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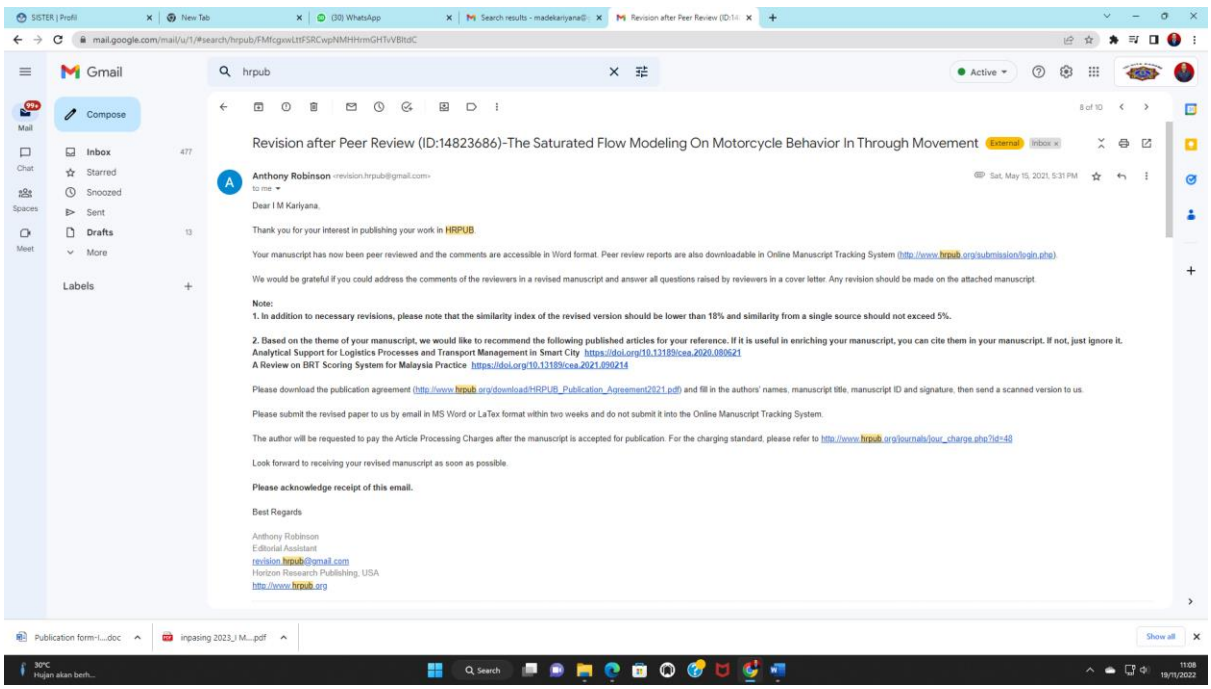

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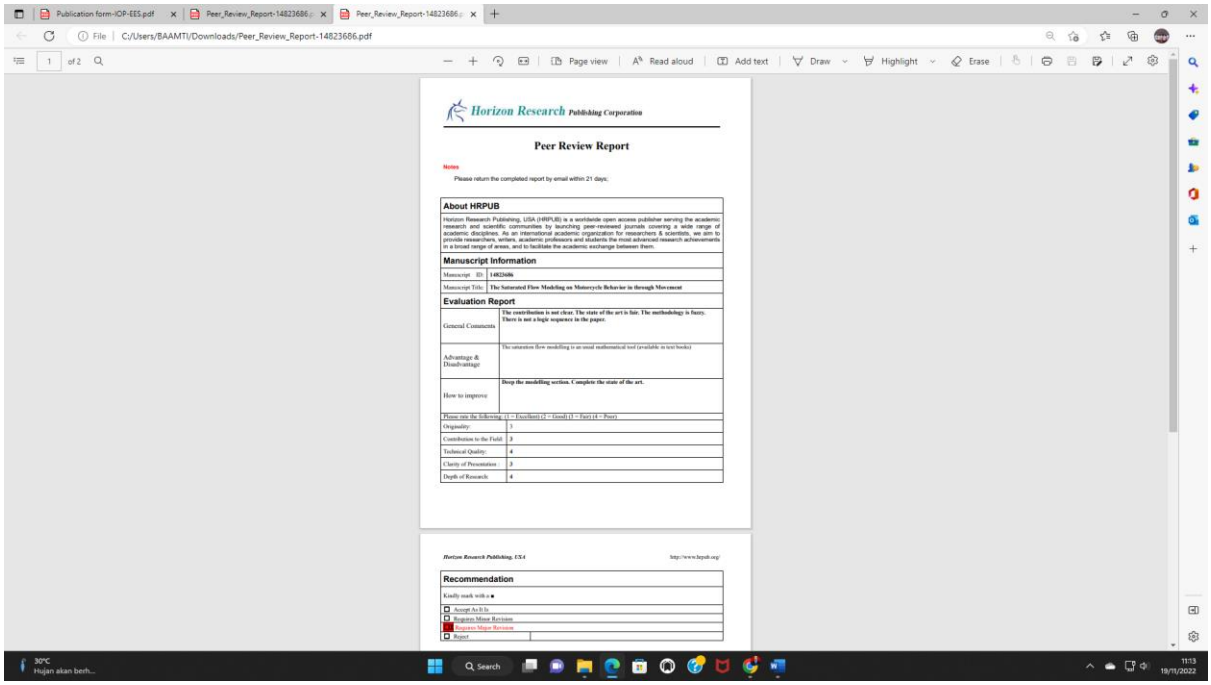

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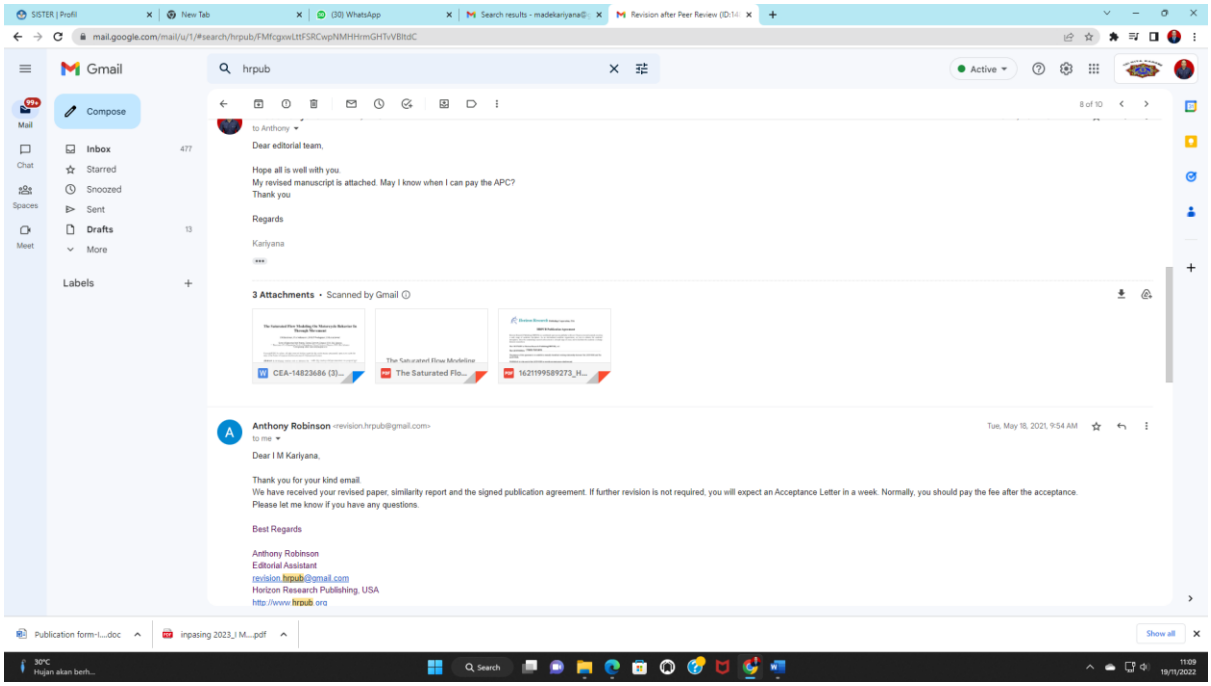

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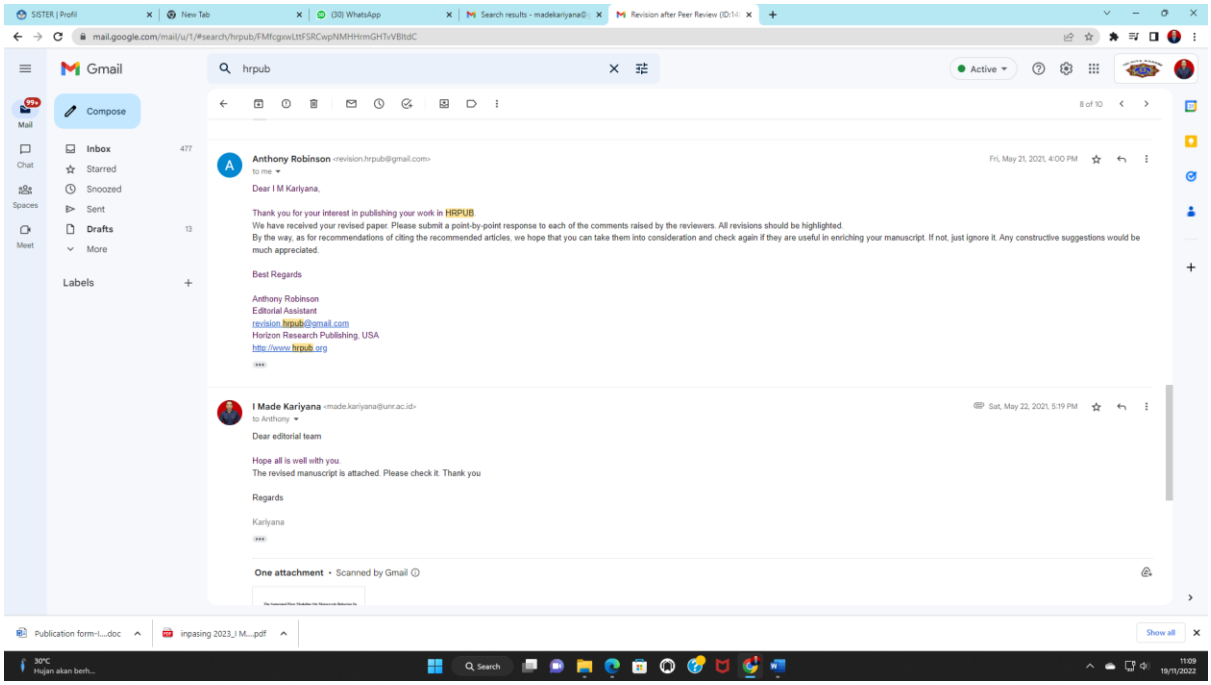
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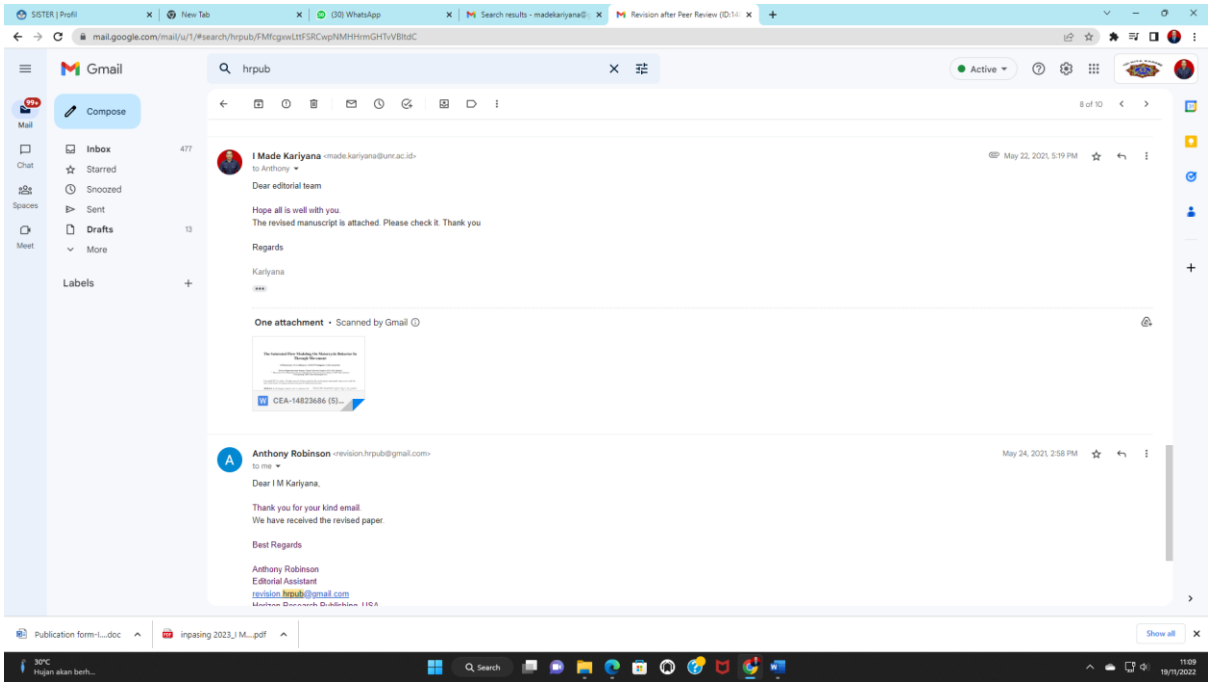
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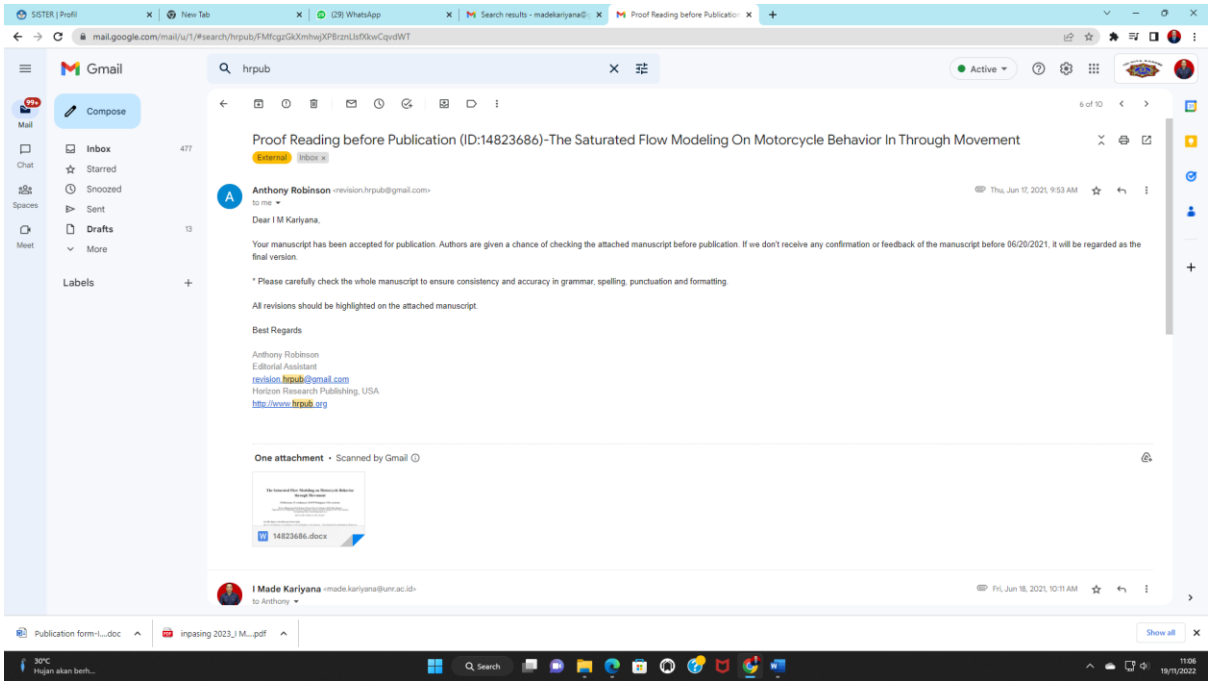
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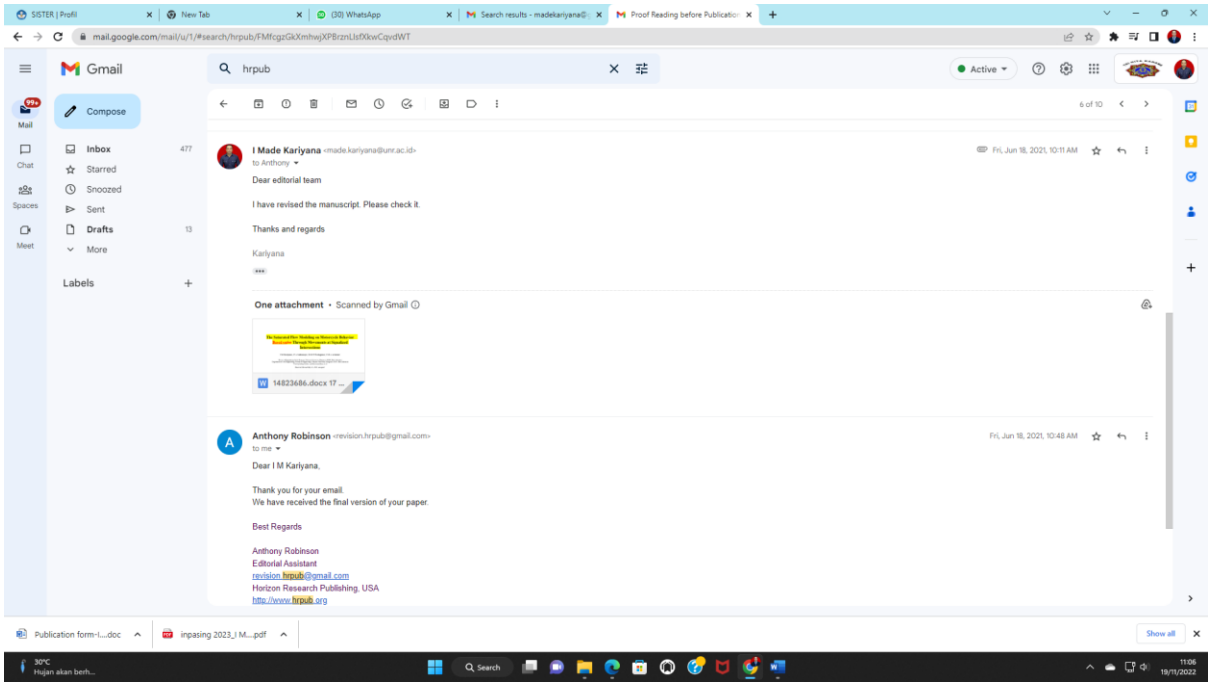
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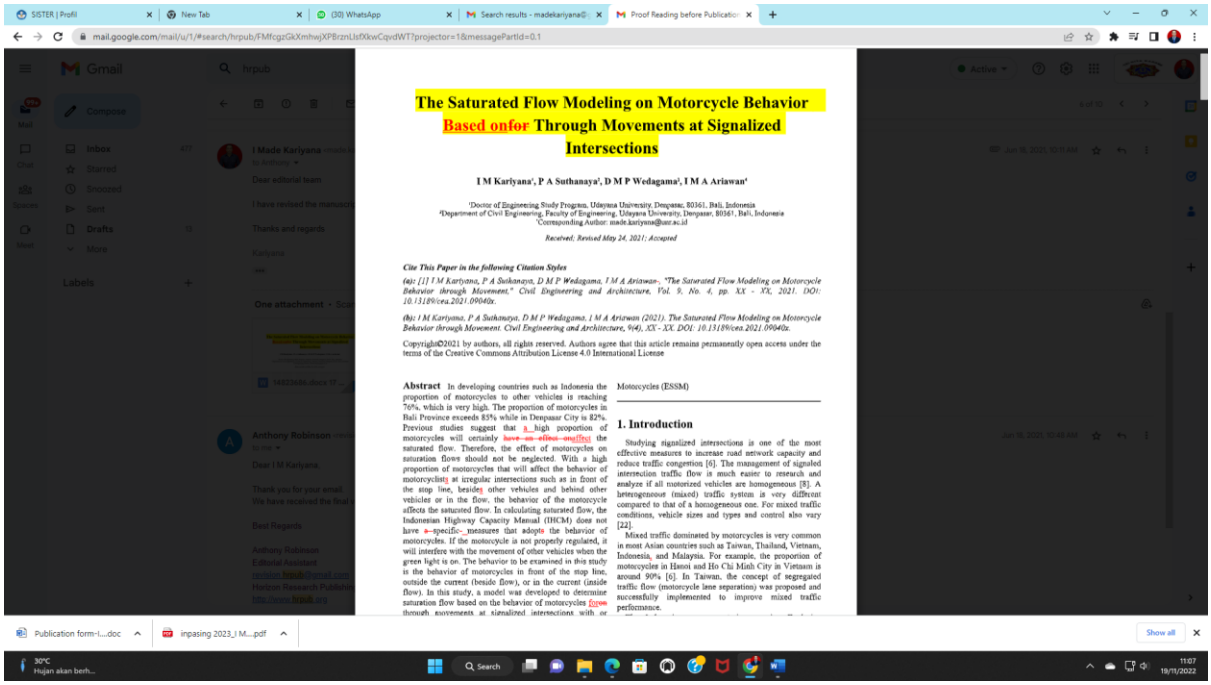

