Platoon Dispersion of Mixed Traffic by Computer Simulation to Optimize Signal Setting: A Case Study in Indonesia

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Abstract: Area Traffic Control System (ATCS) has been installed in Yogyakarta. The signal setting can be adjusted directly from Control Centre Room and queue lengths can be monitored directly through CCTV. There are two signalized intersections along Sugiyono street Yogyakarta, Indonesia. Distance between these two intersections approximately 300 meters. However, it is difficult to set the signal setting to minimize the queues and delays because of the mixed traffic.

A survey, therefore, has been carried out, to count the traffic volumes, the average speed for each type of vehicle and the driver characteristics. VISSIM simulation model has been employed to simulate the traffic flow and queues and delays for each intersection. Some scenarios have been analyzed to optimize the signal setting.

This model has been implemented and the best scenario has been recommended, which can significantly improve the intersection performances.

Keywords: platoon dispersion, area traffic control system, traffic simulation

1. INTRODUCTION

Traffic congestion has existed in many cities since some years ago. It is difficult to build new roads because of the limited available land. Traffic management, therefore, should be implemented to solve this problem. One of the traffic management schemes is traffic signal coordination. Queues and delays can be minimized by traffic signal coordination of the intersections.

Queues and delays at intersections can be analyzed by the use of empirical, mathematical and simulation approaches. Empirical models can predict queues and delays by observations, whereas in the mathematical approach can calculate queues and delays by developing formulas, which are based on mathematical calculation. In contrast, a simulation model can calculate the queues and delays by simulating the traffic flow. Traffic flows and driver characteristics can be inputted in the model. Traffic simulation time may be run as desired and several parameters may be calculated during simulation process. A simulation model can represent the real situation at the site being studied. This model has, therefore, been developed by many researchers in the recent years, such as Munawar and Andriyanto (2013), who have developed a simulation model to predict queues and delays at Toll Plazas.

Simulation model has the flexibility to cover a wide range of highway and traffic conditions. The flexibility depends on the data to be inputted in this model, i.e.: driver characteristics, traffic variation and speed. Therefore, simulation models have been used since many years, such as Munawar et al (2017), who have used the VISSIM simulation software to predict the capacity of urban road in Indonesia.

VISSIM simulation software will be employed to predict queues and delays at intersections.

This software has been developed in Karlsruhe, Germany by PTV (Planung Transports Verkehr) AG. VISSIM stands for "Verkehr In Städten – SIMulations modell" (German for "Traffic in cities - simulation model"). VISSIM formulas are based on Wiedemann approach, psycho physical model for driving behavior (1974). The relationship between speed and distance according to Wiedemann is shown in Fig. 1.

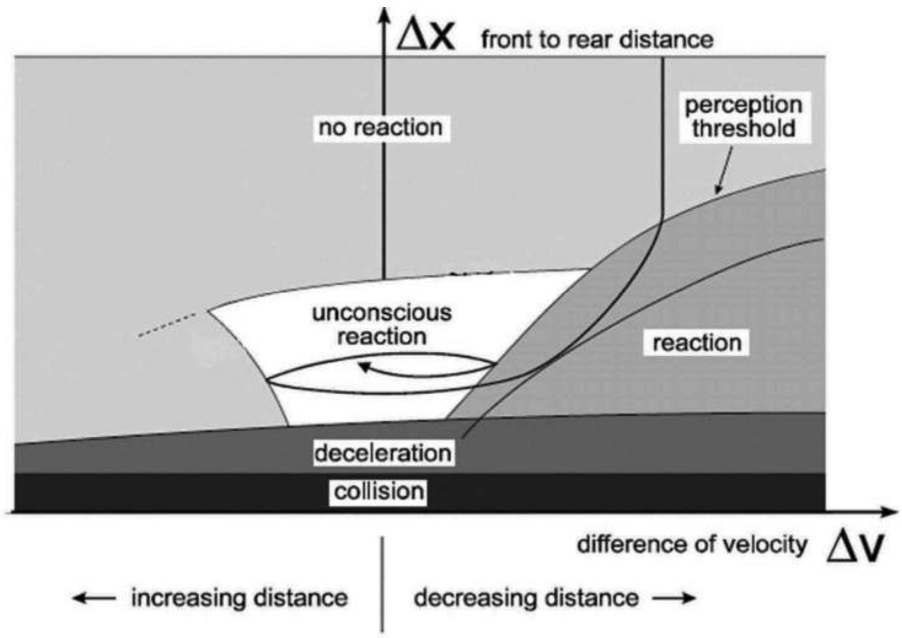

Fig. 1. Relationship between Velocity and Distance

2. PMETHODOLOGY AND ANALYSIS

A. Methodology

Methods for developing coordinates signal timings for road links may be classified into two broad methods:

a. The Bandwith – based methods

b. Simulation – based methods.

Since, this study will concern simulation models the method review focuses on the simulation – based methods. However, to calculate the approximate bandwith between these two intersections, the bandwith method has been implanted. Then, by trial and error, to determine the minimum queue lengths and delays, the simulation method has been implemented.

Recently, computer simulation – based methods have been developed. Among this is VISSIM, a simulation which stands for Verkehr In Städten – SIMulations modell. This study will employ VISSIM to evaluate the coordinated traffic control scheme, besides using the mixed traffic platoon dispersion model, which was developed based on a simulation based methods.

The simulation based methods, actually based on the platoon dispersion theory. This study concerning this theory has been conducted extensively and developed into three different theories: the kinematic wave theory, the diffusion theory and the recurrence theory.

The measurement of the flow was conducted during morning and evening peak hours, by using camera video. The flow was counted based on fifteen minute period, and vehicles are grouped into 4 classes, i.e.: motor cycle, passenger car, heavy vehicle and trailer. Before running the VISSIM software, the parameters, which are shown in Table I, have been calibrated to meet the Indonesian behavior.

According to McShane and Roess (1990), to coordinate several signals, several requirements are needed to be fulfilled, namely:
1. The distance between coordinated intersections is not more than 800 meters. If it's more than 800 meters, the signal coordination won't be effective anymore,
2. All signals must have the same cycle time,
3. Generally used on the main road network (arteries, collectors) and can also be used for road networks in the form of grids, and
4. There is a group of vehicles (platoon) as a result of traffic lights upstream.

Table I. Calibrated Parameters

Parameters	Calibration value	
	Before	After
Desired position at free flow	Middle of lane	Any
Overtake on same lane: on left & on right	off	on
Distance standing (at 0 km/h) (m)	1	0.3
Distance standing (at 50 km/h) (m)	1	0.5
Average standstill distance	2	0.45
Additive part of safety distance	2	0.45
Multiplicative part of safety distance	3	1
Waiting time before diffusion (s)	60	40
Min. headway (front/rear) (m)	0.5	0.4
Safety distance reduction factor	0.6	0.4
Maximum deceleration for cooperative braking (m/s^2)	-3.00	-3.00

According to Taylor and Bonsall (1996), coordination between signaled intersections is one way to reduce delays and queues. The principle of coordinating signal intersections according to Taylor is shown in Fig. 2 which explains some things that need to be considered in coordinating signals, namely:
1. The cycle time of the signal for each intersection is attempted the same, this is to make it easier to determine the green signal difference from the one intersection with the next intersection.
2. We recommend that the intersection pattern used is fixed time signal, because signal coordination is carried out continuously.

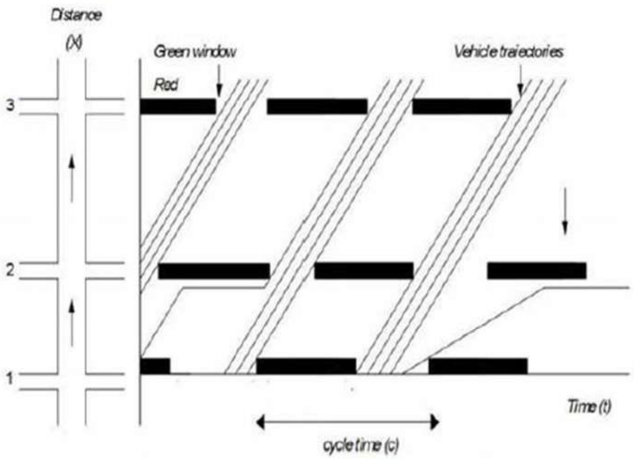

Fig. 2. Principles of Signal Coordination and Green Wave

According to Papacostas and Prevedouros (2005), the offset is the time difference between the start of the green signal at the first intersection and the beginning of the green signal at the next intersection. Time offsets can be calculated through a coordination diagram, but offset times can also be used to start forming a coordination path, while bandwidth is a time difference in a parallel path of a green signal between the first track and the last line. Both are at a constant speed and are a platoon that has no red signal at all.
For more details, the offset and bandwidth coordination diagram of three intersections can be seen in Fig. 3 below.

