

# Indonesian Highway Capacity Guidance (IHCG) correction factor for signalized intersection

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**Abstract.** Indonesian Highway Capacity Guidance or IHCG is a manual developed in 2014 to accommodate traffic characteristics which are no longer appropriate to the preceding manual (Indonesian Highway Capacity Manual or IHCM, established in 1997). From a preliminary study, there are still some differences between theoretical analysis (using IHCG) with the actual conditions. This study aims to obtain IHCG correction factor based on a comparison between predicted performance parameter of a signalized intersection (using IHCG) and measured data, in order to optimize IHCG development. Intersection performance parameters analyzed are the number of queue vehicles ( $N_{Q1}$  and  $N_{Q2}$ ), and queue length (QL). The model of the correction factor was determined with regression analysis, using DS value as the independent variable, and  $N_{Q1}$ ,  $N_{Q2}$ , or QL differences value as the dependent variables. Implementation of the proposed correction factor of queue length on nearby intersections resulted that the corrected guidance could produce more accurate queue length against measured one by 12% deviation.

## 1 Introduction

Indonesian Highway Capacity Manual or IHCM [1] is a manual used to analyze the capacity and performance of roads in Indonesia since 1997. Along with the changes in traffic characteristics, especially due to the rapid growth of motorcycle population, this reference is no longer appropriate to the actual conditions, as stated in some references [2] and in IHCG [3]. To adapt IHCM to current conditions, Indonesian Highway Capacity Guidance or IHCG [3] is published in 2014.

A preliminary survey was carried out on Gajah Intersection [4], a four-leg signalized intersection in East Semarang. This survey was conducted to analyze how traffic conditions at intersections are viewed from the point of view of IHCM and IHCG. It showed that there were differences between theoretical analysis (predicted using IHCM and IHCG) with the real conditions. However, using IHCG, the results were closer to the actual conditions compared to the results of IHCM, but some significant differences were still found. This indicates that IHCG is quite better than IHCM, but some reference value still requires adjustment to the field conditions. Therefore, this research was conducted to obtain IHCG correction factor based on a comparison between IHCG results with measured data, in order to optimize IHCG development.

## 2 Method

The case study was at Gajah Intersection in Semarang City. The observation was conducted at peak time with normal settings (without manual interference, neither Area Traffic Control System/ATCS nor police assistance). IHCG parameters analyzed were the number of queue vehicles ( $N_{Q1}$  and  $N_{Q2}$ ), and queue length (QL), as follows.

$$N_{Q1} = 0.25 \times C \times \left\{ (DS - 1)^2 + \sqrt{(DS - 1)^2 + \frac{8}{c}(DS - 0.5)} \right\}, \text{ for } DS > 0.5$$

And  $N_{Q1} = 0$  for  $DS \leq 0.5$  (1)

$$N_{Q2} = c \times \frac{1-GR}{1-GR \times DS} \times \frac{Q}{3600} \tag{2}$$

$$QL = (N_{Q1} + N_{Q2}) \times \frac{20}{W} \tag{3}$$

$N_{Q1}$  is the number of passenger car unit (pcu) that remain from the previous green phase;  $N_{Q2}$  is the number of queuing pcu that arrive during the red phase; QL is queue length (in m); C is capacity of signalized intersection; DS is degree of saturation or the ratio of flow (Q) and capacity (C); GR is the green ratio (green time per total cycle time); and W is the entry width.

$N_{Q1}$  and  $N_{Q2}$ , and QL from IHCG analysis then compared with the  $N_{Q1}$ ,  $N_{Q2}$ , and QL from field observation, using Paired Sample T-Test method for normally-distributed data or Wilcoxon Test for nonnormally-distributed data [5]. For parameters with significant differences, the correction factor was modeled using regression method.

In IHCG, Degree of Saturation (DS) is a parameter of signalized intersection that mostly used to conclude the field condition. DS also has influences on other parameters, including  $N_{Q1}$ ,  $N_{Q2}$ , and QL. Therefore, the model of the correction factor was determined using regression analysis, using DS value as the independent variable, and  $N_{Q1}$ ,  $N_{Q2}$ , or QL value as the dependent variables.

The proposed model will be implemented to see whether the model is suitable for other intersections. Among three parameters, this paper was focused on the implementation of the proposed queue length correction factor.

