research is time (t) and position of each object for each image (X,Y). From each image, we determine the pore space (r_p) according to the center of gravity X and Y-coordinate for each object to the other object in each image as illustrated in Figure 3. From individual position, we derive the

pore space and density for each aggregate. So the equations are used to approximate the pore space of each object (each vehicle) in the certain time as follows:

$$\Delta \overline{X} = \Delta X - (vehicle.length_n / 2) \tag{2}$$

$$\Delta \overline{Y} = \Delta Y - (vehicle.width_n / 2) \tag{3}$$

$$\Delta \overline{Y} = \Delta Y - vehicle.width_n \tag{4}$$
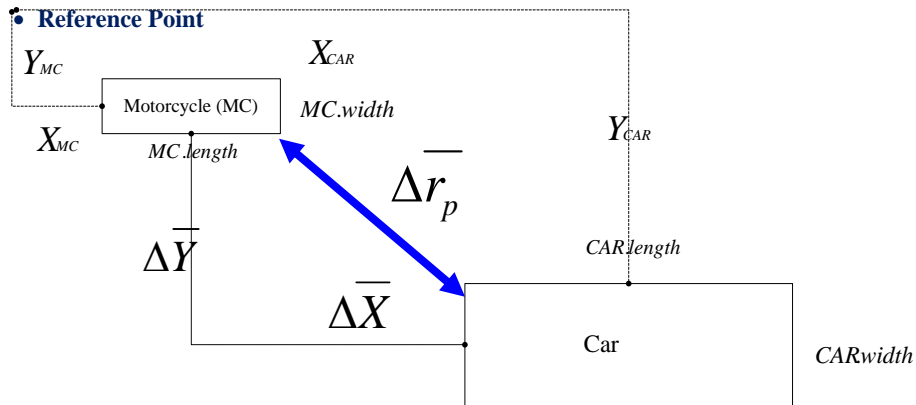
where n is a number of each vehicle type.

Figure 3 Measurement of pore space (r_p)

To apply the porous flow approach, it is important to measure the density that occurred in all lanes for each vehicle type from traffic recording which has been stabilized for all images as individual vehicle trajectory data. The density is determined based on average dimension of each vehicle type and the area of cross-section when the image was recorded ($A_{cross-section}$), as follows:

$$k_v = \sum \frac{vehicle * a_v}{A_{cross.section}} \tag{5}$$

where k_v is density of each image, a_v is average dimension of each vehicle type.

The other parameter measurement is the space mean speed (u_M) which is computed by using a harmonic mean of the measurement of several images for each vehicle depends on the total of vehicles for each image.

$$u_v = \frac{\sqrt{(Y_n - Y_{n-1})^2 + (X_n - X_{n-1})^2}}{\Delta t} \tag{6}$$

$$u_M = \frac{1}{\frac{1}{n}\sum_{v=1}^{n}\frac{1}{u_v}} \tag{7}$$

where u_M is space mean speed and u_v is average speed of vehicles $v=1,\ldots..,n$, Δt is time difference of stabilization between one image to the other image.

4. RESULT AND DISCUSSION

4.1. Distribution of Pore Space and Density, Speed and Density

Related to driver behavior of motorized two wheelers and bicycles that are able to move closer to the other vehicles with the free speed due to their ability for using small gap in the stream, it is necessary to found the appropriate model that replicates the traffic flow particularly on urban roads in developing countries (Arasan et al, 2005). With the illustration of pore space for motorcycle and other vehicle type as seen in Figure 4 and Figure 5, it reveals that the motorcycle has smallest pore space than the others particularly when motorcycle interacts with the other motorcycle.

