Development of Urban Road Capacity and Speed Estimation Methods in Indonesia

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***Abstract*—Recently, the 1997 Indonesian Highway Capacity Manual is commonly used to analyze the performance of road and intersection. However, since the motorized vehicle grows rapidly and significant change of driver behavior, several parameters must be validated so that the calculation result could represent the actual condition. This paper aims to improve the Indonesian HCM formula especially in regards to the value of free flow speed and initial capacity. To support our research, traffic surveys have been carried out on various urban roads in some Indonesian cities for four lane roads with divider. The flows then have been simulated by using VISSIM software (VerkehrInStädten – Simulations Modell). The measured speeds and headways have been compared to the simulation results. The Wiedemann parameters in VISSIM have been calibrated such that there is no significant difference between the measured speeds and headways and the simulation results. After calibration, the flow-speed relationships have been compared to Indonesian HCM formula, by simulating various traffic flows. Our results show that the values of free flow speed need to be verified become 37 kph and 40 kph for car and motorcycle respectively, while the basic capacity becomes 1750 pcu/hour/lane.**

***Index Terms*—traffic flow, headway, simulation, VISSIM.**

I. Introduction

TO predict the road capacity, the 1997 Indonesian Highway Capacity Manual has been widely used in Indonesia. This manual was based on the most comprehensive study, which was carried out as an Indonesian Highway Capacity Manual Project and reported by Bang et al.[1] under the consultancy of Swedish National Road Consulting AB, SweRoad. It identified significant effects of geometric factors (i.e. carriageway width, shoulder width, median), traffic and environmental factors(directional split, city size) and side friction factors (i.e. pedestrians, non-motorized vehicles, public transport vehicles) on speed-flow relationships on Indonesian urban/suburban road links.

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A number of methods for speed modelling were developed [2]. However, speed and capacity relationship in Indonesian Highway Capacity Manual should be improved [3].

This paper will examine the use of Indonesian HCM for predicting free flow speed and initial capacity at urbanroads for four lane road with divider (two lanes for each direction), by comparing the actual speed and capacity and by simulating the traffic by using VISSIM computer program. A simulation model can be flexible enough to cover a wide range of highway and traffic conditions. Input to the model can be specified to any distribution and the form of traffic control and driver characteristics varied. Simulation time may be as long as desired and several figures of merit may be printed out during simulation process. A simulation model requires the formation of a model system which represents the real situation at the site being studied. This model has, therefore, been developed by many researchers in the recent years, such as Tian et al [4].

II. Methodology and Analysis

A. Data Collection

The data is collectedin five different cities in Indonesia, there are Banda Aceh, Pekanbaru, Yogyakarta, Surabaya, and Banjarmasin. It is expected that by taking many samples from those five different cities, this research can represent the real traffic condition in Indonesia. Geographically, the locations of those five cities is shown in figure 1.

Fig. 1.Traffic Survey Locations

The secondary data in this study are obtained from data on the number of population in each city and aerial photographs of the road network which is used as a reference in designing of road section models. Meanwhile, the primary data are obtained through direct survey in the form of traffic volume, speed of each vehicle type, and roads geometrics. The survey is conducted on weekdays from morning to evening by using cctv cameras, in order that the survey can

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produce the data that represent the daily circumstances on the road network. The next step is modeling data to VISSIM software. The modeling of road network is based on the result of road geometric survey and the data input is resulted from the survey of the traffic volume during peak hours.

B. Simulating and Modeling Using VISSIM

VISSIM is a microscopic multi-modal traffic flow simulation software package developed by PTV (Planung Transports Verkehr) AG in Karlsruhe, Germany. The name is derived from "Verkehr In Städten – SIMulations modell" (German for "Traffic in cities - simulation model"). VISSIM was first developed in 1992.VISSIM has used the Wiedemann approach, psycho physical model for driving behavior [5]. These following parameters have been calibrated to meet the Indonesian behavior.

TABLE 1
CALIBRATED PARAMETERS

Parameters	Calibration value	
	Before	After
Desired position at free flow	Middle of lane	Any
Overtake on same lane: on left & on right	off	on
Distance standing (at 0 km/h) (m)	1	0.3
Distance standing (at 50 km/h) (m)	1	0.5
Average standstill distance	2	0.45
Additive part of safety distance	2	0.45
Multiplicative part of safety distance	3	1
Waiting time before diffusion (s)	60	40
Min. headway (front/rear) (m)	0.5	0.4
Safety distance reduction factor	0.6	0.4
Maximum deceleration for cooperative braking (m/s^2)	-3.00	-3.00

The next step is making the model based on road geometric and traffic volume in the five different cities resulted from the traffic survey. Next, the speed result data of VISSIM software are compared with the Indonesian Highway Capacity Manual (IHCM) calculation result [6].