The Saturated Flow Modeling on Motorcycle Behavior Based onfor Through Movements at Signalized Intersections

I M Kariyana[1], P A Suthanaya[2], D M P Wedagama[2], I M A Ariawan[2]

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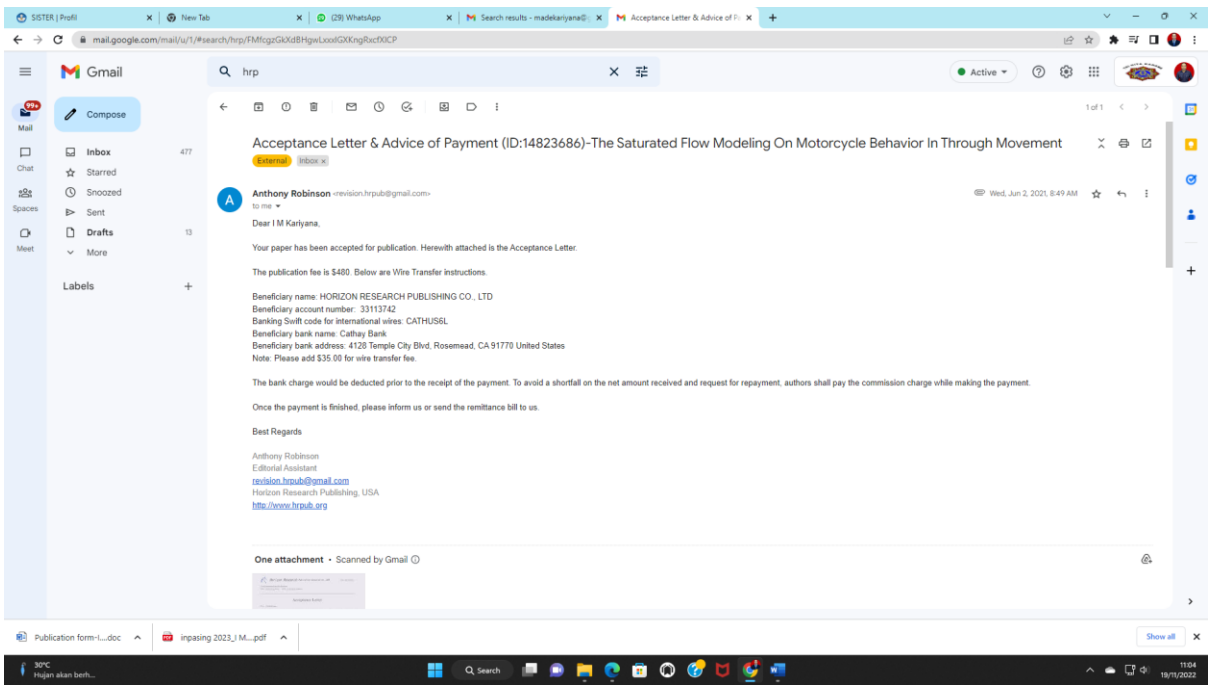
Abstract In developing countries such as Indonesia the proportion of motorcycles to other vehicles is reaching 76%, which is very high. The proportion of motorcycles in Bali Province exceeds 85% while in Denpasar City is 82%. Previous studies suggest that a high proportion of motorcycles will certainly ~~have an effect on~~affect the saturated flow. Therefore, the effect of motorcycles on saturation flows should not be neglected. With a high proportion of motorcycles that will affect the behavior of motorcyclists at irregular intersections such as in front of the stop line, besides other vehicles and behind other vehicles or in the flow, the behavior of the motorcycle affects the saturated flow. In calculating saturated flow, the Indonesian Highway Capacity Manual (IHCM) does not have a specific measures that adopts the behavior of motorcycles. If the motorcycle is not properly regulated, it will interfere with the movement of other vehicles when the green light is on. The behavior to be examined in this study is the behavior of motorcycles in front of the stop line, outside the current (beside flow), or in the current (inside flow). In this study, a model was developed to determine saturation flow based on the behavior of motorcycles ~~from~~ through movements at signalized intersections with or Motorcycles (ESSM)

1. Introduction

Studying signalized intersections is one of the most effective measures to increase road network capacity and reduce traffic congestion [6]. The management of signaled intersection traffic flow is much easier to research and analyze if all motorized vehicles are homogeneous [8]. A heterogeneous (mixed) traffic system is very different compared to that of a homogeneous one. For mixed traffic conditions, vehicle sizes and types and control also vary [22].

Mixed traffic dominated by motorcycles is very common in most Asian countries such as Taiwan, Thailand, Vietnam, Indonesia, and Malaysia. For example, the proportion of motorcycles in Hanoi and Ho Chi Minh City in Vietnam is around 90% [6]. In Taiwan, the concept of segregated traffic flow (motorcycle lane separation) was proposed and successfully implemented to improve mixed traffic performance.



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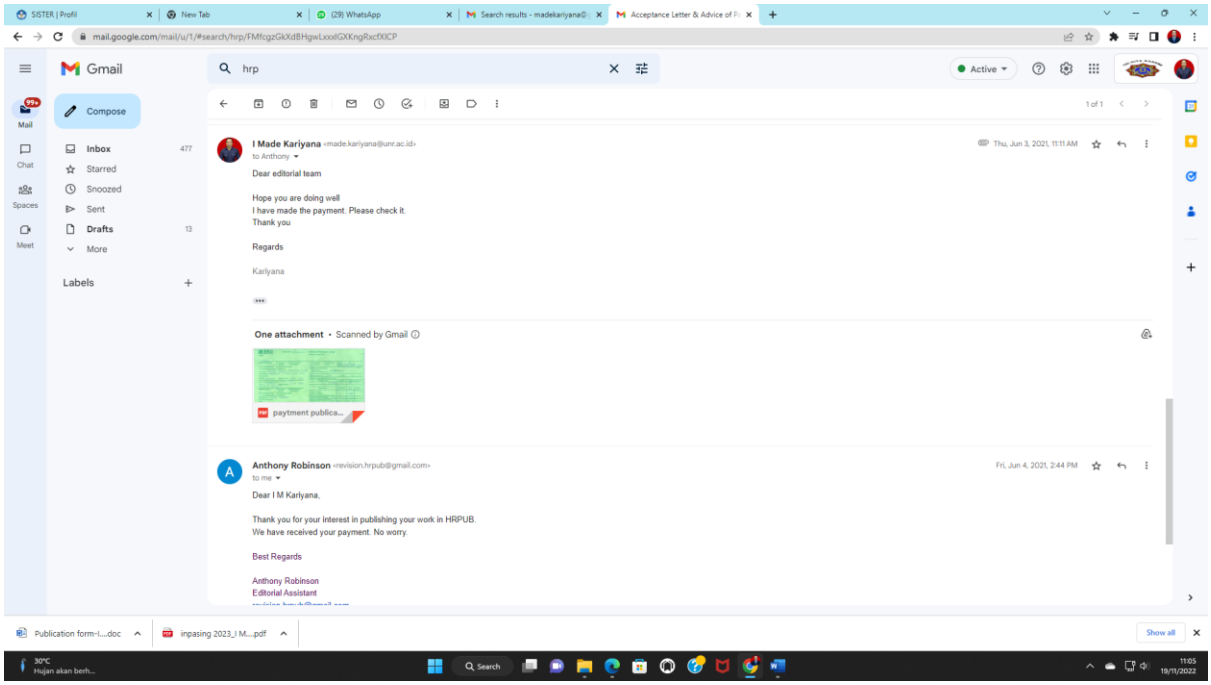
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The Saturated Flow Modeling On Motorcycle Behavior In Through Movement

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Abstract In developing countries such as Indonesia the proportion of motorcycles to other vehicles is reaching 76%, which is very high. The proportion of motorcycles in Bali Province exceeds 85% while in Denpasar City is 82%. Previous studies suggest that high proportion of motorcycles will certainly have an effect on the saturated flow. Therefore, the effect of motorcycles on saturation flows should not be neglected. With a high proportion of motorcycles that will affect the behavior of motorcyclist. at irregular intersections such as in front of the stop line, beside other vehicles and behind other vehicles or in the flow, the behavior of the motorcycle affects the saturated flow. In calculating saturated flow, the Indonesian Highway Capacity Manual (IHCM) does not have a specific-measures that adopts the behavior of motorcycles. If the motorcycle is not properly regulated, it will interfere with the movement of other vehicles when the green light is on. The behavior to be examined in this study is the behavior of motorcycles in front of the stop line, outside the current (beside flow), or in the current (inside flow). In this study, a model was developed to determine saturation flow based on the behavior of motorcycles on through movements at signalized intersections with or without ESSM.

Keywords Motorcycles behavior, Saturation flow, signalized intersections, exclusive stopping space for motorcycles (ESSM).

1. Introduction

Study of signalized intersections is one of the most effective measures to increase road network capacity and reduce traffic congestion [6]. The management of signaled intersection traffic flow is much easier to research and analyze if all motorized vehicles are homogeneous [8]. Mixed traffic dominated by motorcycles is very common in most Asian countries such as Taiwan, Thailand, Vietnam, Indonesia and Malaysia. For example, the proportion of motorcycles in Hanoi and Ho Chi Minh City in Vietnam is around 90% [6]. In Taiwan, the concept of segregated traffic flow (motorcycle lane separation) was proposed and successfully implemented to improve mixed traffic performance.

The Indonesian government is preparing Exclusive Stopping Space for Motorcycle (ESSM) at several signalized intersections, to accommodate the high number of motorcycles. ESSM is a motorcycle facility in the form of providing motorcycle facilities at signalized intersections. ESSM is an alternative solution to the problem of motorcycle congestion at signalized intersections. When entering the green time signal, motorcycles move with various maneuvers to get out of the approach to the intersection, so that it often creates traffic conflicts which are thought to affect the performance and flow of traffic movements at the intersection [12].

A better understanding of the impact of motorcycles on traffic flow affects the development of a more accurate model to determine the effect of motorcycles on saturated flow [6]. Saturation flow plays an important role in the design of a signalized intersection [18]. The saturation flow (S) is the amount of queue departure in an approach during the specified conditions (pcu/green hour). Meanwhile, the basic saturation flow is the amount of queue departure in the approach during ideal conditions (pcu/green hour) [13].

As a reference for determining intersection parameters such as saturated flow and capacity in Indonesia, the Indonesian Highway Capacity Manual (IHCM) was published in 1997. In 1997, the composition of motorcycles for urban areas in Indonesia was at the average of 40.5% [13], which is very different from the current condition. It was found that based on the preliminary survey, the composition of motorcycles in Denpasar City was 82%. Although Indonesian urban areas clearly have a high percentage of motorcycles, there has been no adjustment to IHCM regarding the high percentage of motorcycles, the number of vehicle ownership and the behavior of motorcycles in Indonesia. The IHCM determines the saturation flow based on the basic saturation flow times the adjustment factor. Besides that, the passenger car equivalent (PCE) value also does not reflect the real conditions in the field. The PCE

value has been determined such as the PCE for motorcycle is 0.2, the PCE for light vehicle is 1 and the PCE for heavy vehicle is 1.3, without any PCE analysis at each intersection studied. Improper regulation of motorcycles, especially at intersections, will not only reduce the level of service at intersections, but may also lead to an increase in road traffic accidents.

The behavior of the motorcycle users at a signalized intersection has affected saturated flows, especially motorcycles in the current (inside flow), the greater the composition of the motorcycle in the flow, the higher the saturation flow [11]. According to the [9,14,16,], the behavior of motorcycles at signalized intersections can be grouped into several categories, namely motorcycles in front of the stop line, motorcycles in the current (inside flow), and motorcycles outside the current (beside flow). This study examines the behavior of motorcycles towards saturated flow on through movements because in Denpasar City for large traffic flows, the arrangement of intersections with more signals is through movement to reduce conflict at signalized intersections. Through movements are free movements that are not affected by conflict [18,19] while according to [2,20] through movements are movements (turn right, go straight, turn left) in each approach that is given the green light simultaneously, and given 1 phase per approach so that vehicles turning right do not have to wait to enter opposite traffic. In this study, what is meant by through movement is the movement of traffic at an intersection approach that has 1 phase or an intersection whose approach has the same phase as other approaches but the movement does not affect or be influenced by the movements of other approaches.

The study of traffic flow at signalized intersections is a new topic, several studies have been conducted to examine saturated flow and capacity aimed at improving traffic conditions at signalized intersections or across the transportation network. However, from previous research, no one has determined the influence model of motorcycle behavior at signalized intersections, namely the behavior of motorcycles in front of the stop line, inside flow (inside flow) and outside flow (beside flow), both those with ESSM and without ESSM to saturated flows. Motorcycle behavior research conducted in Malaysia by Leong et al. [11] and in Ghana by Adams et al. [1] only analyzed the effect of motorcycle behavior in the flow (inside flow) without analyzing the behavior of motorcycles in front of the stop line and outside the flow (beside flow) and also does not analyze the differences in behavior at the signalized intersections that have ESSM or without ESSM. There are also many researches related to ESSM, such as research by [3-7], but no research has analyzed the effect of motorcycle behavior with and without ESSM on saturation flow. Most of the studies only examined the effectiveness of ESSM from the level of ESSM filling and the effect of motorcycles (total motorcycles) on saturated flows, not on motorcycle behavior. Research on the behavior of motorcycles at signalized intersections is important to determine policies related to regulating motorcycles at signalized intersections, such as designing the ESSM, making separate lanes between motorcycles and other vehicles and setting traffic lights. In this research, a model of motorcycle behavior towards saturated flow was developed, both with and without ESSM.

2. Materials and Methods

The regression method is more relevant for the estimation of PCE at signalized intersections because its implementation of calculations is easier and simpler. However, this technique relies heavily on accurate estimation of saturation flow which is also a function of determining PCE [15]. In order to obtain an accurate saturation flow estimation, the method of determining the saturation flow at signalized intersections in this study is used from Chang and Xiao [5]. Traditional methods that only use the average discharge headway to estimate the saturation headway can lead to underestimation. Errors in the saturated flow used for the estimation of vehicle delays can cause errors in the prediction of delay and Level of Service (LOS). Therefore, it is necessary to conduct a study to increase the accuracy of the saturation flow estimation. The facts show that driver behavior is the main determinant of saturation flow, therefore a good understanding of the time between discharge headways is essential in estimating the time between saturation headway and saturation flow rate. The stochastic properties of the time between vehicle releases could provide better information for the development of a method of estimating saturation flow rates [5]. It is easy to understand that the time between vehicle releases is a random variable due to differences in driver behavior response times and variations in queue space length. To estimate the saturation headway time, the average time between vehicle releases is calculated as follows:

$$\bar{h}_S = \frac{1}{n}\sum_{i=1}^{n} h_{si} \qquad (1)$$

With,

h: the average time between discharges (s) which is taken as the estimated time between saturations h;

h_{si}: time between vehicles i in queue, i = 1, 2,.., n (n is the sample size), consequently, the level of saturation flow is (conventionally) determined by the time between discharge:

$$S = \frac{3600}{\bar{h}_S} \qquad (2)$$

With,

S is the saturation flow level (vehicle / hour).

