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A Study on the Influences of Exclusive Stopping Space on Saturation Flow (Case Study: Bandar Lampung)

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Abstract: *The existence of exclusive stopping space (ESS) at the signalized intersection is expected to improve the performance of intersection, by collecting the motorcycle in an exclusive space and discharging it early when the signal is display green. This research compares the level of saturation flow on the approach with ESS and approach without ESS and finds that ESS's effectiveness is influenced primarily by occupancy rate. The findings of this study indicated that at 71% of ESS occupancy rate, the approach was able to discharge the saturation flow by 20% higher than the approach with a width of 4.5 m but without ESS. On the contrary, the approach without ESS with a width of 6.5 m looks better in discharge saturation flow compared with the approach with ESS but with an occupancy rate of only 38%. Careful design is highly recommended especially the area of ESS provided for motorcycle so that the functions performed by exclusive space run an effective way as planned.*

Keywords: *Exclusive stopping space, Motorcycle, Saturation flow.*

1. Introduction

The number and use of motorcycles in major cities in Indonesia continues to increase not only due to travel needs but also because of its existence is considered to provide flexibility, cheaper and in some conditions faster than private car or public transportation such as buses. With the composition of motorcycle's mode share on urban roads reaching 60% to 70% of all motorized vehicles, motorcycles will not only dominate the road space, but have the potential to trigger clutter and reduce road capacity and saturation flows at signalized intersections. In order to control the movement of the motorcycle while waiting for the green period behind the stop line at the signalized intersection, Ministry of Public Works and Public Housing enacted circular letter No. 52/SE/M/2015 containing Design Guidelines on Exclusive Stopping Space (ESS) for Motorcycles at Signalized Intersection in Urban Areas (Ministry of Public Works and Public Housing's, 2015).

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The ESS is intended to separate the movement of motorcycles and reduce conflicts originating from motorcycles with other vehicles while waiting for the red period on the approach, leaving first together when it is green and it is expected that the saturation flow of traffic released is higher than irregularly mixed traffic. In the end, the existence of ESS for motorcycles is expected to increase current capacity and improve signalized intersection performance. During the period 2007 to 2011, the ESS has been implemented in 5 big cities, namely Bandung, Bekasi, Bogor, Denpasar and Tangerang and has shown a significant impact on reducing conflict and increasing the flow of vehicles entering the intersection (Idris, 2007). These cities are then followed by Palembang (2014), Medan, Semarang, Purwokerto, Jepara, Kudus, Cirebon (2015) and Bandar Lampung (2016).

This paper intends to test the effectiveness of ESS in several randomly selected approaches at signalized intersections in Bandar Lampung based on the level of saturation flow that can be passed during the green period; the test results on the approach with ESS are then compared with the level of saturation flow in the approach without ESS.

2. Theoretical Framework

2.1. Signalized Intersection and Saturation Flow

Signalized intersections with fully controlled cross-traffic light phases indicate to drivers when to enter the intersection, thus removing the problem for them of selecting safe gaps in the traffic flow. This reduces crashes between turning vehicles and oncoming through traffic. Signalized turn lanes can also be helpful where there is a history of crashes between turning vehicles and pedestrians crossing the road. Signalized turn lanes are created by installing additional display lanterns facing the chosen approach; red, amber and green lanterns for the through movements and for example, red, amber and green turn arrows. Dedicated turn lanes should be provided if they don't already exist at the site. A signalized turn lane may be installed for any of the following reasons: new traffic signals are being installed, there is a history of crashes between turning vehicles and oncoming through traffic, there are two or more

lanes that turn across traffic, turning traffic is opposed by two or more through lanes of traffic, two or more opposing through traffic lanes have high operating speeds, and sight distance to the intersection is limited.

