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QUEUES AND DELAYS AT SIGNALIZED INTERSECTIONS, INDONESIAN EXPERIENCE

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ABSTRACT
To predict queues and delays at signalized intersections in Indonesia, the 1997 Indonesian Highway Capacity Manual (IHCM) has been widely used. However, the queue length at signalized intersection predicted by IHCM was usually over value. The aim of this research is, therefore, to improve the IHCM formula to calculate the queue length at signalized intersection.

Traffic surveys have been carried out at various signalized intersections in some Indonesian cities. The measured queues have been compared to the IHCM predicted queues. IHCM formula has been calibrated by trial and error method in such a way that there was no significant different between the predicted and the measured queues.

A new improved saturation flow formula has been recommended to be used for calculating the queue length and delay. It has also been recommended to reduce the passenger car equivalent for motorcycle.

Keywords: traffic queue length, signalized intersection, saturation flow

1. INTRODUCTION

One of the traffic management strategies, which has very important impact to reduce traffic accident and to regulate the traffic more orderly is traffic signal controlling. In Indonesia, 1997 Indonesian Highway Capacity Manual (HCM) has been widely used to calculate the signal setting. However, according to the experiences, the traffic signal calculation by using 1997 IHCM, especially to predict queues and delays, were usually over values. Therefore, 1997 IHCM method should be corrected.

According to the researchs, which have been carried out in Indonesia, the IHCM saturation flow formula should be corrected. The saturation flow formula from IHCM is as follows:

$$S = S_o \text{ x } F_{cs} \text{ x } F_{sf} \text{ x } F_g \text{ x } F_{rt} \text{ x } F_{lt} \text{ x } F_p$$

where
S_o = base saturation flow (pcu/hour)
Fcs = city size factor (city size may be related to driver behaviour)
Fsf = side friction factor
Fg = gradient factor
Frt = right turning factor
Flt = left turning factor
Fp = parking factor

The recommended base saturation flow is:

$S_o = 600 \times W_e$ passenger car unit/hour (pcu/h)

where

W_e = entry approach width (meter)

According to the researchers, the 1997 IHCM should be calibrated by increasing the base saturation flow. The calibrations were as tabulated below.

Table 1: The Correction of Base Saturation Flow according to the Researchers

No.	According to	Base saturation flow (pcu/h)
1.	1997 Indonesian Highway Capacity Manual	600 x W_e
2.	Widodo (1997)	775 x W_e
3.	Munawar and Mulyadi (2003)	909 to 984 x W_e
4.	Sari (2005)	709 to 840 x W_e

The corections vary from 600 to 984 x W_e. It seems that there is no constant parameter to be used for base saturation flow. The aim of this research is, therefore, to find a new formula, so that there is no significant different between the predicted and the actual queue length.

2. RESEARCH METHODOLOGY AND ANALYSIS

Predicted queues were usually quite different from the existing one in the medium cities, where the number of motorcycles is very high and the the road width does not follow the normal Indonesian standard (3.50 m per lane) and the degree of saturation is very high. Two cities, which have the above criterias, were selected, i.e. Yogyakarta and Banjarmasin. The surveys were carried out at two intersections in Banjarmasin and two intersections in Yogyakarta, which have various entry width and a large number of motorcycles.

Surveys included traffic counting, traffic queue length and signal setting. Surveys were carried out during the morning, afternoon and evening peak hours. The queues and delays have been calculated by using 1997 IHCM formula. The 1997 IHCM formula to predict queues and delays is nearly the same as Akcelik formula (Akcelik, 1981) , i.e.

For degree of saturation (ds) > 0.5 (see also Figure 1)

$$NQ_1 = 0.25 \times C \times \left[(ds-1) - \sqrt{(ds-1)^2 - \frac{8 \times (ds-0.5)}{C}} \right] \quad (1)$$

For ds ≤ 0.5 $NQ_1 = 0$ (2)

where

NQ_1 = the number of pcu that remain from the previous green phase

ds = degree of saturation

GR = green ratio

C = capacity (pcu/hour) = S x GR (3)

