Journal of the Eastern Asia Society for Transportation Studies, Vol.8, 2010

Microscopic Simulation for Modeling Effects of Motorcycles on Traffic Operations at Signalized Intersection

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Abstract: This paper investigates the effects of motorcycles on traffic operations at signalized intersections. Field surveys are conducted to study the effects of motorcycles on other traffic by examining discharge headway. It is found that the effects of motorcycles may be measured in terms of an increase in the start-up lost time of signal phase. Presence of motorcycles does not affect the saturation headway of traffic. A microscopic traffic simulation is developed so that effects of motorcycles can be taken into account in the planning and management of urban streets. It is found that our software can replicate the discharge headway as observed from the actual data.

Keywords: Motorcycles, Start-up lost time, Microscopic simulation

1. BACKGROUND

Motorcycle is a major means of private transportation in many parts of the world. Due to its size and complicated maneuvers, however, it is often neglected by engineers or planners in the planning and management of urban streets. Recently, there are a number of studies which investigate the effects of motorcycles on traffic operations. Most of them are dealt with determining the Passenger Car Equivalence (PCE) value of motorcycle (Hai, 1999,). PCE of motorcycles as obtained from field observations from those studies vary from 0.2 to 0.8.

Quantifying effects of motorcycles in terms of PCE is acceptable for the calculation of road capacity. Nevertheless, the delay of motorcycles at signalized intersection should significantly be different from the other traffic since they can penetrate through the waiting vehicles to the front of the queue. When signal changes to green, motorcycles are the first that discharge from the intersection. Thus, we expect that effects of motorcycles should appear only in the beginning of each signal phase.

Despite the fact that motorcycle is the majority of traffic in many cities, particularly in Asia, there exists no tool for modeling its operations and effects on other traffic (Bang and Palgunadi, 1994, Holroyd, 1963, Hsu et al., 2003). This may partially due to negligible impact of motorcycles in the developed world, which is the origin of most renowned microscopic traffic simulation models. Thus, it could be of interest to develop a microscopic simulation model which can explicitly model motorcycle.

2. METHODOLOGY

Approaches taken to conduct this study may be summarized as follows. Firstly, we conduct field observations by using camcorders to gather discharge headway of traffic and number of motorcycle in each green phase of a leg of a signalized intersection. The data is then analyzed to examine the effects of motorcycles on discharge headway of other traffic.

The effects are measured in terms of changes in start-up lost time and saturation headway. A microscopic traffic simulation is developed to facilitate explicit modeling of motorcycles with other traffic. Lastly, the developed model is validated to ensure that its results are in line with the observed data.

3. DATA COLLECTION

Chan-Nontri Intersection, a 4-way signalized intersection in Bangkok as shown in Figure 1, is chosen as the study site. The target lane for data collection is the second from left most lane due to a high proportion of motorcycles in the traffic. Through movement is the only maneuver allowed in the lane.

Videotaping is used a means for to collect data from the study sites. The following data are then extracted in the laboratory:

- Discharge headway of passenger cars and motorcycles only at the accuracy of 0.01 sec
- Number of motorcycles in the waiting queue at the beginning of green phase

It should be noted the data item 1 and 2 are obtained from signal cycles, in which only passenger cars and motorcycles discharge from the stop line. In total, data was observed from 197 signal cycles.

