Calibration and Validation Indonesian Highway Capacity Manual 1997 Model

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Abstract. Population growth and uncontrolled use of vehicles result in changes in traffic behaviours. This has an impact on the validity of the IHCM 1997 model results when replicating traffic in the real conditions. This study aims to carry out calibration and validation IHCM 1997 signalised intersection model. Case studies are conducted at eleven signalized intersection locations in the Surakarta city. The results of study show that the IHCM 1997 method default values are not relevant to the current conditions. The traffic parameters that need to be changed in the IHCM 1997 model are passenger car equivalent (PCE) and base saturation flow ($S_0$).

1. Introduction

Junction is defined as a location where two or more roads intersect, allowing vehicular traffic to change from one road to another, which causes delay, accidents, and emissions tend to be concentrated. Therefore, traffic sign and signal control needed to manage the vehicle behaviour at the intersection. Traffic signal control at road intersections allow vehicle movements to be controlled by allocating time intervals, during which separate traffic demands for each arm of the intersection can make use of the available road-space. The use of traffic signal control to manage traffic movement can bring about major reductions in congestion, improve road safety and enable specific strategies, which regulate the use of the road network, to be introduced. Signal timing optimization affects the signalized intersection performance, which determines degree of saturation flow, vehicle queue length and delay at intersection.

The signalized intersection performance could be know by doing traffic modelling. The standard traffic modelling in Indonesia to calculate signalized intersection performance is the Indonesian Highway Capacity Manual (IHCM) 1997 method [1]. The IHCM 1997 method uses the empirical formulas in analyzing the signalized intersection performance. It require the intersection geometry data, traffic flow, and accurate signal timing to get good analysis results. Commonly, two traffic parameters are used to calibrate the signalized intersection IHCM 1997 model namely passenger car equivalent (PCE) and base saturation flow ($S_0$). The PCE and $S_0$ values for Indonesian traffic condition has been regulated in the IHCM 1997 method. The IHCM 1997 method is the result of research conducted on the road conditions in year 1997, so that the provision does not necessarily meet the characteristics of traffic in the current year. The population and number of vehicles growth each year causes a difference in traffic conditions every year.

Several studies have been carried out to analyze the PCE and $S_0$ values in the current traffic conditions. [2] conducted a study to find out the value of $S_0$ that produced an output IHCM 1997 signalised intersection model that is relatively the same as the value in the field. The study result...
recommends to use $S_0$ value of 775.00 to get the IHCM 1997 model results close to the field data. [3]
conducted a study of $S_0$ and queue length analysis at signalized intersections. The study is conducted
based on the IHCM 1997 method and aims to correct the constants of $S_0$ in queue length calculations.
Multiplier constants for the calculation of default of $S_0$ are sought using trial and error methods to get
the queue length close to the conditions in the field. The analysis result recommends the PCE for
motorcycle is 0.15, which is originally 0.2 in the IHCM 1997 method. [4] conducted a study of
determining the value of pce by using headway analysis. The headway analysis obtains the value of
PCE for motorcycle is 0.41 and PCE for heavy vehicle is 1.29. The MAPE value of queue length by
PCE using headway analysis is smaller than the MAPE value by PCE using IHCM 1997, which is
compared 5.0% to 5.76%. While the MAPE value of normalized time by PCE using headway analysis
is smaller too than the MAPE value by PCE based on IHCM 1997, which is 3.65% compared to 4.20%.
So the using of PCE based on headway is prefer than PCE based on IHCM 1997. [5] carried out a study
of determining the value of $S_0$ at signalized intersections. The results show that the values of $S_0/m$ at
the peak hours of the Jimbaran and Mojosongo Intersections is 782.37 and 750.54, consecutively,
which is exceed the IHCM 1997 standard which is 600.00. While for the Gendengan Intersection the
value of $S_0/m$ is 515.27, which is smaller than the IHCM 1997 standard. During off peak hours, the
values of $S_0/m$ the Jimbaran Intersection is 712.83, which exceed the IHCM 1997 standard, while for
the Gendengan and Mojosongo Intersections is and 434.93 and 582.34, consecutively, which is smaller
than the IHCM 1997.

