A Microsimulation Model of Median Busway and ATCS (Case Study : Transjogja Bus, Yogyakarta, Indonesia)

Anugrah ILAHI[a], Muhammad Zudhy IRAWAN[b]

[a] *Master Student of Master of Transportation System and Engineering, Gadjah Mada University, Yogyakarta, Jalan Grafika 2 - 55281, Indonesia*
[b] *Lecturer of Master of Transporation System and Engineering, Gadjah Mada University, Yogyakarta, Jalan Grafika 2- 55281, Indonesia*
[a] *E-mail : anugrahilahi23@gmail.com*
[b] *E-mail : irawan@tsipil.ugm.ac.id*

Abstract: This study develop a microsimulation traffic condition related to Bus Transjogja (Bus rapid transit in Yogyakarta). The purposes of this research are find out observe examine whole traffic condition related queue and delay in road section, and to know public transport rute performance when Transjogja operates mixed traffic (existing condition), and when Transjogja bus should be given priority using area traffic control system (ATCS) and median bus lanes. In this research, we use Aimsun microsimulation software, that consider car following model to analyze and measure it.

Key Words: Micro simulation, Area traffic control system, Median bus lanes, Aimsun micro simulation.

1. INTRODUCTION

The Growth of vehicles in Yogyakarta has increased significantly, As a result level of has also. Diverse ideas in the catapult in order to reduce the number of public transport users such as the revitalization of public transportation in Yogyakarta. The government of Yogyakarta introduced Transjogja inorder to reduce the use of private cars. However, after 5 years the number of users of private vehicles in Yogyakarta has not declined.That is the problem that needs to be resolved.

Bus Signal Priority (BSP) is an operational strategy that facilitates the movement of in-service buses through traffic signal controlled intersections (VTA Transit, 2007). Median busway is a dedicated bus facility in the median area that sometimes is shared with other high occupancy vehicles and also separated physically from other forms of traffic with some form of transit priority at locations where it intersects with other traffic (APTA, 2010). By implementing of this method will reduce the delay that transit vehicles spend at intersection queues, it also reduce transit delay, travel time and improve transit service reliability, thereby increasing the quality of transit service. It also has the potential for ton reducing overall delay at an intersection on a individual basis. In addition to provides that can give benefits with minimum impact to other facility users, including cross-traffic and pedestrians BUS.

In this research, the model will be simulated in four types of scenarios: scenario existing, which simulates the network without priotity (existing); scenario 1,which gives Bus Transjogja special priority lane in the median of road section (Busway); scenario 2, which gives the Transjogja signalized intersection priority when passing through intersections area

(ATCS); scenario 4, implement priority busway with ATCS for Bus Transjogja, four scenarios will be used to compare performance indicators that are level of effectiveness and how effective if that scenario performed, related with delays, queues, and the impact of changing patterns of Transjogja operation.

2. AIMSUN MICRO SIMULATION MODEL

2.1 Car-Following Model

Aimsun Microsimulation model, follows a microscopic simulation approach this means the behaviour of each vehicle in the road network continuously modelled throughout the simulation time period while it travels through the traffic network, according to the several vehicle behaviour model e.g., car following, lane changing (Aimsun user's manual, 2010).

Aimsun using car-following model based on the Gipps model (Gipps 1981 and 1896b), that model considering as an ad hoc development of the empirical model, it basically consists of two components acceleration and deceleration, the first formula represents the intention of a vehicle to achieve a certain desired speed, while the second reproduces the limitations imposed by proceding vehicle. The second formula reproduces the limitations imposed by the preceding vehicle when trying to drive at the desired speed. This model explain that the maximum speed a vehicle (n) can accelerate during a time period (t, t+T) is given by:

$$V_a(n,t+T) = V(n,t) + 2.5a(n)T\left(1-\frac{V(n,t)}{V^*(n)}\right)\sqrt{0.025+\frac{V(n,t)}{V^*(n)}} \quad (1)$$

Where:
V (n, t) is the speed of vehicle n at time t;
V*(n) is the desired speed of the vehicle (n);
a(n) is the maximum acceleration for vehicle n; T is the reaction time.

On the other hand, the maximum that the same vehicle (n) can reach during the same time interval (t, t+T), based on its own characteristic and limitations imposed by the presence of the lead vehicle (vehicle n-1) is:

$$V_b(n,t+T) = d(n)T + \sqrt{d(n)^2T^2 - d(n)\left[2\{x(n-1,t)-s(n-1)-x(n,t)\} - V(n,t)T - \frac{V(n-1,t)^2}{d'(n-1)}\right]} \quad (2)$$

where:

d(n) (< 0) is the maximum deceleration desired by vehicle n;
x(n,t) is position of vehicle n at time t;
x(n-1,t) is position of preceding vehicle (n-1) at time t;
s(n-1) is the effective length of vehicle (n-1);
d'(n-1) is an estimation of vehicle (n-1) desired deceleration.

