ANALYSIS OF MOTORCYCLE EFFECTS TO SATURATION FLOW RATE AT SIGNALIZED INTERSECTIONS IN MALANG CITY

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ABSTRACT

For some signalized intersections in Malang City, visually can be seen that motorcycle is the dominant transportation mode. The research aims to know the influence of motorcycle to the characteristic of saturation flow at signalized intersections in Malang City by using Time Slice Method. The main focus of the research is to look at characteristic on first 6 seconds when the greentime period. The method used is Linear Regression with 3 classical assumption test. This study found that there are 66,04% approaches that have base saturation flow rate per effective width (S0/m) value in excess of IHCM 1997 standard (600 pcu/m), while 33,96% approaches still meets the IHCM 1997 standard. The mathematic model for the number of motorcycle at first 6 seconds (X) to Start Value (Y) is Y=-0,132+0,008X. There are proposed direction of design criteria to saturation flow in Malang City. First, review the Start Value based on influence of the number of motorcycle at first 6 seconds (X_1), effective width (X_2), and greentime (X_3). From analysis obtained the model $Y=0,003+0,020X_1-0,128X_2-0,012X_3$. Second, review the Start Value based on influence of the number of light vehicle at first 6 seconds (X) to Start Value (Y). From analysis obtained the model Y=-0,407+0,013X.

Keywords*:* motorcycle, saturation flow, signalized intersections, start value, time slice

INTRODUCTION

The idea for this research is when viewing the daily traffic flow, especially in signalized intersection, which is always dominated by the motorcycle mode. The motorcycle rider tend to try to stop the most front position right behind the stop-line, or fill the gap between the other mode. This will affecting the effective greentime which the duration in accordance with the flow released by an intersection approach. Because of the position of the motorcycle tend to be at the front of the queue, then that will be directly affected is the Start Value. This paper focuses on the motorcycle effect to Start Value by calculating the saturation flow using *Time Slice Method*. The all of standard using IHCM 1997. Minh (2003) performed a research in Hanoi and Bangkok about the effect of motorcycle on start-up lost time. It can be explained that due to motorcycle behavioir, they usually try to stand right behind stop-line during red time, then discharge at all-red time period.

Shao (2011) performed a research about saturation flow rate at signalized intersection in China. The focus of this research is the influence of traffic composition, lane width, and approach grade on saturation flow rate. It is found that lande width and turn radius have significant effect on the capacity.

Mashuri (2007) perform a research about relationshop between saturation flow and vehicle speed. The result of this study indicate that the relationship between saturation flow and vehicle speed discharge from stop-line to the exitlane followed the expontial model, $Y=1284,3.Ln(X)-753,41$; $R^2=0,942$.

Rahayu (2009) perform a research about analyse the saturation flow and delay length based on IHCM 1997. The correction was carried out on coefficient of basic saturation flow in range of 600 to 2200. The results show that the coefficient on basic saturation flow calculating needs to be modified in the range of 600 to 2200 in order to find the similar length of the delay between prediction and field measurement. Passenger Car Unit (PCU) for motorcycle from IHCM 1997 was also corrected from 0,2 to 0,15.

Budiarnaya (2001) perform a result research about the Passenger Car Unit (PCU) in Denpasar City, Indonesia were: car 1; bus 1,422; truck 1,195, motorcycle 0,402, and unmotorized vehicle 0,782.

RESEARCH METHOD

Research Location

The location selected on this research is 15 points of signalized intersections that are spread throughtout Malang City. The determination of signalized intersection to be assessed is based on the premilinary survey to look at the saturation flow condition for each intersection. This research conducted at 3-arm and 4-arm signalized intersection in Malang City presented in **Table 1.**

Data Collection

Research time adapted to the traffic condition at each loation. Traffic flow data and other primary data are collected when the approach is in the high saturation condition. While the geometric data is collected at the time when intensity of traffic are in the low point.

The data used in this research is primary data and secondary data. Primary data include geometric, duration of signal, traffic flow movement, environmental condition, and the number of traffic flow. Data collection for the number of traffic flow done by using video **(Figure 1).** Secondary data consists of the nmber of population of Malang City and map of road networking of Malang City.