## 3 Data

### 3.1 Geometric

Gajah Intersection lies in Eastern Semarang, in a commercial area with a low class of side friction. Geometric condition and dimension are as shown in Table 1.

**Table 1.** Geometric condition of Gajah Intersection

Approach		Width (m)			Median (m)	Parking distance
		Approach	Entry	LTOR		
East	Brigjen. Sudiarto Rd. (to Purwodadi)	12.5	10.0	2.5	0.5	n.a
South	Lamper Tengah St.	4.0	4.0	2.0	n.a	n.a
West	Brigjen. Sudiarto Rd. (to downtown)	10.5	6.5	4.0	0.5	n.a
North	Gajah Raya St.	7.0	6.0	1.0	n.a	n.a

Note : LTOR = Left Turn on Red; n.a = not available

### 3.2 Phase setting and cycle time

Gajah Intersection is arranged with four phases of movement, as follows:

- a. First phase : all movement from east approach and straight movement from west approach
- b. Second phase : right-turning movement from east approach and all movement from west approach
- c. Third phase : all movement from north approach
- d. Fourth phase : all movement from south approach

Thus, left-turning movements from North, East, and West are LTOR (Left Turn on Red). The pattern in a single cycle time is green – yellow – red – yellow, in 150 seconds, as shown in Table 2.

**Table 2.** Phase setting and cycle time of Gajah Intersection (in seconds)

Phase	Green time	Amber time	All red time	Red time	Cycle time
1	60	2	2	82	150
2	20	2	2	122	150
3	25	2	2	117	150
4	25	2	2	117	150

### 3.3 Flow rate

Traffic data used in the study were the flow-rate data ( $Q$ ), the number of vehicles retained by the previous green phase ( $N_{Q1}$ ) and the number of vehicles approaching and stopped on the red phase ( $N_{Q2}$ ). Traffic counting was carried on using the video camera on certain location so that all data needed could be measured.

## 4 Result

### 4.1 Intersection performance comparison between analytical (IHCG) and measured data

Intersection performance parameters reviewed were the number of queue vehicles ( $N_{Q1}$  and  $N_{Q2}$ ), and queue length ( $QL$ ). Analytical data were predicted using IHCG analysis. Meanwhile, measured data were data from the field which are managed so that they have the same unit as IHCG parameters. The comparison between those data is shown in Table 3.

It was found that between the results of predicted (IHCG) and measured data, the variation of  $N_{Q1}$  differed up to 300 pcu, the variation of  $N_{Q2}$  was up to 9 pcu, and the variation of PA was up to 1900 meter.

The statistical difference test or comparative analysis was performed with the t-Two Paired Sample t-Test for normally distributed data and with Wilcoxon test for non-distributed data. From the difference test on the  $N_{Q1}$  parameter, 25% of data were significantly diverse. On parameter  $N_{Q2}$ , 41% were significantly different. On parameter  $QL$ , 50% were significantly dissimilar.

It can be seen that there were still some differences between IHCG calculation result and field observation for all parameters of  $N_{Q1}$ ,  $N_{Q2}$ , and  $QL$ . These differences can be minimized by using correction factor ( $FC$ ), which includes the correction factor of queue vehicle number ( $FC_{N_{Q1}}$  and  $FC_{N_{Q2}}$ ), and the correction factor of queue length ( $FC_{QL}$ ).

