

Traffic Signalizing Application at Unsignalized Intersection Applying Vissim Software Microsimulation

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Abstract

An intersection is a meeting point of several road sections that have potential traffic conflicts. Each of these may become the intersection of opposite traffic flows. Therefore, it is critical to have the best traffic control to avoid potential collisions among vehicles. Simpang Jembatan 5 Kalimalang is an unsignalized-intersection with four legs—one of which is a bridge. The absence of traffic control in the intersection may lead to many traffic conflicts. This study aims to determine the best traffic control to increase safety in Simpang Jembatan 5 Kalimalang. It was a case study with a micro-simulation method of analysis. The data were analyzed using VISSIM and SSAM. VISSIM was used to analyze the performance of the existing intersection condition in Simpang Jembatan 5 and to analyze the counter condition for the recommendation. Meanwhile, SSAM was employed to analyze traffic conflict in the intersection. The result of the study revealed that the alternative counter condition of the intersection in terms of replenishment of two-phased-APILL with 106 seconds of cycle time was effective in reducing 24% of traffic conflict; in addition, the delay value was 12.4 indicating that the intersection service level was down to B level. The reduction of traffic conflict and intersection service implied that the safety level in Simpang Jembatan 5 Kalimalang increased.

Keywords: *Intersection, Conflict, Vissim, SSAM, APILL*



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INTRODUCTION

Indonesia is a developing country with a growing population. Bekasi is a densely populated Indonesian city with 3.899.017 people in 2020 (BPS, 2021). It was the second regency with high density after Bandung. As the population sky-rocketed, mobility raises. High mobility causes traffic issues on certain route segments. For instance, the high traffic volume of an intersection may lead to a decline in its traffic performance. Simpang Jembatan 5 Kalimalang is one of the intersections with such a problem. Since KH. Abu Bakar Street, Kalimalang 5 Bridge, and Kalimalang Inspection Road are all united by the same crossroads, it may generate to what-so-called as traffic conflict, which may result in some traffic accidents as well as some gridlocks. Due to the activity of the nearby shops, schools, and residential areas, the side resistance at the intersection of the Kalimalang 5 Bridge is relatively high. Traffic delays may occur in the intersection; therefore, a scenario (traffic simulation) must be planned to reach smooth traffic.

According to Rusmandani et al. (2020), traffic simulation starts with an analysis of the current circumstances in a region. The analysis of the current circumstances will eventually be the base for formulating a recommendation. However, the use of VISSIM is essential for formulating a recommendation. VISSIM can simulate traffic flows on a micro level. VISSIM offers major 3D animation and capabilities enhancement, and the type of vehicle can be duplicated (i.e., from passenger cars, trucks, light rail, and heavy trains). Other components, including trees, buildings,

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parking lots, train stations, bus stops, and traffic signs, are also provided by VISSIM. Furthermore, video clips can be played with some options; they can, for instance, be dynamically switched based on various viewpoints. Focusing on traffic conflicts, this research aims to increase safety at Simpang Jembatan 5 Kalimalang intersection. It is envisaged that the improved services at the unsignalized intersection can offer drivers comfort and safety. This study intends to provide a solution that can reduce traffic conflicts.

LITERATURE REVIEW

An intersection is a node/meeting point of road sections, each of which has its conflict, and they meet at one point, making the intersection have a high traffic volume. If the intersection can no longer accommodate the capacity of existing vehicles, there will be a traffic jam. The intersection has several problems, namely congestion, delays, traffic accidents, and several other obstacles, from pedestrians crossing or motorized vehicles parked carelessly. These problems can affect the performance of an intersection (Suraji & Cakrawala, 2022). Signalized Intersection is an intersection with a Traffic Signaling Device (APILL) as a traffic controller (Gunawan, 2019). Unsignalized intersections are alternative intersections that have a low traffic volume. At the unsignalized intersection, the main right applies, namely the General Priority Rule, a condition where a vehicle entering an intersection first has the main right or the right to precede the vehicle that will still enter the intersection. In Indonesia, the road section should prioritize vehicles coming from the left to go first, but this is not done well due to a lack of proper traffic culture and knowledge of traffic (Risdiyanto, 2018). Nasrullah and Putra (2021) state that in the manual, there are characteristics of a traffic delay that occurs at intersections, both unsignalized intersections, signalized intersections, and roundabouts, namely:

- a. Reference vehicle speed 40 km/h;
- b. The turning speed of a vehicle does not stop at only 10 km/hour;
- c. The rate of acceleration and deceleration is only 1.5 m/s²;
- d. Vehicles reduce speed to a stop to avoid deceleration that occurs at the intersection.

Microsimulation simulates how vehicles move in the same traffic flow and space-time dimensions. The parameters that strongly influence a vehicle's traffic on the road are discussed in microsimulation. The variables in consideration include lane occupancy, headway, spacing, and gap (clearance) (Irawati & Muldiyanto, 2020). Since simulation makes it simpler to alter road network scenarios while still considering the likelihood that a recommendation would be put into practice in the field, it is highly sought after in the transportation industry. Vissim is one of the programs that may be used to build a traffic microsimulation on a road network since it has many benefits, including the ability to model different vehicle kinds, both motorized and non-motorized (Rusmandani et al., 2020).

1. Delay (T)

According to MKJI (1997), the degree of saturation (DS) value can be used to determine the delay (T). Traffic delays (TLL) and geometric delays are two factors that cause delays (TG). T is the average time in traffic for all motorized vehicles coming from all directions into the intersection.

$$T = T_{LL} + T_G \quad (1)$$

- a. Intersection traffic delay (T_{LL})

$$\text{For } DS \leq 0,60 ; T_{LL} = 2 + 8,2078 DS - (1 - DS)^2 \quad (2)$$

$$DS > 0,60 T_{LL} = (1,0504 / (0,2742 - 0,2042 DS)) - (1 - DS)^2$$

- 1) Traffic Delay for Major Roads

Traffic delay for major roads (T_{LLma}) is the average traffic delay for all motorized vehicles entering the intersection of major roads, can be calculated using the equation:

$$\text{For } DS \leq 0,60; T_{LLma} = 1,8 + 5,8234 DS - (1 - DS)^{1,8} DS \quad (3)$$

$$> 0,60 ; T_{LLma} = (1,0503 / (0,346 - 0,246 DS)) - (1 - DS)^{1,8}$$

- 2) Traffic Delay for Minor Road

Traffic delay for minor roads (T_{LLmi}) is the average traffic delay for all motorized vehicles entering the intersection of minor roads, determined from T_{LL} and T_{LLma} , calculated using the equation:

$$T_{LLmi} = (Q_{tot} \times T_{LL}) - (Q_{ma} \times T_{LLma}) / Q_{mi} \quad (4)$$

Information:

Q_{tot} = total current entering the intersection

Q_{ma} = current entering the intersection of the major road

Q_{mi} = current entering the intersection of the minor road

- b. Intersection Geometric Delay (T_G)

The geometric delay of the intersection is the average geometric delay of all motorized vehicles entering the intersection. T_G is calculated from the following formula:

$$\text{For } DS \geq 1,0 \rightarrow T_G = 4 \text{ seconds} \quad (5)$$

$$\text{For } DS < 1,0 \rightarrow T_G = (1 - DS) \times (6 RB + 3 (1 - RB)) + 4 D_j S$$

Information:

T_G = Geometrical delay of the intersection

DS = Degree of Saturation

RB = Total turning ratio

2. Saturated Current (S)

According to Directorate General of Highways (1997) Saturation flow is the amount of queue departure in an approach during the specified conditions (green junior high school/hour). How to determine the saturation current value of a junction using the following equation:

$$S = S_o \times FCS \times FSF \times FG \times FP \times FRT \times FLT \quad (6)$$

Information:

S = Saturated current (pcu/effective green time)

S_o = Basic saturation current (pcu/effective green time)

FCS = Saturation current correction factor due to City size (population)