The definitive speed for vehicle n during time interval (t, t+T) is the minimum of those previously defined speeds:

$$V(n,t+T)=\min\ \{V_a\ (n,t+T), V_b\ (n,t+T)\ \} \tag{3}$$

The position of vehicle (n) inside the current lane is updated by taking the speed into the movement equation:

$$x(n,t+T) = x(n,t) + v(n,t+T)T \tag{4}$$

2.2 Lane-Changing Model

The lane-changing model can also be considered as a development of the Gipps lane-changing model (Gipps 1986a and 1986b). Lane change is modelled as a decision process, analysing the necessity of the lane change (such as for turning manoeuvres determined by the route), the desirability of the lane change (for example to reach the desired speed when the leader vehicle is slower), and the feasibility conditions for the lane change that are also local, depending on the location of the vehicle in the road network.

In order to achieve a more accurate representation of the driver's behaviour in the lane-changing decision process, three different zones inside a section are considered, each zone corresponds to a different lane changing motivation. These zones are characterised by the distance up to the end of the section, i.e., the next point of turning (see Figure 1).

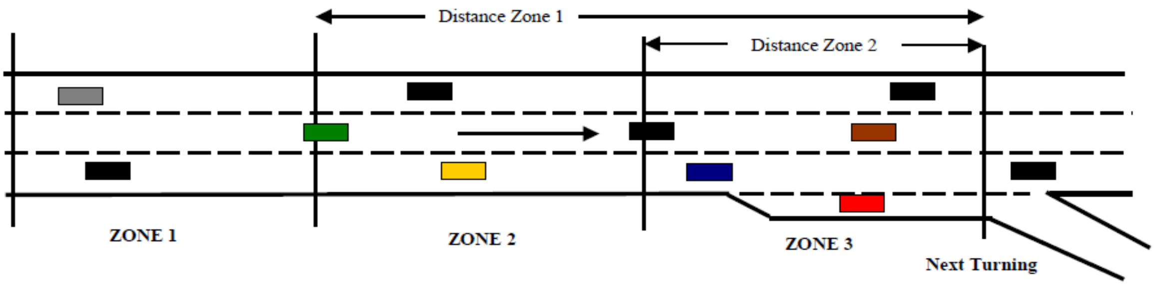

Figure 1. Lane changing zones

Lane changing zones are defined by two parameters, Distance to Zone 1 and Distance to Zone 2. These parameters are defined in time (seconds) and they are converted into distance whenever it is required for each vehicle *i* at each section *s* using the following function:

$$D_m = D_t\ .S_{limit}(s).\left[\frac{S_{limit}(s)}{V_{max}(i,s)}\right] \tag{5}$$

where:

Distance in metres m D
Distance in seconds t D
Speed limit of the section *s*
Maximum desired speed of vehicle *i* on a section or turning *s*

2.3 Cycle Detection Measures

Count number of vehicles that have passed through the detector during the last cycle (vehicles):

$$\text{Count (cycle)} = NbVeh(cycle) \tag{6}$$

Speed: mean speed of the vehicles when crossing the detector during the last cycle (km/h or mph)

$$Speed(cycle) = \frac{\sum_{v \in Veh(cycle)} Speed(v, cycle)}{NbVeh(cycle)} \tag{7}$$

2.4 Section Traffic Statistics

The statistics provided by Aimsun at the section level and turning level are the following:

2.4.1 Delay

To calculate delay of a section, following formula:

$$. \; DT_{\sec} = \frac{\sum_{i=1}^{N\sec} DT\, i}{N\, sec} \tag{8}$$

Where,

DTi= Average link delay time of the i-th vehicle (seconds).

DTsec = Average Delay Time per vehicle on a section (seconds). It considers the section and all its exit turns

$$DT_i = TT_i - \left[\frac{L_s}{Min(SMax_i, S_s * \theta_i} + \frac{L_t}{Min(SMax_i, S_t * \theta_i} \right] \tag{9}$$

Where,

S_s= Speed limit of section s (m/s),

S_t = Speed limit of turning t (m/s),

θ_i= Speed acceptance of vehicle i,

SMaxi = Maximum desired Speed of vehicle i (m/s),

L_s = Distance of section s (metres),

L_t = Distance of turning t (metres).

2.4.2 Queue

To calculate the average and maximum queue length of a section (veh):

$$AQL_{\sec} = \frac{\sum_{l \in \sec} \left(\sum_{t_i \in T_l} \left[QL_{l.t_{(i-1)}} * (t_{l.1} - t_{l,(t-1)}) \right] \big/ I \right)}{NBlanes_{\sec}} \tag{10}$$

$$MaxQL_{\text{sec}} = \frac{\sum l \in \text{sec}\, MaxQl_l}{NBLanes_{\text{sec}}} \quad (11)$$

Where,

QL l,t = Queue Length in the lane l at time t (veh),
MaxQL l = Maximum Queue Length in the lane l (veh),
I = Interval of statistics (seconds),
Tl = (0, tl,1, ..., t l,m, I) : instants when the queue length in lane l changes,
NBLanessec = Number of lanes of section *sec.*

2.5 Public Transport Line Statistics

2.5.1 Travel Time

To calculate travel time of public transport route(veh):

$$TT_l = \frac{\sum_{i=1}^{N_l} TT_i}{N_l} \quad (12)$$

Where,

TTl= Average Travel Time per vehicle (seconds)
TTi = Average travel time of the i-th vehicle (seconds).
TTi = *TEXi* + *TENi*
Tti = *TDTi*
TENi = Entrance time of the i-th vehicle into the system (seconds).
*TEX*i = Exit time of the i-th vehicle from the system (seconds).