**Table 3.** Intersection performance comparison between analytical (IHCG) and empirical data [4]

No. of set data	Flow	DS	N <sub>Q1</sub>		N <sub>Q2</sub>		QL	
			Predicted	Measured	Predicted	Measured	Predicted	Measured
	pcu/h		pcu	pcu	pcu	pcu	m	m
1	428	0.68	0.6	0.0	16.8	16.1	80.8	67.5
2	492	0.79	1.4	0.0	19.7	19.7	98.2	47.0
3	342	0.55	0.1	0.0	13.1	13.1	61.5	25.0
4	541	0.86	2.4	0.0	21.9	14.5	113.8	41.0
5	421	0.67	0.5	0.0	16.4	9.3	78.9	33.5
6	729	0.46	0.0	0.0	22.3	24.3	89.3	92.5
7	853	0.54	0.1	0.0	27.1	29.9	108.8	80.0
8	885	0.55	0.1	0.0	28.4	30.3	114.2	75.0
9	118	0.52	0.0	0.0	4.6	6.9	43.1	25.0
10	60	0.27	0.0	0.0	2.3	2.8	21.1	12.5
11	68	0.30	0.0	0.0	2.6	3.1	24.0	17.5
12	71	0.31	0.0	0.0	2.7	4.4	25.1	17.5
13	1094	0.64	0.4	0.0	36.8	34.3	138.7	90.0
14	1331	0.78	1.2	0.0	48.3	29.8	184.9	102.5
15	1281	0.75	1.0	0.0	45.7	27.4	174.4	110.0
16	1166	0.68	0.6	0.0	40.1	22.6	151.8	65.0
17	110	0.48	0.0	0.0	4.2	5.4	39.6	67.5
18	156	0.69	0.6	0.0	6.2	6.7	63.3	47.0
19	125	0.55	0.1	0.0	4.9	5.9	46.6	25.0
20	129	0.56	0.2	0.0	5.0	4.9	48.3	41.0
21	464	0.74	0.9	0.0	18.4	16.4	89.8	45.0
22	606	0.96	7.7	1.8	25.1	17.0	152.8	68.0
23	1429	0.89	3.6	2.7	55.6	51.6	237.0	147.5
24	183	0.80	1.4	0.0	7.4	3.1	82.2	12.5
25	1174	0.69	0.6	0.0	40.5	20.1	153.3	70.0
26	171	0.75	1.0	0.0	6.9	4.0	73.4	45.0

Note: *pcu* (passenger car unit) is a metric used in Transportation Engineering. A *pcu* is a measure of the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single standard passenger car.

#### 4.2 Model of IHCG correction factors

The IHCG correction factors, which includes the queue vehicle number correction factor ( $FC_{NQ1}$  and  $FC_{NQ2}$ ) and the queue length correction factor ( $FC_{QL}$ ), were developed by comparing the predicted data ( $N_{Q1}$ ,  $N_{Q2}$ , and  $QL$ ) to the measured data. Thus, the differences between the predicted data and the measured data on Gajah Intersection were analyzed using regression approach. The preliminary result of the correction factor modeling is shown in Table 4.

The application of this correction factor was as follows: corrected IHCG parameter value = IHCG parameter value x (1 - FC). Thus, corrected  $N_{Q1} = N_{Q1} \times (1 - FC_{NQ1})$ . Using this equation, the corrected  $N_{Q1}$  value from IHCG prediction on Gajah Intersection was closer to the measured  $N_{Q1}$  up to 2% in average. Corrected  $N_{Q2} = N_{Q2} \times (1 - FC_{NQ2})$ . The corrected

$N_{Q2}$  value from IHCG prediction was less differ to the measured  $N_{Q2}$  up to 30% on average. Finally, corrected  $QL = QL \times (1 - FC_{QL})$ , that brought the average difference between analytical and measured queue length only about 20%.