Saturation flow is a very important road traffic performance measure of the maximum rate of flow of traffic. It is used extensively in signalized intersection control and design. Saturation flow describes the number of passenger car units (pcu) in a dense flow of traffic for a specific intersection lane group. In other words, if an intersection's approach signal were to stay green for an entire hour and the flow of traffic through this intersection were as dense as could be expected, the saturation flow rate would be the amount of passenger car units that passed through this intersection during that hour (Bester and Meyers, 2007).

Studies concerning increasing saturation flow must be recognized as not much done, although topics around saturation flow can be traced in a number of journals, such as the development of a saturation flow model based on case studies in India (Chand et. al., 2017 and Biswas et. al., 2018). The topic of saturation flow rates at signalized intersections in China was discussed (Shao et. al. 2011), which emphasized the US Highway Capacity Manual approach (HCM, 2010) to determine saturation flows, which turned out to be irrelevant in China. Interestingly enough studies that discuss the existence of information or information points and their effect on saturation flow (Gao et. al., 2016) as well as different levels of saturation flow due to differences in approach width (Shang et. al., 2014). Based on the investigation of the authors there are still rarely studies that specifically discuss the effect of the existence of ESS for motorcycles on the level of saturation flow in the signalized intersection approach, which is the main focus of this research.

2.2. Exclusive Stopping Space for Motorcycle

Originally, the implementation of exclusive stopping space for motorcycle at signalized intersections was developed from the concept of advance stop lanes (ASL) for bicycles. ASL also called advanced stop box or bike box is road markings at the signalized approach that allow certain types of vehicles to head start when the traffic

signal changes from red to green. ASL or stop lanes for bicycles were implemented widely in the United Kingdom, the Netherlands, Denmark, and other European countries. Therefore, this concept is tried to be implemented for motorcycles in Indonesia.

Generally, the first ESS was designed by providing front stop lane for motorcycle and backstop lane for other types of vehicles. Both stop lanes are separated by the red area with solid marking. ESS for motorcycle also continuous boundary road marking on the left and right side. There was motorcycle logo in the center of ESS to make it easier for motorcyclists to understand and become aware of the meaning of ESS and also terms of requirements as illustrated in Fig. 1 and Table 1, respectively (Mulyadi, 2017).

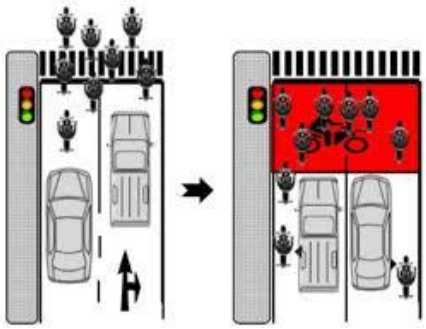

Fig. 1. Illustration of design ESS

Table 1. Terms of requirements

Description	Parameter
At least two lanes per direction which are not left turn directly Width of each lanes approximately 3.50 m	Geometric
At least 30 motorcycles on two lanes or 45 motorcycles on three lanes during waiting at ESS	Traffic condition

3. Data Collection

3.1. Dimension and occupancy of ESS

Data collection was conducted in October 2018 and as many as four approaches were chosen randomly at four main signalized intersections in the city of Bandar

Lampung with different ESS dimensions and different levels of occupancy rates as shown in Table 2.

Table 2. Dimension and occupancy rate of ESS

Intersection/approach	ESS dimension (m^2)	Occupancy rate (%)
Wolter Mongonsidi - Cut Mutia - Basuki Rahmat (north)	16.8	71
Sudirman - Gajah Mada - Ir. H. Juanda (south)	49.4	38
Sudirman -HOS Cokroaminoto (south)	40.2	55
Sudirman - Gajah Mada - Ir. H. Juanda (north)	45.6	45

Based on population data, the most dominant motorcycle classifications used in Indonesia are cylinder size 110-125 cc and one motorcycle in static conditions while waiting for a green period on ESS area requiring 2.0 m length and 0.75 m width or 1.5 m^2. As shown in Table 2 the intersection of the Sudirman - Gajah Mada in the southern and northern approaches has an ESS occupancy rate of 38% and 45%, respectively. Based on observations, these approaches at the signalized intersection surveyed with a low percentage of ESS occupancy rate to the irregular waiting position of the motorcycle and the driver's awareness of the ESS function are still not as expected. The Sudirman - HOS Cokroaminoto intersection on the southern approach has an occupancy rate of 55% while the Wolter Mongonsidi - Cut Mutia intersection on the northern approach seems to be occupied with approximately 71% or 8 units of motorcycles waiting during the red phase.