Based on the statistical theory that: If the intermediate time distribution is symmetric, The average intermediate time calculated by equation (1) is a good (unbiased) estimate of h and equation (2) can be a good estimate for the saturation flow rate [14]. However, if the intermediate time distribution is not symmetrical, hs is not a good

estimate and equation (2) will give a saturation flow level value that is too high (overestimate) or too low (underestimate). Therefore, it is necessary to study the stochastic nature of the time between queuing vehicles and to analyze the effect of time variation between the estimated saturation flow rates [5].

When the mean time between queue releases is greater than the median value and the skewness of the intermediate time values is positive, this characteristic indicates that the time distribution between queues releases tends to be asymmetrical and the normal distribution function does not match the intermediate time data [5]. Therefore, the conventional saturation flow rate estimation method (equation 2) can produce an underestimated saturation flow level value.

If the time distribution between queue releases tends to be asymmetrical, then the intermediate time value can be modeled with a lognormal distribution [5,17] If it is known that when the random variable hs function density is lognormal, then ln hs will follow the normal distribution. Therefore, it is very relevant to use the median value to calculate the saturation flow rate in the following way:

$$S_1 = 3600 \times \frac{1}{h_{med}} \qquad (3)$$

With,
S_1: new estimate of the saturation flow rate (vehicles/hour);
h_{med}: the median value of the intermediate time or the estimated median value of the intermediate time.

In addition, there are two new estimates for the saturation flow rate [14]

$$S_2 = 3600 \times \exp\left(-\frac{1}{n} \sum_{i=1}^{n} \ln h_{si} \right) \qquad (4)$$

$$S_3 = \frac{3600}{\bar{h}_s} \times \left(1 + \frac{{\sigma_s}^2}{{\bar{h}_s}^2} \right)^{0.5} \qquad (5)$$

With,
S_2 and S_3 are two new estimates of the saturation flow rate (vehicles / hour).
$\sigma_s^2 = \left[\frac{1}{n} - 1 \cdot \sum_{i=1}^{n} \left(h_{si} - \bar{h}_s \right)^2 \right]$ represents the variance of the intermediate time sample

The location of the selected intersection is one that has a large volume of motorcycles, namely 82 percent [4], minor side barriers, namely interference from factors such as pedestrians, vehicles turning left or right, parking vehicles (on street parking) and bus stops or stops, both those with ESSM and those without ESSM at one of the intersection approaches. The intersection chosen is also one of the approaches that has a through movement of motorcycles or is not affected by conflict, whether there is an ESSM or no ESSM.

This study was conducted in Denpasar City. Based on data obtained from the Denpasar City Department of Transportation, Denpasar City has 66 intersections with signals, of which 15 intersections have Exclusive Stopping Space for Motorcycle and 51 intersections have no ESSM [10]. For the purposes of the analysis, an approach has been chosen at the four signalized intersections which have approximately the same volume of vehicles passing through the intersection, The same approach width and has the proportion of motorcycles that reflect the same mixed traffic flow conditions between the existing ESSM and those without the ESSM as in Table 1. Headway data is obtained from video recordings of the Denpasar City Area Traffic Control System (ATCS), data retrieval is carried out at peak hours in the morning, afternoon and evening for 2.5 hours per each busy hour.

Table 1. Intersections with the same Approach Width and Traffic Characteristics

No.	Approach Width (m)	Intersection		Approach	
		With ESSM	Without ESSM	With ESSM	Without ESSM
1	7	Dewi Sartika Dewi Sartika	Kebo Iwa Kebo Iwa	Dewi Sartika Teuku Umar	Gatot Subroto Barat (T) Gatot Subroto Barat (B)
2	5	Kapten Japa Kapten Japa	Saelus Surabi Kenyeri	Hayam Wuruk (T) Hayam Wuruk (B)	Diponegoro (S) Supratman (B) Gatot Subroto Tengah (B)
3	3	Nangka Unud	Perumnas Saelus	Nangka (U) Serma Mendra	Buana Raya Pulau Saelus

3. Results and Discussion

Headway data were obtained from the Denpasar City Area Traffic Control System (ATCS) video recordings, which include 9440 headway data for an approach with an effective width of 3 meters with ESSM and 10833 without ESSM. Headway data from the approach of the effective width of 5 meters with ESSM as much as 14161 and without ESSM 19667 data. Headway data from the approach of the effective width of 7 meters with ESSM as much as 14002 and without ESSM 14932 data. Headway data from each approach were combined into one for each approach width, both with ESSM and without ESSM to get the saturated flow value.

In Table 2, it can be seen that the proportion of vehicles in each approach with an approach width of 3 meters, 5 meters and 7 meters, both with ESSM and without ESSM.

Based on Table 2, the percentage of the proportion of motorcycles is relatively the same as the 1-2 percent difference between the approach with ESSM and without ESSM except for the 3 meters width of the approach, there is a difference of 5.6% of the approach without ESSM, the greater the percentage of motorcycles compared to those with ESSM approach.

Table 2. Percentage of proportion of vehicles in each approach with and without ESSM

Approach Width		Vehicle		
		Motor cycle	Light Vehicle	High Vehicle
3m	Non ESSM	90,36	8,79	0,85
	ESSM	84,76	14,66	0,59
5m	Non ESSM	82,09	16,11	1,80
	ESSM	81,60	17,99	0,41
7m	Non ESSM	78,74	19,40	1,86
	ESSM	76,78	22,62	0,61

Meanwhile, the percentage of motorcycle behaviour in each approach, both with ESSM and without ESSM, is as shown in Table 3. Based on Table 3, motorcycles at a signalized intersection tend to behave beside flow (beside other vehicles), both those with ESSM and without ESSM, this happens because motorcycles has more freedom to maneuverer because there are no light vehicles in front of them. The percentage of the behaviour of motorcycles beside flow is greater than inside flow at a signalized intersection with ESSM, whether the approach width is 3 meters, 5 meters or 7 meters.

Table 3. Percentage of motorcycle behaviour of each approach with and without ESSM

Approach Width		Motorcycle Behaviour		
		Infront of stop line	Beside flow	Inside flow
3m	Non ESSM	3,06	75,45	22,24
	ESSM	1,61	79,54	19,18
5m	Non ESSM	1,87	50,20	48,86
	ESSM	1,46	65,62	33,43
7m	Non ESSM	4,03	55,20	42,58
	ESSM	0,42	57,16	42,61

Furthermore, the headway data analysis was carried out in SPSS descriptively as well as knowing the form of data distribution. The purpose of this analysis is to see whether the data distribution patterns are normally distributed or not. The form of data distribution can be determined through statistical calculations with the Shapiro-Wilk or Kolmogorov Smirnov approach. The data of less than 50 uses the Shapiro Wilk approach, while those more than 50 use the Kolmogorov-Smirnov. The data is said to be normally distributed if the Sig. from the test statistic is greater than 0.05.

Data with normal distribution were calculated to obtain the saturation flow with the Formula 2, while data that were not normally distributed, were calculated using the Formula (3, 4, 5). Based on the observations on the saturation flow values at S1, S2, and S3, the saturation flow values are almost the same. This result is also confirmed by [10] who simulated the calculations using the S1, S2, and S3 formula approaches. Based on the results of this analysis, a similar saturation flow value is obtained, so it can be concluded that the S1, S2, or S3 values can be selected for use by the researcher.

This study uses the S3 formula for data that is not normally distributed, because the S3 formula is the final development of the previous formula and in the formula accommodates the size of centre (mean) and data distribution (variance).

After the S value is obtained based on the various criteria above, then a behavioural analysis of the saturation flow is carried out. The analysis is divided into two, namely as a whole (behaviour of motorcycles inside flow, Infront of stop line, and beside flow) to saturated flow and their respective behaviour by ignoring other behaviours (behaviour of Infront motorcycles to saturated flow, behaviour of motorcycles beside saturated flow and the behaviour of the inside motorcycle to saturated flow). The model obtained is then evaluated based on the value of its fit model using the R-Square approach and F-count (F significance). A model whose fit model is good, deserves to be interpreted, while a model whose fit model is still weak is considered not feasible. For the model of the influence of behaviour individually by ignoring other behaviours, a model is obtained as shown in Figure 1.

The regression model at a signalized intersection with an approach width of 3 meters without ESSM or with partial ESSM by only taking into one behavior and ignoring other behaviors, it is found that the behavior of infront of stop line, inside flow and beside flow has an effect on saturated flow. The regression model at a signalized intersection with an approach width of 5 meters without ESSM shows only that the behavior of the infront of stop line and beside has an effect on saturated currents, while the width of the approach of 5 meters with ESSM shows that only the behavior of the infront of stop line and inside flow has an effect on saturated flow. The regression model at a signalized intersection with an approach width of 7 meters without ESSM shows only that the behavior of infront of stop line and beside has an effect on saturated currents, while the width of the approach of 7 meters with ESSM shows that only inside flow has an effect on the flow.

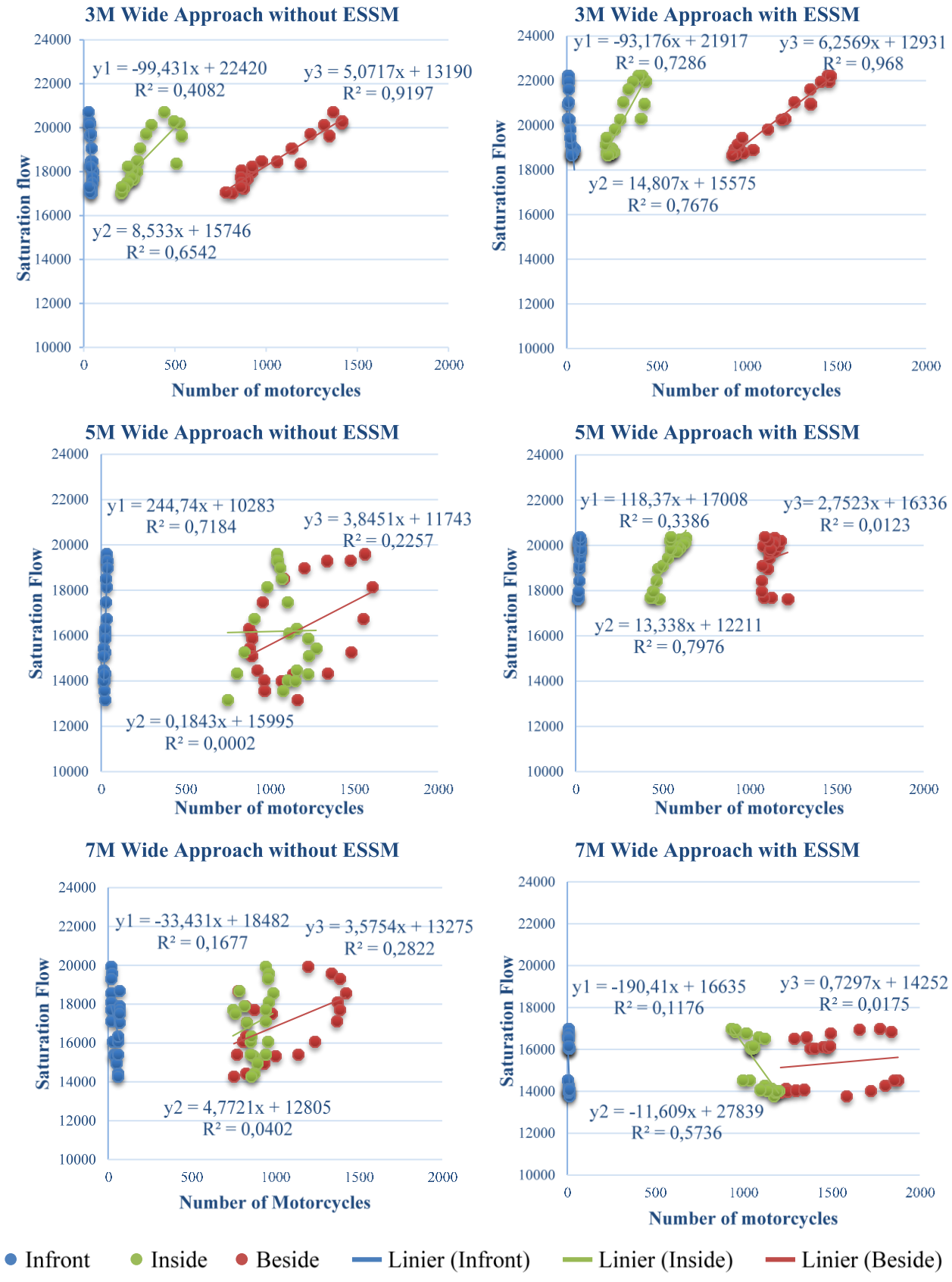

Figure 1. The model of the influence of each motorcycle behaviour on saturated flow ignores the influence of other behaviours

To show the relationship between the effect of motorcycle behaviour on saturated flow together with an approach width of 3 meters, 5 meters and 7 meters without ESSM, it is shown in Table 4. Meanwhile, to show the relationship between the effect of motorcycle behaviour on saturated flow together with the approach width 3 meters, 5 meters and 7 meters with ESSM are shown in Table 5.

The regression model at the intersection with a signal with an approximate width of 3 meters without ESSM taking into account all behaviors in the analysis (Infront of stop line, inside flow and beside flow) The regression analysis model in Non ESSM 3 produces a goodness of fit value with the R-Square approach of 0.945 and the significance of F is 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.945, it indicates that there is an effect of motorcycle behavior on saturation flow of 95.5%, while the remaining 4.5% is influenced by other factors outside the three independent variables at the intersection with a signal without ESSM with an approach width of 3 meters. Partially, a significance value is obtained at the Infront of 0.378, which means that there is no influence on the behavior of motorcycles in front of the stop line on saturated flow, but it is different with beside flow and inside flow, which respectively get a significance value of 0.000 and 0.013 where beside and inside contributes a significant effect on saturation flows at the intersection with no ESSM signal with a width of 3 meters.

The regression model at the intersection with a 3 meters wide approach with ESSM produces a goodness of fit value with the R-Square approach of 0.945 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.972, it indicates that there is an effect of motorcycle behavior on saturation flow of 97.2%, while the rest is influenced by other factors outside the three independent variables.

Table 4. Model of influence of motorcycle behaviour at signalized intersections without ESSM

Statistics	Non ESSM 3	Non ESSM 5	Non ESSM 7
Model	Y=11814.28 + 11.50 X1+ 7.24X2– 4.18X3	Y= -1070.22+ 279.29X1 + 1.50X2 – 8.23X3	Y=34296.55 -46.89X1 + 5.40X2– 23.61X3
R-Squared	0.945	0.915	0.464
Sig. F	0.000	0.000	0.012
Constant	11814.28	-1070.22	24296.55
Uns. Coeff.	Infront:11.50 Beside: 7.24 Inside: -4.18	Infront: 279.29 Beside: 1.50 Inside: 8.23	Infront:46.89 Beside: 5.40 Inside: 23.61
Sig. t	Infront: 0.378 Beside: 0.000 Inside: 0.013	Infront: 0.000 Beside: 0.117 Inside: 0.000	Infront: 0.549 Beside: 0.206 Inside: 0.084

Table 5. Model of influence of motorcycle behaviour at signalized intersections with ESSM

Statistics	ESSM 3	ESSM 5	ESSM 7
Model	Y=12638.69 +0.85X1+ 7.17X2 – 2.52X3	Y= 12771.15 + 63.75X1– 1.05X2 – 12.04X3	Y= 34510.09 + 26.10X1 -2.11X2– 15.00X3
R-Squared	0.972	0.901	0.676
Sig. F	0.000	0.000	0.000
Constant	12638.69	12771.15	34510.09
Uns. Coeff.	Infront:0.85 Beside: 7.17 Inside: -2.52	Infront: 63.75 Beside: -1.05 Inside: 12.04	Infront:46.89 Beside: 5.40 Inside: 23.61
Sig. t	Infront: 0.927 Beside: 0.000 Inside: 0.158	Infront: 0.003 Beside: 0.652 Inside: 0.000	Infront: 0.755 Beside: 0.034 Inside: 0.000

Partially, a significance value is obtained for the Infront of 0.927 and the inside flow of 0.158, which means that there is no influence on the behavior of motorcycles in the Infront of stop line and inside flow on saturated flow, However, it is different with beside flow, obtaining a significance value of 0.000, where beside contributes a significant effect on saturated flow at a signalized intersection with ESSM with a 3 meters wide approach. The regression model at a signalized intersection with an approximate width of 5 meters without ESSM results in a goodness of fit value with the R-Square approach of 0.915 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.915, it indicates that there is an influence of motorcycle behavior on saturation flow of 91.5%, while the rest is influenced by other factors outside the three independent variables. Partially, it is obtained a significance value beside flow of 0.117 which means there is no influence of the behavior of motorcycles beside flow on saturated flow, However, in contrast to the infront of stop line and inside flow, it obtained a significance value of 0.000 where the infront of stop line and inside flow contributed significantly to the saturated flow at the signalized intersection without ESSM with an approach width of 3 meters.