The results of studies on the value of PCE and $S_0$ indicate that, in general, the default values of
the PCE and $S_0$ of the IHCM 1997 is not relevant to the current traffic conditions. For this reasons, it is
necessary to study the calibration and validation process of the signalized intersection performance
using the IHCM 1997 method. The parameters used in the calibration process are PCE and $S_0$, while
for the validation process that is the vehicle queue length (in meters). Case studies are conducted at
eleven signalized intersection locations in the Surakarta city.

2. Study methodology
2.1. Site Description and data Collection
The case study is conducted on several roads that have different traffic characteristics. The Brigjend.
Slamet Riyadi road is the main road in the centre of Surakarta city, where heavy vehicles are not
allowed to cross this road. Along this road there are several signalized intersections including
Purwosari, Gendengan, Sriwedari, Ngapeman, Pasar Pon and Nonongan Intersections. The Monginsidi
road is a city road, where heavy vehicle namely bus pass on this road relatively high. The signalized
intersections on this road includes the Banjarsari and Balapan Intersections. Meanwhile, the Dr.
Radjiman road is a city road where heavy vehicle namely truck and bus pass on this road relatively
high. Signalized intersections on this road includes the Bhayangkara and Baron Intersections. The last
is the Sultan Syahrir road where buses and trucks rarely pass this road. The intersections studied is
Widuran intersection. The location all of intersections in the map can be seen in Figure 1.

2.2. Stage of Study
The stages of study are as follows:

a) Literature study, formulate problems, set goals and prepare study methods.

b) Primary and secondary data collection. This data is used to calculate the signalized intersection
performance. Required data includes traffic volume, composition and turning proportions,
vehicle speed, geometry, signal timing, and traffic performance measure, population, land use
type, and transportation system in the Surakarta city.
Primary data namely traffic volume and vehicle queue length data are collected at each intersection during morning (AM) and afternoon peak (PM) hours. Secondary data related to traffic signal timings is obtained from the Department of Transportation Surakarta.

**Figure 1.** Map of intersection locations

Data analysis and signalized intersection performance calculation. The results of data analysis are used to calculate signalized intersection performance using the IHCM 1997 method. The calculation of signalized intersection performance is carried out into three scenarios, namely:
- Scenario 1 is the Base model (BM), where the model uses default values of PCE and $S_0$.
- Scenario 2 is the Calibration 1 model (C1M), where the model uses the value of $S_0$ according to study result [2].
- Scenario 3 is the Calibration 2 model (C2M), where the model uses the value of PCE for the motorcycle and $S_0$ according to research result [3].

The differences of PCE and $S_0$ values used in each scenario can be seen in Table 1.

| Scenario Model          | PCE                      | $S_0$                      |
|-------------------------|--------------------------|----------------------------|
| Base model              | PCE of motorcycle = 0.2  | $S_0$ = approach width x 600|
| Calibration 1 model     | PCE of motorcycle = 0.2  | $S_0$ = approach width x 775|
| Calibration 2 model     | PCE of motorcycle = 0.15 | $S_0$ = approach width x 775|

Comparison of signalized intersection performance results of the IHCM 1997 model and field data (FD). Vehicle queue length results of the IHCM 1997 model are compared to the field data for all scenarios. Then the vehicle queue length of models is tested with a t-test to determine the significance of the difference between model results and field data.

Conclusion. Drawing conclusions from the results of study conducted.
3. Analysis, Results and Discussion

3.1. Traffic Modelling

Standard traffic modelling is required to measure signalized intersection performance. Signalized intersection geometric under studies are modelled using the IHCM 1997 method. Input data for the IHCM 1997 model include traffic volume, saturation flow along with its adjustment factors and signal timing parameters such as green splits and cycle time. All signalized intersection works under fixed time signal control. The signalized intersection measure of performance that used as a comparison for different scenarios and field data is vehicle queue length. In order to get the valid IHCM 1997 model, therefore the model need to be calibrated its parameters and validated by comparing the model result with the field data.