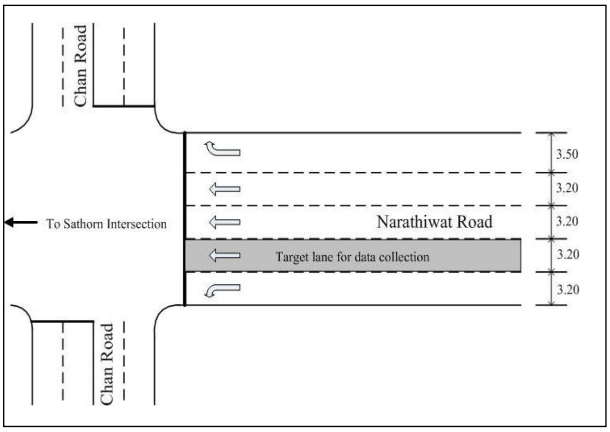


Figure 1 Study site

4. RESULTS

4.1 Effects of Motorcycles at Signalized Intersections

First, it is necessary to test our hypothesis of effects of motorcycles on discharge headway of traffic. We conduct a t-test of the discharge headways of vehicles from the intersection between the case of No-motorcycle and that of With-motorcycle. Table 1 shows average discharge headway of the vehicles from the intersection at different number of motorcycles mixed in the traffic. Table 2 shows the results of our hypothesis test. It is found that discharge headways of the 1^{st} to 4^{th} vehicles in the queue are different. This indicates that effects of motorcycle, with maximum number of motorcycles discharged from the intersection of 20, appear only at the beginning of the signal phase.

Based on the above finding, we investigate the effects of motorcycles in terms of change in start-up lost time. Our hypothesis is that start-up lost time of a signal phase should vary with the number of motorcycles discharged at the beginning of the phase.

Table 1 Average Discharge Headway of Vehicles from the Intersection

Position	Number of MC in Queue (Veh)			
	0	5-9	10-14	15-20
1	2.47	3.43	3.52	3.85
2	3.31	3.21	3.53	4.06
3	2.38	2.40	2.68	2.68
4	2.28	2.26	2.34	2.66
5	2.17	2.07	1.96	2.29
6	2.07	1.83	2.08	1.69
7	1.88	2.04	1.92	1.86
8	1.98	1.82	1.96	1.79

Table 2 t-test of Table 1

Position	No. of MC in Queue (Veh)			
	0	5-9	10-14	15-20
1	-	2.15*	2.37*	2.17*
2	-	0.44	0.75	1.42
3	-	0.35	1.65	1.67
4	-	0.00	0.41	1.22
5	-	0.66	1.4	0.03

** indicates that t-test is significant at 95% level of confidence*

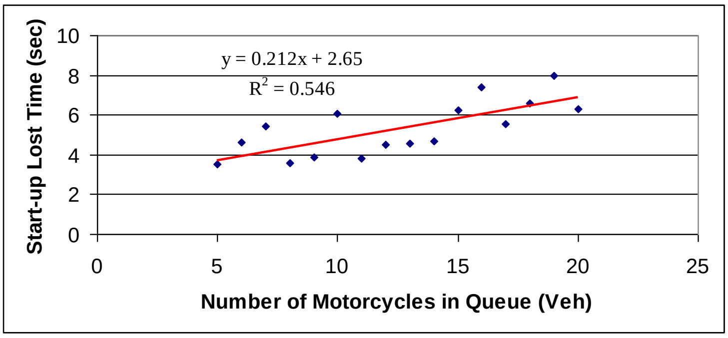


Figure 2 Start-up lost time under different number of motorcycles in queue

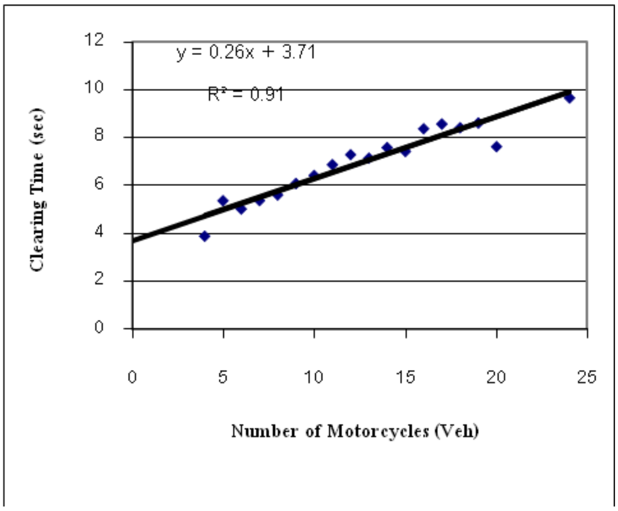


Figure 3 Clearing time of motorcycles

Figure 2 shows the linear relationship between the number of motorcycles and start-up lost time. Degree of correlation is 0.546 with y-intercept equal to 2.65 and the slope of 0.212. The obtained relationship is reasonable since it gives the start-up lost time of 2.65 sec in the case of no motorcycle in queue, which is comparable to the average of 3.24 sec and standard deviation of 1.52 sec as observed from the field.