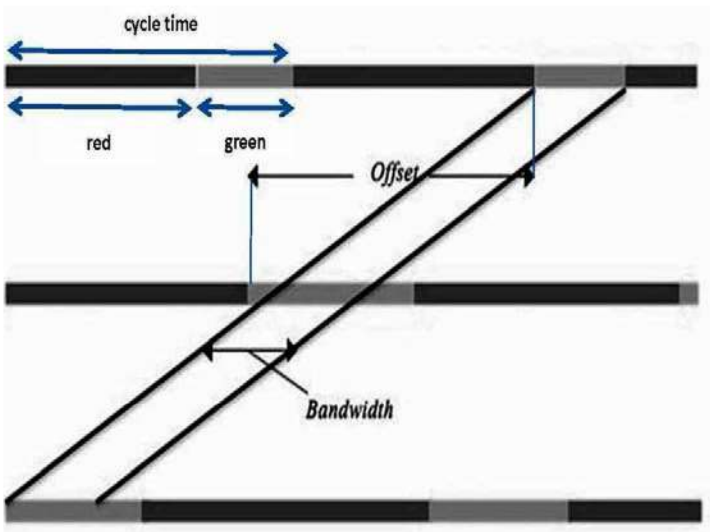

Fig. 3. Bandwith Coordination

B. Analysis

First, the existing condition has been analyzed. The Offset value from West to East (Intersection 2 to 1) is 125 seconds and for East to West (Intersection 1 to 2) is 57 seconds. These two intersections have different cycle time, i.e.: 127 seconds (for intersection 1) and 91 seconds (for intersection 2). The existing bandwith is shown in Fig. 4. It is shown that there is no coordination between these two intersections. Therefore, there is no green wave between intersections.