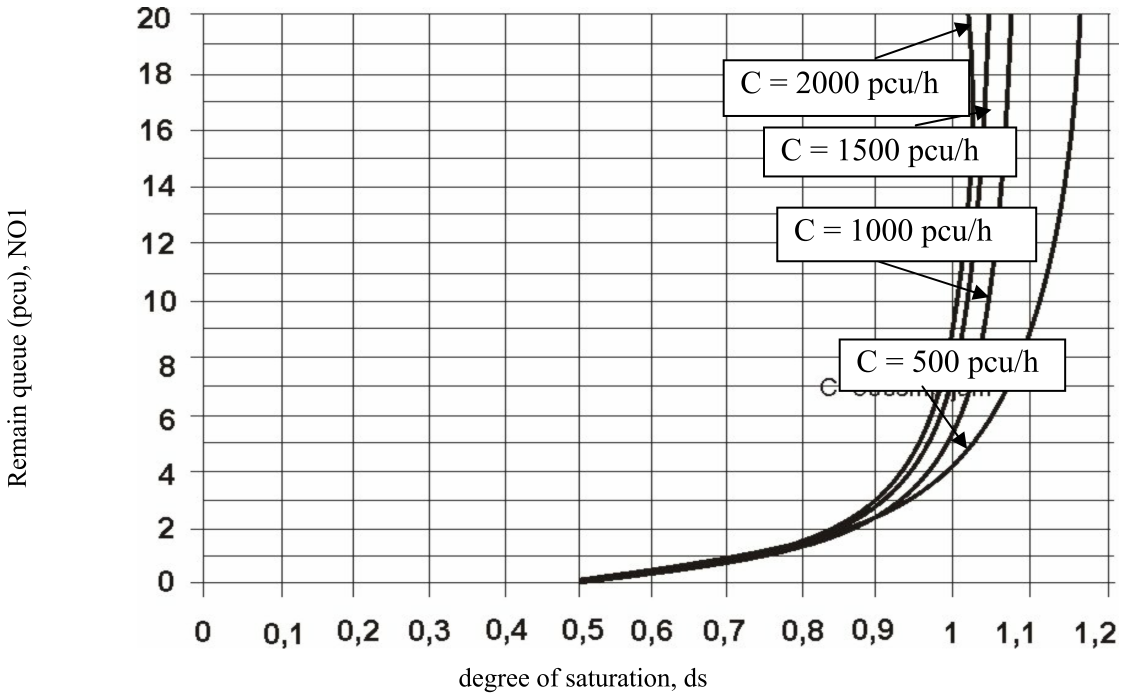

Figure 1: Number of Queueing Vehicles that remain from the previous green phase (NQ_1)

It is then calculated the number of pcu that arrive during the red phase (NQ_2), by using the following formula

$$NQ_2 = c \times \frac{1-GR}{1-GR \times ds} \times \frac{Q}{3600} \qquad (4)$$

where:

- NQ_2 = number of pcu that arrive during the red phase
- Q = traffic volume (pcu/sec)
- c = cycle time (sec)
- ds = degree of saturation
- GR = green ratio (sec)

The total queue length is then calculated as shown below:

$$NQ = NQ_1 + NQ_2 \qquad (5)$$

NQmax can be calculated by using Figure 2 below with regard to the desired probability for overloading P_{OL}. For planning and design $P_{OL} \leq 5$ % is recommended, for operation a $P_{OL} = 5 – 10$ % might be acceptable.

