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# The influence of motorcycle behavior on saturation flow rate at signalized intersections with and without exclusive stopping space for motorcycle (ESSM)

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**Abstract**. Traffic in most developing nations is considered mixed or heterogeneous. Motorcycle and other vehicle's behavior at signalized intersections would not probably have a similar influence on intersection capacity and time of the traffic signals. In theory, the saturation flow rate is a basic parameter to estimate the intersection capacity and time of the traffic signals. This study, therefore, aims to analyze the influence of motorcycle behavior on the saturation flow rate at signalized intersections in Denpasar, Bali. Traffic flow data are observed at four signalized intersection approaches that have similar width and traffic characteristics. Two approaches have exclusive stopping space for motorcycles (ESSM) while the other two do not. The study results show that more than 50% of motorcycles tend to be distributed beside flow at signalized intersections with ESSM on either light or dense traffic flows. In contrast, at the signalized intersections without ESSM, motorcycles are found to be distributed inside flow during low traffic conditions, while distributed beside flow during dense traffic flow. Besides, the saturation flow rates of motorcycle inside flow are less than that of beside flow at signalized intersections both with and without ESSM. A new method to estimate saturation flow is proposed.

## 1. Introduction

The intersection is the meeting point of traffic movements from different directions and can impede traffic flow, cause traffic jams, and accidents. A signalized intersection, play an important role to reduce the bottleneck of traffic flow on urban roads. Study at signalized intersections is one of the most effective measures to increase the capacity of the road network and reduce traffic congestion [1]. Traffic flow management at signalized intersections is much easier to be studied and analyzed as all motorized vehicles are homogeneous [2]. However, in developing countries like Indonesia, there is a mixed traffic flow with different types, sizes, weights and strengths of vehicles. In this situation, it is very difficult to determine the saturation flow in vehicles/hour, because different traffic compositions produce different answers.

A mixed traffic situation 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 approximate 90% [1]. A past study (Branston and van Zuylen (1978) in [3]) suggested that the proportion of motorcycles greater than 20% in traffic flow affects saturated flow. The ratio between motorcycles and all types of motor vehicles in Denpasar and Bali

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however, reached 82.64% and 85.90% respectively. Besides, motorcycles increased by 3.8 times during a period of 4 years from 2012 to 2016 in the city of Denpasar [4].

Motorcycles can reduce the speed of other modes and can make traffic more congested due to the rider's behavior. This is because the motorcycle can move slowly, be next to other vehicles, run slowly into the queue in front when the traffic lights are red so that it blocks traffic flow by disturbing other vehicles behind. The influence of motorcycle behavior must be taken into account because all modes of transportation are considered in traffic flow management. A better understanding of the impact of motorbikes on traffic influences the development of more accurate models and the behavior of motorcycle riders can be modeled better [1].

Besides, the lane width will affect the motorcycle behavior at the signalized intersection, because the wider the lane the high chance of a motorcycle being next to another vehicle. Similarly, the smaller the lane the low chance of a motorcycle being outside the flow (besides other vehicles) and a motorcycle will be either in front of other vehicles or behind other vehicles because it cannot maneuver forward. To overcome this motorcycle behavior, Indonesia has also implemented an exclusive stopping space for motorcycle (ESSM). The dimension of ESSM is adjusted to the traffic volume in the hope that the motorcycle can move immediately when the light is green and can reduce delays from light vehicles at the start of the maneuver.

Several past studies have been carried out for the analysis of the effect of mixed traffic flow on saturated flow and signal crossing capacity [1; 5; 6]. This study, however, aims to investigate motorcycle behavior distribution at signalized intersections with and without ESSM and the influence of motorcycle behavior on the saturation flow at signalized intersections. The motorcycle behavior categories at a signalized intersection were adopted from [7] as follows:

- Motorcycles in front of the stop line are motorcycles at a red light trying to get into the sidelines of other vehicles to occupy a position in front of the stop line.
- Motorcycles next to other vehicles are motorcycles occupy space next to other vehicles.
- Motorcycles inside flow are motorcycles follow the flow both in front and behind other vehicles.

Such influence of motorcycle behaviors on saturated flow has not yet been considered in the Indonesian Road Capacity Manual (IHCM). This study, therefore, is expected to obtain models of motorcycle behaviors at signalized intersections with and without ESSM.