2.5.2 Delay Time

To calculate travel time of public transport route(veh):

$$DT_l = \frac{\sum_{i=1}^{N_l} DT_i}{N_l} \quad (13)$$

Where,

DTl = Average Delay Time per vehicle (seconds
DTi = Average delay time of the i-th vehicle (seconds)

3. STUDY METHODOLOGY

3.1 Research Study

The area modeling contains of 9 signalized intersections with fixed traffic signal and 26 priority junction (see figure 2). Data of traffic volume in the morning at signalized intersection was conducted by yogyakarta transportation agency, and traffic volume at priority junction was survey with interval 15 minutes in the weekdays. Geometry design of section in this research get from Yogyakarta Infrastructure agency, and number of line each section was conducted by direct survey. Demand of road network it consist 4 vehicles (e.g., Bus, car, Motorcycle, Truck) and are operated in mixed traffic for existing condition and ATCS condition, and separated traffic when Transjogja Bus is operated in Busway and busway with ATCS conditions.

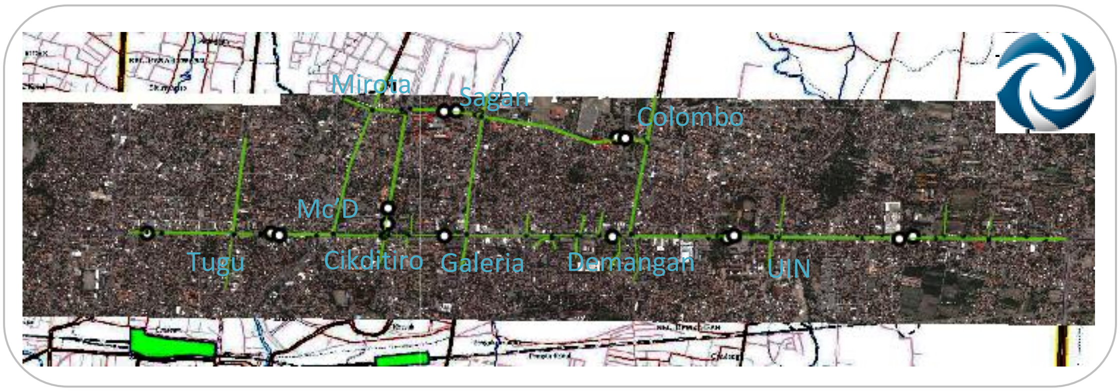

Figure 2.Aimsun model of study area

3.2 Bus Transjogja Route

This study consists of 6 lines Transjogja operation, which consists of lines 1a, 1b, 2a, 2b, 3a, 3b, but In line 3 of this research divided into 3a.1 and 3a.2 because study area at this line. through the study site as shown in Figure 3 below. Transjogja operation pattern in base on data on average time and standard deviation vehicle arrival (Headway) at halte when transjogja stop at halte (table 1)

Table1. Headway public transport route

Route	1a	1b	2a	2b	3a	3b
Mean(minute)	11.7	17.4	14	13.2	16.13	15.1
Stdev (minute)	1.344	1.45	0.818	3.81	0.66	1.41

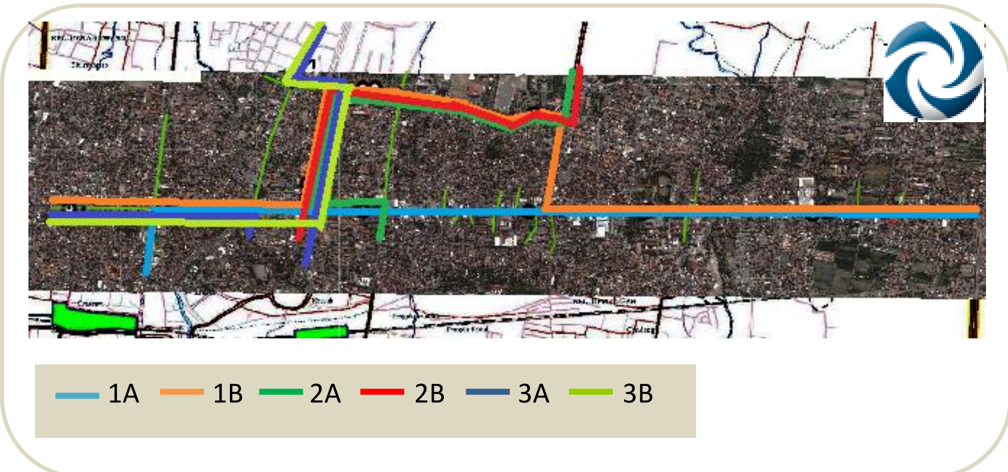

Figure 3. Public transport (Trans jogja) route

3.3 Scenario

This research consists of 4 scenarios, the first scenario is simulate existing condition, Transjogja Bus is operated with mixed traffic, and stop on the side of the road (figure 3), the second scenario is simulating transjogja if it is given special prioty lane (busway) an the road median (figure 4). The third condition is simulating if given signalized intersection priority at signalized intersection, Transjogja is operated with mixed traffic. The last scenario is implementing both conditions when Transjogja Bus is operated with area traffic control systems and busways (figure 6)