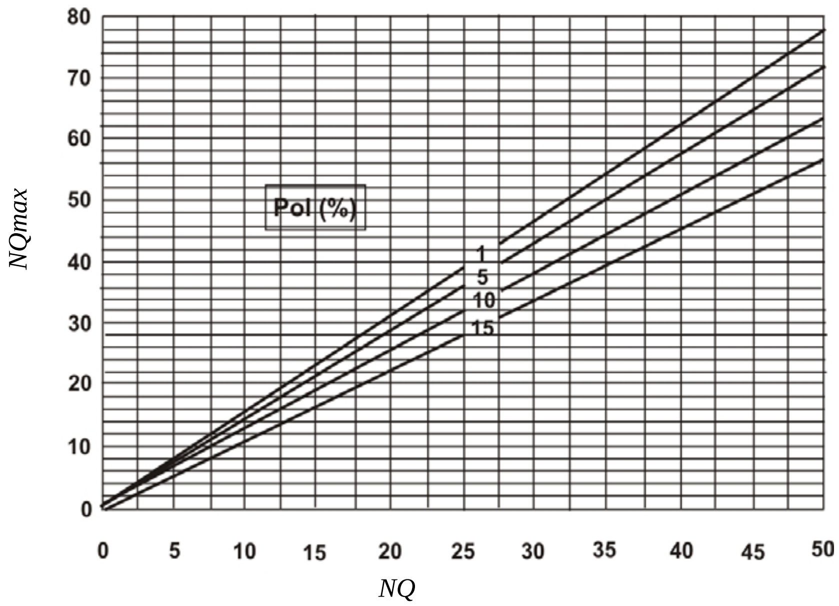

Figure 2: Calculation of NQ_{max}

im The queue length (*QL*) is calculated by multiplying *NQ or* NQ_{MAX} with the average area occupied per pcu (20 m²) and dividing with the entry width (W_{ENTRY}),

$$QL = \frac{NQ \times 20}{W_{ENTRY}} \text{ (meter)} \quad (6)$$

Average traffic delay for each approach can be calculated as below.

$$DT = c \times A + \frac{NQ_1 \times 3600}{C} \quad (7)$$

where:

DT = average traffic delay (sec/pcu)

c = cycle time (sec)

A is calculated by using equation below.

$$A = \frac{0{,}5 \times (1 - GR)^2}{(1 - GR \times ds)} \quad (8)$$

where:

GR = green ratio (g/c)

ds = degree of saturation

NQ_1 = the number of pcu that remain from the previous green phase

C = capacity (pcu/hour)

A computer program to calculate the queue length and delay by 1997 IHCM formula has been employed (Munawar, 2005). The predicted queue lengths have been compared to the actual one. The comparison is shown in Figure 3 below.

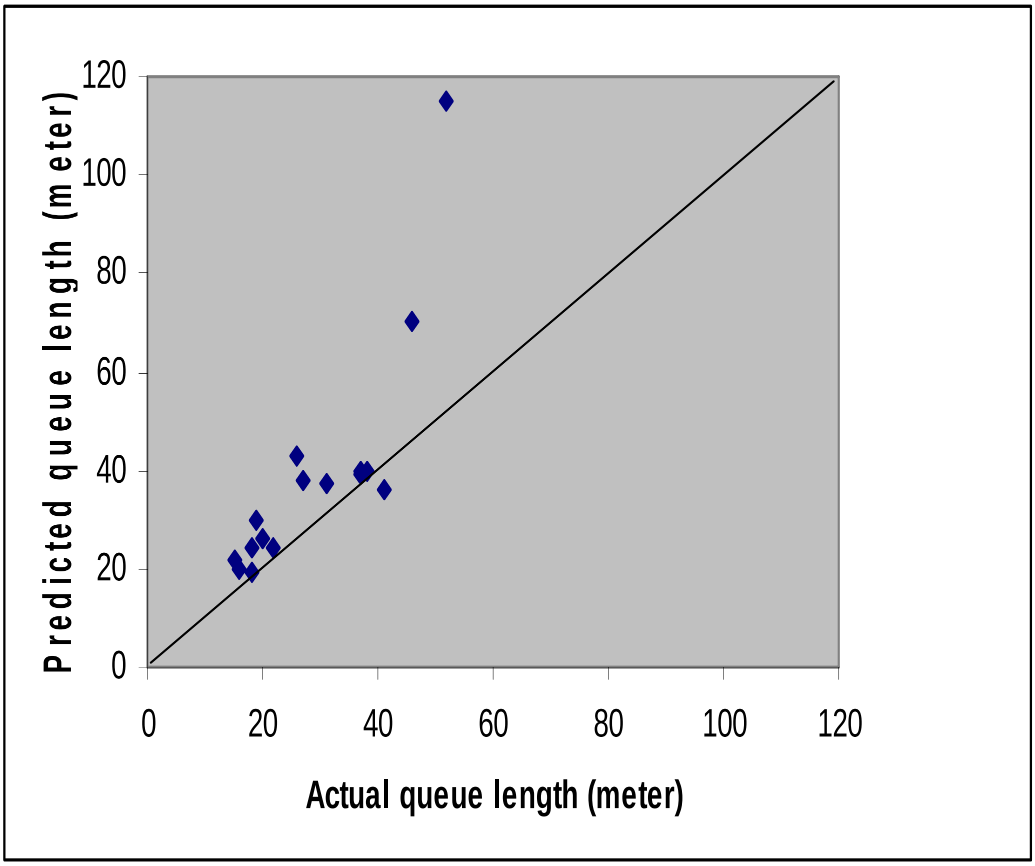

Figure 3: A comparison between actual and predicted queue length

It seems that the predicted queue lengths are much higher than the actual queue lengths. According to the analysis, there are some important points to be considered:

- when the lane width is less than the normal standard width, the different between the predicted and the actual queues will be higher
- the more the number of motorcycles, the more the different between predicted and actual queues

It is, therefore, concluded that the passenger car equivalent for motorcycle should be reduced and the correlation between the entry width and the base saturation flow should be corrected.