From the analysis of the density and pore space for each image, we produce pore space-density distribution for each difference of interactions such as interaction between motorcycles, motorcycle and car, car and car as explained in Figure 4.
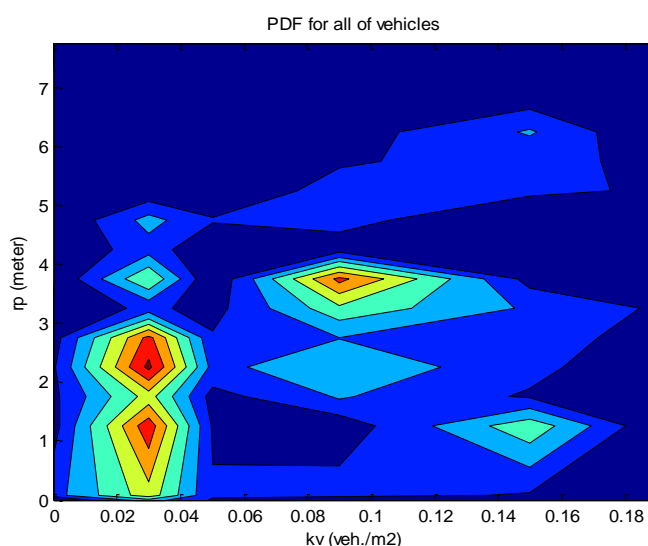

Figure 4 Distribution of pore space (r_p) and density (k_v) for interaction between vehicles on the cross-section road without specific lane

On the basis of the obtained values of pore spaces and densities and understand the driver behavior in various vehicle classes, graphical plots for density (k_v) and pore space (r_p) distribution was illustrated to examine how data points spread. From Figure 4, the distribution seems to be categorized into three groups. First group indicates that vehicles have small pore space below 3 meters with density ranges 0.02-0.04 vehicle/meter^2. The second and third groups were identified as vehicles have pore space 3-4 meters with a medium density range of 0.06-0.12 vehicle/meter^2 and 5.5-6 meters with high density respectively.

In specifying the particular characteristics of interaction between vehicles on national road without specific lane, it is necessary to figure out feature of the three groups. From Figure 5a, it identifies the first group that informs the interaction between small vehicles. This interaction reveals that motorcycle tends to be closer to the other motorcycle in whole density ranges. Almost pore spaces between motorcycles are approximately 1-3 meters at average density 0.025 vehicle/meter^2. This proves that motorcycle drivers wish to be closer and to speed their motorcycle in each possibility of densities. On the other hand, when motorcycle driver interacts with bigger vehicles, they keep the pore space until 3-4 meters at average density 0.08 vehicle/m^2 as seen in Figure 5b. Figure 5c shows that the pore space between cars is approximately 2.5-3.5 meters in the high densities, these values will increase until 5.5.-6.5 meters for low densities.
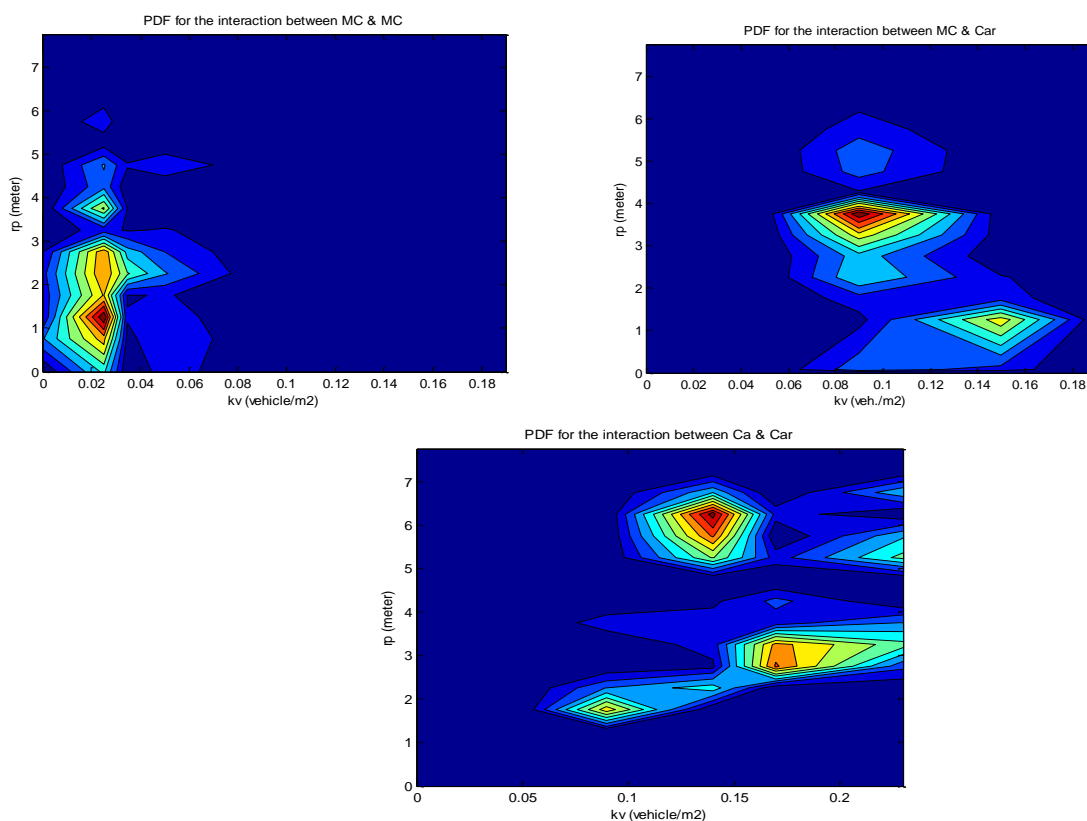
Figure 5 Distribution of pore space (r_p) and density (k_v) for interaction between motorcycles (5a), motorcycle and car(5b), and cars, (5c) Note: k_v in vehicle/meter^2 and r_p in meter