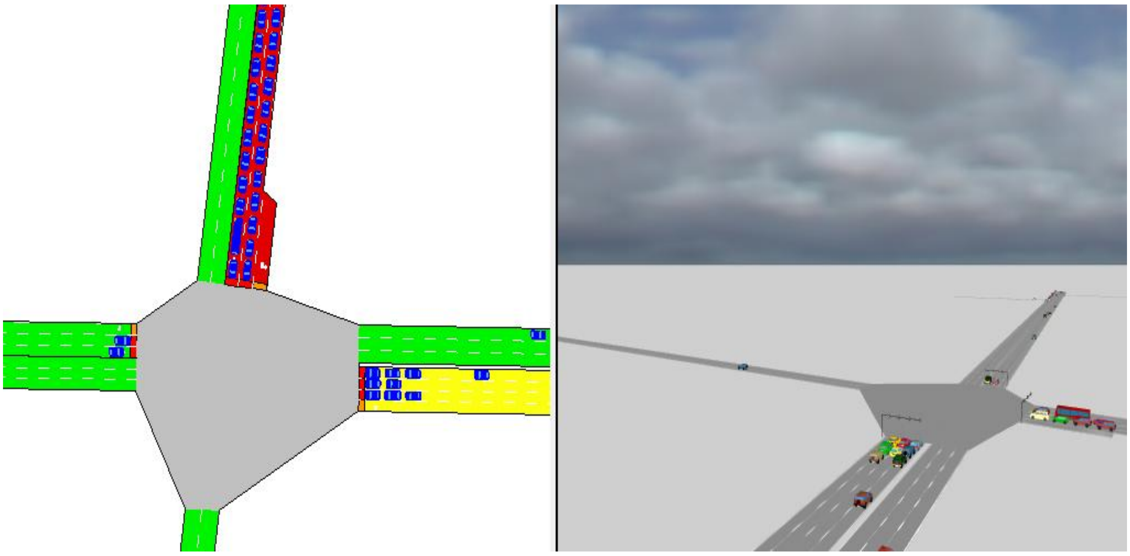

Figure 4. Existing condition

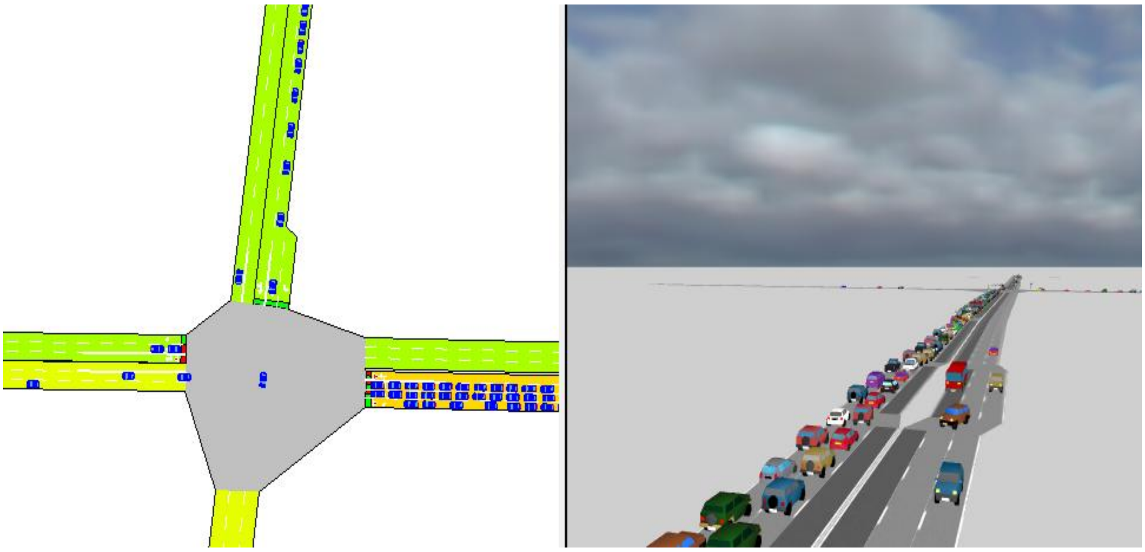

Figure 5. Busway condition

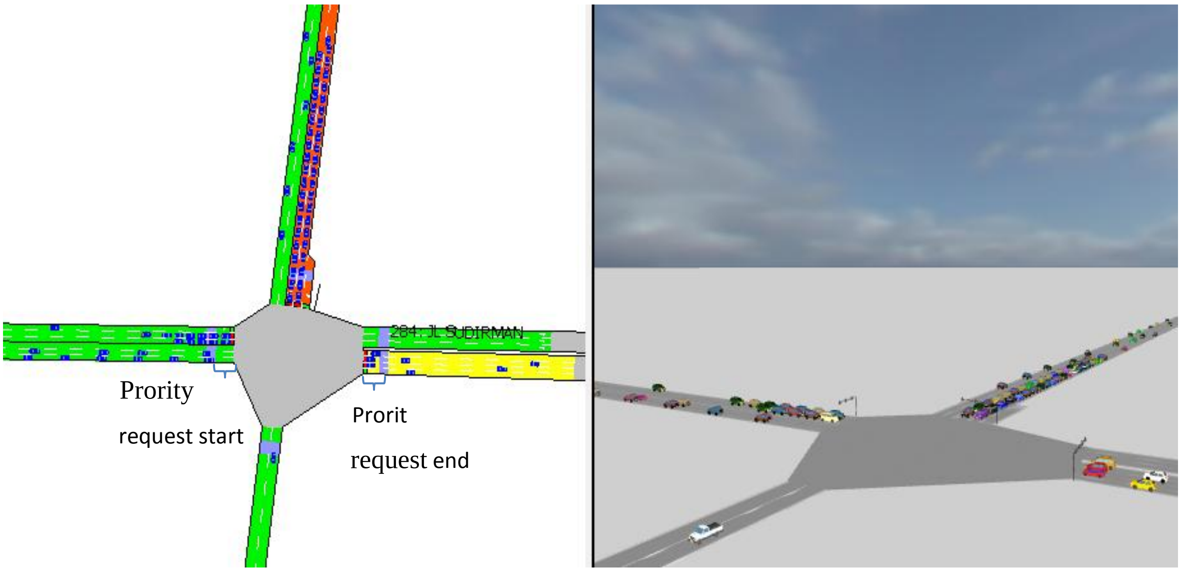

Figure 6. ATCS condition

Figure 7. Busway and ATCS condition

Traffic Signal is simulated in fixed based on observation at the intersections, but when we give priority signal (ATCS) the intersections will synchronise with detector which is author put before and after intersections. That called Priority request start and priority request end.

4. CALIBRATION AND VALIDATION

Calibration is performed by using the parameter Max Desired Speed, Speed Acceptance, and other parameters which are made default. Has been done 15 times of trial and error process to find the best result which is same with real condition, as Table 5. Each number of experiments consists of 5 parts experimentation, as used parameters Max Desired Speed varying from 0.8, 0.9, 1.0, 1.1, and 1.2. Parameter which is compared in this calibration have same location of the installation of speed detector in simulation and field observations. Obtained results, chi-square with chi-square value 16.75 at df table 5 Table 2, Table 3 RMSE values, and the value of R square as Tabel 4 below.

Table 2. Value of trial and error parameters

NO Experiment	*Max Desired Speed* (km/h)			
	Car	Motorcycle	Truck	Bus
1	30	40	50	60
2	50	60	20	30
3	60	70	30	40

Table3. Value of RMSE

Speed Acceptance	Experiment 1	Experiment 2	Experiment 3
0,8	8.25	7.43	7.38
0,9	8.06	8.12	7.82
1.0	9.56	12.41	12.67
1,1	9.56	14.78	15.55
1,2	8.16	15.61	19.56

Table4. Value of Chi-square

Speed Acceptance	Experiment 1	Experiment 2	Experiment 3
0,8	16.04	9.87	9.82
0,9	14.86	10.37	9.65
1.0	31.73	45.66	55.88
1,1	15.94	92.40	66.47
1,2	14.91	51.32	98.68

Table5. R-square

Speed Acceptance	Experiment 1	Experiment 2	Experiment 3
0.80	0.27	0.19	0.21
0.90	0.24	0.11	0.20
1.00	0.19	0.19	0.29
1.10	0.23	0.25	0.21
1.20	0.13	0.26	0.28

Based on the experiment, it is found that Experiment 3 with 0.8 value of speed acceptance is the best possible result. It has a value of RMSE 7.38, Chi-square 9.82 (9.82 <Chi-square table 16.75), and R-square 0.21.