3.2. Traffic Modelling Results and Discussions

The signalized intersection performance under IHCM 1997 model is compared to the field condition in terms of traffic performance measure i.e. degree of saturation and an average vehicle queue length. An IHCM 1997 model run is made for approximately one-hour periods to produce the output traffic performance measures. Comparison of degree of saturation and an average vehicle queue length at intersection for all IHCM 1997 models during morning and afternoon peak hours can be seen in Tables 2 and 3, consecutively. Traffic modeling results show that IHCM 1997 base model produces degree of saturation flow values greater than 0.8 more than the Calibration 1 and 2 models. The absolute percentage difference value between vehicle queue length of the base model and the field data shows a relatively large. The models that produce degree saturation flow greater than 0.8 tend to have large percentage differences in vehicle queue length between model results and the field data, see Figure 2.

![Figure 2](image-url)  
Figure 2. Absolute percentage difference value between vehicle queue length of the base model and field data
This phenomenon shows that the IHCM 1997 model with a default value produces signalized intersection performance that is not relevant to the current traffic conditions, especially in traffic conditions that are close to unstable conditions (degree saturation flow value greater than 0.8).

Table 2. Comparison of IHCM 1997 model results and the field data (morning peak hour)

| No. | Intersection | Approach | Degree of Saturation Flows | Vehicle Queue Length (meter) | % |
|-----|--------------|----------|---------------------------|----------------------------|---|
|     |              |          | BM | C1M | C2M | BM | C1M | C2M | FD | BM-FD |
| 1a  | Purwosari    | North    | 0.8 | 0.6 | 0.5 | 94 | 79 | 67 | 32 | 194% |
| 1b  |             | West     | 1.1 | 0.8 | 0.7 | 333| 121| 102| 76 | 338% |
| 2a  | Gendengan   | South    | 1.2 | 0.9 | 0.8 | 551| 157| 121| 100| 451% |
| 2c  | Sriwedari    | North    | 0.9 | 0.7 | 0.5 | 133| 104| 77 | 70 | 90%  |
| 2i  |             |          |     |     |     |    |    |    |    |      |
| 3b  |             | South    | 0.4 | 0.3 | 0.3 | 38 | 37 | 33 | 41 | 7%   |
| 3i  |             |          |     |     |     |    |    |    |    |      |
| 4b  | Ngapeman     | North    | 1.0 | 0.8 | 0.8 | 201| 93 | 84 | 45 | 347% |
| 5a  |             |          |     |     |     |    |    |    |    |      |
| 5b  | Gendengan   | West     | 0.5 | 0.4 | 0.4 | 62 | 59 | 51 | 32 | 94%  |
| 6a  | Nonongan     | South    | 0.3 | 0.2 | 0.3 | 28 | 27 | 24 | 37 | 24%  |
| 6c  |             |          |     |     |     |    |    |    |    |      |
| 7a  |             |          |     |     |     |    |    |    |    |      |
| 7b  |             |          |     |     |     |    |    |    |    |      |
| 7c  | Raron        | South    | 0.6 | 0.4 | 0.4 | 136| 128| 107| 28 | 377% |
| 7d  |             |          |     |     |     |    |    |    |    |      |
| 8a  |             |          |     |     |     |    |    |    |    |      |
| 8b  |             |          |     |     |     |    |    |    |    |      |
| 8c  | Bhayangkara | East     | 0.9 | 0.8 | 0.5 | 51 | 46 | 26 | 26 | 95%  |
| 9a  |             |          |     |     |     |    |    |    |    |      |
| 9b  | Balapan     | East     | 0.5 | 0.4 | 0.3 | 85 | 81 | 68 | 59 | 45%  |
| 9c  |             |          |     |     |     |    |    |    |    |      |
| 9d  |             |          |     |     |     |    |    |    |    |      |
| 10a |             |          |     |     |     |    |    |    |    |      |
| 10b | Banjarsari  | East     | 0.4 | 0.3 | 0.3 | 22 | 22 | 20 | 30 | 24%  |
| 10c |             |          |     |     |     |    |    |    |    |      |
| 11a | Wijayan     | South    | 0.6 | 0.4 | 0.4 | 51 | 49 | 46 | 32 | 57%  |
| 11b |             |          |     |     |     |    |    |    |    |      |
| 11c |             |          |     |     |     |    |    |    |    |      |
| 11d |             |          |     |     |     |    |    |    |    |      |