FSF = Saturation current correction factor due to side fault
FG = Saturation current correction factor due to road grade
FP = saturation current correction factor due to parking activities near the junction arm
FRT = Capacity correction factor due to right turn movement
FLT = Capacity correction factor due to left turn movement

3. Level Of Service (LOS)

According to Irawati and Muldiyanto (2020), the service level determines the level of service on the road and/or intersection. The service level is divided into several classes starting from A, B, C, D, E, to F. The optimal operating condition of the facility is represented by service level A, while the worst operating condition is indicated by service level F. The service level in an intersection is categorized as follows:

Table 1. Level of Service Signalized Intersection

Level of Service	Delay (seconds/vehicle)
A	≤ 5
B	> 5-15
C	> 15-25
D	> 25-40
E	> 40-60
F	≥ 60

Source: Minister of Transportation Regulation 96 (2015)

4. Traffic Conflict

According to Rusmandani et al. (2020), a traffic conflict is an object of observation between two or more road users who are approaching one another in the same space and time and will collide if they do not move. The intersection is a potential location to become the center of traffic conflicts that meet, the cause of congestion due to changes in capacity, the location where accidents occur, or the concentration of pedestrians, depending on the traffic conditions, where there are road encounters with different directions of movement. The principal issues with interlocking at junctions are:

- a. Volume and capacity, which directly affect the resistance
- b. Geometric design, freedom of view and distance between intersections
- c. Road accidents and safety, speed, streetlights, pedestrians, parking, access and general construction.

In general, traffic regulation using signals is used for several purposes, which include:

- a. Avoiding congestion at intersections caused by traffic flow conflicts, which can be done to maintain a certain capacity during peak traffic conditions.
- b. Provide opportunities for other vehicles and/or pedestrians from smaller intersections to bypass the main road.
- c. Reducing traffic accidents due to vehicle encounters in the opposite direction or conflict.

5. PTV VISSIM

VISSIM is software that can model traffic flow microscopically, according to Maulana and Nugraha (2019). These several vehicles kinds can collide with one another. The Vissim

software is beneficial for providing examples of all the geometric configurations and driving patterns that can be found in real-world transportation systems. The following data and parameters were used in the simulation using the PTV VISSIM 9.0 program (Irzadi et al., 2020):

1. Base Data is the required 3D model data: vehicle types, vehicle classes, vehicle input, desired speed distributions, conflict areas, and signal controllers.
2. Traffic Network, the parameters to create a road network, such as links and connectors.
3. Evaluation, which is a parameter to evaluate the results of modeling such as nodes, data collections, and vehicle travel times.
4. Driver's behavior, which is an individual trait whose predictions will occur in the field due to interactions between road users and other factors such as vehicle distance, acceleration, deceleration, and existing traffic regulations.
5. Calibration and Validation. Calibration is the adjustment of parameters to adjust the modeling to the actual situation, while validation is the process of testing the correctness of the modeling calibration by comparing observations and simulation results. According to Ulfah and Purwanti (2019a), the method used is to use the basic formula of Chi-squared in the form of the GEH Test (Geoffrey E. Havers), a statistical formula modified from Chi-squared by combining the difference between relative values and absolute values. The GEH formula has special provisions for the resulting error value seen in the equation below.

$$GEH : \sqrt{\frac{(q_{\text{simulated}} - q_{\text{observed}})^2}{0,5 \times (q_{\text{simulated}} + q_{\text{observed}})}} \quad (7)$$

Information:

q = traffic volume data (vehicles/hour)

Table 2. Conclusion from the Calculation Results of the GEH

GEH Value	Explanation
$GEH < 5,0$	Accepted
$5,0 \leq GEH < 10,0$	Warning: possible model errors or bad data
$GEH > 10,0$	Rejected

Source: Ulfah and Purwanti (2019a)

Another validation method that can be used is the Mean Absolute Percentage Error (MAPE) method, often known as the mean absolute percentage standard deviation. MAPE is the percentage difference between the estimated and actual data in the field. The parameter that is validated is vehicle speed.

$$MAPE = \frac{1}{n} \sum_{t=1}^n \frac{A_t - F_t}{A_t} \times 100\% \quad (8)$$

Information:

n = lot/amount of data

A_t = data in the field/observation

F_t = simulation data

6. SSAM

The Surrogate Safety Assessment Model (SSAM) was created by the Federal Highway Administration Research and Technology to assess traffic safety without waiting for actual accidents and injuries to occur. It works by automatically combining microsimulation and conflict analysis and analyzing the frequency and type of conflicts between vehicles in a traffic flow (Septyaningrum, 2022).

