TREATING MOTORCYCLES TO INCREASE THE CAPACITY OF A SIGNALIZED INTERSECTION

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Abstract: The high increase of motorcycles in developing countries makes motorcycles traffic needs a special treatment; otherwise capacity at an intersection are sacrificed. This is because most accident involved motorcycles, and intersection capacity decreased due to improper behavior of motorcyclists. Therefore, the intention of this study is to investigate the behavior of motorcyclists and to find out a better solution that may increase intersection capacity. A field study was carried out at an intersection to perform a proposed measure when motorcycles exist at the approach of an intersection. Results of the experiment showed that the behavior of motorcyclists can be influenced by a measure that increases intersection capacity. This solution may be useful to be adopted in some similar countries in treating motorcycles.

Key words: high increase of motorcycles, motorcycles’ position, signal capacity

1. INTRODUCTION

In terms of traffic, intersection in urban areas is a vital point since it is where traffic flows of different directions meet. In a condition where traffic is not crowded, rule of priority usually applies to intersection control. Traffic flow from minor road must decide a gap safe enough to pass through an intersection (Morlok, 1985). Gradually, the rule of priority becomes less efficient and dangerous when traffic is growing crowded. Congestion and long queue are very likely to happen when the moving flow is reluctant to stop and other flows are waiting in a queue for quite long to get their turn. An increasing traffic volume creates blockages particularly at an intersection. The congestion gets worsened by mixed traffic such as in the current situation in Yogyakarta. Motorbike is one of the traffic components calling our attention. In addition to its growing number, motorcyclist also shows a behavior of negligence to traffic measure.

Today, Yogyakarta is among the cities in the world to experience the highest rate of motorcycle growth. Data of 2005 give an average of 6,000 new motorcycles running on roads in Yogyakarta. It is a huge proportion of motorcycle in the traffic, which makes streets in Yogyakarta overloaded.

2. PROBLEMS STATEMENT

Like in Vietnam, Myanmar, and Cambodia, traffic condition in Yogyakarta reflects the presence of a very large number of motorcycles, which dominates the traffic mix. As the result, traffic signal at intersection requires a special operation.
Webster and Cobbe (1966) in Road Research Technical Paper no. 56 propose that an optimum cycle time is shown by a minimum delay caused by traffic-light operation at crossing. The cycle time in use ranges between 0.75 – 1.50 of an optimum cycle time. An optimum duration of cycle time is based on a minimization of delay time or queue length at all intersections or on certain streets. Therefore, the determination of cycle time duration shall consider the total of average minimum delay at intersection.

In Indonesia, the minimum cycle time at signalized intersection is 40 seconds, while the maximum is 130 seconds. A longer or shorter time than this duration makes traffic control using traffic signaling ineffective. Shorter cycle generally results from a less than 10 meter wide intersection, thus, longer cycle is for a wider street. A cycle time shorter than the recommended duration will cause problems for motorists/pedestrians to cross. A longer cycle time than 130 seconds must be avoided at all cost, except in a very special case (e.g. a very large intersection), since it often causes loss within the overall capacity (MKJI, 1997).

The presence of motorcycle in large number at intersection may decrease the intersection capacity. Motorcyclists’ behavior -spreading over the approach of intersection- accounts for the capacity decrease as it creates obstacles for other vehicles to move at the start of green light phase. In relevance with this issue, the research aims to study motorcyclists’ behavior that affects intersection capacity. It conducts field experiment at a signalized intersection in Yogyakarta where motorcycles dominate the traffic flow. To identify any increase of intersection capacity, the research gives motorcycle a treatment by observing motorcyclists’ behavior during red light phase at intersection. It applies seven criteria generally shown by motorcyclists in order to help the observations on their behavior. The criteria are:

- Moving slowly in a queue (A)
- Stopping (B)
- Lane-changing (C).
- Moving slowly then stopping, or vice versa (A+B)
- Moving slowly while lanes changing (A+C)
- Changing lanes and then stopping, or vice versa (B+C)
- Moving slowly while lane changing and then stopping or adopting a variation of these three actions (A+B+C)