Due to the relatively large difference in results between the base model and the field data, therefore, a calibration and validation process is carried out by changing the S0 constant parameter used from 600.00 to 775.00 [2] in the Calibration 1 model. Traffic modelling results show that the Calibration 1 model still produces a relatively large vehicle queue length compared to field data. The next calibration and validation process is changing the value of PCE for motorcycle from 2.0 to 1.5 [3]. Traffic modelling results indicate that the Calibration 2 model yield vehicle queue length close to the field data.
Table 3. Comparison of IHCM 1997 model results and the field data (afternoon peak hour)

| No. | Intersection | Approach | Degree of Saturation Flows | Vehicle Queue Length (meter) | % |
|-----|--------------|----------|---------------------------|-----------------------------|---|
|     |              |          | BM | C1M | C2M | BM | C1M | C2M | FD | BM-FD |
| 1a  | Purwosari    | North   | 0.9 | 0.7 | 0.7 | 121 | 93 | 80 | 45 | 169% |
| 1b  | West         | 0.8 | 0.6 | 0.5 | 132 | 103 | 91 | 77 | 71% |
| 2a  | West         | 0.9 | 0.7 | 0.6 | 177 | 139 | 125 | 98 | 81% |
| 2b  | Gendengan    | South   | 1.0 | 1.0 | 0.9 | 196 | 180 | 125 | 82 | 139% |
| 2c  | Sriwedari    | North   | 0.7 | 0.5 | 0.4 | 93  | 86 | 66 | 28 | 232% |
| 3a  | South        | 0.8 | 0.5 | 0.5 | 89  | 69 | 62 | 50 | 78% |
| 3b  | Ngapeman     | North   | 0.9 | 0.6 | 0.6 | 185 | 130 | 114 | 47 | 294% |
| 4a  | North        | 0.8 | 0.4 | 0.4 | 69  | 62 | 54 | 48 | 44% |
| 4b  | South        | 0.6 | 0.5 | 0.5 | 132 | 103 | 91 | 77 | 71% |
| 5a  | West         | 1.0 | 0.7 | 0.6 | 176 | 129 | 112 | 73 | 141% |
| 5b  | Nonongan     | South   | 0.6 | 0.5 | 0.5 | 196 | 180 | 125 | 82 | 139% |
| 6a  | West         | 0.9 | 0.7 | 0.7 | 121 | 93 | 80 | 45 | 169% |
| 6b  | Gendengan    | South   | 1.0 | 1.0 | 0.9 | 196 | 180 | 125 | 82 | 139% |
| 6c  | Sriwedari    | North   | 0.7 | 0.5 | 0.4 | 93  | 86 | 66 | 28 | 232% |
| 7a  | South        | 0.9 | 0.6 | 0.6 | 185 | 130 | 114 | 47 | 294% |
| 7b  | Baran        | East    | 1.0 | 0.8 | 0.8 | 269 | 172 | 150 | 79 | 256% |
| 7c  | South        | 0.6 | 0.5 | 0.5 | 146 | 136 | 125 | 29 | 401% |
| 7d  | West         | 0.7 | 0.6 | 0.5 | 85  | 79 | 70 | 57 | 51% |
| 8a  | North        | 0.1 | 0.0 | 0.1 | 14  | 13 | 19 | 20 | 31% |
| 8b  | South        | 0.2 | 0.2 | 0.2 | 28  | 27 | 25 | 18 | 54% |
| 8c  | West         | 0.7 | 0.5 | 0.5 | 64  | 58 | 58 | 36 | 81% |
| 8d  | South        | 0.2 | 0.2 | 0.2 | 28  | 30 | 28 | 18 | 55% |
| 8e  | West         | 0.6 | 0.4 | 0.4 | 59  | 55 | 50 | 33 | 78% |
| 9a  | North        | 0.4 | 0.3 | 0.2 | 73  | 70 | 60 | 55 | 33% |
| 9b  | Balapan      | East    | 0.4 | 0.3 | 0.2 | 37  | 37 | 34 | 62 | 40% |
| 9c  | South        | 0.9 | 0.7 | 0.6 | 117 | 103 | 88 | 34 | 241% |
| 9d  | West         | 0.4 | 0.3 | 0.3 | 44  | 43 | 37 | 46 | 4% |
| 10a | North        | 0.4 | 0.3 | 0.3 | 62  | 60 | 53 | 47 | 32% |
| 10b | Banjarsari   | East    | 0.5 | 0.4 | 0.4 | 29  | 28 | 26 | 65 | 55% |
| 10c | West         | 0.4 | 0.3 | 0.3 | 30  | 29 | 27 | 40 | 25% |
| 11a | North        | 0.3 | 0.3 | 0.3 | 37  | 37 | 37 | 12 | 205% |
| 11b | Wishuran     | East    | 1.0 | 0.7 | 0.7 | 114 | 85 | 73 | 44 | 156% |
| 11c | South        | 1.1 | 0.9 | 0.8 | 271 | 95 | 88 | 48 | 465% |
| 11d | West         | 0.5 | 0.4 | 0.3 | 44  | 43 | 38 | 12 | 273% |