The regression model at the signalized intersection with an

approximate width of 5 meters with ESSM produces a goodness of fit value with the R-Square approach of 0.901 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.901, it indicates that there is an influence of motorcycle behavior on saturation flow of 90.1%, while the rest is influenced by other factors outside the three independent variables. Partially, it is obtained a significance value beside flow of 0.652, which means that there is no influence of the behavior of motorcycles beside flow on saturated flow, However, in contrast to the infront of stop line and inside flow, it has a significance value of 0.003 and 0.000 where the infront of stop line and inside flow have a significant effect on saturated flow at the signalized intersection with ESSM with a 5 meters wide approach.

The regression model at the signalized intersection with an approach width of 7 meters without ESSM results in a goodness of fit value with the R-Square approach of 0.464 and a significance of F of 0.012. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.464, it indicates that there is an effect of motorcycle behavior on saturated flow of 46.4%, while the rest is influenced by other factors outside the three independent variables. Partially, the significant values of infront of stop line, beside flow and inside flow are obtained, respectively 0.549, 0.206 and 0.084, which means that there is no influence on the behavior of motorcycles, infront of stop line, beside flow and inside flow separately.

The regression model at a signalized intersection with an approximate width of 7 meters with ESSM produces a goodness of fit value with the R-Square approach of 0.464 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.676, it indicates that there is an effect of motorcycle behaviour on saturated flow of 67.6%, while the rest is influenced by other factors outside the three independent variables. Partially, the Infront of stop line significance value is 0.755, which means that there is no effect of the behaviour of motorcycles in front of the stop line on saturated flows, However, it is different with beside flow and inside flow, obtaining a significance value of 0.034 and 0.000 where beside flow and inside flow have a significant effect on saturated flow at the signalized intersection with ESSM with a 7 meters wide approach.

4. Conclusion

This model of the effect of saturated flow on motorcycle behavior applies to through movement with traffic conditions dominated by motorcycles, the percentage of motorcycles is 76% to 90% and the effective width of the approach is 3 meters, 5 meters, and 7 meters with or without ESSM. The model generated from the regression analysis of the influence of motorcycle behavior (infront of stop line, beside flow and inside flow) together produces a better model than the model obtained from the regression analysis separately, namely the effect of the behavior of motorcycles on the infont of stop line on saturated flow, the effect of the behavior of motorcycles beside flow on saturated flow and the influence of the behavior of motorcycles inside flow on saturated flow.

By knowing the behavior of motorcycles at a signalized intersection with an approach width of 3 meters, 5 meters, 7 meters with or without ESSM, the saturation flow can be determined without counting the number of light or heavy vehicles, especially for the 3 and 5 meter approach widths.Further research is needed with conditions like this in other cities, so that better results can be obtained.

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The Saturated Flow Modeling On Motorcycle Behavior In Through Movement

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Abstract In developing countries such as Indonesia the proportion of motorcycles to other vehicles is reaching 76%, which is very high. The proportion of motorcycles in Bali Province exceeds 85% while in Denpasar City is 82%. Previous studies suggest that high proportion of motorcycles will certainly have an effect on the saturated flow. Therefore, the effect of motorcycles on saturation flows should not be neglected. With a high proportion of motorcycles that will affect the behavior of motorcyclist. at irregular intersections such as in front of the stop line, beside other vehicles and behind other vehicles or in the flow, the behavior of the motorcycle affects the saturated flow. In calculating saturated flow, the Indonesian Highway Capacity Manual (IHCM) does not have a specific-measures that adopts the behavior of motorcycles. If the motorcycle is not properly regulated, it will interfere with the movement of other vehicles when the green light is on. The behavior to be examined in this study is the behavior of motorcycles in front of the stop line, outside the current (beside flow), or in the current (inside flow). In this study, a model was developed to determine saturation flow based on the behavior of motorcycles on through movements at signalized intersections with or without ESSM.

Keywords Motorcycles behavior, Saturation flow, signalized intersections, exclusive stopping space for motorcycles (ESSM).

1. Introduction

Study of signalized intersections is one of the most effective measures to increase road network capacity and reduce traffic congestion [6]. The management of signaled intersection traffic flow is much easier to research and analyze if all motorized vehicles are homogeneous [8]. Mixed traffic dominated by motorcycles is very common in most Asian countries such as Taiwan, Thailand, Vietnam, Indonesia and Malaysia. For example, the proportion of motorcycles in Hanoi and Ho Chi Minh City in Vietnam is around 90% [6]. In Taiwan, the concept of segregated traffic flow (motorcycle lane separation) was proposed and successfully implemented to improve mixed traffic performance.

The Indonesian government is preparing Exclusive Stopping Space for Motorcycle (ESSM) at several signalized intersections, to accommodate the high number of motorcycles. ESSM is a motorcycle facility in the form of providing motorcycle facilities at signalized intersections. ESSM is an alternative solution to the problem of motorcycle congestion at signalized intersections. When entering the green time signal, motorcycles move with various maneuvers to get out of the approach to the intersection, so that it often creates traffic conflicts which are thought to affect the performance and flow of traffic movements at the intersection [12].

A better understanding of the impact of motorcycles on traffic flow affects the development of a more accurate model to determine the effect of motorcycles on saturated flow [6]. Saturation flow plays an important role in the design of a signalized intersection [18]. The saturation flow (S) is the amount of queue departure in an approach during the specified conditions (pcu/green hour). Meanwhile, the basic saturation flow is the amount of queue departure in the approach during ideal conditions (pcu/green hour) [13].

As a reference for determining intersection parameters such as saturated flow and capacity in Indonesia, the Indonesian Highway Capacity Manual (IHCM) was published in 1997. In 1997, the composition of motorcycles for urban areas in Indonesia was at the average of 40.5% [13], which is very different from the current condition. It was found that based on the preliminary survey, the composition of motorcycles in Denpasar City was 82%. Although Indonesian urban areas clearly have a high percentage of motorcycles, there has been no adjustment to IHCM regarding the high percentage of motorcycles, the number of vehicle ownership and the behavior of motorcycles in Indonesia. The IHCM determines the saturation flow based on the basic saturation flow times the adjustment factor. Besides that, the passenger car equivalent (PCE) value also does not reflect the real conditions in the field. The PCE

value has been determined such as the PCE for motorcycle is 0.2, the PCE for light vehicle is 1 and the PCE for heavy vehicle is 1.3, without any PCE analysis at each intersection studied. Improper regulation of motorcycles, especially at intersections, will not only reduce the level of service at intersections, but may also lead to an increase in road traffic accidents.

The behavior of the motorcycle users at a signalized intersection has affected saturated flows, especially motorcycles in the current (inside flow), the greater the composition of the motorcycle in the flow, the higher the saturation flow [11]. According to the [9,14,16,], the behavior of motorcycles at signalized intersections can be grouped into several categories, namely motorcycles in front of the stop line, motorcycles in the current (inside flow), and motorcycles outside the current (beside flow). This study examines the behavior of motorcycles towards saturated flow on through movements because in Denpasar City for large traffic flows, the arrangement of intersections with more signals is through movement to reduce conflict at signalized intersections. Through movements are free movements that are not affected by conflict [18,19] while according to [2,20] through movements are movements (turn right, go straight, turn left) in each approach that is given the green light simultaneously, and given 1 phase per approach so that vehicles turning right do not have to wait to enter opposite traffic. In this study, what is meant by through movement is the movement of traffic at an intersection approach that has 1 phase or an intersection whose approach has the same phase as other approaches but the movement does not affect or be influenced by the movements of other approaches.

The study of traffic flow at signalized intersections is a new topic, several studies have been conducted to examine saturated flow and capacity aimed at improving traffic conditions at signalized intersections or across the transportation network. However, from previous research, no one has determined the influence model of motorcycle behavior at signalized intersections, namely the behavior of motorcycles in front of the stop line, inside flow (inside flow) and outside flow (beside flow), both those with ESSM and without ESSM to saturated flows. Motorcycle behavior research conducted in Malaysia by Leong et al. [11] and in Ghana by Adams et al. [1] only analyzed the effect of motorcycle behavior in the flow (inside flow) without analyzing the behavior of motorcycles in front of the stop line and outside the flow (beside flow) and also does not analyze the differences in behavior at the signalized intersections that have ESSM or without ESSM. There are also many researches related to ESSM, such as research by [3-7], but no research has analyzed the effect of motorcycle behavior with and without ESSM on saturation flow. Most of the studies only examined the effectiveness of ESSM from the level of ESSM filling and the effect of motorcycles (total motorcycles) on saturated flows, not on motorcycle behavior. Research on the behavior of motorcycles at signalized intersections is important to determine policies related to regulating motorcycles at signalized intersections, such as designing the ESSM, making separate lanes between motorcycles and other vehicles and setting traffic lights. In this research, a model of motorcycle behavior towards saturated flow was developed, both with and without ESSM.

2. Materials and Methods

The regression method is more relevant for the estimation of PCE at signalized intersections because its implementation of calculations is easier and simpler. However, this technique relies heavily on accurate estimation of saturation flow which is also a function of determining PCE [15]. In order to obtain an accurate saturation flow estimation, the method of determining the saturation flow at signalized intersections in this study is used from Chang and Xiao [5]. Traditional methods that only use the average discharge headway to estimate the saturation headway can lead to underestimation. Errors in the saturated flow used for the estimation of vehicle delays can cause errors in the prediction of delay and Level of Service (LOS). Therefore, it is necessary to conduct a study to increase the accuracy of the saturation flow estimation. The facts show that driver behavior is the main determinant of saturation flow, therefore a good understanding of the time between discharge headways is essential in estimating the time between saturation headway and saturation flow rate. The stochastic properties of the time between vehicle releases could provide better information for the development of a method of estimating saturation flow rates [5]. It is easy to understand that the time between vehicle releases is a random variable due to differences in driver behavior response times and variations in queue space length. To estimate the saturation headway time, the average time between vehicle releases is calculated as follows:

$$\bar{h}_S = \frac{1}{n}\sum_{i=1}^{n} h_{si} \qquad (1)$$

With,

h: the average time between discharges (s) which is taken as the estimated time between saturations h;

h_{si}: time between vehicles i in queue, i = 1, 2,.., n (n is the sample size), consequently, the level of saturation flow is (conventionally) determined by the time between discharge:

$$S = \frac{3600}{\bar{h}_S} \qquad (2)$$

With,

S is the saturation flow level (vehicle / hour).

Based on the statistical theory that: If the intermediate time distribution is symmetric, The average intermediate time calculated by equation (1) is a good (unbiased) estimate of h and equation (2) can be a good estimate for the saturation flow rate [14]. However, if the intermediate time distribution is not symmetrical, hs is not a good

estimate and equation (2) will give a saturation flow level value that is too high (overestimate) or too low (underestimate). Therefore, it is necessary to study the stochastic nature of the time between queuing vehicles and to analyze the effect of time variation between the estimated saturation flow rates [5].

When the mean time between queue releases is greater than the median value and the skewness of the intermediate time values is positive, this characteristic indicates that the time distribution between queues releases tends to be asymmetrical and the normal distribution function does not match the intermediate time data [5]. Therefore, the conventional saturation flow rate estimation method (equation 2) can produce an underestimated saturation flow level value.

If the time distribution between queue releases tends to be asymmetrical, then the intermediate time value can be modeled with a lognormal distribution [5,17] If it is known that when the random variable hs function density is lognormal, then ln hs will follow the normal distribution. Therefore, it is very relevant to use the median value to calculate the saturation flow rate in the following way:

$$S_1 = 3600 \times \frac{1}{h_{med}} \qquad (3)$$

With,

S_1: new estimate of the saturation flow rate (vehicles/hour);

h_{med}: the median value of the intermediate time or the estimated median value of the intermediate time.

In addition, there are two new estimates for the saturation flow rate [14]

$$S_2 = 3600 \times \exp\left(-\frac{1}{n} \sum_{i=1}^{n} \ln h_{si} \right) \qquad (4)$$

$$S_3 = \frac{3600}{\bar{h}_s} \times \left(1 + \frac{{\sigma_s}^2}{{\bar{h}_s}^2} \right)^{0.5} \qquad (5)$$

With,

S_2 and S_3 are two new estimates of the saturation flow rate (vehicles / hour).

$\sigma_s^2 = \left[\frac{1}{n} - 1 \cdot \sum_{i=1}^{n} \left(h_{si} - \bar{h}_s \right)^2 \right]$ represents the variance of the intermediate time sample

The location of the selected intersection is one that has a large volume of motorcycles, namely 82 percent [4], minor side barriers, namely interference from factors such as pedestrians, vehicles turning left or right, parking vehicles (on street parking) and bus stops or stops, both those with ESSM and those without ESSM at one of the intersection approaches. The intersection chosen is also one of the approaches that has a through movement of motorcycles or is not affected by conflict, whether there is an ESSM or no ESSM.

This study was conducted in Denpasar City. Based on data obtained from the Denpasar City Department of Transportation, Denpasar City has 66 intersections with signals, of which 15 intersections have Exclusive Stopping Space for Motorcycle and 51 intersections have no ESSM [10]. For the purposes of the analysis, an approach has been chosen at the four signalized intersections which have approximately the same volume of vehicles passing through the intersection, The same approach width and has the proportion of motorcycles that reflect the same mixed traffic flow conditions between the existing ESSM and those without the ESSM as in Table 1. Headway data is obtained from video recordings of the Denpasar City Area Traffic Control System (ATCS), data retrieval is carried out at peak hours in the morning, afternoon and evening for 2.5 hours per each busy hour.

Table 1. Intersections with the same Approach Width and Traffic Characteristics

No.	Approach Width (m)	Intersection		Approach	
		With ESSM	Without ESSM	With ESSM	Without ESSM
1	7	Dewi Sartika Dewi Sartika	Kebo Iwa Kebo Iwa	Dewi Sartika Teuku Umar	Gatot Subroto Barat (T) Gatot Subroto Barat (B)
2	5	Kapten Japa Kapten Japa	Saelus Surabi Kenyeri	Hayam Wuruk (T) Hayam Wuruk (B)	Diponegoro (S) Supratman (B) Gatot Subroto Tengah (B)
3	3	Nangka Unud	Perumnas Saelus	Nangka (U) Serma Mendra	Buana Raya Pulau Saelus

3. Results and Discussion

Headway data were obtained from the Denpasar City Area Traffic Control System (ATCS) video recordings, which include 9440 headway data for an approach with an effective width of 3 meters with ESSM and 10833 without ESSM. Headway data from the approach of the effective width of 5 meters with ESSM as much as 14161 and without ESSM 19667 data. Headway data from the approach of the effective width of 7 meters with ESSM as much as 14002 and without ESSM 14932 data. Headway data from each approach were combined into one for each approach width, both with ESSM and without ESSM to get the saturated flow value.

In Table 2, it can be seen that the proportion of vehicles in each approach with an approach width of 3 meters, 5 meters and 7 meters, both with ESSM and without ESSM.

Based on Table 2, the percentage of the proportion of motorcycles is relatively the same as the 1-2 percent difference between the approach with ESSM and without ESSM except for the 3 meters width of the approach, there is a difference of 5.6% of the approach without ESSM, the greater the percentage of motorcycles compared to those with ESSM approach.

Table 2. Percentage of proportion of vehicles in each approach with and without ESSM

Approach Width		Vehicle		
		Motor cycle	Light Vehicle	High Vehicle
3m	Non ESSM	90,36	8,79	0,85
	ESSM	84,76	14,66	0,59
5m	Non ESSM	82,09	16,11	1,80
	ESSM	81,60	17,99	0,41
7m	Non ESSM	78,74	19,40	1,86
	ESSM	76,78	22,62	0,61

Meanwhile, the percentage of motorcycle behaviour in each approach, both with ESSM and without ESSM, is as shown in Table 3. Based on Table 3, motorcycles at a signalized intersection tend to behave beside flow (beside other vehicles), both those with ESSM and without ESSM, this happens because motorcycles has more freedom to maneuverer because there are no light vehicles in front of them. The percentage of the behaviour of motorcycles beside flow is greater than inside flow at a signalized intersection with ESSM, whether the approach width is 3 meters, 5 meters or 7 meters.

Table 3. Percentage of motorcycle behaviour of each approach with and without ESSM

Approach Width		Motorcycle Behaviour		
		Infront of stop line	Beside flow	Inside flow
3m	Non ESSM	3,06	75,45	22,24
	ESSM	1,61	79,54	19,18
5m	Non ESSM	1,87	50,20	48,86
	ESSM	1,46	65,62	33,43
7m	Non ESSM	4,03	55,20	42,58
	ESSM	0,42	57,16	42,61

Furthermore, the headway data analysis was carried out in SPSS descriptively as well as knowing the form of data distribution. The purpose of this analysis is to see whether the data distribution patterns are normally distributed or not. The form of data distribution can be determined through statistical calculations with the Shapiro-Wilk or Kolmogorov Smirnov approach. The data of less than 50 uses the Shapiro Wilk approach, while those more than 50 use the Kolmogorov-Smirnov. The data is said to be normally distributed if the Sig. from the test statistic is greater than 0.05.

Data with normal distribution were calculated to obtain the saturation flow with the Formula 2, while data that were not normally distributed, were calculated using the Formula (3, 4, 5). Based on the observations on the saturation flow values at S1, S2, and S3, the saturation flow values are almost the same. This result is also confirmed by [10] who simulated the calculations using the S1, S2, and S3 formula approaches. Based on the results of this analysis, a similar saturation flow value is obtained, so it can be concluded that the S1, S2, or S3 values can be selected for use by the researcher.

This study uses the S3 formula for data that is not normally distributed, because the S3 formula is the final development of the previous formula and in the formula accommodates the size of centre (mean) and data distribution (variance).

After the S value is obtained based on the various criteria above, then a behavioural analysis of the saturation flow is carried out. The analysis is divided into two, namely as a whole (behaviour of motorcycles inside flow, Infront of stop line, and beside flow) to saturated flow and their respective behaviour by ignoring other behaviours (behaviour of Infront motorcycles to saturated flow, behaviour of motorcycles beside saturated flow and the behaviour of the inside motorcycle to saturated flow). The model obtained is then evaluated based on the value of its fit model using the R-Square approach and F-count (F significance). A model whose fit model is good, deserves to be interpreted, while a model whose fit model is still weak is considered not feasible. For the model of the influence of behaviour individually by ignoring other behaviours, a model is obtained as shown in Figure 1.