## 2. Exclusive stopping space for a motorcycle, saturation flow, and time Slice

The ESSM was developed from Advanced Stop Lines (ASLs) for bicycles. It is a facility for bicycles to be placed in front of the queues of motorized vehicles [8]. This is one solution in solving the problem of the accumulation of motorcycles at signal intersections. It is a stop for motorcycles at signal intersections during the red phase which is placed in front of a queue of four-wheeled motorized vehicles [9].

An ESSM is located in front of a four-wheeled motorized vehicle and does not cross the end of the intersection approach line. It is limited by stop lines for motorcycles with stop line markings for four-wheeled vehicles. It consists of approaching lanes and waiting areas (reservoirs) whose main function is to help motorcycles move first than four-wheeled vehicles so that they can make intersections clean faster and reduce traffic conflicts caused by motorcycle maneuvers.

Meanwhile, the saturation flow is defined as the maximum departure flow that can be generated from an intersection arm during a specified green time interval (pcu/green time) which is a function of the effective width of the intersection arm [10]. The basic model of saturation flow is shown in Figure 1.

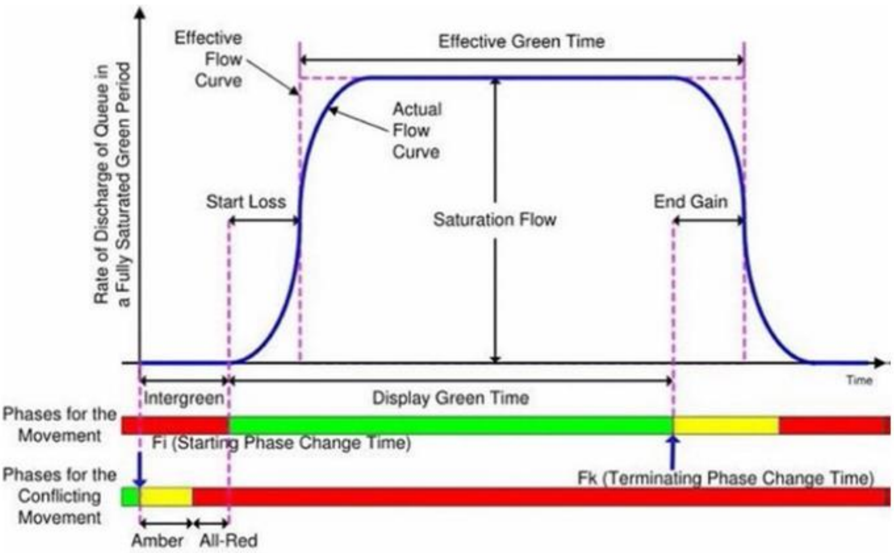


**Figure 1** The basic model for saturation flow [15].

$$S=S_0\times F1\times F2\times F3\times F4\ldots.\times Fn \quad (1)$$

For protected approach, the base saturated flow is determined as a function of the effective width of the approach (We)

$$S_0=600\times We \text{ (pcu/green time)} \quad (2)$$

where,
S : Saturation flow
$S_0$ : Base saturated flow
F : (F1, F2, F3, F4,...Fn) are adjustment factors of city size, side friction, road gradient, parking and turning movement

In the meantime, saturation flow can also be determined using the time-slice method by dividing every green time under saturated conditions and evenly distributing the traffic flow in a saturated condition that is free from the effects of time loss. The green period, in this case, is the green time plus amber. Saturated flow is the average flow under saturated conditions in green time, excluding the initial and final time slices [12].

In this study, passenger car equivalent is adopted from a past study conducted in Vietnam [1]. The speed of the vehicle, however, for this study is examined from the discharge speed of the vehicle from the intersection stop line.

$$PCE_i = \frac{V_{LV}/V_i}{A_{LV}/A_i} \quad (3)$$

where:
$PCE_i$ : The equivalent value of passenger car for the ith type of vehicle
$V_{LV}$ ; $V_i$ : The average discharge speed of light vehicles & of ith type of vehicle (km/hour) respectively
$A_{LV}$ ; $A_i$ : Area (length x width) of a light vehicle & of ith type of vehicle on the road ($m^2$) respectively

Table 1 shows the average dimensions of motor vehicle classifications. The arranged vehicle classification incorporates small, medium and large vehicles adapted from the Guidelines for Inter-City Road Geometric Planning Procedures [13] while, the motorcycle dimension is taken from Chandra, et.al (2003) in [14].