5. RESULT

5.1 Section Performance

From the simulation results that have been done on each signalized intersection obtained the results as in Table 6, which shows the number of queues that occur at each signalized intersection. Red printed value indicates the number of the lowest queue, from the simulated comparison of four scenarios shows that scenario 2 has the lowest number of queues. Almost all intersections which are using scenario 2 had the lowest queue, but the lowest queue occurred at Tugu intersection and at UIN intersection in the existing condition. Application of ATCS on the road network at Yogyakarta has a positive impact in queue reducing at signalized intersections.

Table 6. Avarage queues at intersections

Signalized Intersection	Queue(vehicles)			
	Existing	Scenario 1	Scenario 2	Scenario 3
Tugu	22.27	30.97	23.04	31.48
Mc'D	2.57	6.99	1.49	9.89
Mirota	13.21	15.99	12.45	17.10
Sagan	141.93	400.72	131.28	246.96
Cikditiro	14.56	51.16	11.37	52.30
Colombo	9.27	7.94	2.69	3.35
Galeria	7.94	35.35	6.24	30.80
Demangan	28.93	25.18	21.24	47.51
UIN	76.00	88.45	76.15	99.55

Table 7. Avarage delays at intersections

Signalized intersection	Delays(second)			
	existing	scenario 1	scenario 2	scenario 3
Tugu	242.51	423.51	253.14	366.40
Mc'D	26.65	123.11	28.70	79.24
Mirota	167.35	205.37	161.53	212.45
Sagan	142.85	264.31	121.66	173.38
Cikditiro	140.24	610.76	117.14	464.77
Colombo	74.40	67.20	35.32	35.06
Galeria	75.30	448.22	60.46	187.86
Demangan	393.91	242.18	287.97	427.85
UIN	586.79	637.20	577.86	870.73

Performance of signalized intersection is also influenced by delaying that occurred on each arm of signalized intersection, Table 7 shows the delay that occurs at each signalized intersection, for each signalized intersection was obtained that scenario 2 had the lowest delay which is compared to the other scenarios, red printed value show the lowest delay at each signalized intersection, it appears that almost all the signalized intersections of scenario 2 has the lowest delay. However, at Tugu and Mc'D intersections, the lowest delay occur in the existing condition, and Demangan intersection the lowest delay occurs in scenario1.