The regression model at a signalized intersection with an approach width of 3 meters without ESSM or with partial ESSM by only taking into one behavior and ignoring other behaviors, it is found that the behavior of infront of stop line, inside flow and beside flow has an effect on saturated flow. The regression model at a signalized intersection with an approach width of 5 meters without ESSM shows only that the behavior of the infront of stop line and beside has an effect on saturated currents, while the width of the approach of 5 meters with ESSM shows that only the behavior of the infront of stop line and inside flow has an effect on saturated flow. The regression model at a signalized intersection with an approach width of 7 meters without ESSM shows only that the behavior of infront of stop line and beside has an effect on saturated currents, while the width of the approach of 7 meters with ESSM shows that only inside flow has an effect on the flow.

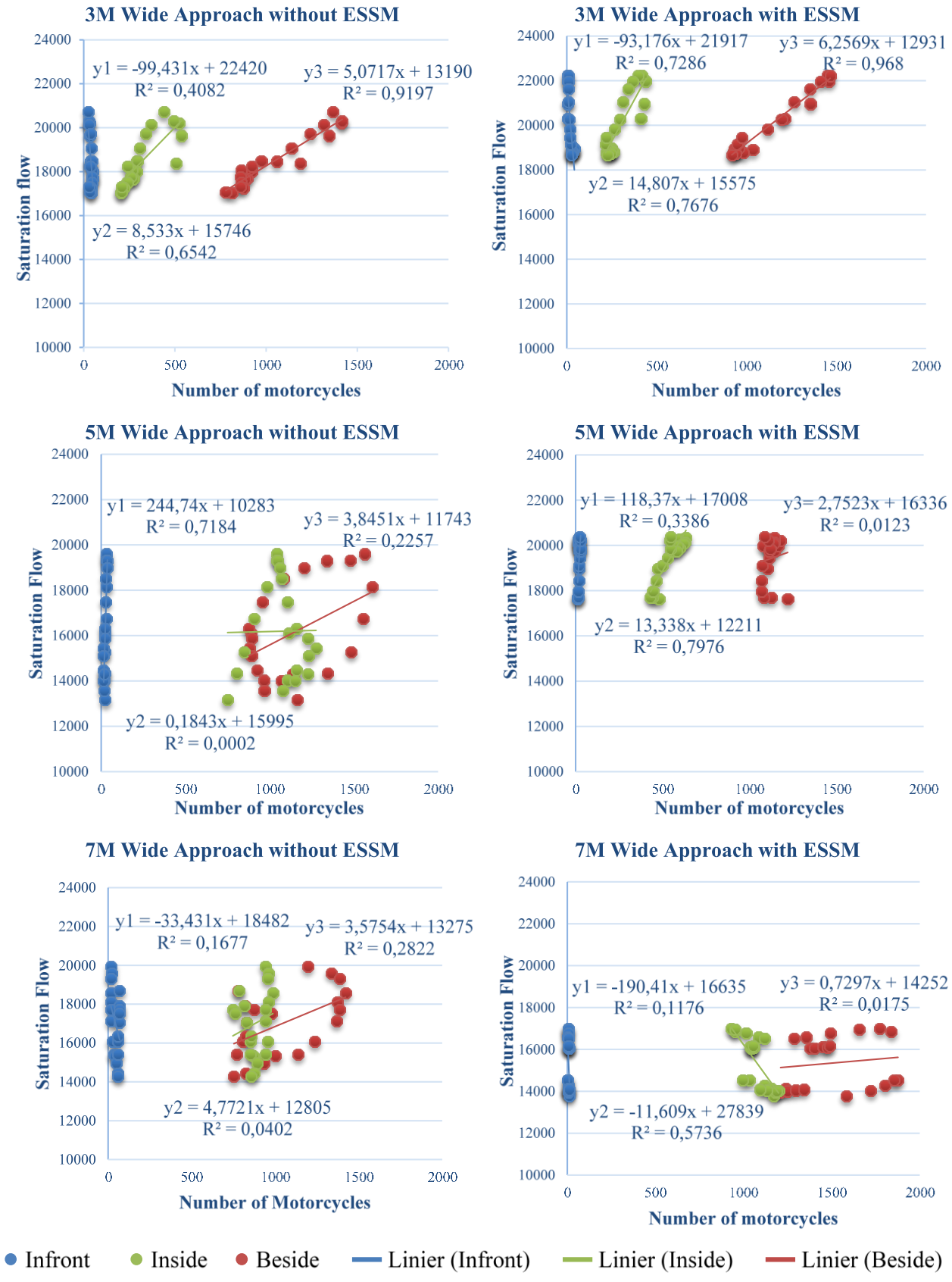

Figure 1. The model of the influence of each motorcycle behaviour on saturated flow ignores the influence of other behaviours

To show the relationship between the effect of motorcycle behaviour on saturated flow together with an approach width of 3 meters, 5 meters and 7 meters without ESSM, it is shown in Table 4. Meanwhile, to show the relationship between the effect of motorcycle behaviour on saturated flow together with the approach width 3 meters, 5 meters and 7 meters with ESSM are shown in Table 5.

The regression model at the intersection with a signal with an approximate width of 3 meters without ESSM taking into account all behaviors in the analysis (Infront of stop line, inside flow and beside flow) The regression analysis model in Non ESSM 3 produces a goodness of fit value with the R-Square approach of 0.945 and the significance of F is 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.945, it indicates that there is an effect of motorcycle behavior on saturation flow of 95.5%, while the remaining 4.5% is influenced by other factors outside the three independent variables at the intersection with a signal without ESSM with an approach width of 3 meters. Partially, a significance value is obtained at the Infront of 0.378, which means that there is no influence on the behavior of motorcycles in front of the stop line on saturated flow, but it is different with beside flow and inside flow, which respectively get a significance value of 0.000 and 0.013 where beside and inside contributes a significant effect on saturation flows at the intersection with no ESSM signal with a width of 3 meters.

The regression model at the intersection with a 3 meters wide approach with ESSM produces a goodness of fit value with the R-Square approach of 0.945 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.972, it indicates that there is an effect of motorcycle behavior on saturation flow of 97.2%, while the rest is influenced by other factors outside the three independent variables.

Table 4. Model of influence of motorcycle behaviour at signalized intersections without ESSM

Statistics	Non ESSM 3	Non ESSM 5	Non ESSM 7
Model	Y=11814.28 + 11.50 X1+ 7.24X2– 4.18X3	Y= -1070.22+ 279.29X1 + 1.50X2 – 8.23X3	Y=34296.55 -46.89X1 + 5.40X2– 23.61X3
R-Squared	0.945	0.915	0.464
Sig. F	0.000	0.000	0.012
Constant	11814.28	-1070.22	24296.55
Uns. Coeff.	Infront:11.50 Beside: 7.24 Inside: -4.18	Infront: 279.29 Beside: 1.50 Inside: 8.23	Infront:46.89 Beside: 5.40 Inside: 23.61
Sig. t	Infront: 0.378 Beside: 0.000 Inside: 0.013	Infront: 0.000 Beside: 0.117 Inside: 0.000	Infront: 0.549 Beside: 0.206 Inside: 0.084

Table 5. Model of influence of motorcycle behaviour at signalized intersections with ESSM

Statistics	ESSM 3	ESSM 5	ESSM 7
Model	Y=12638.69 +0.85X1+ 7.17X2 – 2.52X3	Y= 12771.15 + 63.75X1– 1.05X2 – 12.04X3	Y= 34510.09 + 26.10X1 -2.11X2– 15.00X3
R-Squared	0.972	0.901	0.676
Sig. F	0.000	0.000	0.000
Constant	12638.69	12771.15	34510.09
Uns. Coeff.	Infront:0.85 Beside: 7.17 Inside: -2.52	Infront: 63.75 Beside: -1.05 Inside: 12.04	Infront:46.89 Beside: 5.40 Inside: 23.61
Sig. t	Infront: 0.927 Beside: 0.000 Inside: 0.158	Infront: 0.003 Beside: 0.652 Inside: 0.000	Infront: 0.755 Beside: 0.034 Inside: 0.000

Partially, a significance value is obtained for the Infront of 0.927 and the inside flow of 0.158, which means that there is no influence on the behavior of motorcycles in the Infront of stop line and inside flow on saturated flow, However, it is different with beside flow, obtaining a significance value of 0.000, where beside contributes a significant effect on saturated flow at a signalized intersection with ESSM with a 3 meters wide approach. The regression model at a signalized intersection with an approximate width of 5 meters without ESSM results in a goodness of fit value with the R-Square approach of 0.915 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.915, it indicates that there is an influence of motorcycle behavior on saturation flow of 91.5%, while the rest is influenced by other factors outside the three independent variables. Partially, it is obtained a significance value beside flow of 0.117 which means there is no influence of the behavior of motorcycles beside flow on saturated flow, However, in contrast to the infront of stop line and inside flow, it obtained a significance value of 0.000 where the infront of stop line and inside flow contributed significantly to the saturated flow at the signalized intersection without ESSM with an approach width of 3 meters.

The regression model at the signalized intersection with an

approximate width of 5 meters with ESSM produces a goodness of fit value with the R-Square approach of 0.901 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.901, it indicates that there is an influence of motorcycle behavior on saturation flow of 90.1%, while the rest is influenced by other factors outside the three independent variables. Partially, it is obtained a significance value beside flow of 0.652, which means that there is no influence of the behavior of motorcycles beside flow on saturated flow, However, in contrast to the infront of stop line and inside flow, it has a significance value of 0.003 and 0.000 where the infront of stop line and inside flow have a significant effect on saturated flow at the signalized intersection with ESSM with a 5 meters wide approach.

The regression model at the signalized intersection with an approach width of 7 meters without ESSM results in a goodness of fit value with the R-Square approach of 0.464 and a significance of F of 0.012. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.464, it indicates that there is an effect of motorcycle behavior on saturated flow of 46.4%, while the rest is influenced by other factors outside the three independent variables. Partially, the significant values of infront of stop line, beside flow and inside flow are obtained, respectively 0.549, 0.206 and 0.084, which means that there is no influence on the behavior of motorcycles, infront of stop line, beside flow and inside flow separately.

The regression model at a signalized intersection with an approximate width of 7 meters with ESSM produces a goodness of fit value with the R-Square approach of 0.464 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.676, it indicates that there is an effect of motorcycle behaviour on saturated flow of 67.6%, while the rest is influenced by other factors outside the three independent variables. Partially, the Infront of stop line significance value is 0.755, which means that there is no effect of the behaviour of motorcycles in front of the stop line on saturated flows, However, it is different with beside flow and inside flow, obtaining a significance value of 0.034 and 0.000 where beside flow and inside flow have a significant effect on saturated flow at the signalized intersection with ESSM with a 7 meters wide approach.

4. Conclusion

This model of the effect of saturated flow on motorcycle behavior applies to through movement with traffic conditions dominated by motorcycles, the percentage of motorcycles is 76% to 90% and the effective width of the approach is 3 meters, 5 meters, and 7 meters with or without ESSM. The model generated from the regression analysis of the influence of motorcycle behavior (infront of stop line, beside flow and inside flow) together produces a better model than the model obtained from the regression analysis separately, namely the effect of the behavior of motorcycles on the infont of stop line on saturated flow, the effect of the behavior of motorcycles beside flow on saturated flow and the influence of the behavior of motorcycles inside flow on saturated flow.

By knowing the behavior of motorcycles at a signalized intersection with an approach width of 3 meters, 5 meters, 7 meters with or without ESSM, the saturation flow can be determined without counting the number of light or heavy vehicles, especially for the 3 and 5 meter approach widths.Further research is needed with conditions like this in other cities, so that better results can be obtained.

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The Saturated Flow Modeling On Motorcycle Behavior In Through Movement

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Abstract In developing countries such as Indonesia the proportion of motorcycles to other vehicles is reaching 76%, which is very high. The proportion of motorcycles in Bali Province exceeds 85% while in Denpasar City is 82%. Previous studies suggest that high proportion of motorcycles will certainly have an effect on the saturated flow. Therefore, the effect of motorcycles on saturation flows should not be neglected. With a high proportion of motorcycles that will affect the behavior of motorcyclist. at irregular intersections such as in front of the stop line, beside other vehicles and behind other vehicles or in the flow, the behavior of the motorcycle affects the saturated flow. In calculating saturated flow, the Indonesian Highway Capacity Manual (IHCM) does not have a specific-measures that adopts the behavior of motorcycles. If the motorcycle is not properly regulated, it will interfere with the movement of other vehicles when the green light is on. The behavior to be examined in this study is the behavior of motorcycles in front of the stop line, outside the current (beside flow), or in the current (inside flow). In this study, a model was developed to determine saturation flow based on the behavior of motorcycles on through movements at signalized intersections with or without ESSM.

Keywords Motorcycles behavior, Saturation flow, signalized intersections, exclusive stopping space for motorcycles (ESSM).

1. Introduction

Study of signalized intersections is one of the most effective measures to increase road network capacity and reduce traffic congestion [6]. The management of signaled intersection traffic flow is much easier to research and analyze if all motorized vehicles are homogeneous [8]. A heterogeneous (mixed) traffic system is very different compared to that of a homogeneous one. For mixed traffic conditions, vehicle sizes and types and control also vary [22].

Mixed traffic dominated by motorcycles is very common in most Asian countries such as Taiwan, Thailand, Vietnam, Indonesia and Malaysia. For example, the proportion of motorcycles in Hanoi and Ho Chi Minh City in Vietnam is around 90% [6]. In Taiwan, the concept of segregated traffic flow (motorcycle lane separation) was proposed and successfully implemented to improve mixed traffic performance.

The Indonesian government is preparing Exclusive Stopping Space for Motorcycle (ESSM) at several signalized intersections, to accommodate the high number of motorcycles. ESSM is a motorcycle facility in the form of providing motorcycle facilities at signalized intersections. ESSM is an alternative solution to the problem of motorcycle congestion at signalized intersections. When entering the green time signal, motorcycles move with various maneuvers to get out of the approach to the intersection, so that it often creates traffic conflicts which are thought to affect the performance and flow of traffic movements at the intersection [12].

A better understanding of the impact of motorcycles on traffic flow affects the development of a more accurate model to determine the effect of motorcycles on saturated flow [6]. Saturation flow plays an important role in the design of a signalized intersection [18]. The saturation flow (S) is the amount of queue departure in an approach during the specified conditions (pcu/green hour). Meanwhile, the basic saturation flow is the amount of queue departure in the approach during ideal conditions (pcu/green hour) [13].

As a reference for determining intersection parameters such as saturated flow and capacity in Indonesia, the Indonesian Highway Capacity Manual (IHCM) was published in 1997. In 1997, the composition of motorcycles for urban areas in Indonesia was at the average of 40.5% [13], which is very different from the current condition. It was found that based on the preliminary survey, the composition of motorcycles in Denpasar City was 82%. Although Indonesian urban areas clearly have a high percentage of motorcycles, there has been no adjustment to IHCM regarding the high percentage of motorcycles, the number of

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vehicle ownership and the behavior of motorcycles in Indonesia. The IHCM determines the saturation flow based on the basic saturation flow times the adjustment factor. Besides that, the passenger car equivalent (PCE) value also does not reflect the real conditions in the field. The PCE value has been determined such as the PCE for motorcycle is 0.2, the PCE for light vehicle is 1 and the PCE for heavy vehicle is 1.3, without any PCE analysis at each intersection studied. Improper regulation of motorcycles, especially at intersections, will not only reduce the level of service at intersections, but may also lead to an increase in road traffic accidents.

The behavior of the motorcycle users at a signalized intersection has affected saturated flows, especially motorcycles in the current (inside flow), the greater the composition of the motorcycle in the flow, the higher the saturation flow [11]. According to the [9,14,16,], the behavior of motorcycles at signalized intersections can be grouped into several categories, namely motorcycles in front of the stop line, motorcycles in the current (inside flow), and motorcycles outside the current (beside flow). This study examines the behavior of motorcycles towards saturated flow on through movements because in Denpasar City for large traffic flows, the arrangement of intersections with more signals is through movement to reduce conflict at signalized intersections. Through movements are free movements that are not affected by conflict [18,19] while according to [2,20] through movements are movements (turn right, go straight, turn left) in each approach that is given the green light simultaneously, and given 1 phase per approach so that vehicles turning right do not have to wait to enter opposite traffic. In this study, what is meant by through movement is the movement of traffic at an intersection approach that has 1 phase or an intersection whose approach has the same phase as other approaches but the movement does not affect or be influenced by the movements of other approaches.

The study of traffic flow at signalized intersections is a new topic, several studies have been conducted to examine saturated flow and capacity aimed at improving traffic conditions at signalized intersections or across the transportation network. However, from previous research, no one has determined the influence model of motorcycle behavior at signalized intersections, namely the behavior of motorcycles in front of the stop line, inside flow (inside flow) and outside flow (beside flow), both those with ESSM and without ESSM to saturated flows. Motorcycle behavior research conducted in Malaysia by Leong et al. [11] and in Ghana by Adams et al. [1] only analyzed the effect of motorcycle behavior in the flow (inside flow) without analyzing the behavior of motorcycles in front of the stop line and outside the flow (beside flow) and also does not analyze the differences in behavior at the signalized intersections that have ESSM or without ESSM. There are also many researches related to ESSM, such as research by [3-7], but no research has analyzed the effect of motorcycle behavior with and without ESSM on saturation flow. Most of the studies only examined the effectiveness of ESSM from the level of ESSM filling and the effect of motorcycles (total motorcycles) on saturated flows, not on motorcycle behavior. Research on the behavior of motorcycles at signalized intersections is important to obtain the best model in determining the saturation flow of the motorcycles behavior model at signalized intersections which are partially or simultaneously dominated by motorcycles. determine policies related to regulating motorcycles at signalized intersections, such as designing the ESSM, making separate lanes between motorcycles and other vehicles and setting traffic lights. In this research, we will obtain a model or formula to determine the saturation flow only by knowing the behavior of motorcycles at signalized intersections which are dominated by motorcycles. This study also provides suggestions for overcoming the accumulation of vehicles at intersections with signals that are dominated by motorcycles which may be applicable to other areas that have the same characteristics, both the geometric and the proportions of the motorcycles. A model of motorcycle behavior towards saturated flow was developed, both with and without ESSM.