**Table 1** The dimension of each type of vehicle.

| No. | Type | Vehicle | Average dimension (m) | Area (m2) |
|---|---|---|---|---|
| 1. | Small vehicles | Passenger car | 2.10 x 5.80 | 12.18 |
| 2. | Medium vehicles | Truck 2 axles and bus 2 axles | 2.60 x 12.10 | 31.46 |
| 3. | Large vehicles | Semi-trailer trucks | 2.60 x 21.00 | 54.60 |
| 4. | Motorcycles | Scooter, motorcycles, mopeds | 1.87 x 0.64 | 1.20 |

## 3. Data Collection

The primary data is collected from the Automatic Traffic Counting System (ATCS) video of the Department of Transportation of Denpasar City. Traffic flows are recorded at four signalized intersection approaches, which have the same width and traffic characteristics where two approaches each with and without ESSM. Two approaches at Jl. Dewi Sartika and Jl. Teuku Umar with ESSM respectively, are located at a signalized intersection of Dewi Sartika – Teuku Umar.

Meanwhile, two approaches at Jl. Gatot Subroto west and east are without ESSM, situated at a signalized intersection of Gatot Subroto-Kebo Iwa. Traffic data is recorded for six (6) hours consisting of 2 hours at morning peak hours between 06.30 and 8.30, 2 hours at noon and afternoon peak hours between 11.00 and 13.00, and 2 hours in the evening peak hours between 16.00 and 18.00. These four approaches are protected and no parking is found as side frictions.

## 4. Model Development and Analysis

The distribution of motorcycle behavior in front of the stop line, beside flow (besides other vehicles) and inside flow (in front or behind other vehicles) at all approaches with and without the ESSM can be seen in Figure 2. The blue, green and red lines represent in front of the stop line, beside and inside flows respectively. Figure 2 shows that the motorcycles are dominant beside flow in which next to other vehicles. The proportion of motorcycles beside other vehicles is higher than inside flow in which in front of or behind other vehicles. This is due to the motor vehicle density so that the motorcycles do not have a gap to maneuver into the flows.

The proportions of motorcycles in front of the stop line, beside flow and inside flows at the Dewi Sartika approach with the ESSM are 0.1%, 57.69%, and 42.2% respectively. The proportions of motorcycles in front of the stop line, beside flow and inside flows at the Teuku Umar approach with the ESSM are 0.3%, 56.57%, and 43.05% respectively. The proportions of motorcycles in front of the stop line, beside flow and inside flow at Hayam Wuruk approach with ESSM are 1.19%, 62.89%, and 35.92% respectively. Meanwhile, the proportions of motorcycles in front of the stop line, beside flow and inside flows at Gatot Subroto east approach without the ESSM are of 2.01%, 62.67%, and 35.32% respectively. The proportions of motorcycles in front of the stop line, beside flow and inside flows at Gatot Subroto west approach without the ESSM are 2.4%, 49.08%, and 48.52% respectively. The proportions of motorcycles in front of the stop line, beside flow and inside flows at the Diponegoro approach without ESSM are 0.93%, 52.94%, and 46.13% respectively. These show that more than half of the total number of motorcycles passing through signalized intersections are besides other vehicles.

The regression equation shown in Figure 2 can be used to estimate motorcycle volume per green time as shown in Table 2. Traffic conditions are less dense with the number of vehicles under 50 and 110 vehicles at Gatot Subroto east, Gatot Subroto west and Diponegoro approach respectively. Motorcycle tends to inside flow i.e. in front or behind other vehicles and when the traffic is getting more solid the motorcycle chooses to be beside flow i.e. next to other vehicles. The proportion of motorcycles is higher beside flow than being inside the flow. This may be due to traffic density so that the motorcycles cannot maneuver ahead into the flows.