Since 2009 with regulation in Law No. 22/2009 on Road Traffic and Transportation (LLAJ) at Article 108 paragraph 3 which confirms that motorcycle, motor vehicle whose speed is lower, freight cars, and non-motorized vehicles are in the left lane roads. The motorcycle exclusive lane should be facilitated on such road with such performance indicators (safety and smooth flow) (Idris,M., 2010). This lane aims to increase the road performance with increasing motorcycle number, and to decline the motorcyclist number as victim. Motorcycle and bus lanes are facilitated at the certain extent of national and provincial roads in Surabaya City as representatively at Darmo Raya Street.

As expected in Figure 6, the motorcycle has similar pore space with road without motorcycle lane approximately 1-3 meters, this values occurs at the higher densities 0.06-0.1 vehicle/m^2. It means that motorcyclist keeps their distance to the other motorcycle with several values of pore space at those densities.
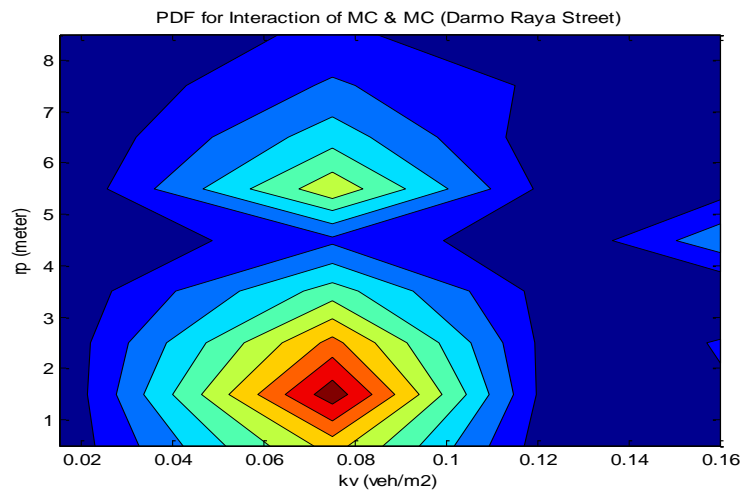
Figure 6 Distribution of pore space (r_p) and density (k_v) for interaction between motorcycles at the exclusive motorcycle lane
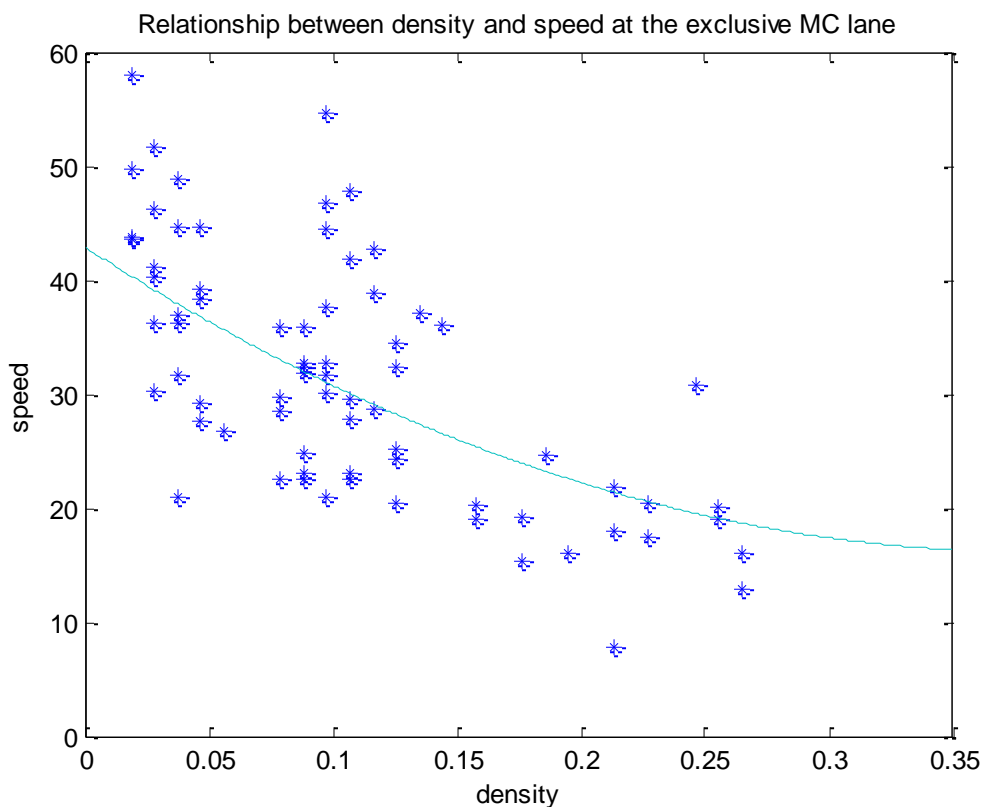