Next, we examine the effects of motorcycle on the saturation headway of traffic. It is expected that motorcycles should not affect the saturation headway since most of them discharge from the intersection at the beginning of the signal phase. It is found that the saturation headway for the case of No-motorcycle is equivalent to 1.88, while that for the case of with-motorcycle is equivalent to 1.89. Thus, it may be concluded that presence of motorcycle does not affect the saturation headway of traffic.

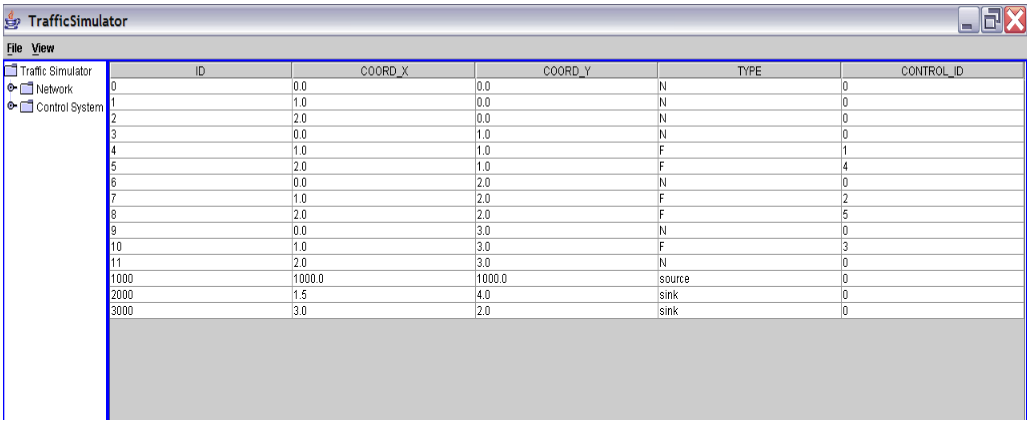
Lastly, we study the relationship between the number of motorcycles discharged and time required to clear the motorcycles from the intersection. Figure 3 shows the linear relationship between the variables with high degree of correlation of 0.91. The obtained relationship indicates that it takes 0.26 sec to discharge another motorcycle from the intersection given that the number of motorcycles in queue is large enough so that the saturation flow is reached.

4.2 Microscopic Traffic Simulation for Modeling Effects of Motorcycles

Based on the above findings, the effects of motorcycles could be quantified in terms of additional start-up lost time. Average queue clearing time of motorcycles is also obtained. Thus, we attempted to utilize these findings for modeling the effects of motorcycles at signalized intersection. The developed simulation model, called Mixed Traffic Simulation or MixTrafSIM, is based on the car-following concept as used in PARAMICS (Duncan, 1998). Movements of motorcycle are governed by our simplified rules.

- Motorcycles move at the mid-block with no interference from other traffic at constant speed of 60% of the link's free flow speed.
- Motorcycles move in the waiting queue of other traffic at constant speed of 20 km/h
- In a waiting queue, up to 3 motorcycles can be parallel in a row. Otherwise, they can be on either side of a waiting car. In this simulation, motorcycle crossing the stop line is not considered.
- Motorcycles waiting in the queue discharge from the intersection at the rate of 0.25 sec per vehicle under First-In-First-Out discipline.