**Table 4.** Preliminary model of correction factor [4]

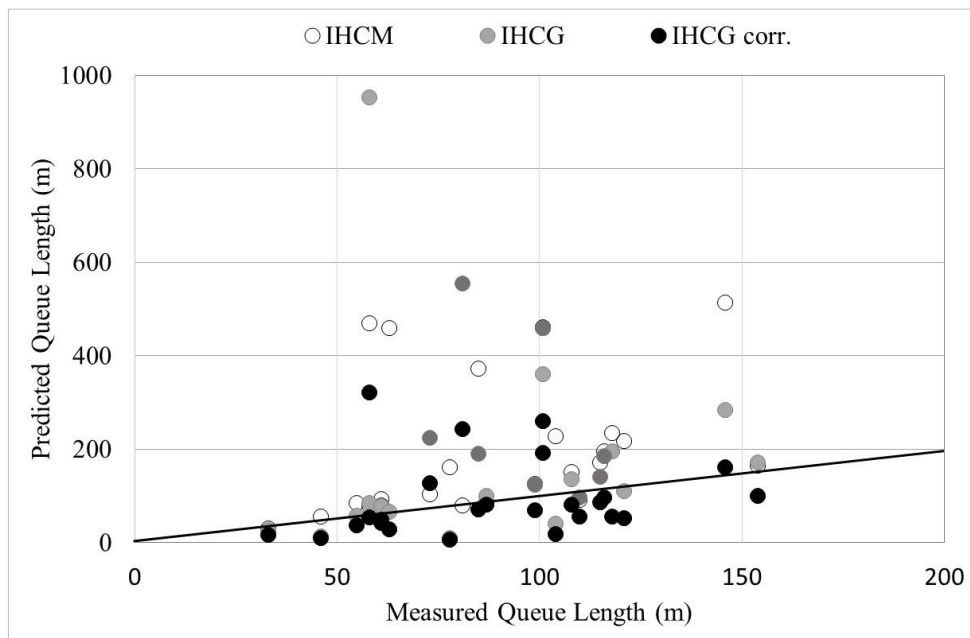
Variables	Model	Limitation
<b><math>N_{Q1} - DS</math></b>	$FC_{NQ1} = 0$	$DS < 0.85$
	$FC_{NQ1} = -0.003 DS^4 + 0.069 DS^3 - 0.515 DS^2 + 1.629 DS - 0.928$	$0.85 \leq DS < 1.00$
	$FC_{NQ1} = 0.024 DS^3 - 0.213 DS^2 + 0.630 DS + 0.331$	$DS \geq 1.00$
<b><math>N_{Q2} - DS</math></b>	$FC_{NQ2} = 2784 DS^4 - 4576.3 DS^3 + 2759.1 DS^2 - 721.5 DS + 68.712$	$DS < 0.55$
	$FC_{NQ2} = -407.03 DS^3 + 797.92 DS^2 - 515.28 DS + 109.84$	$0.55 \leq DS < 0.80$
	$FC_{NQ2} = 897.76 DS^3 - 2333.2 DS^2 + 2013 DS - 576.25$	$0.80 \leq DS < 1.00$
	$FC_{NQ2} = 0.1026 DS^3 - 0.7564 DS^2 + 1.8792 DS - 1.2186$	$DS \geq 1.00$
<b><math>QL - DS</math></b>	$FC_{QL} = 578.53 DS^5 - 1417.5 DS^4 + 1321.2 DS^3 - 578.59 DS^2 + 117.61 DS - 8.4937$	$DS < 0.85$
	$FC_{QL} = 1.6347 DS^4 - 11.05 DS^3 + 26.99 DS^2 - 27.677 DS + 10.541$	$DS \geq 0.85$

### 4.3 Implementation on other intersections

The implementation on other intersections nearby (Bangkong, Milo, and Sompok Intersection) was focused on the queue length correction factor. The result was presented in Figure 1. This figure compares the measured and predicted queue lengths using IHCM, IHCG, and IHCG corrected methods.

From Figure 1, it can be seen that the implementation of IHCG correction factor on these intersection gives predicted queue length that was more similar to the measured queue length, compare to IHCM and IHCG. In Bangkong Intersection, the average deviation of the predicted queue length was -0.29 (using IHCG corrected), 0.28 (using IHCG) and 0.70 (using IHCM). In Milo Intersection, the average deviations were 0.23, 1.40, and 0.99 for predicted queue length using IHCG corrected, IHCG and IHCM, respectively. In Sompok Intersection, the average deviation of predicted queue length was -0.29, 0.31, and 2.04 for IHCG corrected, IHCG and IHCM successively. The lower value of average deviation means the closer value of predicted data to measured data. The minus sign (-) means that the prediction is underestimated, vice versa. On average, the proposed queue length correction factor of IHCG could produce more accurate queue length against measured one by 12% deviation.

The result of these models are quite good for Gajah Intersection and the three nearby intersections (Bangkong, Milo, and Sompok Intersection), but further research by involving other types of intersections is still needed to know whether this model can be applied on other typical intersection and to find out the limitation of intersection category in order to obtain a more general model for signalized intersections.



**Figure 1.** Comparison of predicted and measured queue lengths at several intersections

## 5 Conclusion

This paper presented a proposed correction to existing Indonesian Highway Capacity Guidance (IHCG) in order to improve the accurateness of the guidance in predicting queue length in intersections. It resulted that the corrected guidance could produce more accurate queue length against measured one by 12% deviation.

## References

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