In Figure 8 shows the location of the signalized intersection that becomes the object of research and shows the queue that occurs at the signalized intersection for each scenario.

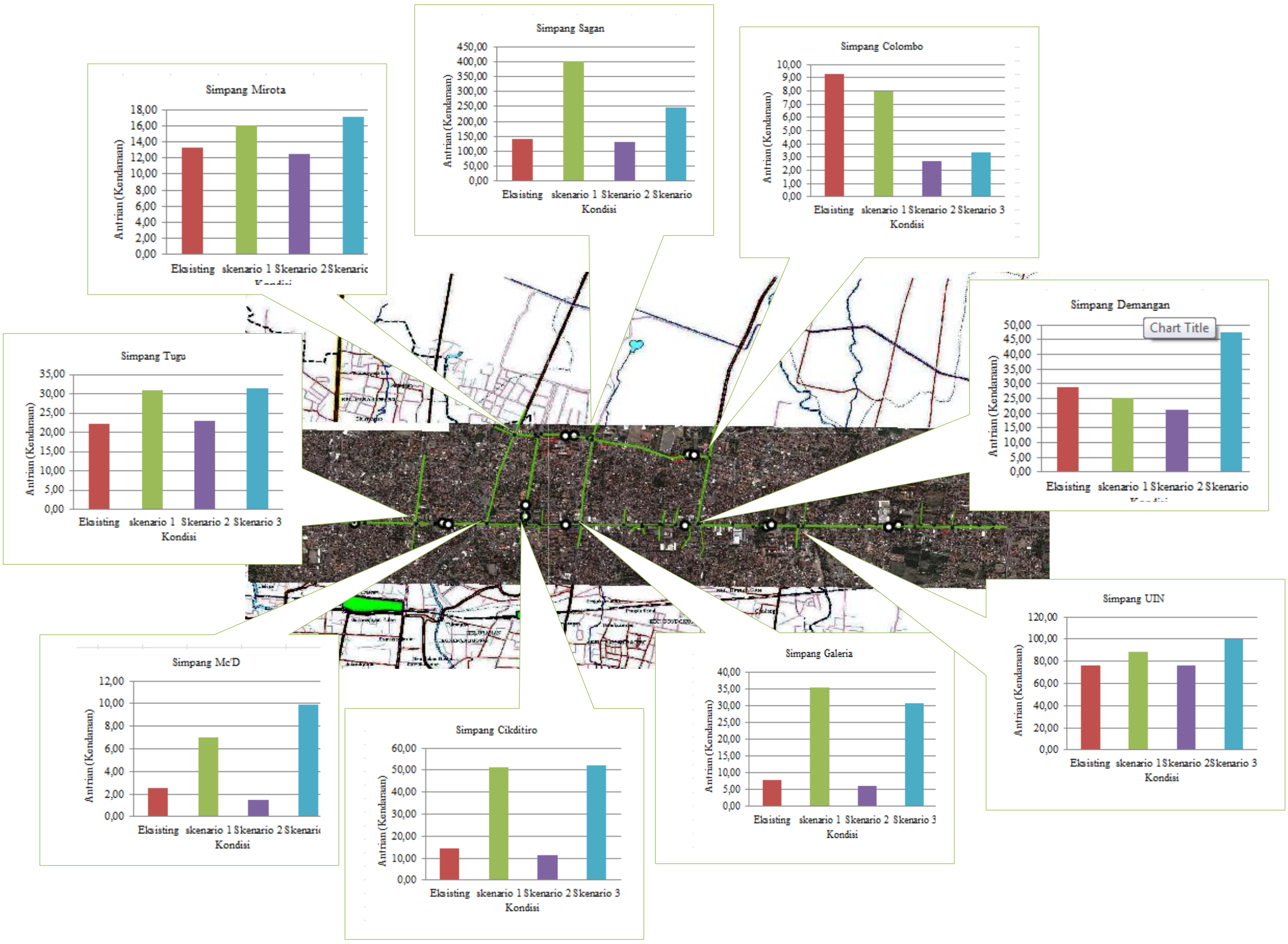

Figure 8. Intersections queue

In Figure 9 shows the location of the signalized intersection research that becomes the object of research and displayed a delay that occurs at the signalized intersection for each scenario.

