Characteristics Of Signalized Intersections Which Need Advanced Traffic Control Systems Application

Karakteristik Persimpangan Bersinyal Yang Membutuhkan Penerapan *Advanced Traffic Control System*

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ABSTRACT

Advanced Traffic Control Systems (ATCS) are usually used in large cities in developing countries to ease congestion problems. However, the application of the systems is not to all signalized intersections in the city. Local conditions such as geometric conditions and traffic conditions should be taken into account seriously. The aim of this study is to identify characteristics of signalized intersections which need to be under ATCS. Field data were collected at 19 signalized intersections under ATCS surveillance and 10 streams related to the intersections, in Bandung Indonesia. 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). Measurements to determine the characteristics of signalized intersections are throughput per capacity at each leg intersection, number of queue at each leg intersection, and travel time at each stream. The results found that the application of ATCS is recommended to signalized intersections with characteristics of many leg intersections, located in CBD, closed distance to adjacent intersection and high side frictions. The findings of this study are very beneficial not only for Bandung but for other large cities in Indonesia that have similar local conditions. Therefore, the application of ATCS with very high cost can be implemented only to the necessary signalised intersections.
Key words: characteristics of signalized intersections, ATCS, local traffic conditions

ABSTRAK

Advanced traffic control system atau sering disebut ATCS biasanya digunakan di kota besar di negara berkembang untuk mengurangi masalah kemacetan. Namun sistem ini tidak dapat diterapkan di semua persimpangan bersinyal yang ada di suatu kota. Kondisi lokal misanya kondisi geometrik dan lalu lintas harus dipertimbangkan secara matang. Tujuan studi ini adalah untuk melakukan identifikasi karakteristik persimpangan bersinyal yang harus dikendalikan menggunakan ATCS. Data lapangan telah dikumpulkan dari 19 lokasi persimpangan bersinyal yang menggunakan ATCS, dan 10 arus yang terkait dengan persimpangan tersebut di Bandung, Indonesia. Perhitungan manual lalu lintas, video kamera, dan metode *floating car* digunakan untuk mengumpulkan data pada jam sibuk pagi (pukul 07.00-08.00), pada jam *off peak* (pukul 10.00-11.00), dan jam sibuk sore (16.30-17.30). Pengukuran dalam penentuan karakteristik persimpangan bersinyal dihitung per kapasitas setiap lengan persimpangan, jumlah antrian setiap lengan, dan waktu tempuh pada setiap arus. Berdasarkan hasil investigasi dapat dinyatakan bahwa penerapan ATCS diekomendasikan di persimpangan bersinyal dengan karakteristik memiliki banyak lengan, berada di CBD, persimpangan yang berdekatan dan hambatan samping tinggi. Hasil studi ini sangat bermanfaat tidak hanya untuk kota Bandung tetapi juga untuk kota besar lain di Indonesia yang mempunyai kondisi sama. Sehingga penerapan ATCS dengan biaya tinggi hanya diperlukan oleh persimpangan bersinyal yang membutuhkan.
Kata-kata kunci: karakteristik persimpangan bersinyal, ATCS, kondisi lalu lintas lokal

INTRODUCTION

The application Advanced Traffic Control Systems (ATCS) in large cities in developing countries is to improve efficiency and capacity of existing road infrastructure (US DOT, 2010, ITS Australia, 2010). Since application of ATCS needs very high cost, the application of this system is not at all signalized intersections, but only at necessary signalized intersections. However, what characteristics of signalized intersections that need to be under ATCS are unknown yet.

The aim of this study is to identify characteristics of signalized intersection which need to be under ATCS. The characteristics are closed related to local conditions. Therefore, geometric conditions and traffic conditions as local conditions should be taken into account.

Measurements used to determine the characteristics of signalized intersections are throughput per capacity at each leg intersection, number of queue (veh) at each leg intersection, and travel time (hh:mm:ss) at each stream. A stream is a set of sections that are consecutive and connected through intersection (TSS, 2010).

Road network in Bandung, Indonesia was used as a case study. Data collection was carried out at 19 signalized intersections under ATCS 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).

By finding out the characteristics, specific signalized intersections can be recommended to be under ATCS. The results of this study are very beneficial to reduce high cost since application of ATCS is only to the recommended signalized intersections.

RESEARCH METHOD

The measurements that are most widely used to evaluate signalized intersections under ATCS and then determine the characteristics of the intersections are throughput (Liu, et.al, 2005; Xia and Shao, 2005; Nigarnjanagool and Dia, 2005; Clement, et al., 2004; Bose and Iovannou, 2003; Mirchandani and Head, 2001; AWA Plessey, 1997a; AWA Plessey, 1997b; Montgomery, 1996), number of queue, and travel time (Abdel-Rahim, and Taylor, 2000; AWA Plessey, 1997a).

