PERFORMANCE EVALUATION OF SYDNEY COORDINATED ADAPTIVE TRAFFIC SYSTEMS IN BANDUNG INDONESIA

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ABSTRACT

Sydney Coordinated Adaptive Traffic Control Systems (SCATS) are recognised as one of Advanced Traffic Systems (ATCS) technologies that have most potential to ease congestion problems in many large cities in developing countries. The application of SCATS in Bandung since June 1997 as a pilot project is unique. Bandung is a large city in developing country usually face more severe transportation problems than those in developed countries and characterised by specific geometric and traffic local conditions, for examples: low road network densities with poor conditions, narrow lane width, poor lane discipline, and level of side friction in connection with on street parking and street vendor activities. High technology built in a developed country can be successfully implemented in a developing country if the specific geometric and traffic conditions in the large cities and the local traffic behaviour are taken into account. This study evaluates the performance of SCATS in Bandung, Indonesia based on existing conditions. Field data were collected from 19 signalised intersections and 10 streams using manual traffic count, video camera, and floating car technique during morning peak period (07:00-08:00 am), off peak periods (10:00-11:00 am), and afternoon peak period (04:30- 05:30 pm). Parameters to measure the performance of SCATS are throughput per capacity at each leg intersection, number of queue at each leg intersection, and travel time at each stream. Paired T Test and Two Sample T Test are statistical methods used to evaluate the performance. By finding out the performance of SCATS in Bandung, Indonesia, further significant improvements of the performance of SCATS can be recommended.

Key words: performance evaluation, SCATS, specific geometric and traffic conditions, traffic measures.

1. INTRODUCTION

Advanced traffic control systems (ATCS) have been recognised as advanced technology used in large cities in developed and developing countries to ease traffic congestion using real time data. A number of kinds of ATCS are Sydney Coordinated Adaptive Traffic System (SCATS), Split Cycle Offset Optimisation Technique (SCOOTS), Brisbane Linked Intersection Signal System (BLISS), Traffic Responsive Area Control (TRAC) System and Synergised Transport Resources Ensuring an Advanced Management System (STREAMS) (Dia, 2001). SCATS has been implemented in Bandung since June 1997 as a pilot project. However, the application of high technology built in a developed country can be successfully implemented in a developing country if the specific geometric and traffic conditions in the large cities and the local traffic behaviour are taken into account. The aim of this study is to evaluate the implementation of SCATS based on existing conditions. 19 signalised intersections and 10 streams in Bandung are used as a case study. Manual traffic count, video camera, and floating car technique are used to collect the field data during morning peak period (07:00-08:00 am), off peak periods (10:00-11:00 am), and afternoon peak period (04:30- 05:30 pm). Parameters used to evaluate the performance of SCATS are throughput per capacity at each leg intersection, number of queue at each leg intersection, and travel time at each stream. Paired T Test and Two Sample T Test are statistical methods used to evaluate the performance. By finding out the performance of SCATS in Bandung, Indonesia, significant improvements of the performance of SCATS can be recommended.

2. ADVANCED TRAFFIC CONTROL SYSTEMS

Adaptive traffic control systems (ATCS) allow for adjusting signal timings according to prevailing traffic flow conditions. Unlike fixed time control systems, ATCS adapt to minute by minute changes in traffic flow. A number of ATCS are currently operational around the world. These systems have different system architectures and employ different algorithms and data acquisition methods. The SCATS system from the Road Traffic Authority (RTA) in New South Wales, Australia has been operational since the 1970s and is currently undergoing further development.

These systems provide surveillance, communications, and control strategies, by collecting, analysing, storing and disseminating the real-time data, and then control the underlying dynamic systems.

Advanced traffic control systems are mainly concerned with maximising the efficiency of existing transport infrastructure. They include components that are responsible for data collection from a variety of sources in the field. This data is then transmitted through communication systems to a central location (e.g. a traffic control centre) where it is analysed and used to control the operation of the various components of the traffic control system (e.g. traffic signal timing & ramp metering). The data is typically stored in real-time and historical data bases. Many ITS operations require the data collected from the previous time intervals (e.g. 1 to 15 minutes) to be available for use in predicting future traffic conditions. The data also needs to be stored in a historical data base to be used in calibrating or benchmarking various traffic control strategies. An advanced traffic control system is typically comprised of the above mentioned support systems which are needed to manage and monitor the performance of the system and its associated components.