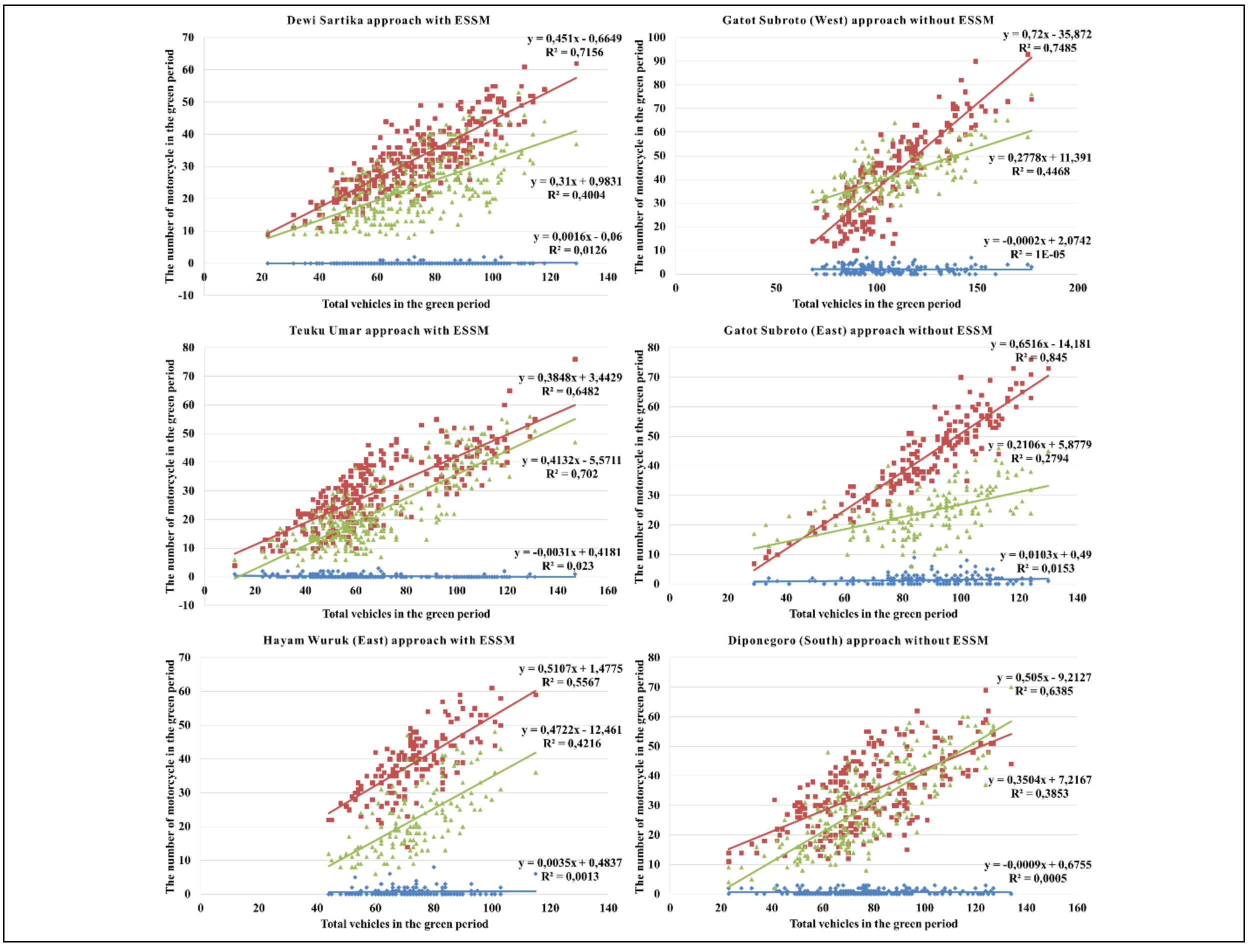


**Figure 2** Motorcycle behavior at all approaches with and without the ESSM.

**Table 2** Model of motorcycle volume per green time.

| Approaches | Regression models |
|---|---|
| Dewi sartika with ESSM | $y_1 = 0.45x - 0.67$ ($R^2 = 0.72$), $y_2 = 0.31x + 0.98$ ($R^2 = 0.40$) and $y_3 = 0.0016x - 0.06$ ($R^2 = 0.01$) |
| Teuku Umar with ESSM | $y_1 = 0.38x + 3.44$ ($R^2 = 0.62$), $y_2 = 0.41x - 5.57$ ($R^2 = 0.70$) and $y_3 = 0.003x + 0.42$($R^2 = 0.023$) |
| Hayam Wuruk (east) with ESSM | $y_1 = 0.51x + 1.48$ ($R^2 = 0.56$), $y_2 = 0.47x - 12.46$ ($R^2 = 0.42$) and $y_3 = 0.004x + 0.48$ ($R^2 = 0.001$) |
| Gatot Subroto (west) without ESSM | $y_1 = 0.72x - 35.87$ ($R^2 = 0.75$), $y_2 = 0.28x + 11.39$ ($R^2 = 0.45$) and $y_3 = -0.0002x - 2.07$ ($R^2 = 1e\text{-}05$) |
| Gatot Subroto (east) without ESSM | $y_1 = 0.65x - 14.18$ ($R^2 = 0.85$), $y_2 = 0.21x + 5.88$ ($R^2 = 0.28$) and $y_3 = 0.01x + 0.49$ ($R^2 = 0.015$) |
| Diponegoro (south) without ESSM | $y_1 = 0.51x - 9.21$ ($R^2 = 0.64$), $y_2 = 0.35x + 7.22$ ($R^2 = 0.39$) and $y_3 = -0.0009x + 0.68$ ($R^2 = 0.0005$) |