2. Materials and Methods

The regression method is more relevant for the estimation of saturation flow at signalized intersections because its implementation of calculations is easier and simpler. However, this technique relies heavily on accurate estimation of saturation flow which is also a function of determining PCE [15]. In order to obtain an accurate saturation flow estimation, the method of determining the saturation flow at signalized intersections in this study is used from Chang and Xiao [5]. Traditional methods that only use the average discharge headway to estimate the saturation headway can lead to underestimation. Errors in the saturated flow used for the estimation of vehicle delays can cause errors in the prediction of delay and Level of Service (LOS). Therefore, it is necessary to conduct a study to increase the accuracy of the saturation flow estimation. The facts show that driver behavior is the main determinant of saturation flow, therefore a good understanding of the time between discharge headways is essential in estimating the time between saturation headway and saturation flow rate. The stochastic properties of the time between vehicle releases could provide better information for the development of a method of estimating saturation flow rates [5]. It is easy to understand that the time between vehicle releases is a random variable due to differences in driver behavior response times and variations in queue space length. To estimate the saturation headway time, the average time between vehicle releases is calculated as follows:

$$\overline{h_s} = \frac{1}{n}\sum_{i=1}^{n} h_{si} \qquad (1)$$

With,

Commented [A2]: The saturation flow modelling in IHCM isn't relevant for it, so we need to research again with this case

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h_s : the average time between discharges (s) which is taken as the estimated time between saturations h ;
h_{si} : time between vehicles i in queue, i = 1, 2, ..., n (n is the sample size), consequently, the level of saturation flow is (conventionally) determined by the time between discharge:

$$S = \frac{3600}{\bar{h}_s} \qquad (2)$$

With,
S is the saturation flow level (vehicle / hour).

Based on the statistical theory that: If the intermediate time distribution is symmetric, The average intermediate time calculated by equation (1) is a good (unbiased) estimate of h and equation (2) can be a good estimate for the saturation flow rate [14]. However, if the intermediate time distribution is not symmetrical, h_s is not a good estimate and equation (2) will give a saturation flow level value that is too high (overestimate) or too low (underestimate). Therefore, it is necessary to study the stochastic nature of the time between queuing vehicles and to analyze the effect of time variation between the estimated saturation flow rates [5].

When the mean time between queue releases is greater than the median value and the skewness of the intermediate time values is positive, this characteristic indicates that the time distribution between queues releases tends to be asymmetrical and the normal distribution function does not match the intermediate time data [5]. Therefore, the conventional saturation flow rate estimation method (equation 2) can produce an underestimated saturation flow level value.

If the time distribution between queue releases tends to be asymmetrical, then the intermediate time value can be modeled with a lognormal distribution [5,17] If it is known that when the random variable h_s function density is lognormal, then ln h_s will follow the normal distribution. Therefore, it is very relevant to use the median value to calculate the saturation flow rate in the following way:

$$S_1 = 3600 \times \frac{1}{h_{med}} \qquad (3)$$

With,
S_1 : new estimate of the saturation flow rate (vehicles/hour);
h_{med} : the median value of the intermediate time or the estimated median value of the intermediate time.

In addition, there are two new estimates for the saturation flow rate [14]

$$S_2 = 3600 \times \exp\left(-\frac{1}{n}\sum_{i=1}^{n} \ln h_{si}\right) \qquad (4)$$

$$S_3 = \frac{3600}{\bar{h}_s} \times \left(1 + \frac{\sigma_s^2}{\bar{h}_s^2}\right)^{0.5} \qquad (5)$$

With,
S_2 and S_3 are two new estimates of the saturation flow rate (vehicles / hour).

$$\sigma_s^2 = \left[\frac{1}{n} - 1 \cdot \sum_{i=1}^{n}\left(h_{si} - \bar{h}_s\right)^2\right] \qquad (6)$$

represents the variance of the intermediate time sample.

The location of the selected intersection is one that has a large volume of motorcycles, namely 82 percent [4], minor side barriers, namely interference from factors such as pedestrians, vehicles turning left or right, parking vehicles (on street parking) and bus stops or stops, both those with ESSM and those without ESSM at one of the intersection approaches. The intersection chosen is also one of the approaches that has a through movement of motorcycles or is not affected by conflict, whether there is an ESSM or no ESSM.

This study was conducted in Denpasar City. Based on data obtained from the Denpasar City Department of Transportation, Denpasar City has 66 intersections with signals, of which 15 intersections have Exclusive Stopping Space for Motorcycle and 51 intersections have no ESSM [10]. For the purposes of the analysis, an approach has been chosen at the four signalized intersections which have approximately the same volume of vehicles passing through the intersection, The same approach width and has the proportion of motorcycles that reflect the same mixed traffic flow conditions between the existing ESSM and those without the ESSM as in Table 1. Discharge Headway data is obtained from video recordings of the Denpasar City Area Traffic Control System (ATCS), data retrieval is carried out at peak hours in the morning, afternoon and evening for 2.5 hours per each busy hour.

Table 1. Intersections with the same Approach Width and Traffic Characteristics

No.	Approach Width (m)	Intersection		Approach	
		With ESSM	Without ESSM	With ESSM	Without ESSM
1	7	Dewi Sartika Dewi Sartika	Kebo Iwa Kebo Iwa	Dewi Sartika Teuku Umar	Gatot Subroto Barat (T) Gatot Subroto Barat (B)
2	5	Kapten Japa Kapten Japa	Saelus Surabi Kenyeri	Hayam Wuruk (T) Hayam Wuruk (B)	Diponegoro (S) Supratman (B) Gatot Subroto Tengah (B)
3	3	Nangka Unud	Perumnas Saelus	Nangka (U) Serma Mendra	Buana Raya Pulau Saelus

3. Results and Discussion

Headway data were obtained from the Denpasar City Area Traffic Control System (ATCS) video recordings, which include 9440 headway data for an approach with an effective width of 3 meters with ESSM and 10833 without ESSM. Discharge headway data from the approach of the effective width of 5 meters with ESSM as much as 14161 and without ESSM 19667 data. Discharge headway data from the approach of the effective width of 7 meters with ESSM as much as 14002 and without ESSM 14932 data. Discharge headway data from each approach were combined into one for each approach width, both with ESSM and without ESSM to get the saturated flow value.

In Table 2, it can be seen that the proportion of vehicles in each approach with an approach width of 3 meters, 5 meters and 7 meters, both with ESSM and without ESSM. Based on Table 2, the percentage of the proportion of motorcycles is relatively the same as the 1-2 percent difference between the approach with ESSM and without ESSM except for the 3 meters width of the approach, there is a difference of 5.6% of the approach without ESSM, the greater the percentage of motorcycles compared to those with ESSM approach.

Table 2. Percentage of proportion of vehicles in each approach with and without ESSM

Approach Width		Vehicle		
		Motor cycle	Light Vehicle	High Vehicle
3m	Non ESSM	90,36	8,79	0,85
	ESSM	84,76	14,66	0,59
5m	Non ESSM	82,09	16,11	1,80
	ESSM	81,60	17,99	0,41
7m	Non ESSM	78,74	19,40	1,86
	ESSM	76,78	22,62	0,61

Meanwhile, the percentage of motorcycle behaviour in each approach, both with ESSM and without ESSM, is as shown in Table 3. Based on Table 3, motorcycles at a signalized intersection tend to behave beside flow (beside other vehicles), both those with ESSM and without ESSM, this happens because motorcycles has more freedom to maneuverer because there are no light vehicles in front of them. The percentage of the behaviour of motorcycles beside flow is greater than inside flow at a signalized intersection with ESSM, whether the approach width is 3 meters, 5 meters or 7 meters.

Table 3. Percentage of motorcycle behaviour of each approach with and without ESSM

Approach Width		Motorcycle Behaviour		
		Infront of stop line	Beside flow	Inside flow
3m	Non ESSM	3,06	75,45	22,24
	ESSM	1,61	79,54	19,18
5m	Non ESSM	1,87	50,20	48,86
	ESSM	1,46	65,62	33,43
7m	Non ESSM	4,03	55,20	42,58
	ESSM	0,42	57,16	42,61

Furthermore, the headway data analysis was carried out in SPSS descriptively as well as knowing the form of data distribution. The purpose of this analysis is to see whether the data distribution patterns are normally distributed or not. The form of data distribution can be determined through statistical calculations with the Shapiro-Wilk or Kolmogorov Smirnov approach. The data of less than 50 uses the Shapiro Wilk approach, while those more than 50 use the Kolmogorov-Smirnov. The data is said to be normally distributed if the Sig. from the test statistic is greater than 0.05.

Data with normal distribution were calculated to obtain the saturation flow with the Formula 2, while data that were not normally distributed, were calculated using the Formula (3, 4, 5). Based on the observations on the saturation flow values at S_1, S_2, and S_3, the saturation flow values are almost the same. This result is also confirmed by [10] who simulated the calculations using the S_1, S_2, and S_3 formula approaches. Based on the results of this analysis, a similar saturation flow value is obtained, so it can be concluded that the S_1, S_2, or S_3 values can be selected for use by the researcher.

This study uses the S_3 formula for data that is not normally distributed, because the S_3 formula is the final development of the previous formula and in the formula accommodates the size of centre (mean) and data distribution (variance).

After the S value is obtained based on the various criteria above, then a behavioural analysis of the saturation flow is carried out by using multiple linear regression. The analysis is divided into two, namely as a whole (behaviour of motorcycles inside flow, Infront of stop line, and beside flow) to saturated flow and their respective behaviour by ignoring other behaviours (behaviour of Infront motorcycles to saturated flow, behaviour of motorcycles beside saturated flow and the behaviour of the inside motorcycle to saturated flow). The model obtained is then evaluated based on the value of its fit model using the R-Square approach and F-count (F significance). A model whose fit model is good, deserves to be interpreted, while a model whose fit model is still weak is considered not feasible. For the model of the influence of behaviour individually by ignoring other behaviours, a model is obtained as shown in Figure 1.

The regression model at a signalized intersection with an approach width of 3 meters without ESSM or with partial ESSM by only taking into one behavior and ignoring other behaviors, it is found that the behavior of infront of stop line, inside flow and beside flow has an effect on saturated flow. The regression model at a signalized intersection with an approach width of 5 meters without ESSM shows only that the behavior of the infront of stop line and beside has an effect on saturated currents, while the width of the approach of 5 meters with ESSM shows that only the behavior of the infront of stop line and inside flow has an effect on saturated flow. The regression model at a signalized intersection with an approach width of 7 meters without ESSM shows only that beside flow has an effect on saturation flow, while the width of the approach of 7 meters

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with ESSM shows that only inside flow has an effect on the saturation flow.

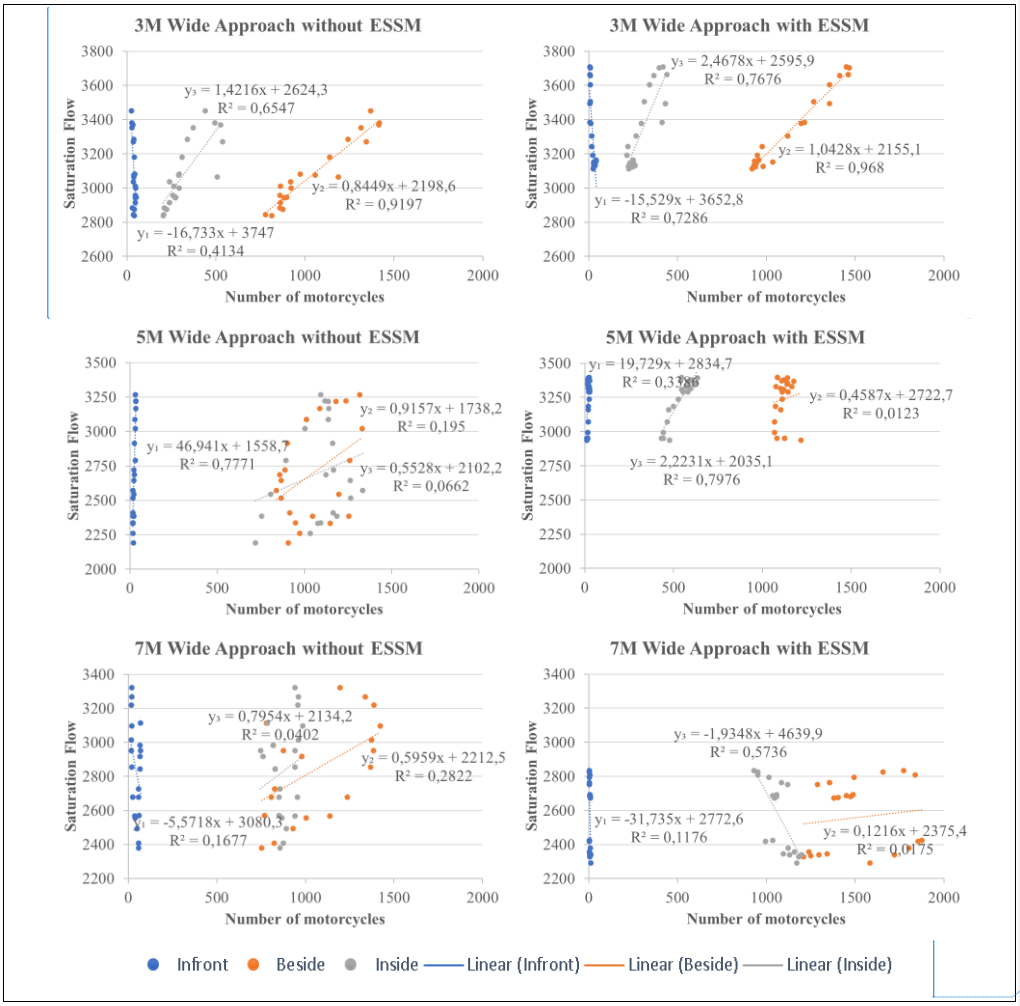

Figure 1. The model of the influence of each motorcycle behaviour on saturated flow ignores the influence of other behaviours

To show the relationship between the effect of motorcycle behaviour on saturated flow together with an approach width of 3 meters, 5 meters and 7 meters without ESSM, it is shown in Table 4. Meanwhile, to show the relationship between the effect of motorcycle behaviour on saturated flow together with the approach width 3 meters, 5 meters and 7 meters with ESSM are shown in Table 5.

The regression model at the intersection with a signal with an approximate width of 3 meters without ESSM taking into account all behaviors in the analysis (Infront of stop line, inside flow and beside flow) The regression analysis model in Non ESSM 3 produces a goodness of fit value with the R-Square approach of 0.945 and the significance of F is 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.945, it indicates that there is an effect of motorcycle behavior on saturation flow of 94.5%, while the remaining 5.5% is influenced by other factors outside the three independent variables at the intersection with a signal without ESSM with an approach width of 3 meters. Partially, a significance value is obtained at the Infront of 0.38, which

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means that there is no influence on the behavior of motorcycles in front of the stop line on saturated flow, but it is different with beside flow and inside flow, which respectively get a significance value of 0.000 and 0.013 where beside and inside contributes a significant effect on saturation flows at the intersection with no ESSM signal with a width of 3 meters. The model for the saturation flow is obtained :

S=1968.85 + 1.92 MC Infront of stop line+1.21 MC beside– 0.7 MC Inside (7)

The regression model at the intersection with a 3 meters wide approach with ESSM produces a goodness of fit value with the R-Square approach of 0.972 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.972, it indicates that there is an effect of motorcycle behavior on saturation flow of 97.2%, while the rest is influenced by other factors outside the three independent variables.

