Proceedings of the Eastern Asia Society for Transportation Studies, Vol.11,2017

# Effects of Road Width and Number of Lanes on Capacity in Urban Streets

Nguyen Van ANH [a], Tran Vu TU [b], Kazushi SANO [c]

[a] *Hanoi University of Transport and Communication, Vietnam*
[a] *E-mail: trvutu123@yahoo.com*
[b] *Department of Civil Engineering, Ho Chi Minh City University of Technology and Education, Vietnam*
[b] *E-mail: tutv@hcmute.edu.vn*
[c] *Department of Civil and Environmental Engineering, Nagaoka University of Technology, Japan*
[c] *E-mail: sano@vos.nagaokaut.ac.jp*

**Abstract**: This study focuses on the effects of road width and number of lanes on capacity in urban streets based on the relationship between traffic characteristics such as speed, flow, and density. Based on the real data of mixed traffic in Vietnam, the fundamental diagrams of speed, flow, density relationship in pairs were plotted in this research. Regression analysis is used to estimate the capacity of different types of road segments. The value of critical speed, critical density, maximum flow of each kind of road are computed. The data indicates that capacity in 1 lane road, 2 lane road, 3 lane road and 4 lane road are 7634, 11668, 17689, 26460 motorcycle per hour respectively. The results shows that in urban street the capacity increase when the number of lane or road with increases. The regression analysis indicates that if the road width increases by 1m capacity will increases by 1981 mc/hr. In addition to this, two new exclusive lanes for motorcycle only and for car only are proposed with the dimension of width is 1.5 m and 3.5m, and their capacities are calculated. This research gives the comparison between the exclusive lanes and the real situation

*Keywords*: Capacity, Road width, Number of lanes, MEU, mixed traffic

## 1. INTRODUCTION

Capacity analysis is the study and analysis of the operational characteristics that will result when various facilities serve various levels of demand. Capacity analysis does not seek to identify merely the maximum amount of traffic that a facility can handle, but also the amount of traffic that can be accommodated at various defined level of operational quality. Capacity analysis is part of virtually every form of traffic analysis, including planning and design, operational analysis, analysis and evaluation of controls, and analysis of alternatives (McShane and Roess, 1990).

There were many works have been done to estimate the capacity and level of service of facility in developed countries. Highway Capacity Manual (HCM) provides a systematic and consistent basis for assessing the capacity and level of service for individual elements of the surface transport systems and for systems, which contains a series or combination of individual facilities. Nevertheless, the procedure in HCM and other studies assume that the

traffic flow is homogenous and follows lane discipline.

In urban street of Vietnam, there is large proportion of motorcycles, lane width is not fixed, and vehicles do not follow any lane discipline. Viet Nam has to face with many traffic problems, they are lack of traffic law understanding, traffic congestion, infrastructure, and facilities do not meet the demand. This study concentrates on estimating capacity of different types of road segments and the effects of the number of lanes and road width on urban streets. In addition to this, two type of new lane with include exclusive lane for cars and exclusive lane for motorcycles are supposed in order to enhance traffic safety.

## 2. PAPER OBJECTIVES

The general target of this thesis is to obtain a better understanding of capacity under mixed traffic at road segments in urban road system in Hanoi capital of Vietnam. The specific objectives include exploring the relationship between traffic characteristics (speed, density, flow) as well as road capacity and road width. Based on that, the research investigates the changes of road capacity for the scenario of exclusive lane for motorcycle and that of exclusive lane for car.

## 3. METHODOLOGY

### 3.1 The value of mean speeds

The data is collected during the determined time period. The volumes and mean speeds of all kinds of vehicles at every minute are recorded. The various volumes of all vehicle types are converted into MEU, in which the same stream speed is applied for the current study locations.

$$v = \frac{n}{\sum_{i=1}^{n} \frac{1}{v_i}} \quad (1)$$

where:

*n :* *Total number of vehicle categories present in stream;*

*v :* *Mean stream speed (km/h);*

$v_i$: *Speed of vehicle i (km/h);*

### 3.2 Capacity estimation

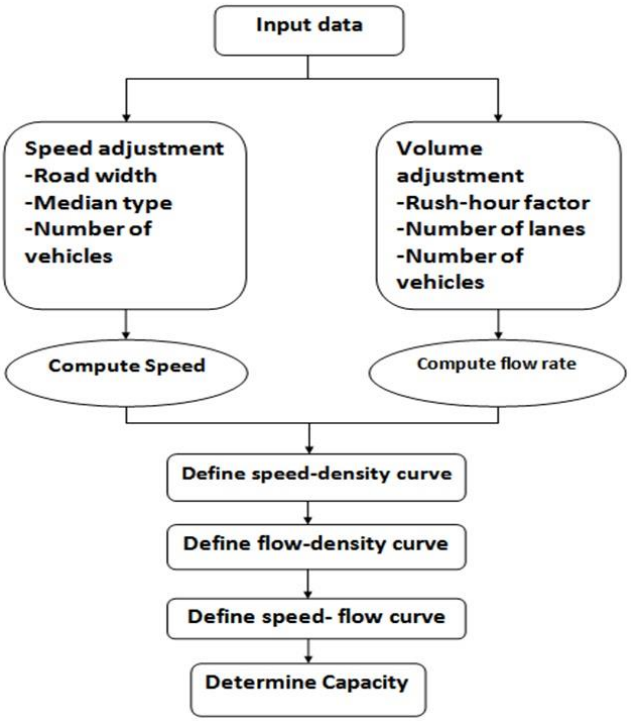



Figure 1. Capacity estimation steps

From the input data, with speed adjustment included road width, median type, number of vehicles, mean stream speed is computed. From the input data with volume adjustment included number of lane and number of vehicles, flow rate is computed. After getting mean stream speed and flow rate, speed and density curve is defined. Then flow-density curve and speed-flow curve is defined. Ultimately, capacity is determined.

Traffic flow collected in 1 minute is converted to equivalent rate of flow in 1 hour.

Number of vehicle is converted to MEU:

1 Sedan = 3.326 MEU

1 Van = 3.624 MEU

1 Bus = 8.568 MEU

(Adapted from Tan *et al* 2010)

In order to calculate mean stream speed, space mean speed which is the average speed of vehicles measured at an instant of time over a stretch of road is used.

$$v = \frac{n}{\sum_{i=1}^{n} \frac{1}{v_i}} \quad (2)$$

where:

*n :* *Total number of vehicle categories present in stream;*

*v :* *Mean stream speed (km/h);*

$v_i$: *Speed of vehicle i (km/h);*

From regression analysis, mean stream speed and density relationship could be expressed as equation follow:

$$S = x + y \ln D \quad (3)$$

where:

*x,y is unknown parameters*

*S is mean stream speed (km/hr)*

*D is traffic density (mc/hr)*

Based on Greenberg's logarithmic model which may be expressed in linear form as follow:

$$S = S_c \ln(D_j) - S_c \ln(D) \quad (4)$$

where

$S_c$ *is critical speed*

$D_j$ *is jam density*

*D is traffic density*

The model building process for S-D relationship incorporated scientific knowledge of Greenberg's logarithmic model in the model selection.

## 4. DATA COLLECTION

The following criteria were used with the aim of selecting of the suitable study sites: High traffic volume; ease of setting up; good mix of different vehicle types; no nearby intersections to avoid unusual behaviors of motorcyclists; sufficient motorcycle volumes; insignificant disturbance from bus stops. road surface: normal condition, slope of road: <2%, horizontal curvature: <3% ,limited speed: 40 km/h, distance from intersection: >400m. The map is as follows:

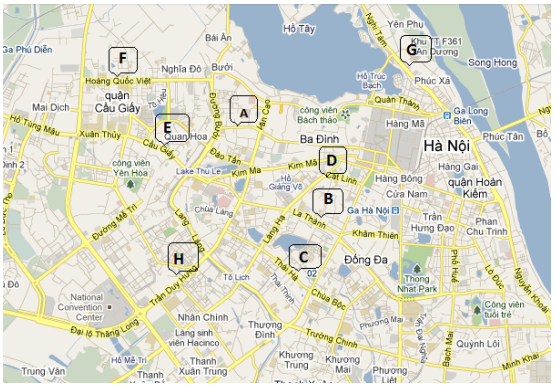


Figure 2. Sites selection in Hanoi, Vietnam

Eight road segments in Ha Noi- Viet Nam were selected for this study. 2 road segments (A,B) are 1 lane road with 4.5m road width per direction.2 road segments (C,D) are 2 lane road with 6.5m road width per direction. 2 road segments (E,F) are 1 lane road with 9.5m road width per direction. 2 road segments (G,H) are 4 lane road with 14m road width per direction. The traffic flow data in this study was gathered totally by using a video camera. Each road segments was collected under the dry-weather conditions during two hours in the morning (07h00 – 09h00) and in the afternoon (16h30 – 18h30). These periods were considered as peak hours. Dimensions of segments were measured in advance. One digital video recorder was set up at high-rise buildings about 10 meter high nearby these chosen study sites, captured all traffic movements at the specified time periods. From these points the traffic movement was observed very clearly and wasn't obstructed by anything. This technique required two corresponding persons in the field to observe proper positions for recording the video and install the video. The video data were first transferred to available compact discs in the form of the file format. These compact discs were then played in a computer by using the SEV software. After that, vehicle positions were identified clearly from the image video file and these positions regarding time events were calculated according to screen co-ordinates and then converted into roadway co-ordinates by using the transformation method. This method helped extract data more easily under heavy traffic – flow conditions.

## 5. RESULTS

### 5.1 Relationships between flow, speed and density with different numbers of lanes

The relationship between speed, flow and density after converting into MCU are illustrated in the following figures for the cases of different numbers of lanes. The distributions are generally the same for each pair: speed and density, flow and density, flow and speed. The typical relationship for the pair of speed and flow is shown as follows:

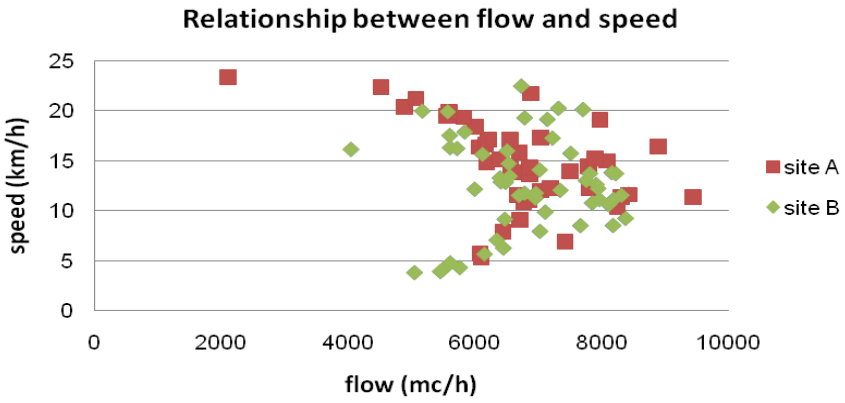



Figure 3. The relationship between flow and density for 1 lane road per direction

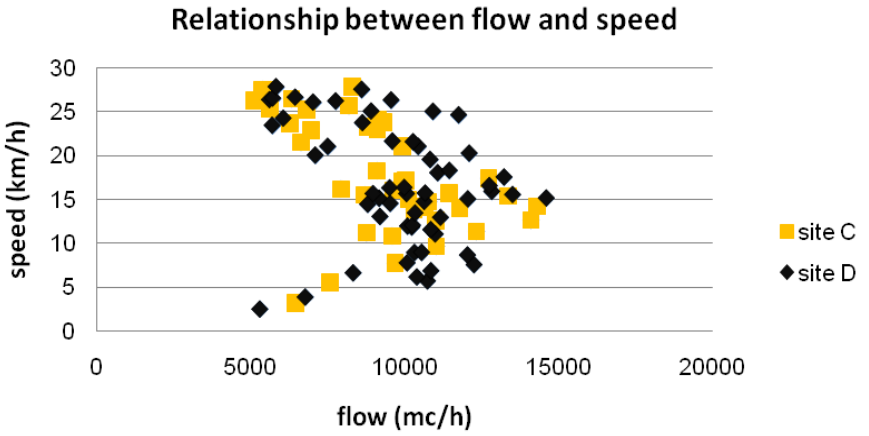



Figure 4. The relationship between flow and density for 2 lane road per direction