3.2. Approach width and saturation flow

Furthermore, saturation flow that can be discharged by the approach with ESS and without ESS can be seen in the following Table 3. The saturation flow in the table is obtained by the time slice method as explained in the Indonesian Highway Capacity Manual chapter 2 Signalized Intersection (IHCM, 1997). Moreover, both Fig. 2 and Fig. 3 below show a comparison of the number of motorcycles and the total number

of vehicles that can be discharged by the approach with ESS and approach without ESS.

Table 3. Comparison of saturation flow

Intersection/approach	Approach Width (m)	ESS	Saturation Flow (pcu/h-g)
Wolter Mongonsidi - Cut Mutia - Basuki Rahmat (north)	4.5	Yes	2464
P. Polim - Pagar Alam Sukardi Hamdani (north)		No	2050
Sudirman - Gajah Mada - Ir. H. Juanda (south)	6.5	Yes	1928
Sultan Agung - Kimaja (west)		No	2788
Sudirman -HOS Cokroaminoto (south)	5.5	Yes	2080
Cut Nyak Dien - P. Emir M.Noer (west)		No	1963
Sudirman - Gajah Mada - Ir. H. Juanda (north)	6.0	Yes	2047
Dr. Susilo - KH Ahmad Dahlan (south)		No	2059

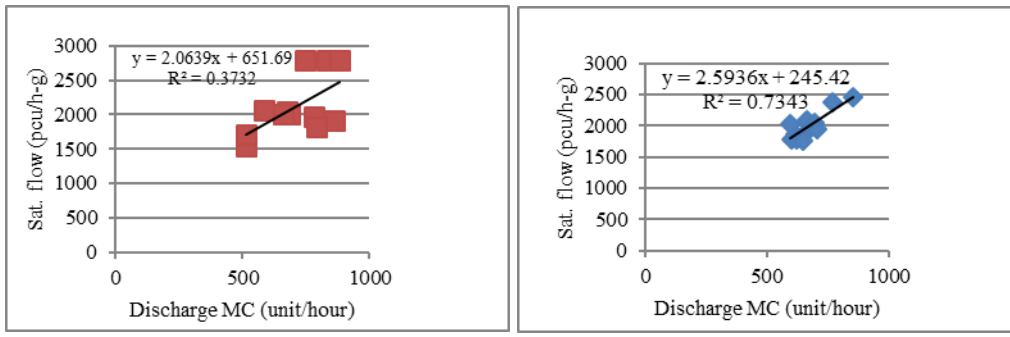

Fig. 2. Saturation flow vs Discharge MC without ESS (left) and with ESS (right)

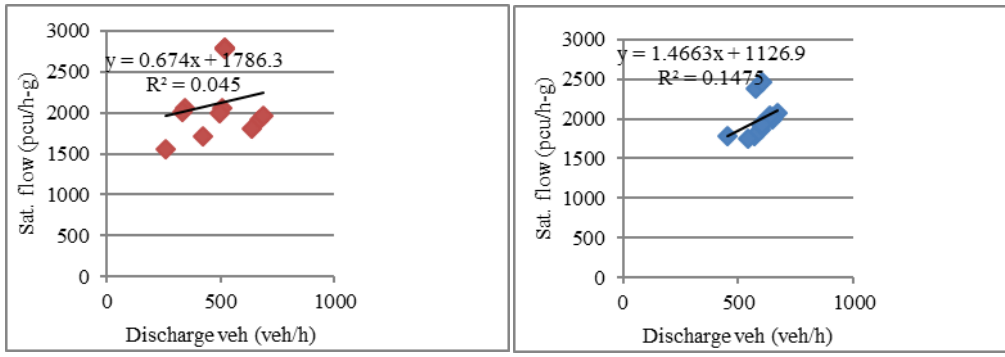

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Fig. 3. Saturation flow vs Discharge vehicle without ESS (left) and with ESS (right)