Motorcyclists’ behavior may influence intersection capacity owing to motorcycle flexible movement, such as maneuvering amid car queue, and its needs for a narrow space to move. In addition, with high acceleration and deceleration ability, motorcycle can run at higher speeds from a stop condition in particular. The influence can be negative and positive. Increasing intersection capacity is a positive effect, while decreasing intersection capacity is a negative effect.
Figure 1 Motorcyclists’ behavior at the approach of intersection

From Figure 1, type B behavior, i.e., motorcycle stopping behind stop line, may increase the intersection capacity. When the light turns green, motorcycle will be able to move ahead at high acceleration leaving other vehicles behind, so it experiences less lost time. On the contrary, types A and C behaviors may cause capacity decrease. The positions prevent other vehicles in queue to use their acceleration well, so they suffer bigger lost time; thus, intersection capacity decreases. Type C behavior, in which motorcycle moves along or between cars in queue forcing cars to move cautiously when the light turn green, causes even bigger lost time and significant decrease of intersection capacity.

In real situation, motorcyclists’ behavior is a combination of A and B, A and C, or B and C, or even of A, B and C, which are major causes of intersection capacity decrease. Therefore, the idea to control motorcyclists’ behavior is, in fact, to lead them toward type B behavior to increase intersection capacity.

3. FIELD MEASUREMENT

In general, traffic movement in Yogyakarta city in the morning and afternoon is dominated by travels to places of activity. During rush hours in the morning and afternoon, traffic flow is entering and leaving urban agglomeration area confined by ring-roads on the north, south, east, and west. This phenomenon is called urban sprawl, and it becomes the consideration in selecting research location. Research location is also selected based on the direction of traffic flows motorcycles dominate and at intersection which accommodates traffic from north and east directions toward city center, and from South toward city center.

This research adopts criteria based on intersection physical condition, namely intersection which has good and clear view, ordinary traffic and a simple signal phase, a relatively big proportion of motorcycle, and ease for research instrument installation. It collects primary data from a camera-using survey, so it requires placing that enables the camera to view traffic movements from all directions. Based on these considerations, it decides to choose Demangan intersection on Adisucipto Street. See Figure 2.
Based on field observation and considering the percentage of motorcycle in the field location, the alternative 3 was considered to be the most appropriate for this research. Therefore, visual data collection uses camera that is placed at a height enabling it to record traffic movement that goes at green light. Subsequently, the recorded data are reduced after record rewinding. Data after reduction are flow of saturation, stop delay, and queue length. Data on lost time are obtained by comparing data in early interval and saturation interval of saturation flow. Analysis is done by comparing two conditions: existing condition or condition Without Measure (WOM) that provides data on motorcycles when they are mixing with other vehicles, and condition With Measure (WM), i.e., motorcycles’ position on an intersection approach is regulated.

Different positions are possible for motorcycles at intersection in relation with the tendency of space occupied by motorcycle queue in WOM condition, width of space occupied by motorcycles queue in WOM condition, and dominant direction of motorcycle movement in WOM condition, and motorcyclists’ behavior. Table 1 and Figure 3 give illustration of alternative positioning of motorcycle in WM condition, including the advantages and disadvantages of the implementation in research location.

<table>
<thead>
<tr>
<th>Lane position</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Motorcyclists’ behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left lane (alt. 1)</td>
<td>Effective for big proportion of motorcycle on left lane with movement to 2 directions (turning left and going straight)</td>
<td>difficult for vehicles which are forced to take right lane but going to take a left turn</td>
<td>Likely to be more orderly, for it has a special lane and is not mixed with other vehicles.</td>
</tr>
</tbody>
</table>

Table 1 Alternative of positioning of motorcycle in queue
Right lane (alt. 2) Effective for big proportion of motorcycle on right lane with movement of turning to right direction difficult for vehicles which are forced to take left lane but going to take a right turn. Alternatives 1 and 2 require adequate width of intersection arm for motorcycle. Likely to be more orderly, for it has a special lane and is not mixed with other vehicles.

Front (alt. 3) Effective for big proportion of motorcycle with movement to all directions. Rate of motorcycles’ arrival after green light phase is relatively high, or movement to the front of queue is high. Difficult to make sure that motorcycles are to arrive first after the green light phase is over. Likely to be more orderly, for it has a special lane and is not mixed with other vehicles.