An integral part of an ATMS is the software tools and models that are needed to analyse the performance of the system and adjust the different parameters in real time. The SCOOT system (UK), for example, employs loop detectors that are embedded in the pavement some 300 metres upstream of the intersection's stop line to allow for measuring queue length which is an important parameter in its operation. In Brisbane, two ATCS were operational prior to 2000. More recently, the two systems have been integrated into the new STREAMS system which will be discussed in the latter part of this session. A wide range of surveillance and monitoring technologies are currently available in-pavement, roadside/overhead mounted, probe vehicles, A number of ATMS examples were introduced and their potential benefits highlighted, adaptive traffic control systems, automated incident detection, ramp metering, electronic toll collection, and electronic road pricing (Dia, 2001).

3. SYDNEY COORDINATED ADAPTEIVE TRAFFIC SYSTEMS IN BANDUNG

Sydney Coordinated Adaptive Traffic System (SCATS) is one of the most direct methods that has been recognised for relieving urban traffic congestion. SCATS are effective tools in co-ordinating traffic signals to reduce delay, stops, fuel consumption (Liu, Ronghui, et al., 2005, Midenet, Sophie, et al., 2004, Taylor, James C., et al., 2004, Ogden and Taylor, 1999, Hendrickson, et al., 1998), maximise traffic throughput as respond to traffic demand via detectors (Giannakodakis, 1995) and improve safety (PATH, ITS, 2005).

The control system is concerned with the selection and implementation of three control elements for every signalised intersection in the network i.e. cycle time, phase split and offset. An offset is the time difference in the starting times of the green phases of adjacent intersections (Transportation Research Board, 2000, Ogden and Taylor, 1999). SCATS uses inductive loop detectors (intersection stop-line), traffic signal control boxes, dedicated telephone lines, regional computers, and master computer**.** The SCATS system is currently operational in a number of cities in Asia, Australia and America (Dia, 2001).

The advanced traffic control system SCATS was implemented in Bandung since June 1997, as a pilot project. SCATS currently controls 117 signalised intersections out of 135 signalised intersections in Bandung. The Traffic Control and Communication Centre of SCATS traffic control is located in the Bandung Traffic Control Room in the second floor of Bandung City Council Office. A large computerised wall map, 12 screens to view the traffic condition from 12 closed circuit televisions (CCTV) at critical intersections, 6 control desks with 6 computers and CCTV monitors as the work-stations of the operators, and an overhead projector system are the facilities in Bandung Traffic Control Room. Figure 4.1 presents the road network in Bandung, while the signalised intersections connected and isolated from SCATS is presented in Figure 4.2. The signalised intersections isolated from SCATS are under fixed time traffic control system (Sutandi, 2006).

Based on the existing traffic conditions in Bandung, 27 out of 117 signalised intersections connected to SCATS signal control are changed into the flashing yellow signal because of the change of traffic direction. Therefore, 90 signalised intersections are currently under SCATS signal control.

4. DATA COLLECTION

Field data is carried out at19 signalised intersections and 10 streams in Bandung, Indonesia. Methods of data collections and detailed field data will be discussed in this section.

Methods of Data Collection

Data collection used in this study is manual data collection methods. These methods require tests vehicles, drivers, observers, stopwatch, and data collection forms. The distances between control points and the length of the total route may be obtained from accurate, drawn to scale plans or maps or from the vehicle odometer. Since Floating Car Technique is used, the driver of the test vehicle "floats" along the study route in accordance with the traffic by attempting to safely pass as many vehicles as pass the test vehicle (Sutandi, 2006).

The test car begins at a short distance upstream of the begin point. As the test vehicle passes the begin point the driver starts the stopwatch. The test car proceeds through the study section being studied according to the driving technique selected. As the test car passes the end point of the study section, the driver stops and reads the stopwatch. The test car turns around and travels the same section in the opposite direction. Both directions may be studied simultaneously. Test runs should begin promptly at the beginning of the desired study period so as to complete the required sample of runs before conditions along the route change (Roess, et. al., 1998 and Robertson, et al., 1994). Three surveyors needed to collect the field data at each observed stream.

The measurements used to evaluate signalized intersections under SCATS are throughput (Liu, Ronghui, 2005, Xia, Liping and Shao Yaping, 2005, Nigarnjanagool and Dia, 2005, Clement, Stuart J., et al., 2004, Bose, Arnab and Iovannou, Petros, 2003, Mirchandani, Pitu and Head, Larry, 2001, AWA Plessey, 1997a, AWA Plessey, 1997b, Montgomery, Jeff, 1996), number of queue, and travel time (Abdel-Rahim, Ahmed, Taylor, William C., 2000, AWA Plessey, 1997a).