SSAM software was developed to automate traffic conflict analysis by directly processing the data from simulations of passing vehicle movements. The researchers established an open standard vehicle movement data format designed to provide the location and dimensions of each vehicle approximately every tenth of a second (Halim et al., 2019).

RESEARCH METHOD

This research is located at the unsignalized intersection of Bridge 5 Inspection Kalimalang, that often passed by vehicles because it is the access from the origin to the destination, especially in factories, shops, and schools (Septyaningrum, 2022). The data collected in this study consisted of primary and secondary data. Primary data collection was obtained from a survey at the location consisting of the following data:

- a. Geometric condition data
- b. Traffic flow (traffic flow enumeration survey)
- c. Vehicle Speed
- d. Side Barriers
- e. Traffic conflict

While secondary data is obtained from BPS data (2021), namely, Bekasi Regency had a population in 2020 reaching 3,113,017 people and an average population density of 2,444 people/km². Based on data BPS (2021), it is stated that the most densely populated area is South Tambun District, with 10,001 people per km² or 13.85% of the total population of Bekasi Regency. In the data analysis stage, the data collected from the survey results and the calculation process were carried out using the 1997 Indonesian Road Capacity Manual (MKJI) and supported by supporting applications. Data analysis can also be interpreted as an activity to change the data obtained from research into information that can later be used to conclude. The intersection inventory is displayed in a 2D floor plan using AutoCAD 2017 software. It is intended to describe the intersection geometry and the state of the road equipment. The intersection analysis uses the Indonesian Road Capacity Manual (MKJI) to determine the level of service and then uses VISSIM for simulation. Its purpose is to retrieve the output data fed to the SSAM software and count the number of conflicts that occurred.

FINDINGS AND DISCUSSION

A. Intersection Performance

1. Existing Condition

The Existing Condition of the Kalimalang 5 Intersection Inspection can be clarified in the following Figure 1.

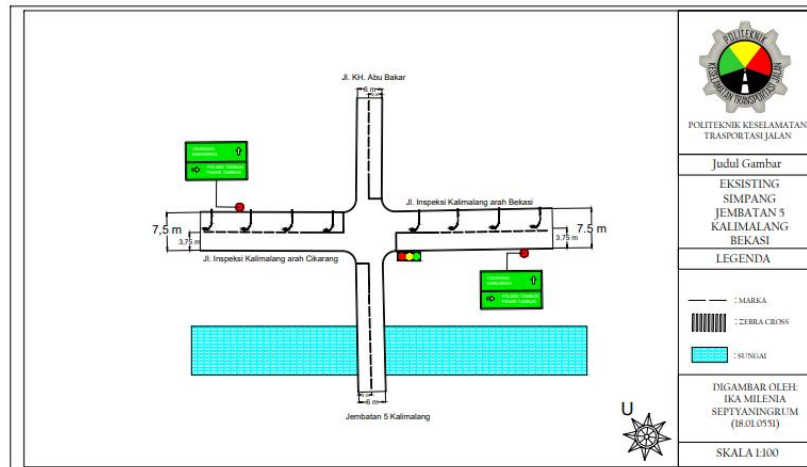






Figure 1. Autocad 2D Existing Condition of Kalimalang 5 Bridge Intersection
 Result of Analysis, 2022