Table 1. Research location

INT.	ARM CODE	STREET
FLY OVER	A1	Bale Arjosari /N
	A2	Raden Intan
	A3	Bale Arjosari /S
LA SUCIPTO	B1	Raden Panji Suroso
	B2	LA Sucipto /E
	B3	Sunandar Priyo Sudarmo
	B4	LA Sucipto /W
PDAM BLIMBING	C1	A. Yani /N
	C2	LA Sucipto
	C3	A. Yani /S
BOROBUDUR	D1	A. Yani /N
	D2	A. Yani /S
	D3	Borobudur
SAWOJAJAR	E1	Ranugrati /E
	E2	Raya Sawojajar
	E3	Ranugrati /W
RAMPAL	F1	Panglima Sudirman /N
	F2	Urip Sumoharjo /E
	F3	Panglima Sudirman /S
	F4	Pattimura /W
SULFAT	G1	Sunandar Priyo Sudarmo /N
	G2	Sulfat
	G3.1	Sunandar Priyo Sudarmo /S - Straight
	G3.2	Sunandar Priyo Sudarmo /S - Right
CILIWUNG	H1	Sunandar Priyo Sudarmo /N
	H2	Ciliwung
	H3	Sunandar Priyo Sudarmo
GADANG	I1	Kol. Sugiono /N
	I2	Gadang Bumiayu
	I3	Kol. Sugiono /S
	I4	Satsuit Tubun
KOTALAMA	J1	Sartono
	J2	Laksamana Martadinata
	J3	Kol. Sugiono /S
	J4	Kebalen Wetan
GAJAYANA	K1	MT Haryono /E
	K2	Gajayana
	K3	MT Haryono /W
ITN	L1	Sumbersari
	L2	Veteran
	L3	Bendungan Sutami
	L4	Bendungan Sigura-gura
GALUNGGUNG	M1	Galunggung /N
	M2	Bondowoso
	M3	Galunggung /S
	M4	Tidar Raya
CILIWUNG	N1	Jaksa Agung Suprapto
	N2	Jendral Basuki Rahmat
	N3	Brigjen Slamet Riyadi
BCA SEMERU	O1	Jendral Basuki Rahmat /N
	O2	Kahuripan
	O3	Jendral Basuki Rahmat /S
	O4	Semeru

Figure 1. Illustration of video recording

ANALYSIS AND DISCUSSION

Analysis Flowchart

Analysis flowchart will be presented in **Figure 2.**

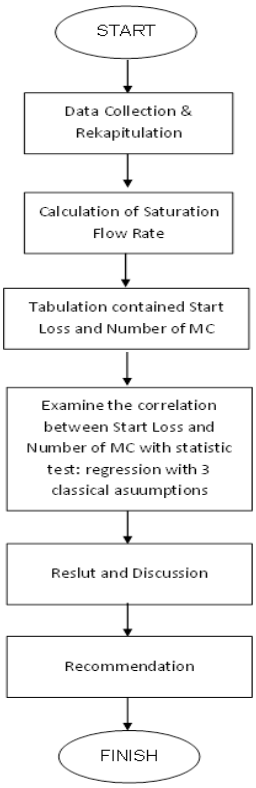

Figure 2. Analysis flowchart

Calculation of $S_{average}$

Saturation flow data analyzed by using *Time Slice Method* with interval 6 seconds. Analysis conducted to gain average saturation value ($S_{average}$) and Start Value. The example graph of the $S_{average}$ and Start Value can be seen in **Figure 3.** The result of $S_{average}$ and Start Value can be seen at **Table 2.**