Table 4. Model of influence of motorcycle behaviour at signalized intersections without ESSM

Statistics	Non ESSM 3	Non ESSM 5	Non ESSM 7
Model	Y=1968.85 + 1.92X1+1.21X2– 0.7X3	Y= 346.31+ 46.78X1 + 0.27X2+0.86X3	Y=5710.93 -7.79X1 + 0.90X2– 3.93X3
R-Squared	0.945	0.915	0.464
Sig. F	0.000	0.000	0.012
Constant	1968.85	346.31	5710.93
Uns. Coeff.	Infront (X1):1.92 Beside (X2): 1.21 Inside (X3): -0.7	Infront (X1): 46.78 Beside (X2): 0.27 Inside (X3): 0.86	Infront (X1):-7.79 Beside (X2): 0.90 Inside (X3): -3.93
Sig. t	Infront (X1): 0.38 Beside (X2): 0.000 Inside (X3): 0.013	Infront (X1): 0.000 Beside (X2): 0.15 Inside (X3): 0.000	Infront (X1): 0.55 Beside (X2): 0.21 Inside (X3): 0.084

Table 5. Model of influence of motorcycle behaviour at signalized intersections with ESSM

Statistics	ESSM 3	ESSM 5	ESSM 7
Model	Y=2017.18+0.14+ 1.19–0.42X3	Y=2131.43+10.61X1–0.18X2+2.01X3	Y= 5748.76+4.35X1 -0.35X2– 2.5X3
R-Squared	0.972	0.901	0.574
Sig. F	0.000	0.000	0.000
Constant	2107.18	2131.43	5748.76
Uns. Coeff.	Infront (X1):0.14 Beside (X2): 1.19 Inside (X3): -0.42	Infront (X1): 10.61 Beside (X2): -0.18 Inside (X3): 2.01	Infront (X1):4.35 Beside (X2): -0.35 Inside (X3):- 2.5
Sig. t	Infront (X1): 0.928 Beside (X2): 0.000 Inside (X3): 0.16	Infront (X1): 0.003 Beside (X2): 0.65 Inside (X3): 0.000	Infront (X1): 0.755 Beside (X2): 0.034 Inside (X3): 0.000

Partially, a significance value is obtained for the Infront of 0.928 and the inside flow of 0.158, which means that there is no influence on the behavior of motorcycles in the Infront of stop line and inside flow on saturated flow, However, it is different with beside flow, obtaining a significance value of 0.000, where beside contributes a significant effect on saturated flow at a signalized intersection with ESSM with a 3 meters wide approach. The model for the saturation flow is obtained:

S=2017.18 + 0.14 MC Infront of stop line+1.19 MC beside– 0.42 MC Inside (8)

The regression model at a signalized intersection with an approximate width of 5 meters without ESSM results in a goodness of fit value with the R-Square approach of 0.915 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.915, it indicates that there is an influence of motorcycle behavior on saturation flow of 91.5%, while the rest is influenced by other factors outside the three independent variables. Partially, it is obtained a significance value beside flow of 0.15 which means there is no influence of the behavior of motorcycles beside flow on saturated flow, However, in contrast to the infront of stop line and inside flow, it obtained a significance value of 0.000 where the infront of stop line and inside flow contributed significantly to the saturated flow at the signalized intersection without ESSM with an approach width of 5 meters. The model for the saturation flow is obtained: S=346.31 + 46.78 MC Infront of stop line+0.27 MC beside– 0.86 MC Inside (9)

The regression model at the signalized intersection with an approximate width of 5 meters with ESSM produces a goodness of fit value with the R-Square approach of 0.901 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.901, it indicates that there is an influence of motorcycle behavior on saturation flow of 90.1%, while the rest is influenced by other factors outside the three independent variables. Partially, it is obtained a significance value beside flow of 0.65, which

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means that there is no influence of the behavior of motorcycles beside flow on saturated flow, However, in contrast to the infront of stop line and inside flow, it has a significance value of 0.003 and 0.000 where the infront of stop line and inside flow have a significant effect on saturated flow at the signalized intersection with ESSM with a 5 meters wide approach. The model for the saturation flow is obtained:

S=2131.43 + 10.61 MC Infront of stop line–0.18 MC beside+2.01 MC Inside. (10)

The regression model at the signalized intersection with an approach width of 7 meters without ESSM results in a goodness of fit value with the R-Square approach of 0.464 and a significance of F of 0.012. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.464, it indicates that there is an effect of motorcycle behavior on saturated flow of 46.4%, while the rest is influenced by other factors outside the three independent variables. Partially, the significant values of infront of stop line, beside flow and inside flow are obtained, respectively 0.549, 0.206 and 0.084, which means that there is no influence on the behavior of motorcycles, infront of stop line, beside flow and inside flow separately. The model for the saturation flow is obtained:

S=5710.93 – 7.79 MC Infront of stop line+0.90 MC beside–3.93 MC Inside (11)

The regression model at a signalized intersection with an approximate width of 7 meters with ESSM produces a goodness of fit value with the R-Square approach of 0.574 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built on the basis of the data obtained is feasible. By paying attention to the R-Square value of 0.574, it indicates that there is an effect of motorcycle behaviour on saturated flow of 57.4%, while the rest is influenced by other factors outside the three independent variables. Partially, the Infront of stop line significance value is 0.755, which means that there is no effect of the behaviour of motorcycles in front of the stop line on saturated flows, However, it is different with beside flow and inside flow, obtaining a significance value of 0.034 and 0.000 where beside flow and inside flow have a significant effect on saturated flow at the signalized intersection with ESSM with a 7 meters wide approach. The model for the saturation flow is obtained:

S=5748.76 + 4.35 MC Infront of stop line–0.35 MC beside–2.5 MC Inside (12)

The addition of the number of motorcycles that are in the inside flow of the approach which has a lane width of 3 meters and 7 meters with and without ESSM can reduce saturation currents. Increasing the number of motorcycles on the front of the stop line can reduce the saturation current in the approach with 7 meters lane width without ESSM. The increase in the number of motorcycles on the beside flow reduces the saturated current in the approach with a lane width of 5 meters and 7 meters with ESSM.

4. Conclusion

This model of the effect of saturated flow on motorcycle behavior applies to through movement with traffic conditions dominated by motorcycles, the percentage of motorcycles is 76% to 90% and the effective width of the approach is 3 meters, 5 meters, and 7 meters with or without ESSM. The model generated from the regression analysis of the influence of motorcycle behavior (infront of stop line, beside flow and inside flow) together produces a better model than the model obtained from the regression analysis separately, namely the effect of the behavior of motorcycles on the infont of stop line on saturated flow, the effect of the behavior of motorcycles beside flow on saturated flow and the influence of the behavior of motorcycles inside flow on saturated flow.

The ESSM in Denpasar, Bali is currently unable to accommodate a large number of motorcycles at a signalized intersection, so special lanes are needed for motorcycles. At the intersection with 3 meters width of approach with or without motorcycle ESSM, the motorcycle beside flow affects the saturation flow the most, so it is necessary to make a motorcycle lane on the left or right of another vehicle. Whereas for a signal intersection with a 5 lanes width with and without ESSM and a 7 lanes width with the ESSM of the motorcycle inside the most influencing the saturated flow so that a motorcycle lane is needed in the middle of another vehicle.

By knowing the behavior of motorcycles at a signalized intersection with an approach width of 3 meters, 5 meters, 7 meters with or without ESSM, the saturation flow can be determined without counting the number of light or heavy vehicles, especially for the 3 and 5 meter approach widths.Further research is needed with conditions like this in other cities, so that better results can be obtained

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The Saturated Flow Modeling on Motorcycle Behavior Based on~~for~~ Through Movements at Signalized Intersections

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Abstract In developing countries such as Indonesia the proportion of motorcycles to other vehicles is reaching 76%, which is very high. The proportion of motorcycles in Bali Province exceeds 85% while in Denpasar City is 82%. Previous studies suggest that a high proportion of motorcycles will certainly ~~have an effect on~~affect the saturated flow. Therefore, the effect of motorcycles on saturation flows should not be neglected. With a high proportion of motorcycles that will affect the behavior of motorcyclists at irregular intersections such as in front of the stop line, besides other vehicles and behind other vehicles or in the flow, the behavior of the motorcycle affects the saturated flow. In calculating saturated flow, the Indonesian Highway Capacity Manual (IHCM) does not have ~~a~~ specific measures that adopt~~s~~ the behavior of motorcycles. If the motorcycle is not properly regulated, it will interfere with the movement of other vehicles when the green light is on. The behavior to be examined in this study is the behavior of motorcycles in front of the stop line, outside the current (beside flow), or in the current (inside flow). In this study, a model was developed to determine saturation flow based on the behavior of motorcycles for~~on~~ through movements at signalized intersections with or without ESSM.

Keywords Motorcycles Behavior, Saturation Flow, Signalized Intersections, Exclusive Stopping Space for Motorcycles (ESSM)

1. Introduction

Studying signalized intersections is one of the most effective measures to increase road network capacity and reduce traffic congestion [6]. The management of signaled intersection traffic flow is much easier to research and analyze if all motorized vehicles are homogeneous [8]. A heterogeneous (mixed) traffic system is very different compared to that of a homogeneous one. For mixed traffic conditions, vehicle sizes and types and control also vary [22].

Mixed traffic dominated by motorcycles is very common in most Asian countries such as Taiwan, Thailand, Vietnam, Indonesia, and Malaysia. For example, the proportion of motorcycles in Hanoi and Ho Chi Minh City in Vietnam is around 90% [6]. In Taiwan, the concept of segregated traffic flow (motorcycle lane separation) was proposed and successfully implemented to improve mixed traffic performance.

The Indonesian government is preparing Exclusive Stopping Space for Motorcycle (ESSM) at several signalized intersections, to accommodate the high number of motorcycles. ESSM is a motorcycle facility in the form of providing motorcycle facilities at signalized intersections. ESSM is an alternative solution to the problem of motorcycle congestion at signalized intersections. When

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entering the green time signal, motorcycles move with various maneuvers to get out of the approach to the intersection, so that it often creates traffic conflicts which are thought to affect the performance and flow of traffic movements at the intersection [12].

A better understanding of the impact of motorcycles on traffic flow affects the development of a more accurate model to determine the effect of motorcycles on the saturated flow [6]. Saturation flow plays an important role in the design of a signalized intersection [18]. The saturation flow (S) is the amount of queue departure in an approach during the specified conditions (pcu/green hour). Meanwhile, the basic saturation flow is the amount of queue departure in the approach during ideal conditions (pcu/green hour) [13].

As a reference for determining intersection parameters such as saturated flow and capacity in Indonesia, the Indonesian Highway Capacity Manual (IHCM) was published in 1997. In 1997, the composition of motorcycles for urban areas in Indonesia was at ~~the~~ an average of 40.5% [13], which is very different from the current condition. It was found that based on the preliminary survey, the composition of motorcycles in Denpasar City was 82%. Although Indonesian urban areas ~~clearly~~ have a high percentage of motorcycles, there has been no adjustment to IHCM regarding the high percentage of motorcycles, the number of vehicle ownership, and the behavior of motorcycles in Indonesia. The IHCM determines the saturation flow based on the basic saturation flow times the adjustment factor. Besides that, the passenger car equivalent (PCE) value does not reflect the real conditions in the field, either. The PCE value has been determined, for example, the PCE for motorcycle is 0.2, the PCE for the light vehicle is 1 and the PCE for the heavy vehicle is 1.3, without any PCE analysis at each intersection studied. Improper regulation of motorcycles, especially at intersections, will not only reduce the level of service at intersections~~,~~ but may also lead to an increase in road traffic accidents.

The behavior of the motorcycle users at a signalized intersection has affected saturated flows, especially motorcycles in the current (inside flow), the greater the composition of the motorcycle in the flow, the higher the saturation flow [11]. According to the [9,14,16,], the behavior of motorcycles at signalized intersections can be grouped into several categories, namely motorcycles in front of the stop line, motorcycles ~~in the current (~~inside flow~~s)~~, and motorcycles outside the flows~~current~~ (beside flow). This study examines the behavior of motorcycles towards saturated flow on through movements because in Denpasar City for large traffic flows, the arrangement of intersections with more signals is done through movement to reduce conflict at signalized intersections. Through movements are free movements that are not affected by conflict [18,19] while according to [2,20] through movements are movements (turn right, go straight, turn left) in each approach that is given the green light simultaneously, and given 1 phase per approach so that vehicles turning right do not have to wait to enter opposite traffic. In this study, what is meant by through movement is the movement of traffic at an intersection approach that has 1 phase or an intersection whose approach has the same phase as other approaches but the movement does not affect or be influenced by the movements of other approaches.

The study of traffic flow at signalized intersections is a new topic. Several studies have been conducted to examine saturated flow and capacity, aimed at improving traffic conditions at signalized intersections or across the transportation network. However, from previous research, no one has determined the influence model of motorcycle behavior at signalized intersections, namely the behavior of motorcycles in front of the stop line, inside flow (inside flow) and outside flow (beside flow), both those with ESSM and without ESSM to saturated flows. Motorcycle behavior research conducted in Malaysia by Leong et al. [11] and in Ghana by Adams et al. [1] only analyzed the effect of motorcycle behavior in the flow (inside flow) without analyzing the behavior of motorcycles in front of the stop line and outside the flow (beside flow) and does not analyze the differences in behavior at the signalized intersections that have ESSM or without ESSM. There are also many ~~researches~~ kinds of research related to ESSM, such as research by [3-7], but no research has analyzed the effect of motorcycle behavior with and without ESSM on saturation flow. Most of the studies only examined the effectiveness of ESSM based on the effect of total motorcycles on saturated flows. This study aims to determine the effect of motorcycle behavior on saturation flow based on ~~for~~ through movements at signalized intersections ~~which~~ that are partially or simultaneously dominated by motorcycles. This benefits to establishing regulations associated with motorcycles at signalized intersections, inclusive of designing the ESSM, creating separate lanes among motorcycles and other vehicles, and setting up the traffic signal. In this research, we will obtain a model or formula to determine the saturation flow only by knowing the behavior of motorcycles at signalized intersections ~~which~~ that are dominated by motorcycles. This study also provides suggestions for overcoming the accumulation of vehicles at signalized intersections ~~with signals~~ that are dominated by motorcycles which may ~~be applicable~~apply to other areas that have the same characteristics, both the geometric and the proportions of the motorcycles. A model of motorcycle behavior towards saturated flow was developed, both with and without ESSM.

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2. Materials and Methods

The regression method is more relevant for the estimation of saturation flow at signalized intersections because its implementation of calculations is easier and simpler. However, this technique relies heavily on accurate

estimation of saturation flow which is also a function of determining PCE [15]. ~~In order t~~To obtain an accurate saturation flow estimation, the method of determining the saturation flow at signalized intersections in this study is used by Chang and Xiao [5]. Traditional methods that only use the average discharge headway to estimate the saturation headway can lead to underestimation. Errors in the saturated flow used for the estimation of vehicle delays can cause errors in the prediction of delay and Level of Service (LOS). Therefore, it is necessary to conduct a study to increase the accuracy of the saturation flow estimation. The facts show that driver behavior is the main determinant of saturation flow. Therefore, a good understanding of the time between discharge headways is essential in estimating the time between saturation headway and saturation flow rate. The stochastic properties of the time between vehicle releases could provide better information for the development of a method of estimating saturation flow rates [5]. It is easy to understand that the time between vehicle releases is a random variable due to differences in driver behavior response times and variations in queue space length. To estimate the saturation headway time, the average time between vehicle releases is calculated as follows:

$$\overline{h_s} = \frac{1}{n}\sum_{i=1}^{n} h_{si} \quad (1)$$

With,

h_s : the average time between discharges (s) which is taken as the estimated time between saturations h;

h_{si} : time between vehicles i in the queue, i = 1, 2, ..., n (n is the sample size), consequently, the level of saturation flow is (conventionally) determined by the time between discharge:

$$S = \frac{3600}{\overline{h_s}} \quad (2)$$

With,

S is the saturation flow level (vehicle~~/~~/hour).

Based on the statistical theory that "If the intermediate time distribution is symmetric, the average intermediate time calculated by equation (1) is a good (unbiased) estimate of h and equation (2) can be a good estimate for the saturation flow rate" [14]. However, if the intermediate time distribution is not symmetrical, h_s is not a good estimate, and equation (2) will give a saturation flow level value that is too high (overestimate) or too low (underestimate). Therefore, it is necessary to study the stochastic nature of the time between queuing vehicles and to analyze the effect of time variation between the estimated saturation flow rates [5].

When the mean time between queue releases is greater than the median value and the skewness of the intermediate time values is positive, this characteristic indicates that the time distribution between queue~~s~~ releases tends to be asymmetrical and the normal distribution function does not match the intermediate time data [5]. Therefore, the conventional saturation flow rate estimation method (equation 2) can produce an underestimated saturation flow level value.

If the time distribution between queue releases tends to be asymmetrical, then the intermediate time value can be modeled with a lognormal distribution [5,17]. If it is known that when the random variable h_s function density is lognormal, then ln h_s will follow the normal distribution. Therefore, it is very relevant to use the median value to calculate the saturation flow rate in the following way:

$$S_1 = 3600 \times \frac{1}{h_{med}} \quad (3)$$

With,

S_1 : a new estimate of the saturation flow rate (vehicles/hour);

h_{med} : the median value of the intermediate time or the estimated median value of the intermediate time.

In addition, there are two new estimates for the saturation flow rate [14]

$$S_2 = 3600 \times \exp\left(-\frac{1}{n}\sum_{i=1}^{n} \ln h_{si}\right) \quad (4)$$

$$S_3 = \frac{3600}{\bar{h}_s} \times \left(1 + \frac{\sigma_s^2}{\bar{h}_s^2}\right)^{0.5} \quad (5)$$

With,

S_2 and S_3 are two new estimates of the saturation flow rate (vehicles~~/~~/hour).

$$\sigma_s^2 = \left[\frac{1}{n} - 1 \cdot \sum_{i=1}^{n}\left(h_{si} - \bar{h}_s\right)^2\right] \quad (6)$$

represents the variance of the intermediate time sample.

The selected intersection has a large volume of motorcycles, namely 82 percent [4]. Minor side barriers, namely interference from factors such as pedestrians, vehicles turning left or right, parking vehicles (~~on~~ on-street parking), and bus stops or stops, both those with ESSM and those without ESSM are at one of the intersection approaches. The intersection chosen is also one of the approaches that ~~has~~ have a through movement of motorcycles or is not affected by conflict, whether there is an ESSM or no ESSM.

This study was conducted in Denpasar City. Based on data obtained from the Denpasar City Department of Transportation, Denpasar City has 66 intersections with signals, of which 15 intersections have Exclusive Stopping Space for Motorcycle and 51 intersections have no ESSM [10]. For ~~the purposes of~~ the analysis, an approach has been chosen at the four signalized intersections which have approximately the same volume of vehicles passing through the intersection. The same approach width has the proportion of motorcycles that reflect the same mixed

traffic flow conditions between the existing ESSM and those without the ESSM, as shown in Table 1. Discharge Headway data is obtained from video recordings of the Denpasar City Area Traffic Control System (ATCS), data retrieval is conducted forcarried out at 2.5 hours during peak hours in the morning, afternoon, and evening for 2.5 hours per each busypeak hours.

3. Results and Discussion

Headway data were obtained from the Denpasar City Area Traffic Control System (ATCS) video recordings, which include 9440 headway data for an approach with an effective width of 3 meters with ESSM and 10833 without ESSM. Discharge headway data from the approach of the effective width of 5 meters with ESSM as much as 14161 and without ESSM 19667 data. Discharge headway data from the approach of the effective width of 7 meters with ESSM as much as 14002 and without ESSM 14932 data. Discharge headway data from each approach were combined into one for each approach width, both with ESSM and without ESSM to get the saturated flow value.