where,
$y_1$ = motorcycle besides other vehicles (outside flow),
$y_2$ = motorcycle in front of/behind other vehicles (inside flow) and
$y_3$ = motorcycle in front of the stop line.

The approach width at each intersection is important in calculating the saturation flow rate. For each intersection, cycle length, green time and flows for each vehicle on each approach are noted down as shown in Table 3. All approach widths are seven (7) meters except for two approaches of Hayam Wuruk and Diponogero are five (5) meters. The saturation flow rate mainly varies with the width of the approach lane. As greater the width of the approach lane, a greater number of vehicles can pass through the intersection, hence logically greater will be the saturation flow rate as shown in Table 5. The cycle time varies from 60 to 160 seconds however, the range of green time is between 28 and 58 seconds.

**Tabel 3** Approach width, cycle and green times dan vehicle volumes.

| Approaches | Lane width (m) | Cycle time (s) | Green time (s) | Beside flow motorcycle | Inside flow motorcycle | Light vehicle | Heavy vehicle |
|---|---|---|---|---|---|---|---|
| Dewi sartika with ESSM | 7 | 60 | 28 | 3546 | 2663 | 1364 | 52 |
| Teuku Umar with ESSM | 7 | 95 | 46 | 3076 | 2866 | 1635 | 45 |
| Hayam Wuruk (east) with ESSM | 5 | 160 | 40 | 2177 | 1073 | 580 | 5 |
| Gatot Subroto (east) without ESSM | 7 | 132 | 34 | 2920 | 1366 | 993 | 69 |
| Gatot Subroto (west) without ESSM | 7 | 132 | 34 | 3021 | 2484 | 1113 | 90 |
| Diponegoro (south) without ESSM | 5 | 114 | 58 | 2497 | 2896 | 1048 | 43 |

Using equation (3), the PCE for motorcycles and heavy vehicles at all approaches were determined as shown in Table 4. Hayam Wuruk and Diponegoro approaches have the same road width, as shown in Table 3, which may affect the discharge speed of the vehicle. Thus, the road width may influence the PCE values of motorcycle and heavy vehicles as shown in Table 4. The discharge speed variation, however, is relatively high for motorcycles and heavy vehicles. Interestingly, the PCE differs for each approach applied only for heavy vehicles. The PCE of motorcycle for all approaches, however, has the same value because of the small dimension of a motorcycle but at Hayam Wuruk and Diponegoro approaches. These various equivalency factors indicate traffic heterogeneity. In other words, these intersection approaches represented road traffic under heterogeneous conditions.

**Table 4** PCE for motorcycles and heavy vehicles at four intersection approaches.

| Intersection | Approaches | VLV | VMC | VHV | ALV | AMC | AHV | PCEMC | PCEHV |
|---|---|---|---|---|---|---|---|---|---|
| Dewi Sartika | Dewi Sartika | 18.61 | 14.61 | 17.32 | 12.18 | 1.2 | 31.46 | 0.13 | 2.77 |
| Dewi Sartika | Teuku Umar | 12.58 | 9.80 | 11.75 | 12.18 | 1.2 | 31.46 | 0.13 | 2.77 |
| Kapten Japa | Hayam wuruk (east) | 18.92 | 26.80 | 16.38 | 12.18 | 1.2 | 31.46 | 0.07 | 2.98 |
| Keboiwa | Gatsu (east) | 17.41 | 12.36 | 16.95 | 12.18 | 1.2 | 31.46 | 0.14 | 2.65 |
| Keboiwa | Gatsu (west) | 10.88 | 7.72 | 10.60 | 12.18 | 1.2 | 31.46 | 0.14 | 2.65 |
| Pulau Saelus | Diponegoro (south) | 14.70 | 19.27 | 12.72 | 12.18 | 1.2 | 31.46 | 0.08 | 2.98 |

The saturation flow subsequently is determined using the flow which is divided into a slice time of six (6) seconds as shown in Table 5. The saturated flow of motorcycle behavior inside flow is less than that beside flow at all types of intersections with and without ESSM. Light vehicles have the highest saturation flow among other vehicles at the four observed approaches.