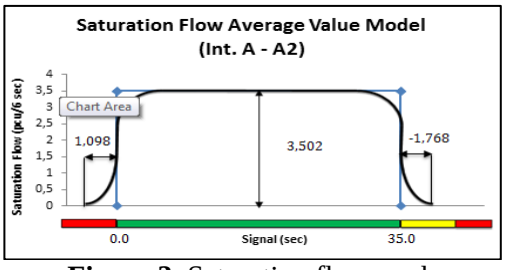

Figure 3. Saturation flowgraph

Table 2. Recapitulation of Saturation Flow Rate

App Code	STREET	Saverage pcu/hr	Start Value (first 6 sec)	
			Start Gain	Start Loss
A1	Bale Arjosari /N	2572,2	1,674	
A2	Raden Intan	2101,2	1,098	
A3	Bale Arjosari /S	1885,8		0,477
B1	Raden Panji Suroso	2307,0	0,601	
B2	LA Sucipto /E	1744,2	3,963	
B3	Sunandar Priyo Sudarmo	1846,2	0,577	
B4	LA Sucipto /W	2034,0	1,103	
C1	A. Yani /N	2884,2		0,483
C2	LA Sucipto	2792,4	1,748	
C3	A. Yani /S	3156,0	0,407	
D1	A. Yani /N	2916,6		0,479
D2	A. Yani /S	3912,0		0,055
D3	Borobudur	2705,4	1,252	
E1	Ranugrati /E	1325,4	1,986	
E2	Raya Sawojajar	1279,8		2,194
E3	Ranugrati /W	1764,6	0,155	
F1	Panglima Sudirman /N	2706,0	0,102	
F2	Urip Sumoharjo /E	2503,2	1,589	
F3	Panglima Sudirman /S	2757,0		0,011
F4	Pattimura /W	2592,0	0,458	
G1	SP. Sudarmo /N	2714,4		1,420
G2	Sulfat	2457,0	2,322	
G3.1	SP. Sudarmo /S - Straight	1060,2	0,667	
G3.2	SP. Sudarmo /S - Right	1398,0	1,177	
H1	SP. Sudarmo /N	1623,0	1,748	
H2	Ciliwung	2083,8		1,192
H3	SP Sudarmo	2309,4		1,001
I1	Kol. Sugiono /N	1353,6	0,002	
I2	Gadang Bumiayu	876,6	5,265	
I3	Kol. Sugiono /S	1997,4		1,669
I4	Satsuit Tubun	1735,2		0,654
J1	Sartono	2424,6	0,157	
J2	Laksamana Martadinata	952,8		1,855
J3	Kol. Sugiono /S	1624,2		2,216
J4	Kebalen Wetan	2196,0		0,246
K1	MT Haryono /E	2043,6	1,157	
K2	Gajayana	1117,8	2,052	
K3	MT Haryono /W	2339,4		0,286
L1	Sumbersari	1852,2	0,847	
L2	Veteran	4038,6	0,899	
L3	Bendungan Sutami	2568,0	1,799	
L4	Bendungan Sigura-gura	2412,0	0,772	
M1	Galunggung /N	2226,6	1,378	
M2	Bondowoso	1636,2	2,464	
M3	Galunggung /S	2922,0	0,070	
M4	Tidar Raya	1243,2	0,350	
N1	Jaksa Agung Suprapto	2182,8	0,031	
N2	Jendral Basuki Rahmat	3445,8		1,552
N3	Brigjen Slamet Riyadi	1681,2	0,081	
O1	Jend. Basuki Rahmat /N	2629,2		3,194
O2	Kahuripan	1940,4	0,748	
O3	Jend. Basuki Rahmat /S	2995,2		1,913
O4	Semeru	2725,8	1,215	