In order to find out the significance of the difference between the IHCM 1997 model result and the field data, a statistical test with t-test is performed. Table 4 shows the t-test results of the Calibration 2 model at the Bhayangkara Intersection in the morning peak hour. The t-test results show that there is no significant difference between the IHCM 1997 model result and the field data. Table 5 shows a resume of the t-test results for all scenario IHCM 1997 models in the morning and afternoon peak hours. The Calibration 2 models produce no significant difference in results compare others scenario models. It can be concluded that by changing the parameters S0 and PCE of motorcycle [3] produce statistically valid IHCM 1997 model.
### Table 4. The t test results between IHCM 1997 model and the field data

| Variable 1 | Variable 2 |
|------------|------------|
| Mean       | 23.92126   |
| Variance   | 42.47669   |
| Observations | 5        |
| Pooled Variance | 32.22809 |
| Hypothesized Mean Difference | 0        |
| df         | 8          |
| t Stat     | 1.248395   |
| P(T<=t) one-tail | 0.123591 |
| t Critical one-tail | 1.859548 |
| P(T<=t) two-tail | 0.247182 |
| t Critical two-tail | 2.306004 |

### Table 5. Resume of the t-test results for all scenario IHCM 1997 models

| Intersection | Morning Peak hour | Afternoon Peak Hour |
|--------------|-------------------|---------------------|
|              | BM C1M C2M        | BM C1M C2M          |
| Purwosari    | No Significant    | No Significant      |
| Gendengan    | No Significant    | No Significant      |
| Sriwedari    | No Significant    | No Significant      |
| Ngapeman     | No Significant    | No Significant      |
| Pasar Pon    | Significant       | No Significant      |
| Nonongan     | No Significant    | No Significant      |
| Baron        | Significant       | No Significant      |
| Bhayangkara  | Significant       | No Significant      |
| Balapan      | Significant       | No Significant      |
| Banjarsari   | No Significant    | No Significant      |
| Widuran      | Significant       | No Significant      |
4. Conclusion

Intersection is a conflict point of vehicles movement from intersection approaches. For this reason, it is necessary to regulate the vehicles movement at intersection with traffic signal control to avoid traffic jams and traffic accidents. Signal timing optimization plays an important role in minimizing vehicle delays and queues. Traffic models are needed to analyze the signalized intersection performance. However, the standard traffic modelling namely IHCM 1997 method, is no longer relevant to current conditions. The results of studies related to the 1997 IHCM model calibration and validation process models show that the default $S_0$ and PCE motorcycle values need to be replaced. The value recommended by [3] results in a vehicle queue length of the IHCM 1997 model does not differ significantly from field data.

References

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