**Tabel 5** Saturation flow using a time slice method.

| Approaches | Saturation flow Beside flow (motorcycle) | Saturation flow Inside flow (motorcycle) | Saturation flow (Light vehicle) | Saturation flow (Heavy vehicle) | Total Saturation flow |
|---|---|---|---|---|---|
| | pcu/hour | pcu/hour | pcu/hour | pcu/hour | pcu/hour |
| Dewi sartika with ESSM | 468.91 | 273.86 | 1691.22 | 0.00 | 2607.76 |
| Teuku Umar with ESSM | 384.53 | 304.04 | 1832.58 | 0.00 | 2613.48 |
| Hayam Wuruk (east) with ESSM | 249.88 | 124.31 | 1222.87 | 0.00 | 1617.96 |
| Gatot Subroto (east) without ESSM | 1156.60 | 508.33 | 2068.91 | 277.28 | 4157.59 |
| Gatot Subroto (west) without ESSM | 793.08 | 628.52 | 2314.86 | 437.95 | 4266.60 |
| Diponegoro (south) without ESSM | 170.83 | 204.45 | 1069.24 | 0.00 | 1552.76 |

Saturation flows were identified to have a direct relationship with green time and lane width. The discharge rate of motorcycles and heavy vehicles shows no specific pattern with lane width and percentage share of motorcycles in traffic composition because motorcycles are of smaller size and accelerate fast with high maneuverability.

