オートバイ交通の信号 交差点での特性分析*
CHARACTERISTICS OF MOTORCYCLE TRAFFIC AT SIGNALIZED INTERSECTIONS*

チュ コン ミン** 佐野可寸志*** 松本昌二***
By Chu Cong MINH**, Kazushi SANO***, Shoji MATSUMOTO***

1. INTRODUCTION

Transportation－involved matters are usual in most urban areas in the world. Many developed countries confront troubles, which relate to four-wheel vehicles. Besides, in the other parts of the world, developing countries are facing with small size motorized vehicles, such as motorcycles, mopeds, etc. Several cities in developing countries have been suffering from a high degree of the congestion problem, which is mostly caused by two-wheel vehicles. In Hanoi, Vietnam, for example, where two-wheelers are more than 80% of the total transportation means, motorcycle reduces the speed of other modes and makes the traffic more congested due to its shapes and behaviors. It is capable of zigzag maneuvers, creeps up slowly to the front of the queue when the signals are red, and impedes traffic flow by disturbing the start of other vehicles behind.

In order to obtain a better understanding about this mode, the present study aims (i) to draw the techniques applied for collecting and analyzing data, (ii) to develop models to describe the behaviors of motorcyclists, and (iii) to explain and discuss for better understanding this mode.

2. DATA COLLECTION AND ANALYSIS

With high proportion of motorcycle, Hanoi and Hochiminh city, Vietnam, are good representatives to conduct this research. The operation data determined the needs for this study include speed, acceleration/deceleration and road configuration and characteristics. The digital video recorder was set up overhead at the study sites, right angles to the direction of vehicle traffic. The filming traffic was converted into video file then replayed in a computer.

(1) Data Analysis by Using SEV Software

In order to analyze traffic data about trajectory, speed and acceleration/deceleration of traveling motorcycle, it is useful to apply the computer software, namely SEV.exe. The input file is a movie clip with 640 × 480 pixels resolution, which captures traffic at a candidate location. The output file is an Excel compatible file, which advances in analyzing trajectory data as well other necessary information about operation of motorcycle traffic. SEV has several advantages over conventional counting techniques as describing as below:

- The ability of measuring the trajectory, speed, and acceleration/deceleration of several vehicles simultaneously;
- The ability of measuring the of multi-position, speed, and acceleration/ deceleration of a vehicle over time interval as low as one thirtieth second;
- The ability to repeat several times to verify preceding results or recollect missing data as well as to skim unnecessary data;
- Less requirements in equipment and installation, few observers required in both on-site and laboratory;
- The user-friendly software. It is simple to learn as well as easy to operate.

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**正員,工博,長岡技術科学大学都市交通研究室
(新潟県長岡市上富岡町 1603-1, TEL:0258-47-6635,
E-mail:ccminh@stn.nagaokaut.ac.jp)
***正員, 工博,長岡技術科学大学
(新潟県長岡市上富岡町 1603-1, TEL:0258-47-9616,
E-mail:sano@nagaokaut.ac.jp)

(2) Coordinate Transformation Technique

In order to match the coordinate between screen and roadway, according Khan *et al.*, 2001 (1), Coordinate Transformation Technique was applied. For every screen coordinate pair x_s, y_s and roadway coordinate pair x_r, y_r, the following expression may be derived:

$$x_r = \frac{C_1 + C_2 x_s + C_3 y_s}{C_4 x_s + C_5 y_s + 1} \qquad (1)$$

$$y_r = \frac{C_6 + C_7 x_s + C_8 y_s}{C_4 x_s + C_5 y_s + 1} \qquad (2)$$

where

x_r, y_r : Roadway x and y coordinates;

x_s, y_s : Screen x and y coordinates;

C_1, .., C_8: Coefficients.

In order to match the coordinate between screen and roadway, all coefficients will be computed by solving two types of equations above. This process required at least four points, so-call based points, in which, screen and roadway coordinates were determined. The trajectory data, speed and acceleration/ deceleration data for any vehicle is achieved by clicking on the same position at that vehicle over time intervals.

3. METHODOLOGY

Due to small size and shape, a motorcycle has maneuvers which are much more flexible than a passenger car does. To model the behaviors of motorcycle traffic, this research has applied the knowledge from passenger car with some modifications.

(1) Effective lane-width of motorcycle

For motorcycle traffic, since a stream of motorcycles may not be assigned well-defined lanes as that of four-wheel vehicles may, the adapted definition of the motorcycle's lane is necessary. The lateral distance between two motorcycles in paired riding is estimated and defined as effective lane width of a motorcycle. In this study, the paired riding is considered when motorcycle travel together as a group over a certain distance, while maintaining a minimum of a given distance of both longitudinal and lateral spacing. The concept of motorcycle lane introduced in the present research may be understood as a dynamic one. The lane of a given motorcycle does not fix on a roadway as a normal lane does, it may displace from a position to other positions depending on the position of that motorcycle. The width of a given motorcycle lane may change according to that motorcycle's speed. Based on the definition of effective lane width of a motorcycle, other vehicles in different lanes will have no any affect to the subject motorcycle.

