

# A TREATMENT OF SIGNALIZED INTERSECTIONS WITH HIGH V/C RATIO UNDER ADVANCED TRAFFIC CONTROL SYSTEMS

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## **Abstract**

*Advanced Traffic Control Systems (ATCS) have been recognized as one of the most direct methods for relieving urban traffic congestion. However, the application of the systems in developing countries is unique because road intersections in their cities are usually very congested with high v/c ratio. The aim of this study is to evaluate the treatments of signalized in-tersections with high v/c ratio under ATCS. Moreover, is to recommend how to improve traffic performance in an existing severe transportation problem. Road network in Bandung-Indonesia was used as a case study. AIMSUN (Advanced Interactive Microscopic Simulation for Urban and Un-urban Network) micro-simulator was conducted to evaluate the treat-ment during peak and off peak periods. The results indicate that by chang-ing two-way into one-way road will cause an increase in traffic flows by 7%-58%, and a decrease in queue length by 87%-100%. In general, all performance measures in related streams were better*

## **Keywords:**

*Advanced Traffic Control Systems, Developing Country, high v/c ratio, Signalized intersections*

## **INTRODUCTION**

Traffic congestion is increasingly becomes a severe problem in many large cities around the world. The problem is more complex in developing countries where cities are growing much faster than those in the developed world. The average annual population growth in developing countries is estimated at around 5 per cent compared to 0.7 per cent in developed countries (Sinha, 2000).

Advanced Traffic Control Systems (ATCS) are one of the ITS (Intelligent Transportation Systems) technologies that have been used as a tool to ease congestion problems (US DOT, 2005, ITS Australia, 2005) in many large cities in developing countries. However, the application of ATCS in developing countries is unique because cities in developing countries face more severe transportation problems than those in developed countries (Sinha, 2000). Signalized intersections in road networks in developing countries, cities usually in a very congested traffic condition indicated by high value of v/c ratio.

The aim of this paper is to undertake and then to evaluate the treatments of signalized intersections with high v/c ratio under ATCS. Moreover, is to recommend how to improve traffic performance in severe transportation problems. Road network in Bandung, Indonesia, where SCATS (Sydney Coordinated Adaptive Traffic Control Systems) was implemented as a pilot project in June 1997 (AWA Plessey, 1996a and AWA Plessey, 1996b), were used as a case study. The experiments using

microscopic traffic simulation AIMSUN (Advanced Interactive Microscopic Simulation for Urban and Un-urban Network) were conducted to evaluate the treatment during morning peak (7:00 – 8:00am), off peak (10:00-11:00am), and afternoon peak (4:30-5:30pm) periods.

## **ATCS In Developing Countries**

ATCS have been recognized as one of the most direct methods for relieving urban traffic congestion. ATCS are effective tools in coordinating traffic signals to reduce delay, stops and fuel consumption (Luk, 1992); and also in maximizing traffic throughput and responding traffic demand (Giannakodakis, 1995) and also in improving safety (PATH, ITS DSS, 2005).

SCATS is one of traffic control systems that is currently used around the world. SCAT was developed by New South Wales Department of Main Roads Australia. This system is a dynamic control system that can accommodate the changing conditions using real time input from a number of different sources, such as road detectors at the stop line, video cameras (CCTV), and pedestrian push buttons. This system updates intersection cycle length, stage split, and coordinates adjacent intersections within a road network to meet the variation in demand and to improve traffic flow (US DOT, 2005). SCATS is the system currently running in Bandung and is the subject of evaluation in this study.

SCATS application in developing countries is noteworthy, because cities in these countries face more severe transportation problems than those in developed countries (Sinha, 2000). These cities have low density road networks, only 6 percents up to 11 percents of the total city area compare to 20 percents up to 25 percents in large cities in developed countries, such as London, Paris and New York (Morichi, 2005). This limited road infrastructure has to serve city resident with high population density and has also to serve vehicle with high annual vehicle growth rate (Sutandi and Dia, 2005a, 2005b). Road authorities realized that application of Intelligent Transportation is needed to improve efficiency and capacity of existing road infrastructure.