Figure 3 Measure alternative in condition with measure (WM)

4. RESULT AND DISCUSSION

4.1. Motorcyclist’s Behavior at Intersection

4.1.1. Condition Without Measure (WOM)
In WOM condition both in the morning and at noon, a high percentage is for motorcycles stopping on left lane which are going to continue the straight direction. However, a few motorcyclists are not disciplined, i.e. from left lane taking a right turn. It happens mostly at noon, reaching 5.10% as shown in Figure 5. Their ignorance causes an intersection capacity decrease, for they block other vehicles continuing a straight direction.
Figures 6-7 illustrate recapitulation for right lane as in the following. The figure shows that motorcyclists on right lane are disciplined, the evidence of which is shown by a high percentage of motorcyclists on right lane taking a right turn. This condition can increase an intersection capacity, for vehicles going a straight direction do not encounter any obstacle. Motorcyclists on right lane but going straight are observed mostly in the morning, with a percentage of 18.32%.

Moreover, it indicates motorcyclists’ disciplined behavior and knowledge to use right lane when going to take a right turn. This condition is expected to be able to increase intersection capacity, for it does not create any obstruction for vehicles continuing a straight direction.

Based on the criteria mentioned above, the findings of field experiment on motorcyclists’ behavior at red light, which are obtained by following the criteria discussed in the previous part, are presented in Table 2 below. The research location is in Demangan intersection.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>A+B</th>
<th>A+C</th>
<th>B+C</th>
<th>A+B+C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demangan intersection (average of motorcycle/cycle time)</td>
<td>0.5</td>
<td>4.5</td>
<td>6.5</td>
<td>4.45</td>
<td>6.5</td>
<td>1.2</td>
<td>1.4</td>
</tr>
</tbody>
</table>
From this table is seen that behavior of criterion C, in which motorcyclists changing lanes, frequently happens in the research location. It happens because the lane is quite wide for motorcycles to move along cars in queue. Besides, A+C condition in which motorcyclists move slowly and switch lanes and B+C condition in which motorcyclists switch lanes and then stop also happens in Demangan intersection.

4.1.2. Condition With Measure (WM)

In WM condition, motorcycles are given a stopping space - 10 meter long from stop line. The findings are presented in the following figures.

The figures show that motorcyclists have a disciplined behavior. The evidence is no motorcycle changing lane. Figures 8-9 in the following illustrate WM condition on left lane outside the designated stopping space.

Motorcyclists in WM condition outside the designated stopping area on left lane are not disciplined as still many from left lane take a right turn. As exhibited in Figure 8, the percentage of motorcycles taking a right turn from left lane in the morning is 12.5%. On the other hand, in noon condition, the number of motorcyclists taking a right turn from left lane exceeds the number of vehicles going a straight direction. The percentage of ignorant motorcyclists reaches 54.04%, as exhibited in Figure 9.

The following figures 10 and 11 present WM condition on right lane. As exhibited, the motorcyclists on right lane have a disciplined behavior. The percentage of motorcyclist on right lane moving to a right direction is 62.29% in the morning and 86.65% at noon, which exceeds the percentage of motorcycles going a straight direction.
4.2. Intersection Capacity

4.2.1. Discharge Profile
Discharge profile is traffic flow every 6 seconds during a green light signal, and it is usually marked by a significant increase of flow and then a gradual decrease into flat and finally a sharp decrease. Data can be reduced from a saturation flow at each intersection for every 6-second interval. The result of data reduction is then calculated to get the mean.

Tables 3 below show discharge at Demangan intersection in WOM and WM conditions. Figures 12 gives the illustration.

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Discharge per 6 Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demangan</td>
<td></td>
</tr>
<tr>
<td>WOM</td>
<td>7.63 9.08 8.47 5.09</td>
</tr>
<tr>
<td>WM</td>
<td>6.97 10.09 8.90 4.52</td>
</tr>
</tbody>
</table>

The value in each interval at a concerned intersection, for instance 7.63 at Demangan intersection, is the mean in WOM condition in the morning and at noon. Others are alike.
The above table and figure explain that no difference of flow pattern exists during the first interval, but in WOM condition, more flows are discharged. It is in line with the fact that in WM condition, the value of lost time is higher than in WOM condition. The same pattern happens in the final interval.