Source: Result of Research, 2013

Table 3. The result of S0 and S0/m

App Code	STREET	S0 (pcu/hr)	$S0_{adjustment}$ (pcu/hr)	S0/m
A1	Bale Arjosari /N	2572,2	2943,028	1090,010
A2	Raden Intan	2101,2	2403,356	686,673
A3	Bale Arjosari /S	1885,8	3004,7	883,735
B1	Raden Panji Suroso	2307,0	2497,48	756,812
B2	LA Sucipto /E	1744,2	1898,712	593,348
B3	Sunandar Priyo Sudarmo	1846,2	2034,283	398,879
B4	LA Sucipto /W	2034,0	2249,832	749,944
C1	A. Yani /N	2884,2	3294,867	784,492
C2	LA Sucipto	2792,4	4372,949	892,439
C3	A. Yani /S	3156,0	4803,14	1021,945
D1	A. Yani /N	2916,6	3332,2	595,036
D2	A. Yani /S	3912,0	5568,53	795,504
D3	Borobudur	2705,4	3322,858	639,011
E1	Ranugrati /E	1325,4	1428,178	259,669
E2	Raya Sawojajar	1279,8	1227,567	350,733
E3	Ranugrati /W	1764,6	2019,874	631,211
F1	Panglima Sudirman /N	2706,0	3067,975	807,362
F2	Urip Sumoharjo /E	2503,2	2769,387	1153,911
F3	Panglima Sudirman /S	2757,0	3115,455	759,867
F4	Pattimura /W	2592,0	2966,445	723,523
G1	SP. Sudarmo /N	2714,4	3067,317	766,829
G2	Sulfat	2457,0	2294,303	917,721
G3.1	SP. Sudarmo /S - Straight	1060,2	1210,906	465,733
G3.2	SP. Sudarmo /S - Right	1398,0	1596,724	614,124
H1	SP. Sudarmo /N	1623,0	1799,123	580,362
H2	Ciliwung	2083,8	2014,311	649,778
H3	SP. Sudarmo	2309,4	2645,003	1058,001
I1	Kol. Sugiono /N	1353,6	1894,209	270,601
I2	Gadang Bumiayu	876,6	1393,705	278,741
I3	Kol. Sugiono /S	1997,4	2295,088	655,740
I4	Satsuit Tubun	1735,2	2916,766	972,255
J1	Sartono	2424,6	5322,614	1267,289
J2	Laksamana Martadinata	952,8	1097,38	548,690
J3	Kol. Sugiono /S	1624,2	1879,061	782,942
J4	Kebalen Wetan	2196,0	5097,903	2317,229
K1	MT Haryono /E	2043,6	3706,895	1029,693
K2	Gajayana	1117,8	2170,71	986,686
K3	MT Haryono /W	2339,4	3490,573	969,604
L1	Sumbersari	1852,2	6953,8	3023,391
L2	Veteran	4038,6	4577,855	1173,809
L3	Bendungan Sutami	2568,0	3561,735	1017,639
L4	Bendungan Sigura-gura	2412,0	7166,22	2047,491
M1	Galunggung /N	2226,6	2441,767	488,353
M2	Bondowoso	1636,2	1804,089	334,090
M3	Galunggung /S	2922,0	3215,68	974,448
M4	Tidar Raya	1243,2	1283,436	611,160
N1	Jaksa Agung Suprapto	2182,8	2469,291	465,904
N2	Jendral Basuki Rahmat	3445,8	3919,883	653,314
N3	Brigjen Slamet Riyadi	1681,2	1899,784	333,295
O1	Jendral Basuki Rahmat /N	2629,2	3099,735	373,462
O2	Kahuripan	1940,4	2223,96	313,234
O3	Jendral Basuki Rahmat /S	2995,2	3532,543	483,910
O4	Semeru	2725,8	3158,046	389,882

Source: Result of Research, 2013

Base Saturation Flow Rate

By calculating the average saturation flow rate ($S_{average}$) with adjustment factors will obtain the base saturation flow rate (S0). Then the base saturation flow rate per effective width (W_e) (S0/m) The result of calculation S0 and S0/m can be seen in **Table 3.**

In the result of saturation flow calculation that is summarized in table above, it can be seen that in some of the signalized intersections have base saturation flow per meter (S0/m) that is incompatible with the current formulation of base saturation flow per meter (S0/m) from IHCM 1997, about maximum of 600 pcu/m. Based on the results of this research there are 35 approaches which have the S0/m value is greather than S0/m value in IHCM 1997, about between 611 pcu/m and 3023 pcu/m.

Analysis of Motorcycle Effects to Saturation Flow at Signalized Intersections in Malang City

In this research analysis will be done by comparing the number of motorcycles with saturation flow calculation. The number of motorcycles will be compared with the Start Value. Positive value is the Start Gain and negative value is Start Loss.

The relation of the number of motorcycles with start value determined by Linier Regression Method. Before doing the regression must be preceded with 3 classic assumption regression test: normality test, autocorrelation test, and heterokedastisity test. Dependent variable is Start Value as Y, and independent variable is the number of motorcycle (pcu) at first 6 seconds greentime as X.

a) Normality Test

The result of Normality Test can be seen in **Figure 4.**

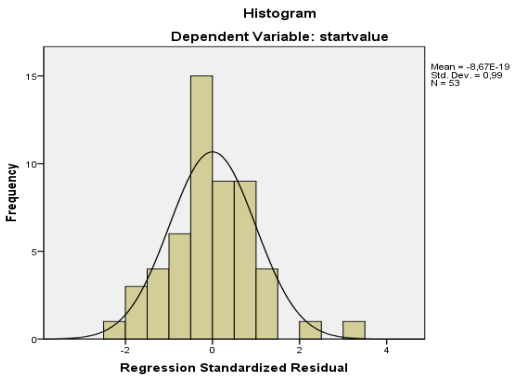

Figure 4 (a)