In order to achieve a good traffic performance, SCATS application in developing country should be based on the specific local conditions that commonly occur in these large cities. Some of these specific conditions include irregular pattern of road network, parking activities near intersections, high level of side friction in connection with on street parking and street vendor activities, and poor lane use regulations.

With specific geometric and traffic conditions and local traffic behaviour, intersections with high value of v/c ratio may decrease throughput and increase traffic congestion at the intersections. In this condition, it is important to undertake and then evaluate the treatment at this kind of intersections.

## **METHOD**

Data collection was carried out at all signalized intersections connected to SCATS and a number of streams in Bandung, Indonesia during morning peak, off peak and afternoon peak periods. All signalized intersections connected to SCATS are divided into two regions, the North Region and the South Region. SCATS currently controls 117 signalized intersections out of 135 intersections in Bandung. The observed intersections in this research were the 90 signalized intersections connected to SCATS, wherein the other 27 were under flashing yellow signal.

The field data collected including throughput, phases, turning movements, and cycle time at all signalized intersections, queue length at signalized intersections under CCTV surveillance, and travel time on the selected streams. The data that was obtained from SCATS was recorded every 15 minutes including throughput data of each loop detector at each intersection plus queue length data from a number of critical intersections with CCTV.

Two data sets (recorded by SCATS and collected from CCTV and direct survey) were collected to use in this research. The first data set was used to develop and calibrate the models and the second data set was used for validation.

## **AIMSUN Micro simulator**

The Generic Environment for Traffic Analysis and Modeling (GETRAM) was used as a tool to evaluate the treatment at intersections with high value of v/c ratio. GETRAM consists of TEDI (Traffic Editor) as a traffic editor and AIMSUN (Advanced Interactive Microscopic Simulator for Urban and Non Urban Networks) as a microscopic traffic simulator (TSS, 2004a, TSS, 2004b).

Previously, the Bandung microscopic traffic simulation models during peak and off peak periods have been developed, calibrated, and validated using GETRAM. Furthermore, a number of statistical tests including Paired T-test, Two Sample T-test, Regression Analysis, Analysis of Variance, and Correlation Tests (Mason, Robert L. et al., 2003, Montgomery, Douglas C., and Runger, George C., 2003, Ott, R. Lyman, and Longnecker, Michael, 2001) were used to determine the adequacy of the models in replicating traffic conditions. Based on the results of five statistical analyses, all of the calibrated and validated models reproduced traffic conditions with an acceptable degree of confidence. Therefore, the models were clearly accepted as significant valid replication of "the real world" (Sutandi, 2006). The validated models were then used to evaluate the treatment at intersections with high value of v/c ratio.

## **Intersections With High V/C Ratio**

In Bandung road network, many signalized intersections are in congested traffic conditions indicated by a very high value of v/c ratio. Intersections with very high or over-saturated v/c ratios are presented in Table 1 below. Although wider leg intersections or larger size of intersections can increase throughput, but building wider leg intersections or additional road capacity physically faces a number of challenges, particularly in a large city in a developing country that has high population density, limited land area and limited financial support. In addition, building additional road capacity is not the right solution to decrease traffic congestion. In these situations, it is recommended to increase throughput at intersections by changing a two-way road into a one-way road and thus widening leg intersections, if there is an alternative road with the same hierarchy to take the vehicles from the direction that was

removed. Intersection numbers 60, 61, 63, 91, 92, and 101 are examples that have very high or over

saturated v/c ratio and have alternative roads at the same road hierarchy.