Figure 7 Speed-Density Diagram for interaction between motorcycles at the exclusive motorcycle lane

Figure 7 illustrates that motorcycle speed increases at road with exclusive lane presence. Motorcyclist tends to speed with this lane and their speed will drop suddenly with increasing of public transport number (paratransit). With the exclusive lane presence for motorcycle and public transport in such national road, the motorcyclist behaves significantly different compare to the national road without exclusive lane. Briefly, it is concluded that if there is an enough pore space to speed the motorcyclist movement, they will increase their speed. This is revealed by high speed occurred approaching speed limit (60 km/h) in density lower than 0.1 vehicle/m2, the speed gradually decrease with increasing density.

4.2. Application of Porous Flow Approach

Illustration of test case the interaction between each vehicle is explained by speed density and flow density diagram that results from the porous flow approach. The multi-class kinematic wave model by looking at micro behavior of each vehicle through pore between vehicles has been developed by Nair et al (2011). This approach has been developed to assess the behavior of disordered traffic flow with different types of vehicles. By means of this approach, the test case compares the behavior of each vehicle such as cars, motorcycles, paratransits, and buses from empirical observation.

The scheme that is used in refining the proposed model is to reformulate the proposed approach, to understand the observation traffic data, to classify the vehicle type, and to set up parameters needed in this approach based on the empirical analysis such as the distribution of pore space and density explained in section 4.1.

The fundamental flow is indentified to each class independently as follows:

$$q(v,x,t) = k(v,x,t)u(v,x,t) \quad ; v=1,\ldots\ldots\ldots,n. \tag{8}$$

From the preliminary analysis of distribution of pore space, density and speed, it is necessary to understand this approach, estimate the parameters needed such as critical pore size, reproduce speed-density and flow-density diagram in order to reveal and refine the model proposed related to the mixed flow characteristic with non-based lane traffic. This procedure will be undertaken in the further research.

First step, formulation of the proposed model bases on the multi-class conservation of vehicle equation which defines the traffic state variables flow ($q(v, x, t)$), density ($k(v,x, t)$), and speed ($u(v, x, t)$), and a pore space distribution as probability density function $f_p(r_p, x, t)$ which is r_p is the pore size explained as follows:

$$f_p(r_p,x,t) \geq 0. \quad \text{and} \quad \int_0^\infty f_p(r_p,x,t)dr_p = 1 \tag{9}$$

And the fraction of pores is indicated by $f_p(r_{p,x,t})dr_p$ with size r_p and a r_p+dr_p. The pore space distribution fluctuates depend on the traffic density and composition of traffic at the whole lanes.