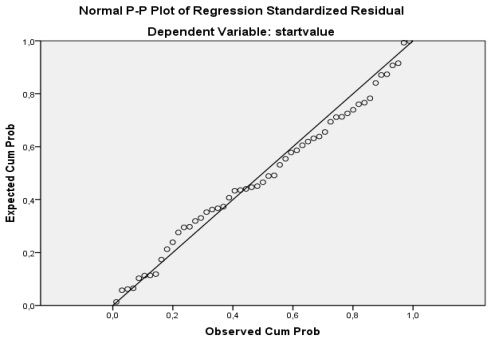

Figure 4 (b)

Figure (a) and (b). Histogram and P-plot graphic for relation of the number of motorcycles (pcu) with start value

In the histogram, residual (error value) is in the normal distribution by following the pattern line. In the p-p plot graphic seems the scatter of residual (dot) is around the straight line that is the data expectation line. In the *Kolmogorov-Smirnov Test* result the result is more than probability value (0,860 > 0,05). These three results show that regression model is in the normal distribution.

b) Autocorrelation Test

In this autocorrelation test, the method that used is Durbin-Watson Test by comparing the calculation value of Durbin-Watson with table value of Durbin-Watson (d_L and d_U). Hypothesis that is used are:

H_0: There is no autocorrelation between residuals

H_1: There is autocorrelation between resdiuals

The result of Autocorrelation Test can be seen in **Table 4.**

From the **Table 4**, the calculation value of Durbin-Watson is 2,079 and it placed between d_U (1,588) and 4-d_U (2,412). Based on the result there is no autocorrelation between residuals, or in the another term the assumption is fulfilled.

Table 4. The Result of Autocorrelation Test

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,166[a]	,028	,009	1,52398	2,079

a. Predictors: (Constant), motorcycle

b. Dependent Variable: startvalue

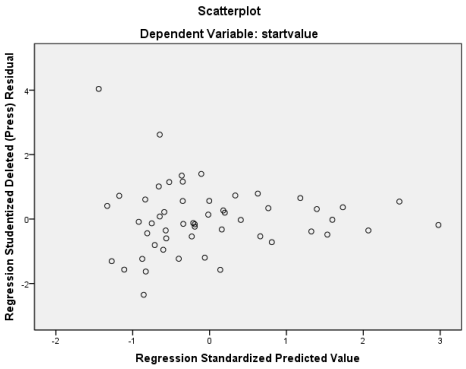

Figure 5. The result of heteroskedastisity test

c) Heteroskedastisity Test

Heterokedastisity Test aims to test the variety of regression model. A good regression model is a model that has the same range of residuals. Hypothesis that is used are:

H_0: Variety of residuals are homogen

H_1: Variety of residuals are not homogen

The result of Heteroskedastisity Test can be seen in **Figure 5.**

Regression model that is obtained from the analysis above is:

Y = -0,132 + 0,008X

β_1 = 0,008 means the relation between X and Y is linear because the coefficient is positive. Linear means that the higher the number of motorcycle then Start Value will be higher. High in this term means more positive, so the higher the number of motorcycle at first 6 seconds then the Start Gain will be higher.

From the analysis obtained that F value is less than F table value (1,453 < 4,030) and significancy value is more than probability value (0,234 > 0,005). That mean there is no significant influence between the number of motorcycle at first 6 seconds with the Start Value.

Coefficient of determination obtained from the result of regression, R^2=0,028. It means that the regression model will be able to explain the relation of the number of motorcycle at first 6 seconds (X) and Start Value (Y) in **2,8%.**

The Direction of Design Crieria for Saturation Flow in Malang City

Based on the stastistic test, the results of this research is the number of motorcycles at the first 6 seconds has no significantly effect to Start Value with influences about 2,8% altough based on existing data the number of motorcycle at the intersections is dominant.

There are two things that is indicated affect this conditions:

1) Intersection Properties: Effective Width (W_e) and Greentime

Regression model that is obtained is:

$$\mathbf{Y = 0{,}003 + 0{,}020X_1 - 0{,}128X_2 - 0{,}012X_3}$$

Y = Start Value
X_1 = The Number of MC at first 6 sec
X_2 = Effective Width (W_e)
X_3 = Greentime

From the model, β_1 = 0,020 means the relation between X and Y is linear because the coefficient is positive. Linear means that the higher the number of

motorcycle then Start Value will be higher. High in this term means more positive, so the higher the number of motorcycle at first 6 seconds then the Start Gain will be higher.