(2) Effective Longitudinal Distance of Motorcycle

The effective longitudinal distance of motorcycle is defined as the distance between the subject motorcycle and the leader, at which a motorcycle starts an action to change its direction or speed with the purpose of preventing collision. That value is measured as the distance when a motorcyclist starts decelerating. The effective longitudinal distance may be modeled as below:

$$D(t) = \eta \frac{V_n(t)^{\rho}}{a_n{}^{\theta}(t)} \Delta V_n(t) + \varepsilon_n^{th} \qquad (3)$$

where

D(t) : Longitudinal perceptual threshold at time t;

t : Current time period;

$a_n(t)$: Acceleration applied at time t;

$V_n(t)$: Speed of subject motorcycle at time t;

$\Delta V_n(t)$: Speed difference between leader and subject motorcycle;

η, ρ, θ: Estimated parameter;

ε_n^{th} : Random term of motorcyclist n at time t, assumed to be distributed i.i.d normal.;

$\varepsilon_n^{th} \sim N[0, \sigma^{th}]$

$$cov(\varepsilon_n^{th}, \varepsilon_{n'}^{th}) = \begin{cases} (\sigma^{th})^2 & \text{if} \quad n = n' \\ 0 & \text{otherwise} \end{cases}$$

(3) Reaction Time Model

The reaction time is assumed to follow a truncated log normal distribution as suggested by Subramanian, 1996 (2). It implies that the reaction time is finite, and the probability of a motorcyclist having a smaller reaction time is higher that of having a large one.

$$f(\tau_n) = \begin{cases} \frac{1}{\Phi\left(\frac{\ln(\tau_{max}) - \mu_\tau}{\sigma_\tau}\right)\tau_n \sigma_\tau \sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{\ln(\tau_n)-\mu_\tau}{\sigma_\tau}\right)^2} & 0 \le \tau_n \le \tau_{max} \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

where,

- τ_n : Reaction time of motorcyclist n;
- μ_τ : Mean of the distribution of $\ln(\tau_n)$;
- σ_τ : Standard deviation of the distribution of $\ln(\tau_n)$;
- τ_{max} : Upper bound of of the distribution of τ_n.

The mean of distribution $\ln(\tau_n)$, μ_τ is assumed to be:

$$\mu_\tau = \beta_\tau . V_n^{ave}$$

which,

- V_n^{ave} : Average speed of n^{th} motorcyclist;
- β_τ : Parameter to be estimated.

(4) Car-Following Model

If the distance between the subject motorcycle and the vehicle ahead is less than the effective longitudinal distance, the motorcyclist will decide either change to another lane nearby or decelerate and follow the leader. In case he follows the leader, car-following model is applied with some adjustments for motorcycle traffic.

$$a_n^{cf}(t) = \alpha \frac{V_n(t-\tau_n)^\beta}{\left(\Delta X_n(t-\tau_n)\right)^\upsilon}\left(\Delta V_n(t-\tau_n)\right) + \varepsilon_n^{cf} \quad (5)$$

where,

- $a_n(t)$: Acceleration applied at time t;
- t : Current time period;
- $V_n(t)$: Speed of subject motorcycle at time t;
- $\Delta V_n(t)$: Speed difference between leader and subject motorcycle;
- $\Delta X(t)$: Space headway at time t;
- α, β, υ: parameter;
- ε_n^{cf} : Random term of motorcyclist n at time t, assumed to be distributed i.i.d normal.;

$\varepsilon_n^{cf} \sim N[0, \sigma^{cf}]$

$$\text{cov}(\varepsilon_n^{cf}, \varepsilon_{n'}^{cf}) = \begin{cases} (\sigma^{cf})^2 & \text{if} \quad n = n' \\ 0 & \text{otherwise} \end{cases}$$

In order to estimate the parameters of the models above, log-likelihood technique is applied. Then, the model is calibrated and validated with on-site traffic data.

4. CONCLUSION

No any adjustment factor for motorcycle has been made for 2000 Highway Capacity Manual (HCM) (3). The procedures cannot be applied successfully in most of developing countries because of large differences in traffic composition, roadside facilities and driver behavior. The present paper provides a basic understanding of the traffic operation of motorcycle, which is necessary to conduct analytical models that serve the motorcycle traffic. The findings provide useful information that can be used to develop speed – flow relationship, to improve geometric designs of motorcycle facilities as well as to provide the data necessary to develop a motorcycle simulation model.

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