Throughput (veh/h) is number of vehicles pass the intersection during green time. Number of queue (veh) is number of vehicles queue at leg intersection at the intersection during red time. Video camera at each observed intersection is used to record traffic movements at each phase and number of queue at each leg intersection. Five surveyors needed to collect the field data at each observed intersection. Travel time (hh:mm:ss) is the time taken by a vehicle to traverse a given segment of street or highway, wherein vehicle speed is directly related to it. The measurement of travel time is along a roadway segment (Transportation Research Board, 2000 and Robertson, et al., 1994).

Field Data

In Bandung, Advanced traffic control system SCATS controls 117 signalized intersections out of 135 intersections in Bandung. Up to this moment, 90 signalized intersections (48 signalized intersections in North Bandung and 42 signalized intersections in South Bandung) connected to SCATS, wherein the other 27 signalized intersections were under flashing yellow signal because of changes to the direction of traffic (Sutandi, 2006).

19 signalised intersections under SCATS surveillance and 10 streams related to the intersections in Bandung, Indonesia are used as a case study. Manual traffic counts, video cameras, and floating car technique were used to collect throughput, queue length, and travel time data during morning peak period (07:00-08:00 am), off peak periods (10:00-11:00 am), and afternoon peak period (04:30-05:30 pm). More than one hundred surveyors collected the field data at observed intersections and streams, in August 2009. Financial support is granted by Directorate of Higher Education, Department of National Education, Republic of Indonesia, 2009.

A number of criteria used to choose signalized intersections as samples. They are typology, in a proportional method (Sutandi and Santosa, 2007), location of signalized intersection in the typology, road detectors that work well at the intersection, and intersections with high level of congested intersections. And criteria used to choose streams as samples are based on road hierarchy (arterial roads, collector roads, local roads) and streams wherein chosen signalized intersection lied. Table 1 presents throughput and number of queue at observed intersections while Table 2 presents travel time in observed streams.

5. PERFORMANCE EVALUATION

SCATS has been implemented in Bandung since 12 years ago (June 2997). Therefore, performance evaluation of SCATS in Bandung cannot carried out using "before" and "after" the implementation of SCATS according to a number of reasons. The reasons are as follow:

- Changes in road infrastructure physically, for example development of *Pasupati* elevated road.
- Changes in road direction from two-way road into one-way road.
- Changes in traffic movements at intersections.
- Changes in traffic conditions in Bandung because of annual increase in number of population and number of vehicles.

Table 1 Throughput and number of queue at observed intersections

No.	Name of Intersections	Throughput (pcu)			Number of Queue (veh)		
		7:00-8:00am	10:00-11:00am	4:30-5:30pm	7:00-8:00am	10:00-11:00am	4:30-5:30pm
1	Lingkar Selatan - Jenderal Sudirman	2357	2500	3662	2	2	2
2	Lingkar Selatan - M Ramdan	2832	2606	2991	2	2	2
3	Jend Sudirman - Gardujati	3872	4115	4506	5	5	6
4	Otista - Asia Afrika	1712	2385	2158	2	2	2
5	Asia Afrika - Tamblong	4439	4576	4907	4	5	5
6	Cihampelas - Abd Rivai	1355	1431	1557	1	1	1
7	Merdeka - R.E. Martadinata	2686	2820	3277	9	10	12
8	Aceh - Merdeka	3561	2481	1222	3	2	1
9	Cipaganti - Sampurna	2009	2013	2434	2	2	2
10	R.E. Martadinata - Trunojoyo	1650	2098	1979	2	2	2
11	Aceh - RE Martadinata	891	841	1445	1	1	1
12	Moh Ramdan - Pungkur	1677	1780	1941	4	5	8
13	A.Yani - Martadinata	3891	3408	3675	4	4	6
14	Pasirkoja - Jamika	3468	3430	3697	5	5	6
15	Pajajaran - Pasirkaliki	2741	2767	2989	10	9	10
16	Dipatiukur-Siliwangi	3684	3083	3284	5	5	7
17	Pahlawan - Surapati	4034	2941	3597	7	5	7
18	Abd. Saleh - Pajajaran	1622	1647	1694	1	1	1
19	Talagabodas - Burangrang	2379	2799	3081	2	3	3