Table 3. The Existing Condition of the Kalimalang 5 Bridge Intersection

Segment	The width of the road (m)	Shoulder Width (m)		Visualization
		Right	Left	
South (Bridge Road 5 Kalimalang)	6	1	1	
West (Kalimalang Inspection Road towards Cikarang)	7.5	1	1	
North (KH. Abu Bakar Street)	6	1	1	

East (Kalimalang Inspection Road towards Bekasi)	7.5	1	1	
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2. Traffic Volume

In the following Figure 2, it can be seen that the peak hour volume at the five intersections of the Kalimalang inspection is at the afternoon peak at 16.30 – 17.30 WIB, which has a volume of 1342 smp/hour. The traffic volume at the west intersection approach is the densest on the Kalimalang Inspection Road, Cikarang Direction.

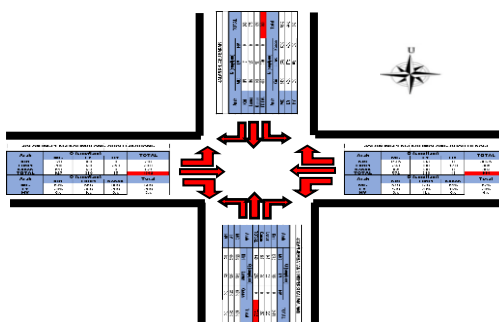


Figure 2. Catograph Diagram of Traffic Movements at Kalimalang 5 Bridge Intersection (Analysis Results, 2022)

3. Intersection Capacity (C)

Table 4. Intersection Capacity

Adjustment Factor	C ₀	F _W	F _M	F _{CS}	F _{RSU}	F _{LT}	F _{RT}	F _{MI}	C
Score	2900	0,977	1	0,94	0,94	1,37	0,78	1,48	3959,36

Source: Analysis Result, 2022

4. Degree of Saturation (DS)

The total traffic flow (Q) at peak hours is 3176.5 smp/hour and capacity (C) is 3959.36, so the degree of saturation (DS) can be calculated as follows:

$$DS = Q_{TOT}/C$$

$$DS = 3176,5 / 3959,36 = 0.8$$

5. Delay (T)

Table 5. Intersection Delay (T)

Delay	T _{LL} (sec/smp)	T _{LLMA} (sec/smp)	T _{LLMI} (sec/smp)	T _G (sec/smp)	Intersection delay (T) (sec/smp)
Score	8.52	6.09	11.13	3.78	12.3

Source: Analysis Result, 2022

6. Probability of Queuing (PA)

The queue probability can be known by the following equation:

Opportunity upper limit:

$$PA = 47,71 DS - 24,68 DS^2 + 56,47 DS^3$$

$$PA = 47,71 \times 0,8 - 24,68 \times 0,64 + 56,47 \times 0,512 = 28,91$$

$$PA = 51\%$$

Opportunity lower limit:

$$PA = 9,02 DS + 20,66 DS^2 + 10,49 DS^3$$

$$PA = 9,02 \times 0,8 + 20,66 \times 0,64 + 10,49 \times 0,512$$

$$PA = 26\%$$

7. Calculation of saturation current

The calculation of the saturation current value according to MKJI 1997 is as follows:

Table 6. Saturated Current Rated

No.	Segment	Saturated Current
1	Bridge Road 5 Kalimalang	3466.5
2	Kalimalang Inspection Road towards Cikarang	1454.2
3	KH. Abu Bakar Street	3452.3
4	Kalimalang Inspection Road towards Bekasi	1473.7

Source: Analysis Result, 2022

8. Vissim Modeling

a. Vissim Calibration

Calibration is done by changing the driving behavior parameters described in Table 7.