The vector of densities for all of vehicle classes is indentified with $K(x,t)$ that means $[k(1,x,t), k(2,x,t),k(n,x,t)]$, briefly, a particular class has the equilibrium speed density relationship influenced by the total vehicle densities, it means $u(v,x,t) = f_e(K(x,t))$. Furthermore, The LWR framework can be derived as:

$$\frac{\partial q(v,x,t).f_e(K(x,t))}{\partial x} + \frac{\partial k(v,x,t)}{\partial t} = 0 \quad ; v=1,\ldots\ldots\ldots,n. \tag{10}$$

In the proposed approach, the traffic stream for each vehicle class consists of two subs reams of fee $u_f(v,x,t)$ and restricted vehicles $u_r(v,x,t)$:

$$u(v,x,t) = u_r(,x,t)\int_0^{r(v)} f_p(r_p,x,t)dr_p + u_f(v,x,t)\int_{r(v)}^\infty f_p(r_p,x,t)dr_p \quad ;v=1,\ldots\ldots\ldots,n \tag{11}$$

The restricted substream and the free substream are defined respectively as follows:

$$u_r(v,x,t) = u^f(v)(1- \int_0^{r(v)} f_p(r_p,x,t)dr_p)^{\alpha_r}{}_r \tag{12}$$

$$u_f(v,x,t) = u^f(v)(1- \int_0^{r(v)} f_p(r_p,x,t)dr_p)^{\alpha_r}{}_f \tag{13}$$

in which $u^f(v)$ is the free flow speed of class v, and $\alpha_r \geq \alpha_f$.

The pore space distribution of multilane without discipline lane is derived to be negative exponentially distributed (Hossain,D., Iqbal,G.,1999, Arasan, V.T., Arkatkar, S.S., 2011) with mean $\lambda(K)$ as a function of density. $\gamma(K)$ indicates the fraction of inaccessible pore space for vehicle class v for given density K, while pore space was assumed by considering as distribution of negative exponential with mean $\lambda(K)$ explained respectively as follows:

$$\gamma_v(\mathrm{K}) = \int_0^{r(v)} f_p(r_p, x, t)dr_p = F(r(v)) = 1 - e^{-\lambda(\mathrm{K})r(v)} \tag{16}$$

$$\lambda(\mathrm{K}) = (l_{max} - l_{min})(1 - \frac{1}{\mathrm{A}}\sum_v a(v)k_v) + l_{min} \tag{17}$$

Second step is that parameters will be assessed from the distribution of pore space and density, and speed. To apply porous flow approach, it is important to simulate critical pore size (r_v) and density (k_v) that occurred in all lanes for each vehicle type from traffic recording data which has been stabilized for all images as an individual vehicle trajectory data.

For example to assess the critical pore size (r_v) for motorcycle, it needs to look at the probability of pore space when motorcycle is able to pass or not able to pass the pore between the other vehicles. Binary logistic regression model is used to estimate the critical pore size for each vehicle. As seen in Figure 8, the critical pores size is estimated by pore space distribution. In that case, motorcycle has two possibilities when motorcyclist position is between the other motorcyclists. The value of 1 is indicated as the motorcyclist having possibility to pass in the pores pace available, value of 0 is indicated as the opposite condition. Using this critical pore size value, the $\gamma(K)$ which indicates the fraction of inaccessible pore space for vehicle class v for given density K is estimated by cumulative distribution function of pore space-density as explained in Figure 9.
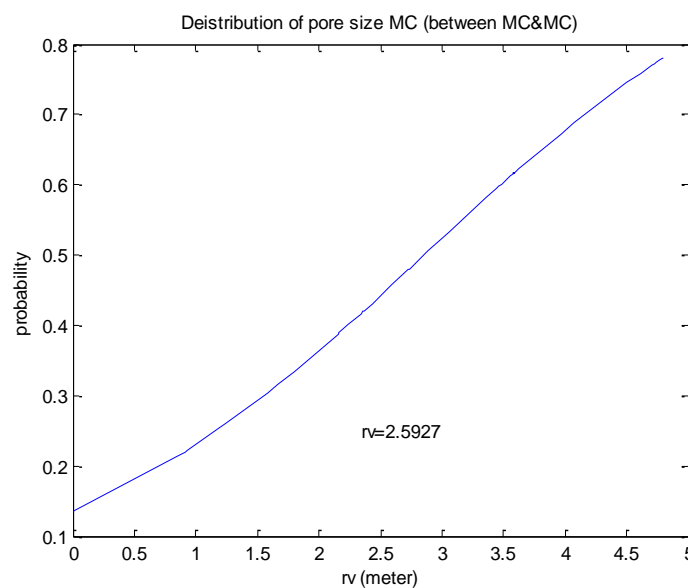