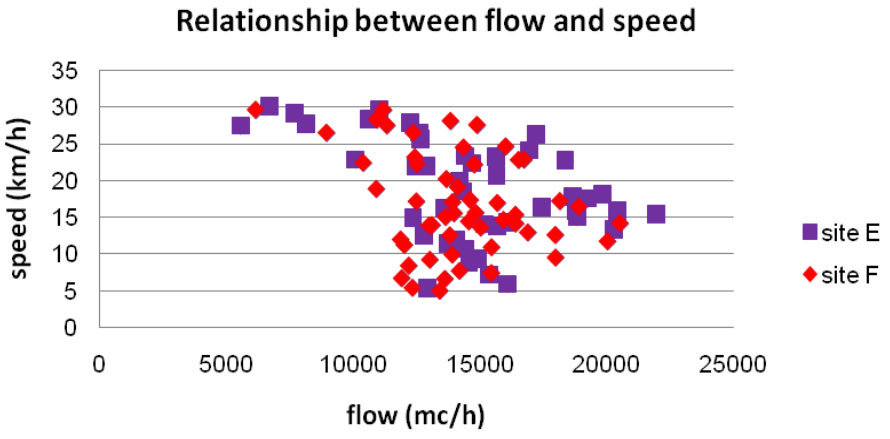



Figure 5. The relationship between flow and density for 3 lane road per direction

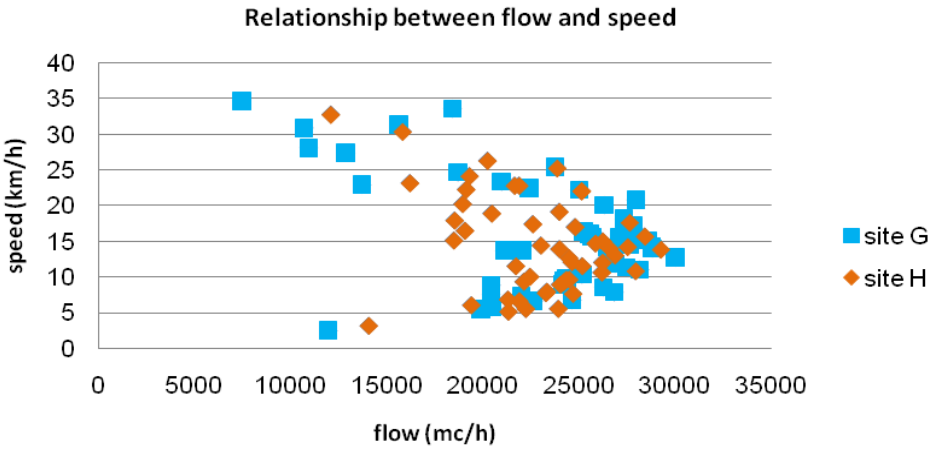



Figure 6. The relationship between flow and density for 4lane road per direction

Table 1. Capacity estimation result of 1, 2, 3,4 lane road per direction

| | 1 lane per direction | 2 lanes per direction | 3 lanes per direction | 4 lanes per direction |
|---|---|---|---|---|
| Road width | 4.5m | 6.5m | 9.5m | 14m |
| Number of samples | 100 | 100 | 100 | 100 |
| Relationship between Speed and Density | S=-10.8lnD+81.7 $R^2$=0.82 | S=-11.3lnD+89.7 $R^2$=0.91 | S=-11.5lnD+95.9 $R^2$=0.76 | S=-11.8.lnD+102.8 $R^2$=0.87 |
| Relationship between Flow and Density | $F = 10.8.D.ln\frac{1922}{D}$ | $F = 11.3.D.ln\frac{2806}{D}$ | $F = 11.5.D.ln\frac{4181}{D}$ | $F = 11.8.D.ln\frac{6095}{D}$ |
| Relationship between Flow and Speed | $F = 1922.S.e^{\frac{-S}{10.8}}$ | $F = 2806.S.e^{\frac{-S}{11.3}}$ | $F = 4181.S.e^{\frac{-S}{11.5}}$ | $F = 6095.S.e^{\frac{-S}{11.8}}$ |
| Critical speed (km/h) | 10.8 | 11.3 | 11.5 | 11.8 |
| Capacity (mc/hr) | 7,634 | 11,668 | 17,689 | 26,460 |
| Capacity (mc/hr/m) | 1,697 | 1,795 | 1,862 | 1,890 |