Table 7. Calibration Value Parameter Change of Vissim

Parameter	Before	After
Average Standstill Distance	2	0.6
Add. Part Of Desired Safety Distance	2	0.6
Mul. Part Of Desired Safety Distance	3	1
Lane Change Rule	Slow Lane Rule	Free Lane
No. of Observed Vehicle	4	2
Desired Position At Free Flow	Middle Of Lane	Any
Lateral Distance Driving	1	0.5
Lateral Distance Standing	0.2	0.2
Safety Distance Reduction Factor	0.6	0.5
Minimum Headway	0.5	0.5

Source: Analysis Result, 2022

b. Vissim Validation

Vissim model validation calculations using the basic statistical formula Geoffrey E. Havers (GEH) are used to measure the accuracy of the vehicle volume observed with the results of vissim. The following table shows the results of the GEH test calculation:

Table 8. GEH Vissim Test Results

Segment	Vehicle volume (vehicles/hour)		GEH	Information
	Observation	Vissim		
Bridge Road 5 Kalimalang	1581	455	1.11	RECEIVED
Kalimalang Inspection Road towards Cikarang	1602	816	0.65	RECEIVED
KH. Abu Bakar Street	1712	1015	0.51	RECEIVED
Kalimalang Inspection Road towards Bekasi	1595	399	1.20	RECEIVED
Average			0.87	RECEIVED

Source: Analysis Result, 2022

Based on Table 8, it is explained that the results of the Vissim GEH test validation on each approach at the intersection show a value of <5.0, which means that the microsimulation model on Vissim is accepted and declared valid. Furthermore, the MAPE test is used to show whether the vehicle speed results from field observations and simulations are appropriate or not. The following are the results of observation and simulation calculations:

Table 9. MAPE Test Results Vissim

Segment	Speed		MAPE Test
	Vissim	Existing	Results
Bridge Road 5 Kalimalang	23.1	24	4%
Kalimalang Inspection Road towards Cikarang	29.09	31	6%
KH. Abu Bakar Street	28.14	31	9%
Kalimalang Inspection Road towards Bekasi	30.75	32	4%
MAPE			6%

Source: Analysis Result, 2022

B. Traffic Conflict

1. Existing

After conducting a traffic conflict survey, the results of the number of crossing and lane change conflicts that occurred at the 5 Kalimalang Bridge Intersection were as follows:

Table 10. Number of Conflicts in Existing Conditions

No.	Conflict Type	Total
1.	Crossing	87
2.	Lane Change	46
	Total Conflict	133

Source: Analysis Result, 2022

2. Alternative

Traffic conflicts that occur with the installation of the 2-phase APILL are obtained by inputting the format.trj file into the SSAM software. Then the results of the traffic conflict analysis are obtained in Table 11 below.

Table 11. Number of Conflicts with 2 Phases of Traffic Light

No.	Conflict Type	Total
1.	Crossing	32
2.	Lane Change	13
Total Conflict		45

Source: Analysis Result, 2022

CONCLUSION AND FURTHER RESEARCH

A. Conclusion

The following conclusions can be taken from the analysis that was done in prior section:

1. According to the VISSIM Software examination of the performance of the Kalimalang 5 Bridge Intersection in its current state, the delay value of the intersection is 1.59, and the queue length is 4.73 meters with a service level of B.
2. Simpang 5 Kalimalang traffic congestion before and after suggestions are made regarding the current situation. Traffic conflicts with the analysis of SSAM software after being given a recommendation in the form of supplying 2-phase APILL obtained as many as 45 conflicts for direct calculations that took place in the field before it was advised to get up to 133 conflicts.
3. Because it can reduce traffic conflicts by 34%, the intersection delay increases by 12.4 seconds, and the degree of service at the intersection is B the alternative handling of the Kalimalang 5 Bridge Intersection is an APILL intersection with a 2-phase setting and a cycle time of 125 seconds.

B. Further Research

The following recommendations can be made based on the findings of the research that has been done:

1. To increase safety, it is suggested that APILL settings with two phases and a cycle time of 125 seconds be added. These settings can lessen traffic conflicts at the Kalimalang Fifth Bridge Intersection while still paying attention to the level of safety at the intersection.
2. Zebra cross markings, pedestrian sidewalks, and the removal of trees that have obscured the current signs at each leg of the crossroads are advised according to the intersection's geometrical features.
3. It is advised that more research be done on traffic conflicts at intersections and proposals made in the form of road geometry modifications to enhance the smoothness and safety of these intersections.

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