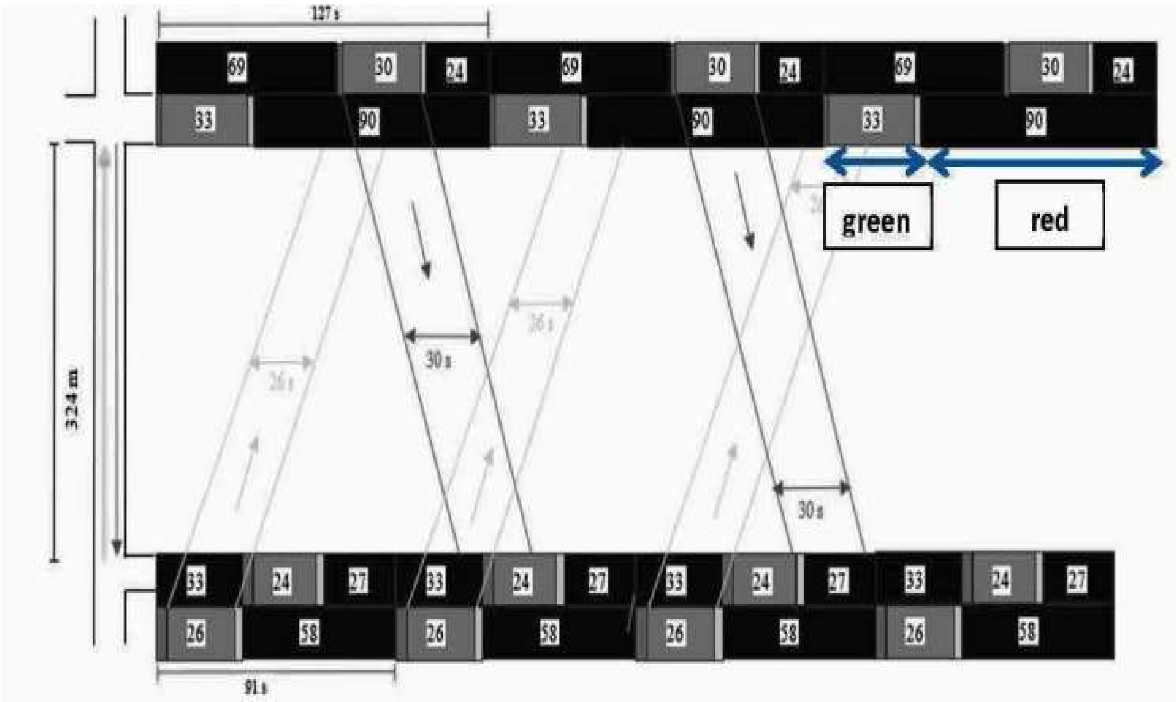

Fig. 4. Existing Signal Setting

The evaluation of the existing condition has been carried out by running the Vissim Simulation Software. The results, i.e.: delay, travel time, speed and level of service are shown in Table II.

Table II
Value of Delays, Travel Time, Speed and Level of Service of the existing condition

Link between intersection	Delay (second)	Travel time (second)	*Queue length (m)*	*Speed* (km/h)	*Level of service*
1 - 2	21,55	51,25	120,2	37,12	E (poor)
2 - 1	33,96	60,13	175,4	24,42	E (poor)

To improve the signal setting, first of all, the cycle time for these two intersections must be the same. The optimum signal setting has been analyzed by using the Indonesian Highway Capacity Manual method (1997). It is determined that the optimum cycle time for these two intersections is 116 seconds. The signal setting for alternative 1 is shown in Table III.

Table III
Signal Setting (Alternative 1)

Junction arm	Time (second)				Cyclel time (second)
	Green	Yellow	Red	*Allred*	
West	43	2	69	2	116
East	38	2	74	2	
South	23	2	89	2	

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There are three alternatives, with different offset, have been run by Vissim Simulation software (trial and error method) to find the best solution (minimum queue/delay/travel time and maximum speed), These alternatives are shown in Table IV.

Table IV
Offset Values between Intersections

Description	Intersection 1 to 2	Intersection 2 to 1
Existing	57	125
Alternative 1	41	56
Alternative 2	47	53
Alternative 3	47	57

It is found that the best offset setting is 53 seconds for West to East link (Intersection 2 to 1) and 47 seconds for East to West link (Intersection 1 to 2). The results of a comparison of the queue, delay, travel time and speed between the existing condition and the best alternative are shown in Tables V to VIII below.

Table V
Comparison of Delay per vehicle during peak hour

Link	Existing	Best alternative (alt. 2)	
	Delay (s)	Delay (s)	Decrease (%)
1 to 2	21.55	13.12	39.12
2 to 1	33.96	14.43	57.51

Tabel VI
Comparison of Travel Time during peak hour

Link	Existing	Best alternative (alt. 2)	
	Travel time (s)	Travel time (s)	Decrease (%)
1 to 2	51.25	38.12	25.62
2 to 1	60.13	44.54	25.93

Table VII
Comparison of Queue per vehicle during peak hour

Link	Existing	Best alternative (alt. 2)	
	Queue length (m)	Queue length (m)	Decrease (%)
1 to 2	120.2	36.8	69.38
2 to 1	175.4	64.2	63.40

Table VIII
Comparison of Speed during peak hour

Link	Existing	Best alternative (alt. 2)	
	Speed (km/h)	Speed (km/h)	Increase (%)
1 to 2	37.2	43.98	18.48
2 to 1	24.42	33.45	36.98

It is shown that the alternative solution can reduce the delay by 39.12 and 57.51 %, travel time by 25.62 and 25.93 %, queue by 69.38 and 63.40 % and increase the speed by 18.48 and 36.98 %.

3. CONCLUSIONS

1. Vissim simulation software can be used to find the best offset between these two intersections to minimize the queue/delay/travel time and to maximize the speed.
2. It is recommended to change the offset by 53 seconds (from 1 to 2) and 33 seconds (from 2 to 1) and to change the cycle time by 116 seconds.

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