Table 1. Intersections with very high or over saturated v/c ratio in Bandung

Region	Intersection		v/c ratio					
			morning peak		off peak		afternoon peak	
			major road	minor road	major road	minor road	major road	minor road
North	19	Pasteur - Pasirkaliki	1.470	1.470	1.404	1.404	1.296	1.296
	22	H. Juanda - Dipati Ukur	1.083	1.083	0.945	0.945	0.899	0.899
	25	KHH. Mustopa - Cikutra	0.926	0.926	0.921	0.921	0.747	0.747
	42	A. Yani - Gudang Utara	0.920	0.920	0.891	0.891	0.892	0.892
	43	Achmad Yani - RE. Martadinata	1.264	1.264	1.233	1.233	1.502	1.502
	60	Pajajaran - Pasirkaliki	1.286	1.286	1.170	1.170	0.894	0.894
	61	Pajajaran - Cicendo	0.907	0.907	0.959	0.959	0.635	0.635
	63	RE. Martadinata - Purnawarman	0.983	0.983	0.830	0.830	0.885	0.885
	64	Merdeka - RE. Martadinata	0.945	0.571	0.839	0.667	0.851	0.615
	66	RE. Martadinata - Banda	0.963	0.963	0.997	0.997	0.963	1.017
	91	Pasirkaliki - Kebon Kawung	0.917	0.917	0.855	0.855	0.855	0.855
	92	Kebon Kawung - Cicendo	1.063	1.063	0.880	0.880	0.907	0.907
	93	Dipati Ukur - Siliwangi	1.091	1.091	1.707	1.707	1.166	1.166
	95	H. Juanda - Sulanjana	1.369	1.369	1.450	1.450	0.866	0.593
101	Cihampelas - Abdul Rivai	1.160	0.780	0.684	0.594	0.684	0.459	
138	RE. Martadinata - Anggrek	1.288	1.001	1.349	1.110	1.433	1.433	
South	40	Asia Afrika - Sunda - Veteran	1.165	1.165	0.759	0.759	1.928	1.928
	75	Braga - Suniaraja	1.061	1.061	1.074	1.074	0.992	0.992
	128	Astana Anyar - Pagarsih	1.750	1.750	0.588	0.588	1.216	1.216

### Treatment Of Intersections With High V/C Ratio

As was mentioned previously, it is recommended to increase throughput at intersections by changing a two-way road into a one-way road and thus widening leg intersections, if there is an alternative road with the same hierarchy to take the vehicles from the direction that was removed. The change to a one-way road not only makes the leg wider but also reduces the number of phases and number of movements at the intersection. Therefore, throughput can be increased and queue length can be decreased. The existing and recommended traffic flows in the stream are shown in Figure 1. The details of changes of traffic flows, number of phases and number of movements at each intersection were described in Figure 2. All of these changes will be incorporated into the validated microscopic traffic simulation models during peak and off peak periods before running the models using AIMSUN.

### Evaluation Of Recommended Treatment

Using the Bandung validated microscopic traffic simulation models performance measure differences

(%) between running the model with and without the recommended treatment are presented in Tables 2, 3 and 4 below. The traffic performance measures are throughput and queue length at intersections and are density, speed, travel time, delay time, stop time and number of stops in related streams. And the details of phases and movements at each intersection are presented in Figure 2 below:

Since building wider legs or additional road capacity physically has a number of challenges, it was recommended to make the leg intersection wider by changing the traffic direction, in the streams containing these intersections, from two-way into one-way roads. Furthermore, as was mentioned previously, the conversion to a one-way road not only made the leg wider but also reduced the number of phases and movements at the intersection. In any case, building additional road capacity is not the right solution to increase the performance of SCATS.