4. Results and Discussion

As seen in Table 2 and Table 3 levels of saturation flows are influenced by the occupancy rate of ESS. With a occupancy rate of 71%, the north approach at Wolter Mongonsidi-Cut Mutia-Basuki Rahmat (with ESS) intersection and north approach at Panglima Polim-Pagar Alam Sukardi Hamdani (without ESS) intersection with wide approach = 4.5 m, has a level of saturation flow of 2464 pcu/h-g and 2050 pcu/h-g respectively. Based on this results it is clearly seen that at the approach with ESS the saturation flow level is 20% higher than the approach without ESS. In contrast to the approach pair with a width of 5.5 m and 6.0 m, there is no noticeable difference in the level of saturation flows that can be discharged by approach with ESS and approach without ESS. At the same time, as shown in Table 2, the occupancy rate for the both approach is reviewed only at a rate of 45%-55%. It is interesting to note that the saturation flowt level of the approach with ESS and without ESS with a width of approach 6.5 m demonstrates that the approach without ESS results in a higher saturation flow rate (2788 pcu/h-g) than the approach with ESS (1928 pcu/h-g). Indeed, the occupancy rate of the approach with ESS is only recorded at 38% or most of the available space is not occupied by motorcycles. Referring to Fig. 2, in general the existence of ESS to discharge motorcycles from the behind of the stop line looks better, among others marked with a higher R^2 value compared to the approach without ESS. In addition, the data group in the approach with ESS looks more homogeneous indicating a large number of motorcycles left the stop line with almost the same time compared to the more disperse approach without ESS (Fig. 2 left). The tendency of motorcycle users in Fig. 2 followed by the whole vehicle as expressed in Fig. 3, where the departure of the whole group of vehicles

(veh/hour) on approach with ESS is more compact (Fig. 3 right) compared to the departure the vehicle without ESS (left). In real conditions at a signalized intersection, a more compact departure queue at the same time indicates the level of conflict between motorcycles and other vehicles on the approach with ESS is lower, so non-motorcycle vehicles can perform maneuver more freely and rapidly during the green period and contributes to increased saturation flow. However, the high or low value of the occupancy rate on the approach with ESS turns out to affect the saturation flow level as described earlier.

5. Conclusion, Implication and Limitation

5.1. Conclusion

This research has successfully tested the level of ESS effectiveness based on occupancy rate and compares to the level of saturation flow in the approach without ESS. The findings of this study indicated that at 71% of ESS occupancy rate, the approach was able to discharge the saturation flow by 20% higher than the approach with a width of 4.5 m but without ESS. On the contrary, the approach without ESS with a width of 6.5 m looks better in discharge saturation flow compared with the approach with ESS but with an occupancy rate of only 38%. The findings of this study indicate that the existence of ESS is less effective or there is a lot of free space in the back stop line that should be occupied only by motorcycle and at the same time cannot be entered by vehicles other than motorcycle. In fact, the further distance of the vehicle against the stop line means it takes more time to leave the conflict area at a signalized intersection that implicates the effective green time becomes reduced and affects the saturation level flow becomes lower.

5.2. Implication and Limitation

Although the signalized intersection and approach is chosen randomly, the results of the research are not able to represent the condition of signalized intersection in one city, because the behavior factor of motorcycle users can be very different between one or two approach with other approach and influenced by age, the presence of

officers in the field, traffic volume and other factors. These external factors need to be examined in more detail, as they are very likely to affect the effectiveness of the ESS but not covered by this research.

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