The difference between the two conditions lies in intervals two and three. Demangan intersection discharges more flows in intervals two and three. At the same time, this difference answers why the saturation flow at Demangan intersection increases in WM condition.

A number of factors affect the high rate of flow in intervals two and three. They are among others:

- Influence of different motorcyclists’ behavior at the placing of location in WM condition; at Demangan intersection, so it is easier for motorcycles to reach the designated space.
- Change of proportion and composition of going through traffic.

4.2.2. Saturation Flow
Saturation flow is calculated based on discharge in intervals 2 and 3. The proportion analysis identifies a difference of going-through motorcycles. At this intersection, which has positive impact, the proportion of going-through motorcycles increases when compared to WOM condition.

<table>
<thead>
<tr>
<th>Table 8 Saturation flow in WOM and WM conditions (vehicle unit/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Demangan</td>
</tr>
</tbody>
</table>

This table describes that saturation flow of WM condition is higher than WOM condition. This means that WM condition can increase signal capacity.

Moreover, motorcycle measure is made by placing motorcycles on a 10 meter long space or outside this designated area toward stop line. The impacts of such measure on saturation flow are presented in the following table.

<table>
<thead>
<tr>
<th>Table 9 Average saturation flow at a number of measures (vehicle unit/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
</tr>
<tr>
<td>----</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>

The following part presents conclusion based on the result of the above measures. In measure of a 10 m distance, saturation flow increases both in the morning and at noon. In measure of other distances, saturation flow increases at noon. The longer the distance, the bigger the saturation flow. It is indicated that WM condition can increase intersection capacity, since any capacity increase relies very much on saturation flow increase.
4.2.3. Early Lost Time
Based on the data analysis, separation of motorcycle having higher acceleration ability seems to bring negative impacts to lost time. The following factors account for it.

(a) In WOM condition, motorcyclists are usually more aggressive and more courageous to use empty spaces among other vehicles. Sutomo (1992) states that the value of vehicle unit for motorcycle tends to be smaller in the first 0.1 minute than in the rest, which is 0.21 and 0.31. The difference results from motorcycle ability to use empty spaces behind stop line. For this research, the value of vehicle unit for both conditions is the same; if the values of vehicle unit are differentiated, the value of early lost time for both conditions may be different.

(b) The proportion of going-through motorcycles in early interval in WM condition is higher than in WOM condition, so the calculation of aggregate early lost time gives lower value, and the early lost time is higher. From the analysis, the proportion of going-through motorcycle is ideally less than 50%. It indeed relates to the width of area designated in WM condition. Data will be taken only when motorcycle queue occupies the designated 10 meter long area.

(c) The presence of an officer during field research may give impact to motorcyclists’ behavior. In WOM condition, most motorcyclists as according to the preliminary survey - have begun preparation to start as soon as the light turns green. However, such a condition very seldom takes place in WM condition. In WM condition, motorcyclists generally start after the light really turns green. The positioning of staff in WM condition is intended to direct vehicles to occupy the designated space.

5. CONCLUSION
Motorcycle is the biggest transportation mode in Yogyakarta. It contributes 84% to the total vehicles on streets. Owing to a flexible characteristic and capacity to move in high speed, motorcycle has brought problems to traffic. The problems include messy traffic that decreases capacity especially at the intersection. Having a small size, motorcycle is able to move into narrow spaces among other vehicles or to stop at anytime. Such conditions disturb the queue systematic, and finally disturb smooth discharge at an intersection approach. Therefore, it needs strategy to position motorcycles at an intersection approach in order to have a more orderly queue system and possible increase of intersection capacity.

Signalized intersection capacity is affected by the value of saturation flow, duration of travel time and cycle time. Saturation flow is the total of maximum traffic flow going through an intersection at a particular condition per unit of green light time. Motorcycle measure is performed by providing a stopping space toward stop line at an intersection approach. It may follow the design as depicted in alternative 3.

REFERENCES