In Table 2, it can be seen that the proportion of vehicles in each approach with an approach width of 3 meters, 5 meters, and 7 meters, both with ESSM and without ESSM. Based on Table 2, the percentage of the proportion of motorcycles is relatively the same as the 1-2 percent difference between the approach with ESSM and without ESSM except for the 3 meters width of the approach. There is a difference of 5.6% of the approach without ESSM. The the percentage of motorcycles is greater compared to those with the ESSM approach.

Meanwhile, the percentage of motorcycle behaviour in each approach, both with ESSM and without ESSM, is shown in Table 3. Based on Table 3, motorcycles at a signalized intersection tend to behave beside flow (beside other vehicles), both those with ESSM and without ESSM, which happens because motorcycles have more freedom to maneuverer because there are no light vehicles in front of them. The percentage of the behaviour of motorcycles beside flow is greater than inside flow at a signalized intersection with ESSM, whether the approach width is 3 meters, 5 meters, or 7 meters.

Furthermore, the headway data analysis was carried out in SPSS descriptively as well as knowing the form of data distribution. The purpose of this analysis is to see whether data distribution patterns are normally distributed or not. The form of data distribution can be determined through statistical calculations with the Shapiro-Wilk or Kolmogorov Smirnov approach. According to the data, less than 50 uses the Shapiro Wilk approach, while more than 50 use the Kolmogorov-Smirnov. The data is said to be normally distributed if the Sig. from the test statistic is greater than 0.05.

Table 1. Intersections with the same Approach Width and Traffic Characteristics

No.	Approach Width (m)	Intersection		Approach	
		With ESSM	Without ESSM	With ESSM	Without ESSM
1	7	Dewi Sartika Dewi Sartika	Kebo Iwa Kebo Iwa	Dewi Sartika Teuku Umar	Gatot Subroto Barat (T) Gatot Subroto Barat (B)
2	5	Kapten Japa Kapten Japa	Saelus Surabi Kenyeri	Hayam Wuruk (T) Hayam Wuruk (B)	Diponegoro (S) Supratman (B) Gatot Subroto Tengah (B)
3	3	Nangka Unud	Perumnas Saelus	Nangka (U) Serma Mendra	Buana Raya Pulau Saelus

Table 2. The Percentage of proportion of vehicles in each approach with and without ESSM

Approach Width		Vehicle		
		Motor cycle	Light Vehicle	High Vehicle
3m	Non ESSM	90,36	8,79	0,85
	ESSM	84,76	14,66	0,59
5m	Non ESSM	82,09	16,11	1,80
	ESSM	81,60	17,99	0,41
7m	Non ESSM	78,74	19,40	1,86
	ESSM	76,78	22,62	0,61

Table 3. Percentage of motorcycle behaviour of each approach with and without ESSM

Approach Width		Motorcycle Behaviour		
		In front of the stop line	Beside flow	Inside flow
3m	Non ESSM	3,06	75,45	22,24
	ESSM	1,61	79,54	19,18
5m	Non ESSM	1,87	50,20	48,86
	ESSM	1,46	65,62	33,43
7m	Non ESSM	4,03	55,20	42,58
	ESSM	0,42	57,16	42,61

Data with normal distribution were calculated to obtain the saturation flow with ~~the~~ Formula 2, while data that were not normally distributed, were calculated using the Formula (3, 4, 5). Based on the observations on the saturation flow values at S_1, S_2, and S_3, the saturation flow values are almost the same. This result is also confirmed by [10] who simulated the calculations using the S_1, S_2, and S_3 formula approaches. Based on the results of this analysis, a similar saturation flow value is obtained, so it can be concluded that the S_1, S_2, or S_3 values can be selected for use by the researcher.

This study uses the S_3 formula for data that is not normally distributed~~,~~ because the S_3 formula is the final development of the previous formula and ~~in~~ the formula accommodates the size of the ~~centre~~ center (mean) and data distribution (variance).

After the S value is obtained based on the various criteria above, then a behavio~~u~~ral analysis of the saturation flow is carried out by using multiple linear regression. The analysis is divided into two, namely as a whole (behavio~~u~~r of motorcycles inside flow, In front of a stop line, and beside flow) to saturated flow and their respective behavio~~u~~r by ignoring other behavio~~u~~rs (behavio~~u~~r of the ~~I~~infront motorcycles to saturated flow, behavio~~u~~r of motorcycles beside saturated flow and the behavio~~u~~r of the inside motorcycle to saturated flow). The model obtained is then evaluated based on the value of its fit model using the R-Square approach and F-count (F significance). A model whose fit model is good, deserves to be interpreted, while a model whose fit model is still weak is considered not feasible. For the model of the influence of behavio~~u~~r individually by ignoring other behavio~~u~~rs, a model is obtained as shown in Figure 1.

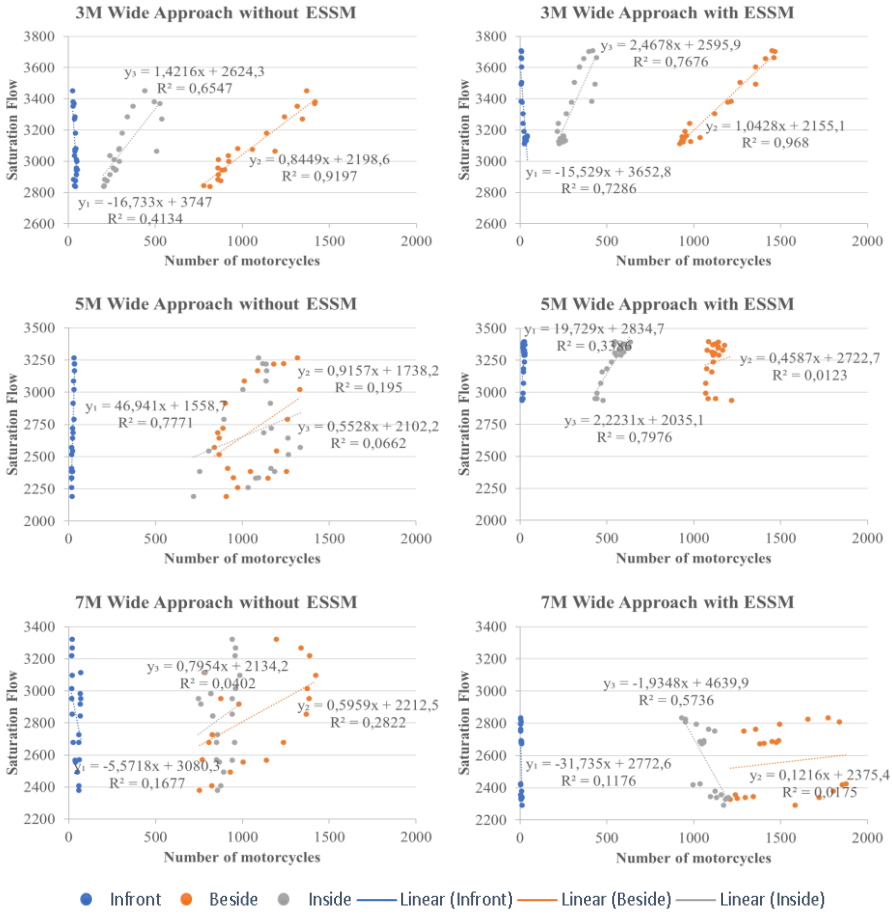

Figure 1. The model of the influence of each motorcycle behavior on saturated flow ignores the influence of other behaviors

The regression model at a signalized intersection with an approach width of 3 meters without ESSM or with partial ESSM by only taking into one behavior and ignoring other behaviors, it is found that the behavior of in front of a stop line, inside flow and beside flow has an effect on saturated flow. The regression model at a signalized intersection with an approach width of 5 meters without ESSM shows only that the behavior of in front of stop line and beside affects saturated currents, while the width of the approach of 5 meters with ESSM shows that only the behavior of in front of stop line and inside flow affects saturated flow. The regression model at a signalized intersection with an approach width of 7 meters without ESSM shows only that beside flow affects saturation flow, while the width of the approach of 7 meters with ESSM shows that only inside flow affects the saturation flow.

Table 4 shows the relationship between the effect of motorcycle behavior on saturated flow and an approach width of 3 meters, 5 meters, and 7 meters without ESSM. Meanwhile, table 5 shows the relationship between the effect of motorcycle behavior on saturated flow and the approach width 3 meters, 5 meters, and 7 meters with ESSM.

The regression model at the intersection with a signal with an approximate width of 3 meters without ESSM taking into account all behaviors in the analysis (In front of a stop line, inside flow, and beside flow). The regression analysis model in Non-ESSM 3 produces a goodness of fit value with the R-Square approach of 0.945 and the significance of F is 0.000. The significance value of F obtained is greater than 0.05, which means that the model built based on the data obtained is feasible. The R-Square value of 0.945 indicates that there is an effect of motorcycle behavior on saturation flow of 94.5%, while the remaining 5.5% is influenced by other factors outside the three independent variables at the intersection with a signal without ESSM with an approach width of 3 meters. Partially, a significance value is obtained at the Infront of 0.38, which means that there is no influence on the behavior of motorcycles in front of the stop line on saturated flow, but there are differences between beside flow and inside flow, which respectively get a significance value of 0.000 and 0.013 where beside and inside has a significant effect on saturation flows at the intersection with no ESSM signal with a width of 3 meters. The model for the saturation flow is obtained:

$$S=1968.85 + 1.92\ MC\ Infront\ of\ stop\ line+1.21\ MC\ beside–0.7\ MC\ Inside \quad (7)$$

The regression model at the intersection with a 3 meters wide approach with ESSM produces a goodness of fit value with the R-Square approach of 0.972 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built based on the data obtained is feasible. The R-Square value of 0.972 indicates that there is an effect of motorcycle behavior on saturation flow of 97.2%, while the rest is influenced by other factors outside the three independent variables.

Table 4. Model of influence of motorcycle behavior at signalized intersections without ESSM

Statistics	Non ESSM 3	Non ESSM 5	Non ESSM 7
Model	Y=1968.85 + 1.92X1+1.21X2–0.7X3	Y= 346.31+ 46.78X1 + 0.27X2+0.86X3	Y=5710.93 -7.79X1 + 0.90X2–3.93X3
R-Squared	0.945	0.915	0.464
Sig. F	0.000	0.000	0.012
Constant	1968.85	346.31	5710.93
Uns. Coeff.	Infront (X1):1.92 Beside (X2): 1.21 Inside (X3): -0.7	Infront (X1): 46.78 Beside (X2): 0.27 Inside (X3): 0.86	Infront (X1):-7.79 Beside (X2): 0.90 Inside (X3): -3.93
Sig. t	Infront (X1): 0.38 Beside (X2): 0.000 Inside (X3): 0.013	Infront (X1): 0.000 Beside (X2): 0.15 Inside (X3): 0.000	Infront (X1): 0.55 Beside (X2): 0.21 Inside (X3): 0.084

Table 5. Model of influence of motorcycle behavior at signalized intersections with ESSM

Statistics	ESSM 3	ESSM 5	ESSM 7
Model	Y=2017.18+0.14+ 1.19–0.42X3	Y=2131.43+10.61X1–0.18X2+2.01X3	Y= 5748.76+4.35X1 -0.35X2–2.5X3
R-Squared	0.972	0.901	0.574
Sig. F	0.000	0.000	0.000
Constant	2107.18	2131.43	5748.76
Uns. Coeff.	Infront (X1):0.14 Beside (X2): 1.19 Inside (X3): -0.42	Infront (X1): 10.61 Beside (X2): -0.18 Inside (X3): 2.01	Infront (X1):4.35 Beside (X2): -0.35 Inside (X3):- 2.5
Sig. t	Infront (X1): 0.928 Beside (X2): 0.000	Infront (X1): 0.003 Beside (X2): 0.65	Infront (X1): 0.755 Beside (X2): 0.034

Inside (X3): 0.16	Inside (X3): 0.000	Inside (X3): 0.000

Partially, a significance value is obtained for the Infront of 0.928 and the inside flow of 0.158, which means that there is no influence on the behavior of motorcycles in the Infront of the stop line and inside flow on saturated flow. However, there are differences between beside flow, obtaining a significance value of 0.000, where beside has a significant effect on saturated flow at a signalized intersection with ESSM with a 3 meters wide approach. The model for the saturation flow is obtained:

S=2017.18 + 0.14 MC Infront of stop line+1.19 MC beside– 0.42 MC Inside (8)

The regression model at a signalized intersection with an approximate width of 5 meters without ESSM results in a goodness of fit value with the R-Square approach of 0.915 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built ~~on the basis of~~based on the data obtained is feasible. The R-Square value of 0.915 indicates that there is an influence of motorcycle behavior on saturation flow of 91.5%, while the rest is influenced by other factors outside the three independent variables. Partially, it is obtained a significance value beside flow of 0.15 which means there is no influence of the behavior of motorcycles beside flow on saturated flow, However, in contrast to ~~the~~ in front of stop line and inside flows, it obtained a significance value of 0.000 where the infront of stop line and inside flow contributed significantly to the saturated flow at the signalized intersection without ESSM with an approach width of 5 meters. The model for the saturation flow is obtained:

S=346.31 + 46.78 MC Infront of stop line+0.27 MC beside– 0.86 MC Inside (9)

The regression model at the signalized intersection with an approximate width of 5 meters with ESSM produces ~~a~~ goodness of fit value with the R-Square approach of 0.901 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built ~~on the basis of~~based on the data obtained is feasible. The R-Square value of 0.901 indicates that there is an influence of motorcycle behavior on saturation flow of 90.1%, while the rest is influenced by other factors outside the three independent variables. Partially, it is obtained a ~~significance~~ significant value beside flow of 0.65, which means that there is no influence of the behavior of motorcycles beside flow on saturated flow, However, in contrast to the infront of stop line and inside flow, it has a ~~significance~~ significant value of 0.003 and 0.000 where the infront of stop line and inside flow have a significant effect on saturated flow at the signalized intersection with ESSM with a 5 meters wide approach. The model for the saturation flow is obtained:

S=2131.43 + 10.61 MC Infront of stop line–0.18 MC beside+2.01 MC Inside. (10)

The regression model at the signalized intersection with an approach width of 7 meters without ESSM results in a goodness of fit value with the R-Square approach of 0.464 and a significance of F of 0.012. The significance value of F obtained is greater than 0.05, which means that the model built ~~on the basis of~~based on the data obtained is feasible. The R-Square value of 0.464 indicates that there is an effect of motorcycle behavior on the saturated flow of 46.4%, while the rest is influenced by other factors outside the three independent variables. Partially, the significant values of the infront of stop line, beside flow and inside flow are obtained, respectively 0.549, 0.206, and 0.084, which means that there is no influence on the behavior of motorcycles, infront of stop line, beside flow and inside flow separately. The model for the saturation flow is obtained:

S=5710.93 – 7.79 MC In front of stop line+0.90 MC beside–3.93 MC Inside (11)

The regression model at a signalized intersection with an approximate width of 7 meters with ESSM produces ~~a~~ goodness of fit value with the R-Square approach of 0.574 and a significance of F of 0.000. The significance value of F obtained is greater than 0.05, which means that the model built ~~on the basis of~~based on the data obtained is feasible. The R-Square value of 0.574 indicates that there is an effect of motorcycle behavio~~u~~r on the saturated flow of 57.4%, while the rest is influenced by other factors outside the three independent variables. Partially, the Infront of stop line significance value is 0.755, which means that there is no effect of the behavio~~u~~r of motorcycles in front of the stop line on saturated flows, However, it is different with beside ~~flow~~ and inside flows, obtaining a significance value of 0.034 and 0.000 where beside ~~flow~~ and inside flows have a significant effect on saturated flow at the signalized intersection with ESSM with a 7 meters wide approach. The model for the saturation flow is obtained:

S=5748.76 + 4.35 MC Infront of stop line–0.35 MC beside–2.5 MC Inside (12)

The addition of the number of motorcycles that are in the inside flow of the approach which has a lane width of 3 meters and 7 meters with and without ESSM can reduce saturation currents. Increasing the number of motorcycles on the front of the stop line can reduce the saturation current in the approach with 7 meters lane width without ESSM. The increase in the number of motorcycles on the beside flow reduces the saturated current in the approach with a lane width of 5 meters and 7 meters with ESSM.

4. Conclusions

This model of the effect of saturated flow on motorcycle behavior applies to through movement with traffic conditions dominated by motorcycles, the

percentage of motorcycles is 76% to 90% and the effective width of the approach is 3 meters, 5 meters, and 7 meters with or without ESSM. The model generated from the regression analysis of the influence of motorcycle behavior (infront of stop line, beside flow, and inside flow) together produces a better model than the model obtained from the regression analysis separately, namely the effect of the behavior of motorcycles on the infont of stop line on saturated flow, the effect of the behavior of motorcycles beside flow on saturated flow and the influence of the behavior of motorcycles inside flow on saturated flow.

~~In relation to~~Concerning ~~putting on~~ the ESSM at signalized intersections, motorcycle behavio~~u~~r must be considered~~–~~ as that highly influences the saturation flow. The application of ESSM in Denpasar, Bali needs to be reviewed because the presence or absence of ESSM does not necessarily affect the saturation flow. The ESSM in Denpasar, Bali is currently unable to accommodate a large number of motorcycles at a signalized intersection, so special lanes are needed by motorcycles. At the intersection with 3 meters width of approach with or without motorcycle ESSM, the motorcycle beside flow affects the saturation flow the most, so it is necessary to make a motorcycle lane on the left or right of another vehicle. Whereas for a signal intersection with a 5 m lanes width with and without ESSM and a 7 m lanes width with the ESSM of the motorcycle inside the most influencing the saturated flow so that a motorcycle lane is needed in the middle of another vehicle.

By knowing the behavior of motorcycles at a signalized intersection with an approach width of 3 meters, 5 meters, 7 meters with or without ESSM, the saturation flow can be determined without counting the number of light or heavy vehicles, especially for the 3 and ~~5~~–5 meters approach widths. Further research is needed with conditions like this in other cities, so that better results can be obtained

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