MixTrafSim was developed by using objected-oriented Java programming. Input data can be imported in format of dbf as shown in Figure 4. Necessary input consists of road network data, OD data and signal plans. Output such as travel time, average speed can be given in graphs as shown in Figure 5. Animation file can also be generated for visualization of output.



ID	COORD_X	COORD_Y	TYPE	CONTROL_ID
0	0.0	0.0	N	0
1	1.0	0.0	N	0
2	2.0	0.0	N	0
3	0.0	1.0	N	0
4	1.0	1.0	F	1
5	2.0	1.0	F	4
6	0.0	2.0	N	0
7	1.0	2.0	F	2
8	2.0	2.0	F	5
9	0.0	3.0	N	0
10	1.0	3.0	F	3
11	2.0	3.0	N	0
1000	1000.0	1000.0	source	0
2000	1.5	4.0	sink	0
3000	3.0	2.0	sink	0

Figure 4 Input screen of MixTrafSim

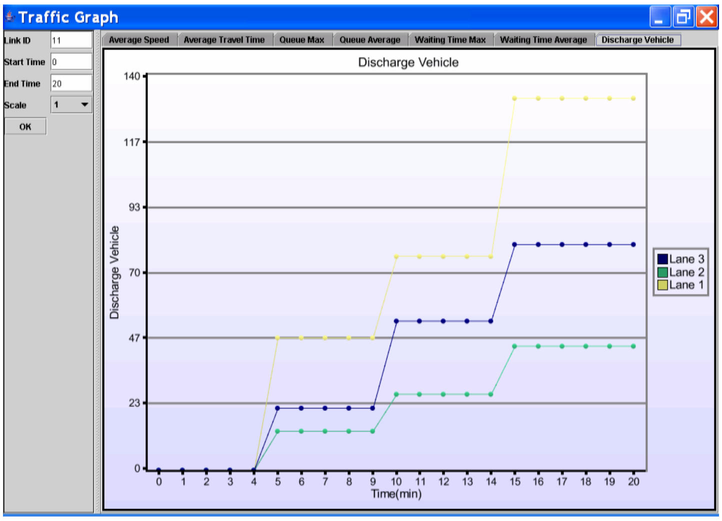


Figure 5 Output from MixTrafSim

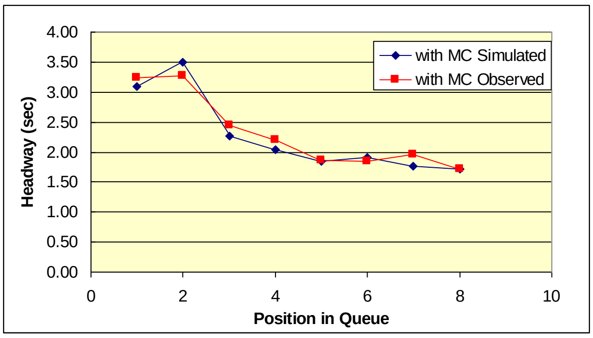


Figure 6 Discharge headway for the case of with-motorcycle in the waiting queue

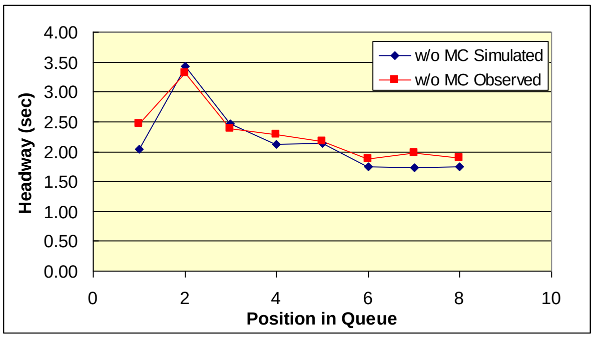


Figure 7 Discharge headway for the case of without motorcycle in the waiting queue

The MixTrafSIM was validated with the observed data to ensure that it can replicate real world condition. In this study only the effects at signalized intersection was investigated, thus start-up lost time and saturation headway were used for the comparison. A number of motorcycles discharged in each phase, ranging from 0 to 20, were tested.