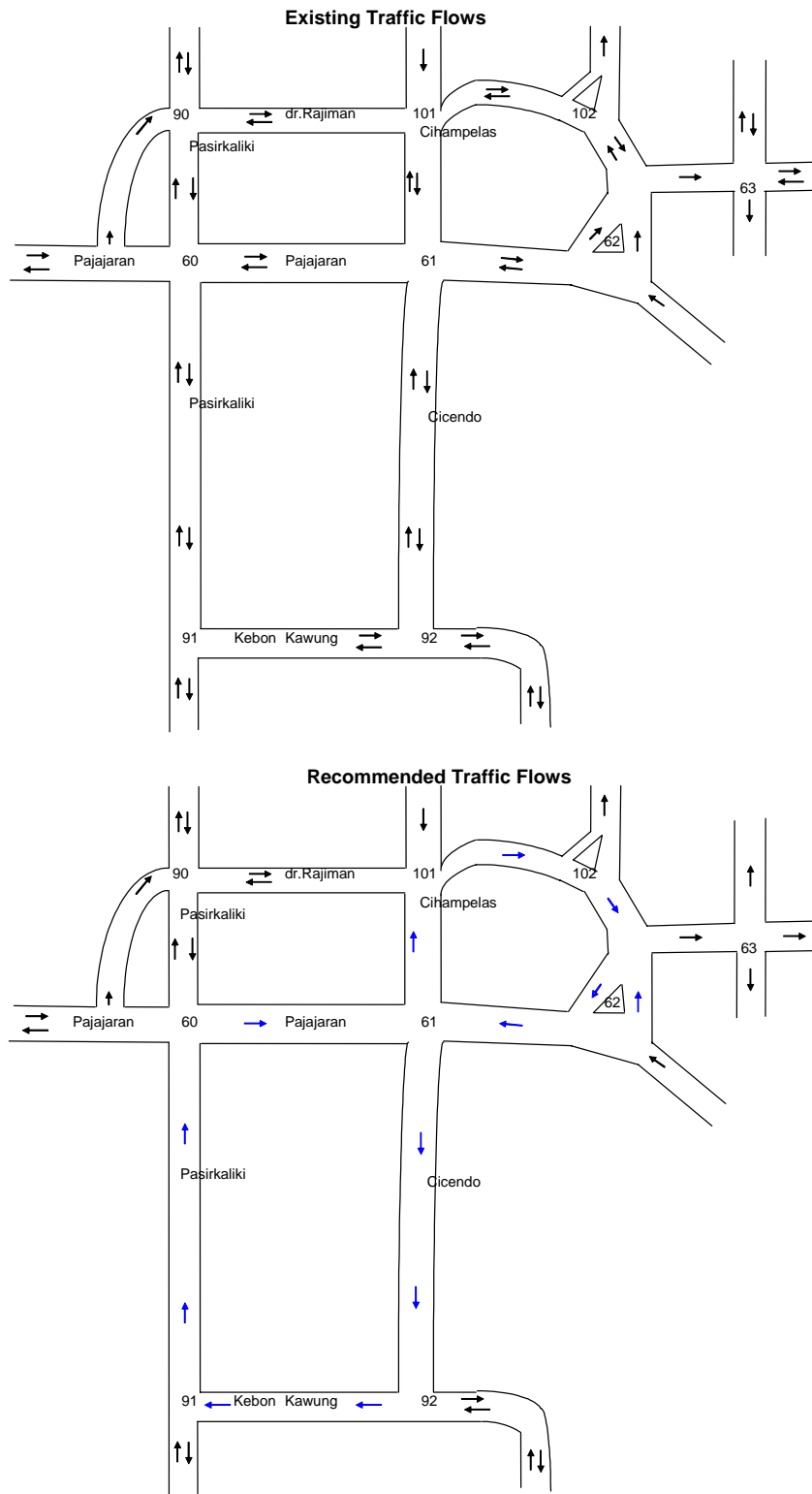


Figure 1. The existing and recommended traffic flows in area of study




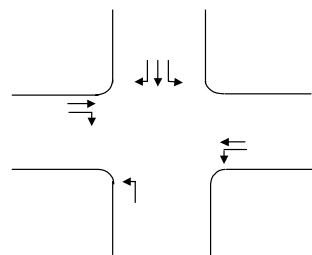


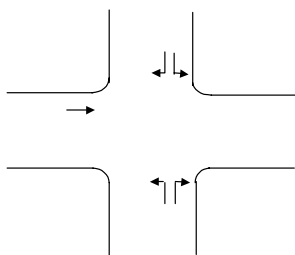


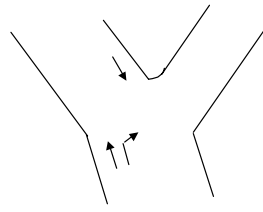
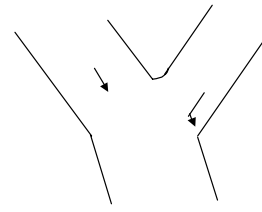