Coefficient of W_e, β_2 = -0,128 means in case of increase W_e then Start Value will decrease. Otherwise, in case of decrease W_e then Start Value will increase. This is in accordance with the logic that when the width of the road is getting narrow the capacity is smaller and more quickly reach saturation. It may influence the riders to compete a place as close as possible to the stop-line in order to get a chance to drove earlier when greentime lighted.

Coefficient of Greentime, β_3 = -0,012 means in case of increase Greentime then Start Value will decrease. Otherwise, in case of decrease Greentime then Start Value will increase. In general the rider had passed a road is a routine and indirectly they will know the length of greentime. On the other hand, in Malang City majority of signalized intersections have a countdown-timer on each approach. For short greentime, riders tending to want a more front position. This will make Start Value to be more positive so that happens Start Gain.

Based on the analysis, R^2=0,145. It means that the regression model will be able to explain the relation of the number of motorcycle at first 6 seconds (X1), W_e (X2), and Greentime (X3) as a unity towards the Start Value (Y) is **14,5%,** and the rest 85,6% is influenced by another independent variable that not observed in this research.

F > F-table about 3,943 > 2,794; and significantcy 0,013 < 0,05 it means simlutantly the number of motorcycle at first 6 seconds, W_e, and greentime as an unity influenced significantly toward Start Value.

2) Light Vehicle (LV)

Light vehicle (LV) is the second largest number of vehicle in the road after motorcycle. Based on IHCM 1997, PCE for LV is 1 and PCE for motorcycle is 0,2 for type protected and 0,4 for type opposite. It means that needed less car to replace some motorcylces, and the increasing of LV will be more significant than motorcycle of the same percentage. Regression model that is obtained is:

$$\mathbf{Y = -0{,}407 + 0{,}013X}$$

Y = Start Value
X = The Number of LV at first 6 sec

From the model, β_1 = 0,013 means the relation between X and Y is linear

because the coefficient is positive. Linear means that the higher the number of light vehicle then Start Value will be higher. High in this term means more positive, so the higher the number of light vehicle at first 6 seconds then the Start Gain will be higher.

Based on the result of analysis, the calculation value of F is 9,005 with the significancy value 0,004. This F value is more than F table value (9,005 > 4,030) and significancy value is less than probability value (0,004 > 0,005). It means there is significant influence between the number of light vehicle at first 6 seconds with the Start Value.

Coefficient of determination obtained from the result of regression, R^2=0,150. It means that the regression model will be able to explain the relation of the number of light vehicle at first 6 seconds (X) and Start Value (Y) in **15%,** and the rest 85% is influenced by another independent variable that not observed in this research.

CONCLUSIONS

Based on the results of this research, there are conclusions can be drawn to answer the problems as follow:

a. Base saturation flow per meter (S0/m) for 15 signalized intersections in Malang City is various. The highest is 270,601 pcu/m and the lowest is 3023,391 pcu/m. At the signalized intersections in Malang City there are 66,04% approaches that have S0/m value in excess of IHCM 1997 standard (600 pcu/m), while 33,96% approaches still meets the IHCM 1997 standard.
b. The number of motorcycle (MC) at first 6 seconds in every greentime always dominating the total vehicles that are in the queue. The model between the number of motorcycle at first 6 seconds (X) and Start Value (Y) is: Start Value = -0,132 + (0,008 x MC). From Linear Regression obtained that the number of motorcycle at first 6 seconds influence about 2,8% to Start Value.
c. Based on the results of the analysis of motorcycle effect to saturation flow rate at signalized intersections in Malang City, there are 2 proposed direction for sustainable study of saturation flow in Malang City:
    - First, formulating an equation of Start Value based on the influence of the number of motorcycles at first 6 seconds, effective width, and greentime. The equation: Start Value = 0,003 + (0,020 x MC) – (0,128 x W_e) - (0,012 x greentime). From Linear Regression obtained that the number of motorcycle at first 6 seconds (X1), effective width (X2), and greentime (X3) as a unity influence about **14,5%** significantly to Start Value (Y).
    - Second, review the Start Value from the effect of Light Vehicle (LV). The model between the number of LV at first 6 seconds (X) and Start Value (Y) is: Start Value = -0,407 + (0,013 x LV). From Linear Regression obtained that the number of LV at first 6 seconds (X) influence about **15%** significantly to Start Value (Y).

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