Table 2 Travel time in observed streams

No.	Streams		Travel Time (hh:mm:mm)		
	Function	Name	7:00-8:00am	10:00-11:00am	4:30-5:30pm
1	Arterial	Surapati Timur ke Barat	0:10:04	0:09:29	0:09:37
2	Arterial	Surapati Barat ke Timur	0:08:35	0:08:38	0:09:37
3	Arterial	Asia Afrika	0:04:06	0:04:40	0:05:18
4	Arterial	PP 45 Utara ke Selatan	0:04:27	0:04:29	0:05:20
5	Arterial	PP 45 Selatan ke Utara	0:04:22	0:04:20	0:06:42
6	Collector	H. Juanda Utara ke Selatan	0:09:48	0:07:44	0:09:54
7	Collector	H. Juanda Selatan ke Utara	0:09:31	0:07:54	0:09:32
8	Collector	Kebonjati	0:02:04	0:01:26	0:02:49
9	Local	Oto Iskandardinata	0:04:32	0:05:09	0:08:47
10	Local	Cipaganti	0:04:36	0:04:29	0:06:48

Parameters to measure the performance of SCATS are throughput per capacity at each leg intersection, number of queue at each leg intersection, and travel time at each stream. Furthermore, the performance is good if there is an increase in throughput per capacity at leg intersection, a decrease in number of queue at leg intersection, and a decrease in travel time in a stream. In order to evaluate the performance, steps of analysis are as follow:

- Comparison of throughput per capacity at each leg intersection, number of queue at each leg intersection, and travel time at each stream between existing conditions and previous conditions.
- Evaluate the comparison using statistical tests i.e. Paired T Test and Two Sample T Test in order to show whether the existing SCATS performance is better than the previous conditions in 2002 wherein previous data was collected. Paired T Test compares both series based on the differences between those both in order to determine whether the differences are zero or not. While Two Sample T Test compares both series based on the differences between those both in order to determine whether statistical results of existing conditions are larger than those of previous conditions (Ott, 2001). Figure 1, Figure 2, and Figure 3 present the comparison of existing conditions and previous conditions of throughput per capacity at each leg intersection, number of queue at each leg intersection, and travel time at each stream respectively.

Figure 1. Comparison of throughput per capacity at each leg intersection between existing and previous conditions

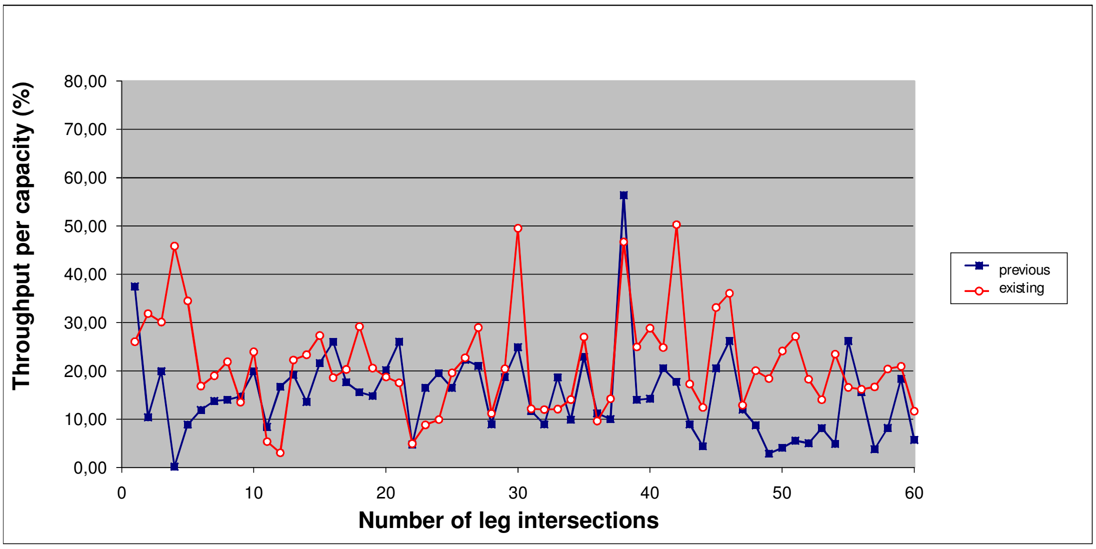

Figure 2. Comparison of number of queue at each leg intersection between existing and previous conditions