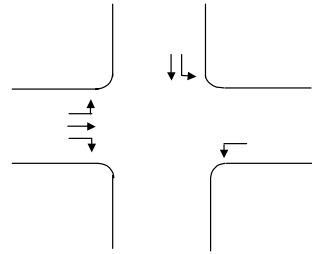
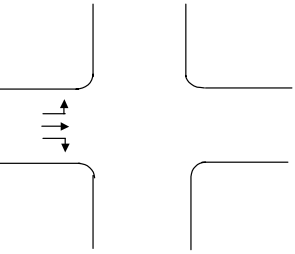
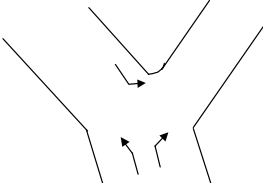
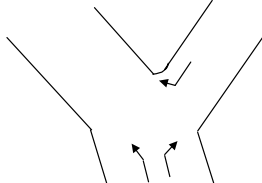
Existing	Recommended
<p>Intersection 101. Cihampelas - A. Rivai</p> <p>Phases:</p> <p>A. </p> <p>B. </p> <p>C. </p> 	<p>Intersection 101. Cihampelas - A. Rivai</p> <p>Phases:</p> <p>A. </p> <p>B. </p> 
<p>Intersection 102. Watukencana - Tamansari</p> <p>Phases:</p> <p>A. </p> <p>B. </p> 	<p>Intersection 102. Watukencana - Tamansari</p> <p>Flashing Yellow</p> 
<p>Intersection 63. R.E. Martadinata - Purnawarman</p> <p>Phases:</p> <p>A. </p> <p>B. </p> 	<p>Intersection 63. R.E. Martadinata - Purnawarman</p> <p>Flashing Yellow</p> 
<p>Intersection 62. Pajajaran - Wastukencana</p> <p>Unsignalised Intersection</p> 	<p>Intersection 62. Pajajaran - Wastukencana</p> <p>Unsignalised Intersection</p> 

Figure 2. The existing and recommended phases and movements at each intersection (continued)