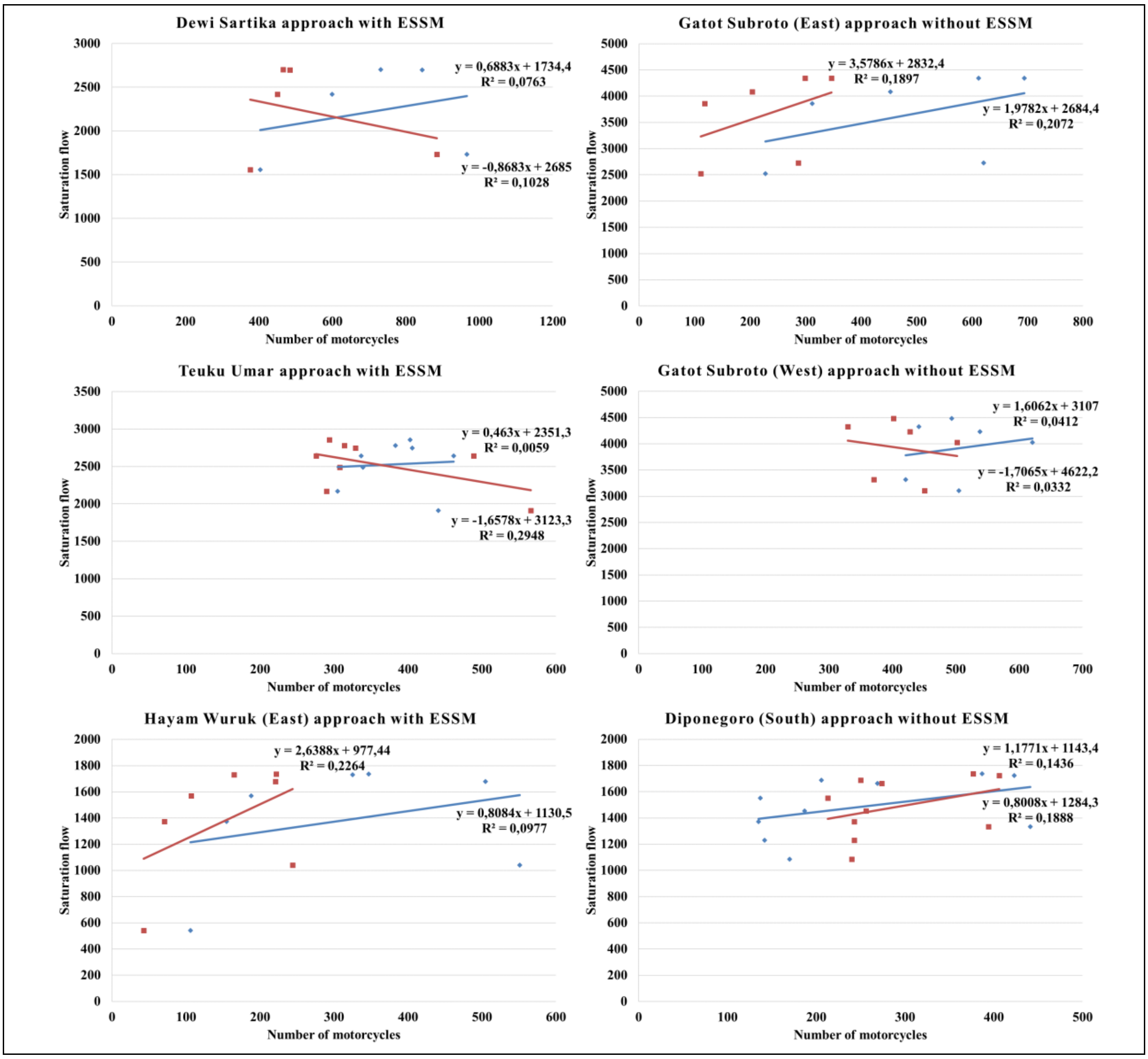


**Figure 3** Saturation flows based on motorcycle behavior.

Figure 3 shows the relationship between saturated flow due to motorcycle behavior and total saturated flow for all vehicles at approaches with and without the ESSM. The coefficient determinations ($R^2$) indicate that no significant relationship between motorcycle behavior and saturation flows were found at all approaches. Besides, Figure 3 and Table 6 show that the developed models give a higher saturation flow rate than the observed one. The linear regression model, therefore, cannot be used to predict the saturation flow at any urban signalized intersection. A further study is required to explore other models (i.e. non-linear models) to estimate the saturation flow rate.

The regression models at all approaches with and without the ESSM are used to estimate the saturation flow due to motorcycle behavior shown in Table 6. In contrast to a past study conducted in Semarang [15], this study found that the saturation flow value for all approaches with and without ESSM might be lower than the basic saturation flow using the IHCM equation ($S_0$ = 600 x effective width). This may indicate the different proportions of vehicles under mixed conditions between Semarang and Denpasar. Similar to a past study carried out in Malaysia found an insignificant relationship between motorcycle behavior and saturation flow [16]. This may be affected by low values of passenger car equivalent of the motorcycle so these will not influence the saturation flow. In contrast to Denpasar, the inside flow of motorcycle is higher than that of beside flow in Malaysia.

**Table 6** Model of saturation flows based on motorcycle behavior.

| Approaches | Regression models |
|---|---|
| Dewi sartika with ESSM | $y_1 = 0.69x + 1734.4$ ($R^2 = 0.0076$), $y_2 = -0.87x + 2685$ ($R^2 = 0.10$) |
| Teuku Umar with ESSM | $y_1 = 0.46x + 2351$ ($R^2 = 0.006$), $y_2 = -1.66x + 3123.3$ ($R^2 = 0.29$) |
| Hayam Wuruk (east) with ESSM | $y_1 = 2.64x + 977.4$ ($R^2 = 0.23$), $y_2 = 0.81x + 1130.5$ ($R^2 = 0.097$) |
| Gatot Subroto (west) without ESSM | $y_1 = 1.61x + 3107$ ($R^2 = 0.04$), $y_2 = -1.71x + 4622.2$ ($R^2 = 0.03$) |
| Gatot Subroto (east) without ESSM | $y_1 = 3.58x + 2832.4$ ($R^2 = 0.19$), $y_2 = 1.98x + 2684.4$ ($R^2 = 0.21$) |
| Diponegoro (south) without ESSM | $y_1 = 1.17x + 1143.4$ ($R^2 = 0.14$), $y_2 = 0.80x + 1284.3$ ($R^2 = 0.19$) |

where,
y1 = motorcycle besides other vehicles (outside flow), and
y2 = motorcycle in front of/behind other vehicles (inside flow).

Meanwhile, a past study conducted in Ghana found that a proportion of motorcycle at approach significantly affects saturation flow, however, the proportion of motorcycles inside flow did not significantly influence saturation flow [17]. The constructed regression models in this study, however, demonstrated the insignificant relationship between motorcycle distributions and intersection approaches both with and without ESSM. This study also found an insignificant relationship between motorcycle behavior and total saturation flow. In other words, the intersection approaches with the ESSM would not increase the saturation flow irrespective of motorcycle behaviors.