Figure 8 The probability of motorcycle passing pore space between the other motorcycles.
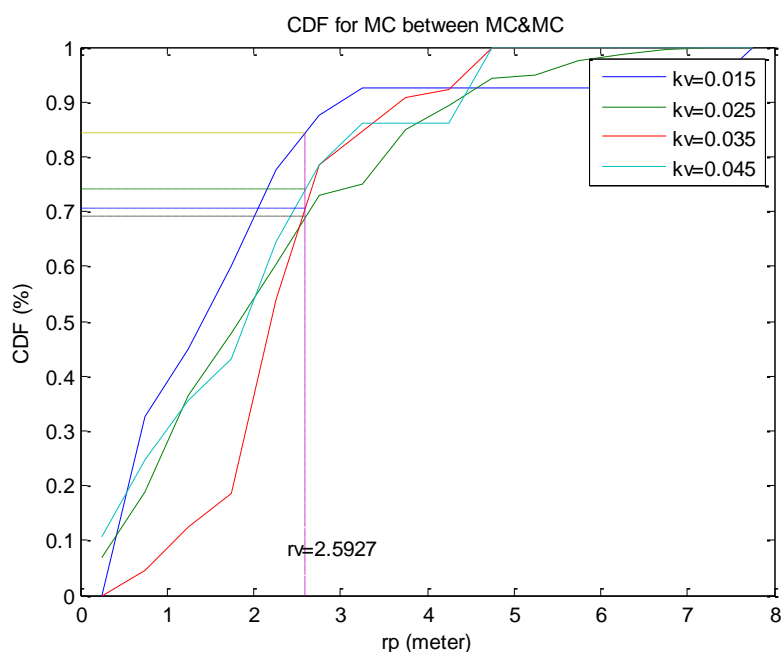
Figure 9 The cumulative distribution function of pore space and density for motorcycle

Using this cumulative distribution diagram, the pore space is revealed that is approached as a distribution negative exponentially depends on the mean density of each vehicle. The other parameters will be considered in the further research by using the observation traffic data from video recording.

Final step, validation of empirical analysis is required to compare the result of empirical analysis and estimation of parameters description with the observation data obtained.

Briefly, in each step of the structural assumption of parameter made for the porous flow approach is expected to be simple and leading to a simple interpretation on the approach that has been expected easily and extensively applied in practice.

5. CONCLUSION AND FUTURE RESEARCH ISSUES

As demonstrated in the pore space-density distribution in this research, driver behavior is assessed for each feature of their interaction, since this behavior is essential factor to understand the interaction between the vehicles from the observation data. The distributions are expected to estimate the parameters of model.

The result of the pore space and density distribution, the motorcycle has smallest pore space than the others particularly when motorcycle interacts with the other motorcycle. It revealed that the pore space depends on dimension of each vehicle.

In order to distinguish the motorcyclist behavior at the national road without and with the exclusive lane, they will increase their speed when their position at the exclusive lane, if there is an enough pore space to speed their movement.

Several other features to reproduce speed-density and flow-density diagrams should be considered in the further research in particularly to estimate the parameters needed for the proposed approach, including: assessing the critical pore size depend on vehicle speed, estimation of free and restricted traffic condition in the substream from the observation data.

Briefly, estimation of the model from empirical observation is expected to support the transport planner understanding to heterogeneous traffic condition based on pore space and density.

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