Table 1 shows that capacity of 1 lane road, 2 lane road, 3 lane road, 4 lane road per direction is 7634, 11668, 17689, 26460 motorcycle per hour respectively. The results shows that in urban street the capacity increase when the number of lane or road with increases.

### 5.2. Relationship between road width and capacity

According to table 1, capacity at 1 lane road (4.5m road width), 2 lane road (6.5m road width), 3 lane road(9.5m road width), 4 lane road (14m road width) is 7634, 11668, 17689, 26460 mc/hr respectively, the relationship between road width and capacity could be expressed as in figure 7.

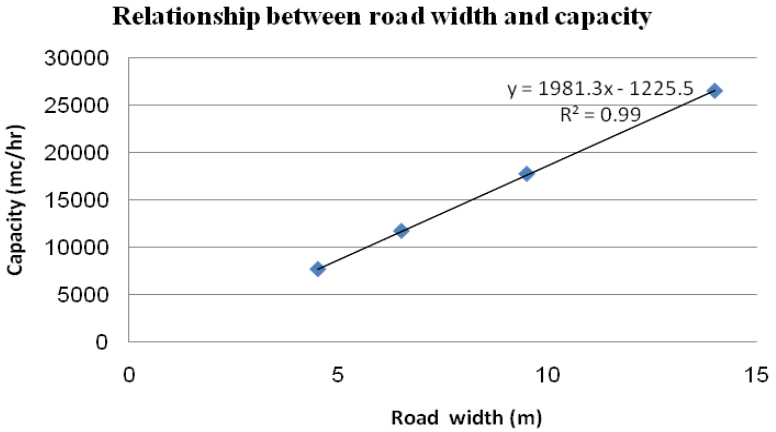



Figure 7. Relationship between road width and capacity

As can be seen on figure 7, capacity rises gradually when road width increases. If the road width increased 1m capacity will increase 1981 mc/hr.

### 5.3. Proposed new lane road

This research recommended two types of new lane road they are exclusive lane for motorcycle and exclusive lane for car. Based on the dimension of vehicle in Vietnam this research proposed the dimension of lanes as follow:

Table 2. Dimension of exclusive lanes

| Type | Dimension of lane |
|---|---|
| Exclusive lane for motorcycle | 1.5m |
| Exclusive lane for motorcycle | 3.5m |

Based on the observation of data from 1 lane, 2 lane. 3 lane, 4 lane road per direction, capacity of exclusive lane for motorcycle and exclusive lane for car was found by analyzing data at the period that maneuver of motorcycle or car do not occur frequently. After estimating capacity of the two new lane width, applying them to Scenario 1 and Scenario 2 as follow:

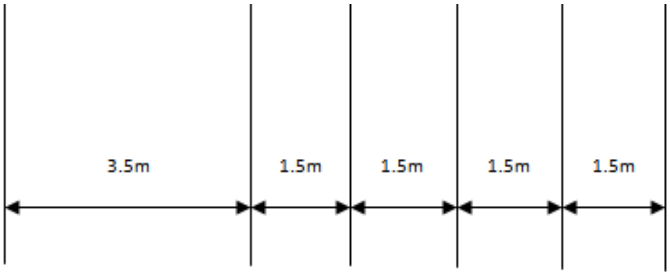



Figure 8. Scenario 1

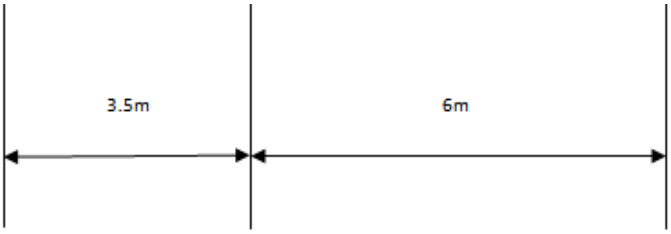



Figure 9. Scenario 2

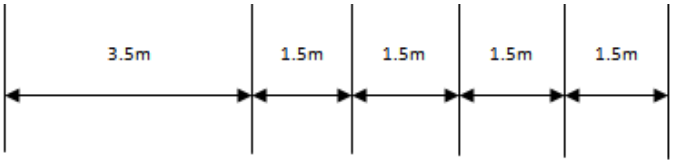
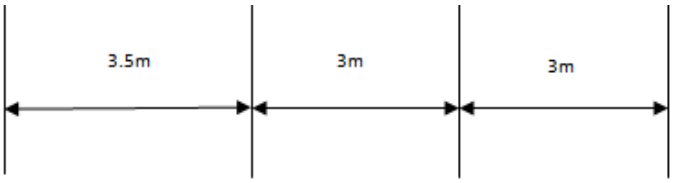
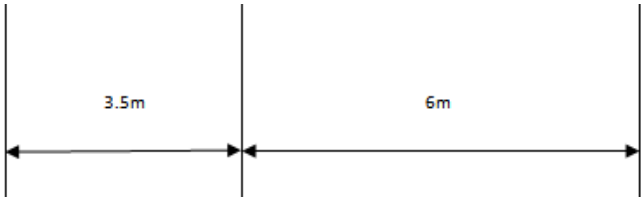
Scenario 1 has 5 lane included 1 exclusive lane for cars and 4 exclusive lanes for motorcycles with total road with is 9.5 m equal to the 3 lane road per direction. Meanwhile, scenario 2 has 2 lane included 1 exclusive lane for cars and the other 6m lane is for motorcycles with total road with is 9.5 m equal to the 3 lane road per direction. Based on the relationship between flow, speed and density, the functions for these relations are estimated with significant index factor ($R^2$ value in this research). The comparison between the two scenarios (in Table 1) as well as the comparisons with the real scenarios are as follows:

Table 3. Capacity estimation result of 1.5m lane road

| Lane width | Relationship between Speed and Density | Relationship between Flow and Density | Relationship between Flow and Speed | Critical speed (km/h) | Capacity (mc/hr) | Capacity (mc/hr/m) |
|---|---|---|---|---|---|---|
| 1.5m | S=-9.6.lnD+61.4 | $F = 9.6.D.ln\frac{601}{D}$ | $F = 601.S.e^{\frac{-S}{9.6}}$ | 9.6 | 2122 | 1415 |
| 3.5m | S=-24.1.lnD+162 | $F = 24.1.D.ln\frac{825}{D}$ | $F = 825.S.e^{\frac{-S}{24.1}}$ | 24.1 | 7286 | 2082 |

Table 4 Comparison of real situation and the two scenarios

| Scenarios | The lay - out | Estimated capacity (mc/hr) |
|---|---|---|

| | | |
|---|---|---|
| Scenario 1 |  | 15,774 |
| Real situation |  | 17,689 |
| Scenario 2 |  | 18,056 |

Capacity of scenario 1 is smaller than capacity of scenario 2, 15,774 motorcycles per hour compared with 18056 motorcycles per hour. It is interesting to note that the capacity of real situation (3 lane road per direction with 9.5m road width) is greater than capacity of scenario 1 but smaller than scenario 2.

Based on that, comparison of real situation and proposed one is given. Compare proposed lane road and the real situation: with proposed lane width, capacity may reduce slightly however traffic safety increases significantly.

## 6. CONCLUSIONS

This thesis investigated traffic characteristics (speed, flow, density) at road segments under mix traffic condition in motorcycles dependence cities of Hanoi capital of Vietnam. The data of this study was collected in Hanoi capital and was analyzed by using the video recording technique.