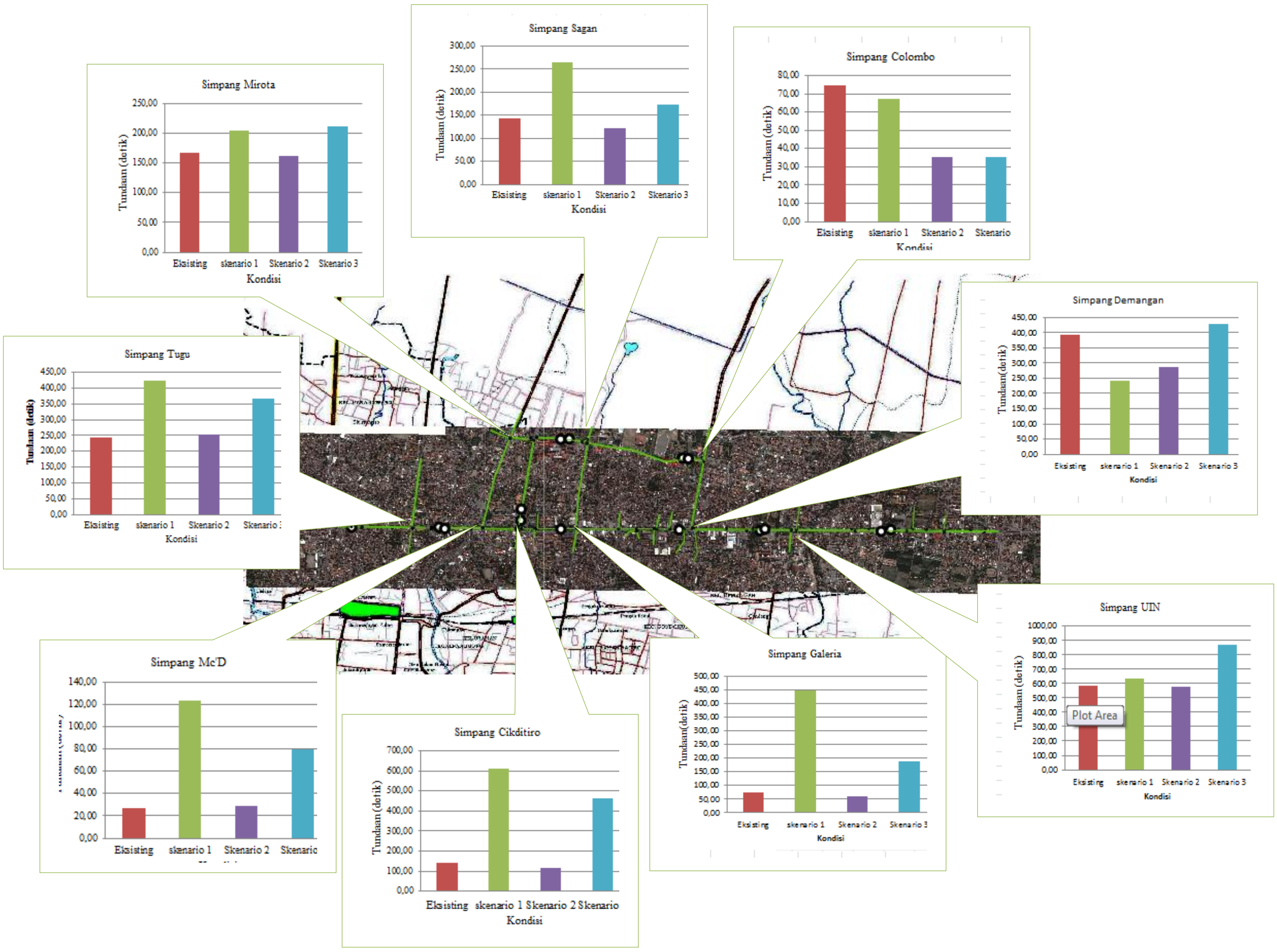

Figure 9. Intersections delays

Figure10-13 shows the location of the queue on the whole road network were observed, a red round mark describing locations on the road network critical queue. Appearing that each of the locations at the center of the queues can be said that it is similar with each scenario, and difference only in how big the number of queues that occur on every street when scenario changing is done.