By trial and error, a new formula has been developed and a pcu correction for motorcycle has been introduced, i.e.

- Base saturation flow:

  $So = 850 \times W_e^{.95}$ (pcu/hour) (9)

  where:

  W_e = entry approach width (meter)
- Reducing passenger car equivalent. According to 1997 IHCM, pce for motorcycle = 0.20. It is recommended to reduce to 0.15.

A comparison between the predicted queue by using the revised 1997 IHCM and the actual one is shown in figure 4.

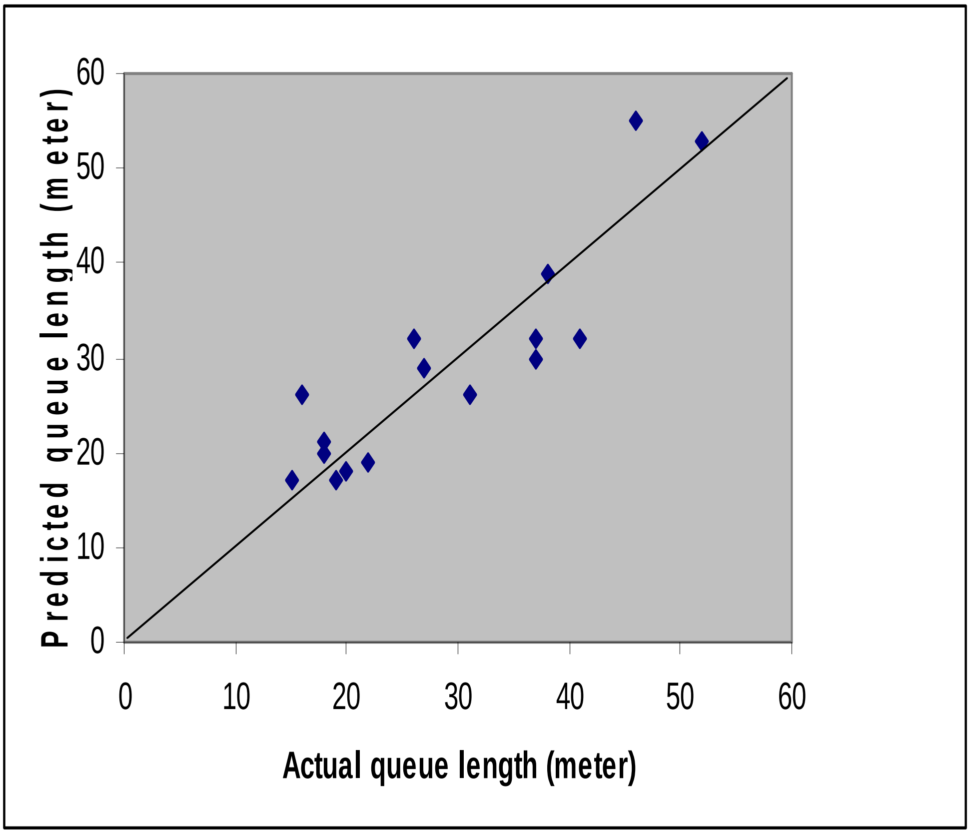

Figure 4: A comparison between actual and revised predicted queue length

By using χ^2 statistical method, it is shown that there is no significant different at 5 % significant level.

3. CONCLUSIONS

- The queue length predicted by 1997 IHCM is higher than the actual one, specially in medium cities, because the entry width in medium cities is usually less than the normal standard, but the capacity is still high.
- The motorcycles need usually less space than the space predicted by 1997 IHCM, when the number of motorcycles is very high. In this case, it is, therefore, recommended to reduce the passenger car equivalent for motorcycle from 0.20 to 0.15.

4. RECOMMENDATION

It is recommended to carry out further research with more surveys to find the more sophisticated formulas for various cities.

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