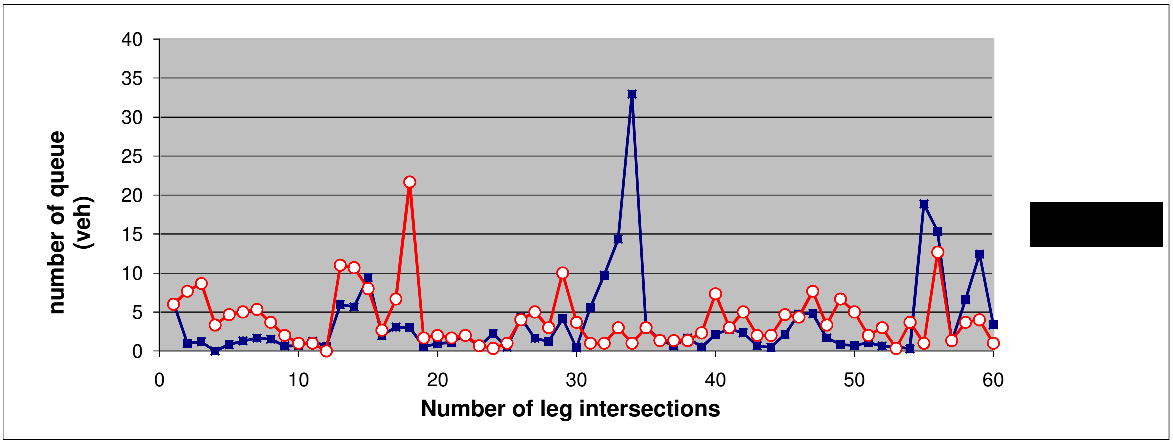

Figure 3. Comparison of travel time at each stream between existing and previous conditions

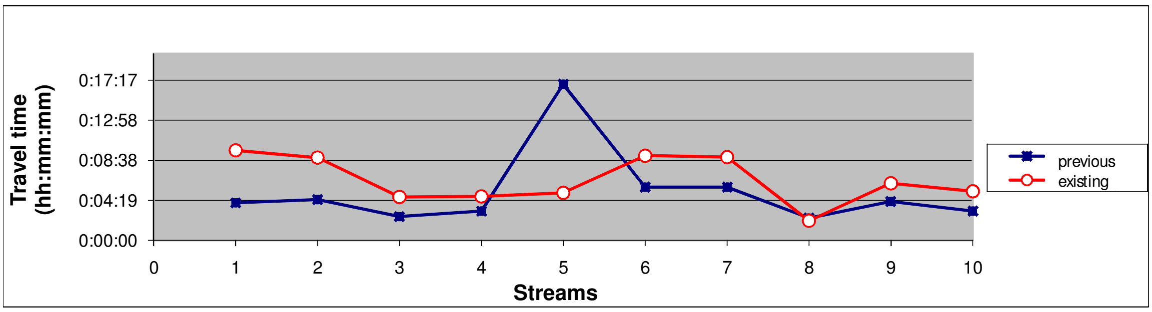

Table 3. Results of statistical tests of throughput per capacity at each leg intersection between existing and previous conditions

Througput per capacity (%)				$d_i=w_{ij}-v_{ij}$, j=1,…,m		
				7:00-8:00am	10:00-11:00am	4:30-5:30pm
		rata-rata di		9,84	9,03	10,23
		sdi		10,12	8,18	8,92
Paired T - test (H_0: di=0, Ha:di≠0)		tm-1		7,53	8,55	8,89
	H_0: di=0	t m-1,a/2 a=0.05	t m-1 = 2,001	reject	reject	reject
		t m-1,a/2 a=0.01	t m-1 = 2,662	reject	reject	reject
	sv			11,45	9,30	12,27
	sw			9,15	9,30	9,75
Two Sample T - test (H_0: vi=wi, Ha: vi>wi)	tm-1			-3,82	-4,14	-5,08
	H_0: vi=wi	t m-1,a a=0.05	t m-1 = 1,671	accept	accept	accept
		t m-1,a a=0.01	t m-1 = 2,391	accept	accept	accept

Table 4. Results of statistical tests of number of queue at each leg intersection between existing and previous conditions