## 5. Conclusions

This study aims to investigate the influence of motorcycle behavior on the saturation flow rate at signalized intersections in Denpasar, Bali. The statistical models were constructed using four approaches with and without ESSM. The study findings are as follows:

- Motorcycle behavior at a signalized intersection with ESSM tends to be beside flow during dense and less dense traffic flow.
- Motorcycle behavior at a signalized intersection without ESSM tends to be inside flow during less dense traffic flow, however, it tends to be beside flow during dense traffic flow.
- The saturation flow of motorcycle behavior beside flow is higher than inside flow at intersection approaches both with and without ESSM.
- The intersection approaches with the ESSM would not increase the saturation flow irrespective of motorcycle behaviors. Further research, therefore, is suggested to examine the influence of the approaching lane width on motorcycle behavior and saturation flow.

## 6. References

[1] Minh C C and Sano K 2003 Analysis of Motorcycle Effects to Saturation Flow Rate at Signalized Intersection in Developing Countries *Journal of the Eastern Asia Society for Transportation Studies* Vol. **5** pp.1211-22.

[2] Nguyen H and Montgomery F 2007 Different Models of Saturation Different Models Of Saturation Flow In Traffic Dominated By Motorcycles *Proceedings of the Eastern Asia Society for Transportation Studies* 7 pp. 2381–95.

[3] Hadiuzzaman M, Rahman, M M and Karim M A 2008 Saturation Flow Model at Signalized Intersection for Non-lane Based Traffic *Canadian Journal of Transportation* Vol. 2(1) pp. 77–90.

[4] Central Bureau of Statistics of the Province of Bali 2018 Bali Province in Figures 2018.

[5] Sinha S and Taneerananon P 2012 A Comparative Study Of Effect Of Motorcycle Volume On Capacity Of Four Lane Urban Roads In India And Thailand *Journal of Society for Transportation and Traffic Studies* (JSTS) Vol.3(4) pp.52-62.

[6] Rajgor T B, Prof. Patel A K and Gundaliya P J 2016 Development of Saturation Flow Rate Model

for Heterogeneous Traffic at Urban Signalized Intersection *International Journal Of Innovative Research In Technology* Vol.2(12) pp.151-155.

[7] Ministry of Works Malaysia 2006 *Malaysian Highway Capacity Manual 2006* Chapter 3.

[8] Wall G T, Davies D G and Crabtree M 2003 Capacity Implications of Advanced Stop Lines for cyclists Crowthorne: *TRL Report* 585.

[9] Idris M 2007 The Effect of an Exclusive Stopping Space for Motorcycles on Traffic Conflicts at a Signalized Intersection in Bandung (in Indonesian language) Unpublished *Thesis* Bandung: Institute of Technology Bandung.

[10] Tamin O Z 2000 *Transportation Planning & Modeling* 2nd edn. ITB.

[11] Directorate General of Bina Marga 1997 *Indonesia Highway Capacity Manual* (IHCM) (in Indonesian language) 1(I) p.564.

[12] Fadli S and Elkhasnet 2012 The Comparison of Saturated Flow Values at Intersection Approaches with and without Exclusive Stopping Space for Motorcycles (in Indonesian language) *Jurnal Transportasi* Vol. 12(3) pp.217-26.

[13] Directorate General of Bina Marga 1997 *Guidelines for Inter-City Road Geometric Planning Procedures* Jakarta.

[14] Minh C C, Sano K and Matsumoto S 2005 The Speed Flow and Headway Analyses of Motorcycle Traffic *Journal of the Eastern Asia Society for Transportation Studies* Vol. 6 pp. 1496–1508.

[15] Indriastuti A K, Priyono E E Y, Widowati L A and Zuhri A S 2019 Adjusted Saturation Flow of Some Signalized Intersection in Semarang, Indonesia *7th International Conference on Euro Asia Civil Engineering Forum IOP Conf. Series: Materials Science and Engineering* 615 (2019) 012131.

[16] Vien L L, Ibrahim W H W and Mohd A F 2008 Effect of Motorcycles Travel Behaviour on Saturation Flow Rates At Signalized Intersections in Malaysia *23rd ARRB Conference-Research Partnering with Practitioners* pp.1–11 2008.

[17] Adam C A, Zambang M A M and Opoku-Boahen R 2015 Effects of Motorcycle on Saturation Flow Rates of Mixed Traffic at Signalized Intersection in Ghana *International Journal of Traffic and Transportation Engineering* Vol.4(3) pp.94-101.