This thesis examined the effects of the number of lanes on urban streets. The finding showed that the average speed slightly increases with increasing number of lane or road width. This paper found the values of capacity of each kind of road segments. Capacity at 1 lane 2 lane 3 lane 4 lane road is 7634, 11668, 17689, 26460 mc/hr respectively. The regression analysis indicated that when the road width increases by 1m capacity will increase by 1981 mc/hr.

Moreover this research proposed exclusive lane for motorcycles with 1.5m lane width and exclusive lane for car with 3.5 m lane width and found that capacity at the 1.5m lane is 2122 mc/hr and that at the 3.5 m lane is 7286 mc/hr. Based on that the research has a comparison of

real situation and proposed one. In comparison with the real situation, exclusive lane for motorcycle, capacity of exclusive lane may reduce slightly however traffic safety increases significantly.

Although this study has given the effects of the number of lanes and road width on urban street, possible further research work are suggested. First of all, the number of sections for the data collection should be increased in order to have more accurate results. Additionally, the road network plan and design problems with the impact of the number of lanes should be further research.

## REFERENCES


Chandra, S. and Sikdar, P.K. (2000), Factors affecting PCU in mixed traffic situations in urban roads, *Road and Transport Research*, Vol. 9(3), Australian Road Research Board.

Chandra, S., and Kumar, U. (2003) Effect of Lane Width on Capacity under Mixed Traffic Condition in India, *Journal of Transportation Engineering*, Mar. Apr., pp. 155 – 160.

Dr. Henk van Zuylen, Capacity and traffic performance of unsignalized intersections under mixed traffic conditions, Bochum, August 2007.

Highway Capacity Manual 2000, *Transportation research board*. Washington D.C, 1999

Indonesian highway capacity manual

Kimber, R.M, McDonald, M. and Hounsell, N. (1985), Passenger Car Units in Saturation Flows: Concept, Definition, Derivation, *Transportation Research – B*, Volume 198, No. 1, pp. 39 – 61.

Nguyen Cao Y et al., Motorcycle equivalent units at road segments and signalized intersections in urban roads, Nagaoka University of Technology, School of Civil and Environmental Engineering, Japan, July 2008.

Zhow Wei, A Method for Capacity Analysis Based on Theoretical and Practical Considerations, *TRB 82nd Annual Meeting and TRR*, 2003

Highway Capacity Manual 2000, *Transportation research board*. Washington D.C, 1999

Nguyen Cao Y, Estimating capacity and vehicle equivalent unit by motorcycles at road segments in urban road, *Transportation Research Board* Washington, D.C, USA.

Xiaobao Yang, Effect of the number of lanes on freeway traffic characteristics in empirical observations and microscopic simulation, *Transportation Research Board* Washington 2010.

Nguyen Cao Y , Motorcycle equivalent units at road segments and signalized intersections in urban roads, Nagaoka University of Technology, School of Civil and Environmental Engineering, Japan, July 2008.

Doan Thanh Tan, A study on motorcycle equivalent unit and capacity estimation on urban street, Nagaoka University of Technology, School of Civil and Environmental Engineering, Japan, July 2010

Vietnam highway standard – design requirement, Vietnam standard 4054-05, Hanoi,2005.

Chandra, S., and Kumar, U. (2003) Effect of Lane Width on Capacity under Mixed Traffic Condition in India, *Journal of Transportation Engineering*,

Del Castillo, J.M and F.G. Bentitez. On the functional form of the speed-density relationship – I: general theory, *Transportation Research* 1995

Hussain Hamid, Radin Uma Radin Sohadi, Estimation capacity for uninterrupted motorcycle path in Malaysia. *TRB 2005* Annual Meeting CD-ROM.

Hussain, H., Radin, U.R.S., Ahmad F.M.S., and Dadang, M.M., (2005) Key Components of a Motorcycle-Traffic System – A Study along the Motorcycle Path in Malaysia, In IATSS Research, Vol. 29, No. 1.

Minh, Chu Cong (2005) The speed, flow and headway analyses of motorcycle traffic, *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 6.