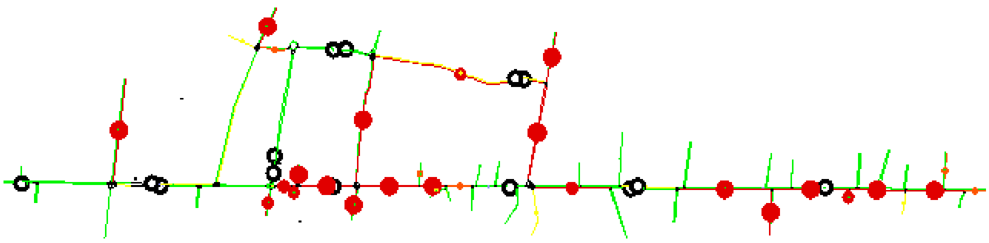

Figure 10. Critical queue location of existing

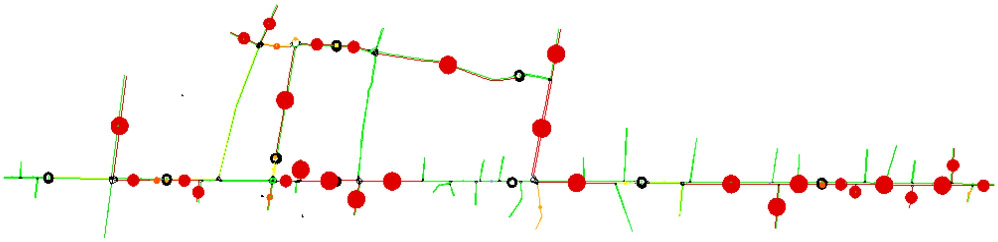

Figure 11. Critical queue location of scenario 1

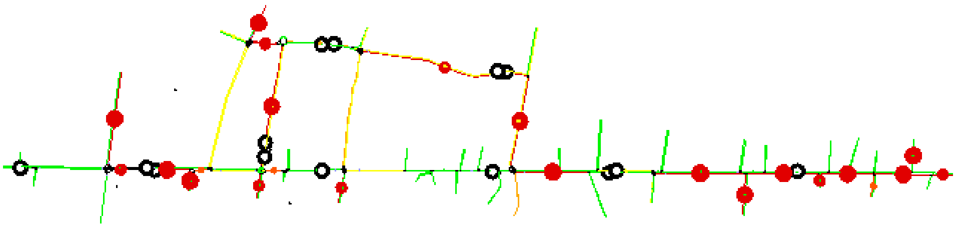

Figure 12. Critical queue location of Scenario 2

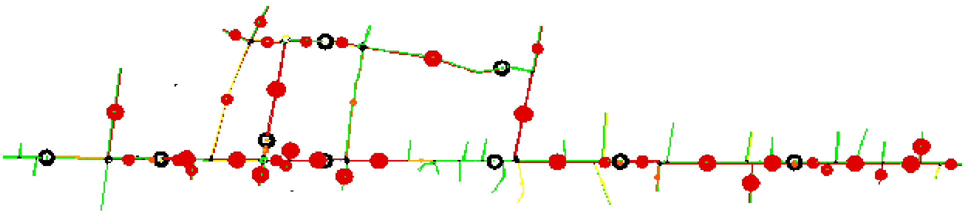

Figure 13. Critical queue location of scenario 3

5.2 Public Transport Performance

Performance of route of Bus Transjogja for each route having a difference in every scenario, it appears that the lowest travel time occurs in scenario 3 with 10.74 minutes, decrease travel time on scenario 3 by 41.23%, followed by scenario 1 at 22.86 %, and 14.15% in scenario 2, the shortest delay also occurs in scenario 3 with an average delay of 5.63 minutes, reduced delay in scenario 3 by 57.45%, followed by 32.13% for scenario 1, and 19,90% in scenario 2. It can be concluded that the provision of special busway lane and traffic signal prioritization at signalized intersections, providing a positive impact on significantly reduction of travel time and delays time.

Table 8. Travel time of Bus Transjogja

Transjogja Route	Travel time				Route length (km)
	Existing	Scenario 1	Scenario 2	Scenario 3	
1a	42.36	19.52	40.46	13.01	5.53
1b	32.27	21.89	27.37	18.02	6.91
2a	12.44	22.50	10.98	13.69	2.71
2b	11.44	13.09	7.68	10.20	2.64
3a.1	11.19	5.55	9.27	7.35	1.40
3a.2	7.80	6.00	7.03	4.85	1.20
3b	10.48	10.16	7.07	8.09	2.65
Average	18.28	14.10	15.69	10.74	
% Travel time Reducing		22.86	14.15	41.23	

Table 9. Delays time of Bus Transjogja

Transjogja Route	Delays time				Route length (km)
	Existing	Scenario 1	Scenario 2	Scenario 3	
1a	34.05	11.65	32.60	5.14	5.53
1b	21.64	11.25	16.77	7.39	6.91
2a	8.19	17.37	5.91	8.57	2.71
2b	7.46	9.09	3.70	6.20	2.64
3a.1	8.98	3.34	7.06	5.14	1.40
3a.2	5.96	4.15	5.19	3.00	1.20
3b	6.37	6.03	2.98	3.98	2.65
Average	13.23	8.98	10.60	5.63	
% Delays time Reducing		32.13	19.90	57.45	

6. CONCLUSION

Based on this research, some conclusions obtained in implementing the Busway and ATCS for Bus Transjogja toward the effect of the signalized intersection and the performance of Bus Transjogja.

By doing the schema changes to Transjogja Bus trip by applying priority such as Busway, ATCS, and busway with ATCS, the best performance of signalized intersections obtained by applying the ATCS (scenario 2). It is found that seven of the nine intersections experiencing queues declined and six of nine experienced becomes decline in the delays at the intersection.

The alternative application by implementing a special busway or busway with ATCS give the negative impact toward the performance of the intersection, which effect is increasing of the resulting queues and delays. It can be caused due to the provision of special lines (busways) for Transjogja involve capacity of the road for other vehicles decline.

The scenarios, which are given ranging from scenario1, scenario 2, and scenario 3,have the positive impact on the performance of the travel time and delay that occurs on Transjogja, and the best scenario occurs in scenario 3.

Transjogja performance and the performance of signalized intersection is inversely, on the one side the application of scenario busway and busway + ATCS gives the positive impact of Transjogja operation. On the other hand, it gives bad effect for signalized intersection performance.

The lowest travel time occurs in scenario 3 with 10.74 minutes, decrease travel time on scenario 3 by 41.23%, followed by scenario 1 at 22.86 %, and 14.15% in scenario 2, the shortest delay also occurs in scenario 3 with an average delay of 5.63 minutes, reduced delay in scenario 3 by 57.45%, followed by 32.13% for scenario 1, and 19,90% in scenario 2. It can be concluded that the provision of special busway lane and traffic signal prioritization at signalized intersections, providing a positive impact on significantly reduction of travel time and delays.

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