According to the Indonesian Highway Capacity Manual, the free flow speed can be calculated as shown below:

$$FV = (FV_0 + FV_W) \times FFV_{SF} \times FFV_{CS} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

With
FV = free flow speed (km/hour)
FV_0 = basic free flow speed (km/hour)
FV_W = road width factor (km/hour)
FFV_{SF} = side friction factor
FFV_{CS} = city size factor

Free flow speed depends on the vehicle type (motorcycle, car or heavy vehicle) and road type (number of lanes and with/without divider). The average space mean speed can be calculated by using IHCM graphically by inputting the free flow speed and the degree of saturation. The capacity can be calculated by using the formula below:

$$C = C_0 \times FC_W \times FC_{SF} \times FC_{CS} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

With
C = basic capacity (pcu/hour)
C_0 = basic capacity (pcu/hour)
FC_W = road width factor
FC_{SF} = side friction factor
FC_{CS} = city size factor

Basic capacity depends on vehicle type (motorcycle, car or heavy vehicle) and road type (number of lanes and with/without divider).

The analysis is then proceeded further by the following steps:

1) The traffic volume of each road in each different city is gradually increased from the existing volume, and then modelled back using VISSIM software.
2) The data of speed estimation from VISSIM software for each traffic volume is then noted and analysed.
3) The estimation of speed data resulted from VISSIM software is then compared with the speed data resulted from the calculation using IHCM.
4) Some changes are made on IHCM parameters such as basic capacity and basic speed, so that data resulted from IHCM calculation is suitable with the data from VISSIM software result.

C. Data Analysis

The speed estimation data from the VISSIM software is then used in capacity calculation analysis based on Greenshield (1934) method by using a linier relationship between density and speed. The capacity calculation result is then compared with the capacity calculation using IHCM. The comparison from the IHCM calculation result and VISSIM software result can be seen in TABLE 2 and Fig. 2 below.

TABLE 2
COMPARISON BETWEEN IHCM AND VISSIM SOFTWARE RESULT IN CAPACITY CALCULATION

City	Capacity (pcu)	
	IHCM	VISSIM
Yogyakarta 1	2951.52	2784.78
Yogyakarta 2	2894.76	2823.87
Banda Aceh 1	3175.50	3394.63
Banda Aceh 2	3175.50	3373.33
Banjarmasin 1	3383.66	3415.08
Banjarmasin 2	3383.66	3679.03
Pekanbaru 1	3039.96	3439.28
Pekanbaru 2	3039.96	3253.97
Surabaya 1	3333.00	3647.04
Surabaya 2	3333.00	3574.10

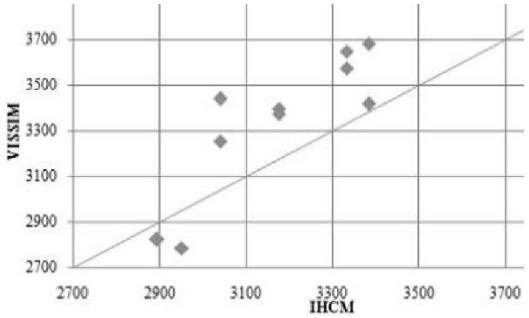

Fig. 2.The Relationship between IHCM and VISSIM in Basic Capacity Calculation

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From the TABLE 2 and Fig. 2 above, it can be concluded that the IHCM based capacities lower compared to the result from VISSIM software. So that, the constants of the IHCM needs to be calibrated. In this research, the trial and error to change the constants in IHCM were conducted. At the end of the trial, the basic capacity for the divided road increased from 1650 passenger car unit (pcu) to 1750 pcu. The result of the trial can be seen in Table 5 and Figure 3 below.

TABLE 3
COMPARISON BETWEEN CALIBRATED IHCM AND VISSIM RESULTS IN CAPACITY CALCULATION

City	Capacity (pcu)	
	IHCM	VISSIM
Yogyakarta 1	3130.40	2784.78
Yogyakarta 2	3070.20	2823.87
Banda Aceh 1	3367.98	3394.63
Banda Aceh 2	3367.98	3373.33
Banjarmasin 1	3588.73	3415.08
Banjarmasin 2	3588.73	3679.03
Pekanbaru 1	3224.20	3439.28
Pekanbaru 2	3224.20	3253.97
Surabaya 1	3535.00	3647.04
Surabaya 2	3535.00	3574.10

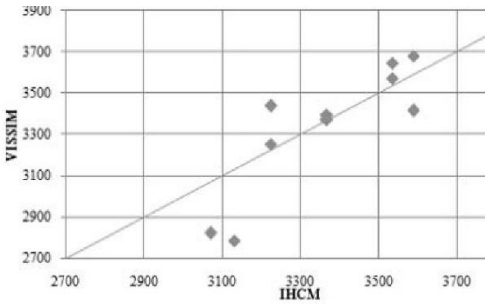

Fig. 3. Relationship between IHCM and VISSIM results in Capacity Calculation

TABLE 3 and Fig. 3 above show that by changing the basic capacity of the IHCM resulting better relation between IHCM and VISSIM software result.