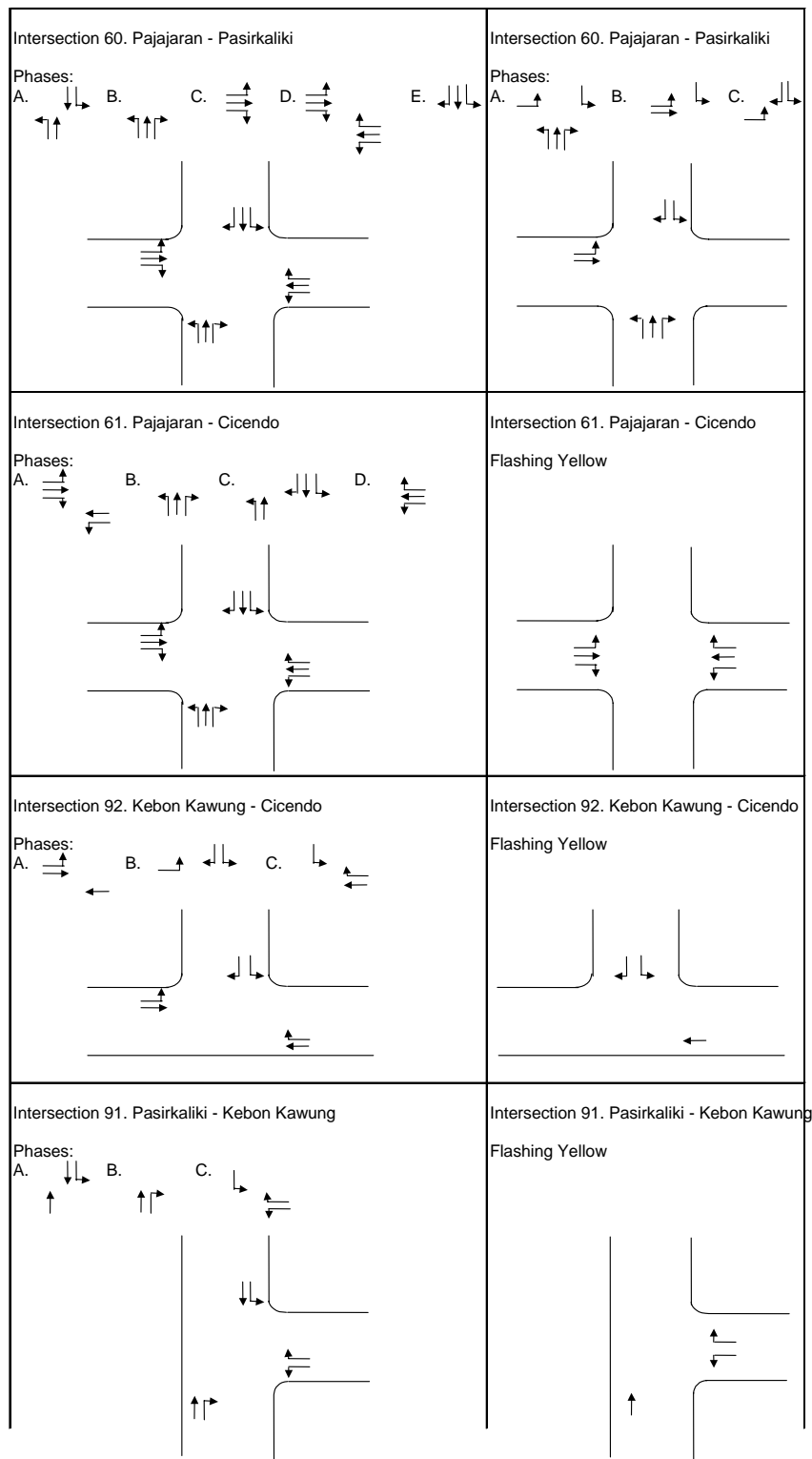


Figure 2. The existing and recommended phases and movements at each intersection

The results in Tables 2 to 4 clearly show that the recommended improvement has a great influence on increasing traffic performance at the intersections as detailed below:

- Traffic flows were found to increase for 7% to 58% at intersections 60, 61, 63, 91, and 92 and

to increase exceptionally by 106% at intersection 101.

- Mean queue lengths were found to decrease markedly for 87% to 100% at intersection 60, 61, 63, 91, 92, and 101, and maximum queue lengths were found to decrease markedly by 77% to 99%.

Table 2 Flow and queue length difference at intersections

No.	Node	INTERSECTION	v/c		Flow difference (%)				Queue Length difference (%)							
			major road	minor road	morning peak	off peak	afternoon peak	average	morning peak		off peak		afternoon peak		average	
									mean ql	max ql	mean ql	max ql	mean ql	max ql	mean ql	max ql
1	60	Pajajaran - Pasirkaliki	1.268	1.268	33.00	-12.55	65.98	28.81	-90.30	-82.81	-71.60	-60.40	-99.60	-87.20	-87.17	-76.80
2	61	Pajajaran - Cicendo	0.907	0.907	52.64	0.37	119.51	57.51	-100.00	-98.90	-100.00	-98.60	-100.00	-98.70	-100.00	-98.73
3	63	RE. Martadinata - Purnawarman	0.983	0.983	-6.02	19.70	20.54	11.41	-86.30	-91.30	-98.70	-92.80	-98.30	-90.60	-94.43	-91.57
4	91	Pasirkaliki - Kebon Kawung	0.917	0.917	27.30	16.38	7.38	17.02	-100.00	-99.50	-100.00	-99.50	-100.00	-99.20	-100.00	-99.40
5	92	Kebon Kawung - Cicendo	1.063	1.063	2.56	13.03	6.26	7.28	-100.00	-99.20	-100.00	-99.70	-100.00	-99.30	-100.00	-99.40
6	101	Cihampelas - Abdul Rival	1.160	0.780	89.42	18.54	210.67	106.21	-97.90	-89.70	-98.40	-89.60	-83.70	-71.20	-96.67	-83.50