Queue length (veh)				di=wij-vij, j=1,…,m		
				7:00-8:00am	10:00-11:00am	4:30-5:30pm
		rata-rata di		3,70	3,72	4,46
	sdi			5,75	5,08	5,44
Paired T - test (H_0: di=0, Ha:di≠0)	tm-1			4,99	5,67	6,35
	H_0: di=0	t m-1,a/2 a=0.05	t m-1 = 2,001	reject	reject	reject
		t m-1,a/2 a=0.01	t m-1 = 2,662	reject	reject	reject
	sv			6,08	5,36	5,91
	sw			3,43	3,56	4,52
Two Sample T - test (H_0: vi=wi, Ha: vi>wi)	tm-1			-0,24	1,05	0,87
	H_0: vi=wi	t m-1,a a=0.05	t m-1 = 1,671	accept	accept	accept
		t m-1,a a=0.01	t m-1 = 2,391	accept	accept	accept

Table 5. Results of statistical tests of number of travel time in streams between existing and previous conditions

Travel time (hh:mm:mm)				$d_i=w_{ij}-v_{ij}$, j=1,…,m		
				7:00-8:00am	10:00-11:00am	4:30-5:30pm
	rata-rata di			0,00	0,00	0,00
	sdi			0,00	0,00	0,00
Paired T - test (H_0: di=0, Ha:di≠0)	tm-1			2,45	3,31	6,83
	H_0: di=0	t m-1,a/2 a=0.05	t m-1 = 2,262	reject	reject	reject
		t m-1,a/2 a=0.01	t m-1 = 3,250	accept	reject	reject
	sv			0,00	0,00	0,00
	sw			0,00	0,00	0,00
Two Sample T - test (H_0: vi=wi, Ha: vi>wi)	tm-1			-0,46	-0,95	-3,39
	H_0: vi=wi	t m-1,a a=0.05	t m-1 = 1,833	accept	accept	accept
		t m-1,a a=0.01	t m-1 = 2,821	accept	accept	accept

Results of statistical tests are presented in Table 3, Table 4, and Table 5. In more detail, Table 3-5 show as follow:

- Paired T - test (H_0: $d_i = 0$, H_a: $d_i \neq 0$) for throughput per capacity is rejected. This means that differences of throughput per capacity between existing and previous conditions is not zero.
- Two Sample T - test (H_0: $v_i = w_i$, H_a: $v_i > w_i$) for throughput per capacity is accepted. This means that differences of throughput per capacity between existing and previous conditions is “the same”.

- Paired T - test (H_0: $d_i = 0$, H_a: $d_i \neq 0$) for number of queue is rejected. This means that differences of number of queue between existing and previous conditions is not zero.
- Two Sample T - test (H_0: $v_i = w_i$, H_a: $v_i > w_i$) for number of queue is rejected. This means that differences of number of queue between existing and previous conditions is "the same".
- Paired T - test (H_0: $d_i = 0$, H_a: $d_i \neq 0$) for travel time is rejected. This means that differences of travel time between existing and previous conditions is not zero.
- Two Sample T - test (H_0: $v_i = w_i$, H_a: $v_i > w_i$) for travel time is rejected. This means that differences of travel time between existing and previous conditions is "the same".

These conditions occur during peak and off peak periods for all observed parameters. Although Paired T - test show that the difference between existing conditions and previous conditions are not zero, Two Sample T - test show that these two conditions are "the same". The statistical results indicated that existing conditions is not better than previous one. Therefore, we have to pay attention to the traffic conditions in Bandung because after using SCATS as advanced technology, there are no better traffic conditions. Further research is needed to find out specific reasons based on specific local and traffic conditions, and driver behaviour.

6. CONCLUSIONS

This study evaluated performance of advanced technology SCATS in Bandung, Indonesia. Data collection was carried out at 19 signalised intersections under SCATS surveillance and 10 streams related to the intersections. Manual traffic counts, video cameras, and floating car technique were used to collect the data during morning peak period (07:00-08:00 am), off peak periods (10:00-11:00 am), and afternoon peak period (04:30- 05:30 pm). The results show that SCATS implementation in large city Bandung that has specific geometric and traffic behaviour and also specific driver behaviour cannot increase traffic performance significantly. This result should make road authority and also road users taken this problem into account seriously. We should be aware for what is happening. Further studies is needed including to find out variables that influence the performance of SCATS, characteristics of signalised intersections that recommended under SCATS surveillance, and improvements to increase traffic performance by using the advance technology.

7. ACKNOWLEDGEMENT

This study is a part of research that is granted by Directorate of Higher Education, Department of National Education, Republic of Indonesia, 2009.

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