Figure 6 and 7 show the discharge headway for the case of no-motorcycle and that of with-motorcycle. Statistical analysis, as shown in Table 3, confirmed that discharge headway obtained from the model are not different from those observed in the field.

Table 3 Paired t-test of Figure 5

	With MC	
	Simulated	*Observed*
Mean	2.269	2.320
Variance	0.445	0.386
Observations	8	8
Hypothesized Mean Difference	0	
Df	7	
t Stat	-0.947	
P(T<=t) one-tail	0.188	
t Critical one-tail	1.895	

Table 4 Paired t-test of Figure 6

	Without MC	
	Simulated	*Observed*
Mean	2.178	2.295
Variance	0.324	0.217
Observations	8	8
Hypothesized Mean Difference	0	
Df	7	
t Stat	-1.829	
P(T<=t) one-tail	0.055	
t Critical one-tail	1.895	

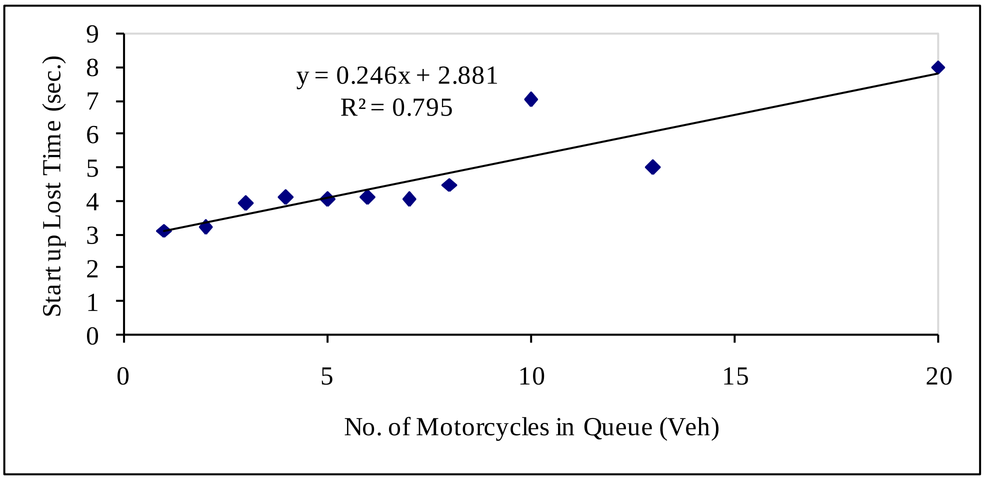


Figure 8 Relationship between number of motorcycles and start-up lost time

Relationship between number of motorcycles and start-up lost time, as obtained from the simulated data, is consistent with the observed data. The coefficients of regression line, as shown in Figure 8, are closed to those obtained from the field data as shown in Figure 2. This indicated that by using MixTrafSIM, it should be possible to incorporate the effects of motorcycle on traffic operations at signalized intersections into the traffic simulation.

5. CONCLUSIONS

This paper investigated the effects of motorcycles on traffic operations at signalized intersections. Field surveys were conducted to study the effects of motorcycles on other traffic by examining discharge headway. Major finding of the study is that the effects of motorcycles could be measured in terms of an increase in the start-up lost time of signal phase. On average, each motorcycle was found to increase the start-up lost time by 0.25 sec and it takes approximately 0.25 sec for each motorcycle to discharge from the intersection. It was also found that presence of motorcycles does not affect the saturation headway of traffic.

A microscopic traffic simulation, called MixTrafSIM, was developed so that effects of motorcycles can be explicitly taken into account. It was found that our model can replicate the discharge headway as observed from the field experiments. The MixTrafSIM also provided reasonable estimates of discharge headway and start-up lost time under different level of motorcycle mix in the traffic.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the Thailand Research Fund for the financial support through research grant number MRG4680116. Special thank is due to Charong Suppatrakul for data collection.

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