Table 3 Density, speed, and travel time difference in the related streams

No.	STREAM	Name	Density difference (%)				Speed difference (%)				Travel Time difference (%)			
			morning peak	off peak	afternoon peak	average	morning peak	off peak	afternoon peak	average	morning peak	off peak	afternoon peak	average
2	Pajajaran	-96.04	-73.83	-93.85	-87.91	982.70	157.30	644.65	594.88	-95.64	-67.03	-90.02	-84.23	
3	RE. Martadinata	27.88	-76.80	-34.92	-27.95	52.62	529.14	85.76	222.51	-61.29	-88.70	-65.22	-71.74	
4	Kebon Kawung	-93.84	-94.69	-91.10	-93.21	831.03	974.47	507.19	770.90	-92.69	-93.71	-87.89	-91.43	
5	Cicendo	-39.60	-59.26	-42.57	-47.14	37.65	68.96	32.20	46.27	-38.89	-66.67	-52.94	-52.83	
6	Cihampelas	-92.06	-84.48	-39.73	-72.09	1,154.19	315.97	-2.02	489.38	-92.47	-81.56	-6.19	-60.07	

Table 4 Delay time, Stop time, and stops difference in the related streams

No.	STREAM	Name	Delay Time difference (%)				Stop Time difference (%)				Stops difference (%)			
			morning peak	off peak	afternoon peak	average	morning peak	off peak	afternoon peak	average	morning peak	off peak	afternoon peak	average
2	Pajajaran	-99.85	-99.19	-99.63	-99.56	-100.00	-100.00	-100.00	-100.00	-95.92	-94.38	-97.06	-95.79	
3	RE. Martadinata	-90.00	-94.01	-86.11	-90.04	-100.00	-98.82	-100.00	-99.61	-100.00	-86.76	-80.00	-88.92	
4	Kebon Kawung	-99.56	-99.64	-99.49	-99.56	-100.00	-100.00	-100.00	-100.00	-99.37	-98.01	-98.85	-98.74	
5	Cicendo	-87.50	-95.00	-85.71	-89.40	-100.00	-100.00	-100.00	-100.00	-100.00	-100.00	-100.00	-100.00	
6	Cihampelas	-98.07	-96.64	-7.69	-67.47	-99.71	-100.00	-4.71	-68.14	-96.28	-96.73	77.78	-38.41	

- Densities in related streams were found to decrease for 13% to 93%.
- Speeds were found to increase for 14% to 77% in all streams, except in Pasirkaliki stream. However, the 2.04% (0.3 km/h) decrease in speed in the Pasirkaliki stream was not significant.
- Travel times were found to decrease markedly for 53% to 91% in all streams, except in the Pasirkaliki stream. However, 9.54% (14 seconds) increase in travel time in Pasirkaliki stream was not significant.
- Delay times were found to decrease by 29% in Pasirkaliki stream, and decrease markedly for 67% to 100% in the other streams.
- Stop times were found to decrease markedly for 68% to 100% in all streams, except in Pasirkaliki stream. However, 16.38% (16 seconds) increase in the stop time in Pasirkaliki stream was not significant.
- Number of stops was found to decrease markedly for 38% to 100% in all streams, except the Pasirkaliki stream. However, 36.11% (0.42 veh/km) increase in number of stops in the Pasirkaliki stream was not significant.

The above results clearly suggest the following conclusions:

Not all of the performance measures indicated significantly better performance. Small parts of performance measures were worse, but not at a

significant level. The possible explanation for this is there is influence of traffic conditions particularly from intersections and streams around the recommended intersections and related streams.

Consequently, these treatments are strongly recommended for implementation in order to increase the traffic performance at intersections with high number of v/c ratio, as long as the required conditions, for example the availability of an alternative road with the same hierarchy, are fulfilled.

### CONCLUSIONS

This study evaluated the treatment at intersections with high value of v/c ratio. AIMSUN micro simulator was used as a tool to evaluate the traffic performances. The results presented in this paper clearly demonstrated that making leg intersections wider without building additional road capacity, but by changing two-way into one-way roads in the stream with higher road hierarchy and with high v/c ratio, has a great impact on increasing the traffic performance. This recommendation is only for roads that have alternative roads to accommodate vehicles from the eliminated direction. Therefore, the choice of intersections to be recommended should be taken seriously into account. The findings of this study are believed to be applicable not only to Bandung, but also beneficial for other large cities

in Indonesia and other developing countries that have similar traffic conditions.

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