The next analysis is comparing the resulted data from VISSIM software and IHCM in estimating the speed of car and motorcycle in different number of traffic volume. The speed of heavy vehicle has not been analyzed, because there is only a few heavy vehicles on the road. The increase of traffic volume will in line with increase of the degree of saturation. In IHCM we can predict the speed of car and motorcycle by calculating the free flow speed and then with the graphic relation between the degree of saturation and the free flow speed, we can predict the actual speed on a road section. These calculations result is then compared with the estimation of speed from VISSIM software that has been simulated before. The result of the comparison between IHCM calculation and data from VISSIM software is shown in Fig. 4 below.

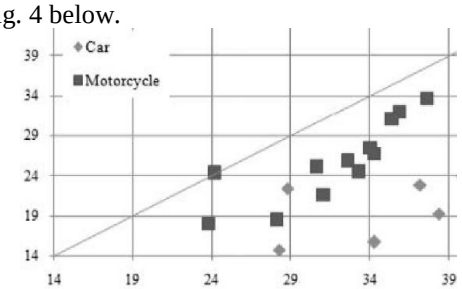

Fig. 4.Relationship between Speed Prediction at Yogyakarta from IHCM Calculation and VISSIM Results

As shown from Figure 4 above, speed prediction from IHCM calculation are mostly too high compared with the data result from VISSIM software. Furthermore, the speed prediction from IHCM calculation showed that motorcycle has lower speed than car, whereas the data from the VISSIM software in line with data from the field observation show that in urban area motorcycle has higher speed than car. These cases were happened in all five cities, so it is necessary to change the constants on IHCM formula to predict the actual speed on the field.

Once again, trial and error to change the constants on IHCM formula were conducted. At the end of the trial, IHCM give the best result when the change was made in decreasing basic free flow speed. Based on the survey analysis, the basic free flow speed for car in divided road was changed from 57 kph to 37 kph, while the basic free flow speed for motorcycle in divided road was changed from 47 kph to 40 kph. And the result from the last trial is shown at the Fig. 5 below.

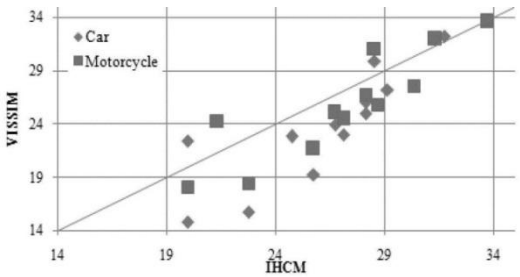

Fig. 5.Relationship between Speed Prediction at Yogyakarta from Calibrated IHCM and VISSIM Software Results

As shown in Figure 5 above, the trial by changing the basic free flow speed in urban area of the IHCM resulting better relation between IHCM and VISSIM software result in speed estimation. It can be proved by the relation between these two has been approaching the 45° reference line (blue line). Comparison between calibrated IHCM result and VISSIM software is shown in figures 6 and 7below.

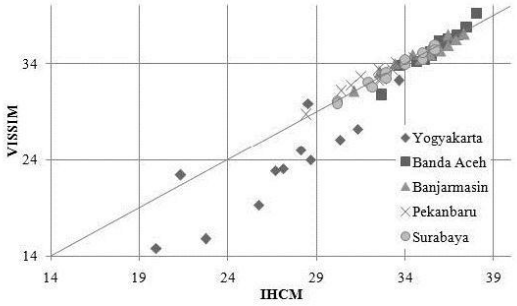

Fig. 6.Relationship between calibrated IHCM Result and VISSIM Software Results for Car Speed Estimation

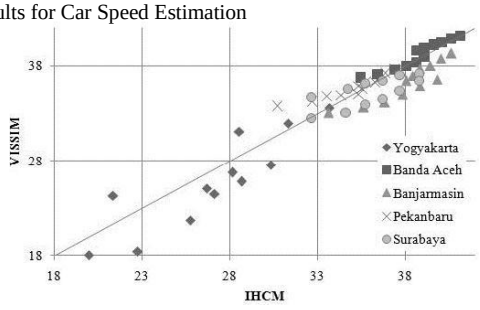

Fig. 7.Relationship between Calibrated IHCM and VISSIM Software Result for Motorcycle Speed Estimation

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As shown in Figure 6 and Figure 7, the graphics show that there is no significant difference between IHCM result after correction and VISSIM software result. It can be proved by the relation between these two has been approaching the reference line. On the other words, the IHCM result already resemble with the real condition, since the model in VISSIM software has been validated before.

III. Conclusion

1) According to the Indonesian Highway Capacity Manual, the speed of car is higher than the speed of motorcycle. But according to the real condition and simulation, the speed of car is lower than the speed of motorcycle
2) The capacity according to the IHCM is lower than the capacity according to the simulation.
3) It is, therefore, recommended to change:
   a) the basic free flow speed for urban road for car: from 57 kph (IHCM 1997) to 37 kph.
   b) the basic free flow speed for urban road for motorcycle: from 47 kph (IHCM 1997) to 40 kph.
   c) the basic capacity for urban road from 1650 pcu/hour/lane (IHCM 1997) to 1750 pcu/hour/lane

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