Throughput (veh/h) is number of vehicles pass the intersection during green time. Throughput data is collected using manual traffic counts including vehicle occupancy, turning movements, phases, and vehicle classifications. Video camera at each observed intersection is used to record traffic movements at each phase.

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 also used to record 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 defined as 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). Manual Data Collection 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 the methods require test vehicles, the driver of the test vehicle proceeds along the study route in accordance with a recommended technique. Technique used in this study is Floating Car Technique wherein driver “floats” with the traffic by attempting to safely pass as many vehicles as pass the test vehicle.

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.

Data Collection

ATCS that is implemented in Bandung is Sydney Coordinated Adaptive Traffic Control Systems (SCATS). Advanced traffic control system SCATS currently 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).

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.

The observed intersections in this study were 19 signalized intersections under ATCS surveillance and 10 streams related to the intersections in Bandung Indonesia. 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).

Criteria used to choose signalized intersections as samples are as follow.

- Based on typology, in a proportional method (Sutandi and Santosa, 2007).
- Based on location of signalized intersection in the typology.
- Based on road detectors that work well at the intersection.
- Signalized intersection chosen is intersection with high level of congested intersection.

Criteria used to choose streams as samples areas follow.

- Based on road hierarchy (arterial roads, collector roads, local roads).
- Streams wherein chosen signalized intersection lied.

Typology of all signalized intersections under SCATS is presented in Table 1. Table 2 presents observed signalized intersections in this study, and Table 3 presents detail observed streams in this study.

RESULTS AND DISCUSSION

In order to determine characteristics of signalized intersections need to be under ATCS, the following steps have to be taken.

a. Determine signalized intersections with high level of congestion including have high level of v/c ratio (AWA Plessey, 1997a; AWA Plessey, 1997b). In case of Bandung, 90 signalized intersections have been determined to be under ATCS and in this study 19 signalized intersections are the observed intersections
b. Classified the intersections based on existing geometric and traffic conditions.
c. Determine measurements i.e. throughput per capacity, number of queue, and travel time based on classification.
d. Determine characteristics of signalized intersections that need to be under ATCS

Throughput alone cannot be used to compare how high the traffic flow at intersections with various numbers of phases and movements, since traffic flow at each intersection depends on number of leg intersections, number of lanes, and lane width at the intersection. Therefore, capacity in each leg is used to divide throughput at the leg. Throughput per capacity is one of indicators to determine traffic congestion.

Observed intersections are classified based on geometric and traffic conditions i.e. size of intersection, number of leg intersections, location of intersection, distance to adjacent intersection, level of side friction, number of phase, and number of movements. Whereas CCTV surveillance, existence of police officers at intersection, road hierarchy, and v/c ratio of roads are not used to classify the observed intersections based on a number of reasons as follow.

- Only a few of CCTV at 12 signalized intersections in Bandung are working well.
- Police officers do not always presence at specific intersections.
- Road hierarchy and v/c ratio of roads are used to determine observed streams.

Classification of the intersections based on geometric and traffic conditions are presented in Table 4 and Table 5. Whereas Table 6 presents travel time and speed in the observed streams.

Table 4 shows the following results.

- based on size of intersections, throughput per capacity at leg intersections seems similar.
- based on number of leg intersections, application of ATCS is more effective at intersections with high number of leg intersections (5 legs). This means that intersections with high number of leg intersections need to be under ATCS.

Table 1. Typology of all signalized intersection under SCATS in Bandung, Indonesia (Sutandi and Santosa, 2007)

No.	Typology (number of intersections in typology)	I (36)	II (19)	III (14)	IV (21)
1	number of leg intersections	3-4	3-4	3-4	3-5
2	number of medians	0-2	0-2	0-4	0-4
3	number of splitter islands	0	0	2-3	0
4	number of phases	2-3	2	2-5	2-4
5	number of movements	4-9	3-9	5-12	12-15
6	the size of intersection	medium	small-medium	medium-large	small-medium
7	the existence of CCTV	yes	no	no	no
8	the existence of policemen at intersection	yes	no	yes	no
9	the location of intersection	91.7% in CBD	73.7% in CBD	92.9% in CBD	66.7% in CBD
10		8.3% in RES	26.3% in RES	7.1% in RES	33.3% in RES
	the distance to the closest intersection	200-400m	200-400m	300-400m	300-400m
11	road hierarchy	39% arterial roads	11% arterial roads	86% arterial roads	19% arterial roads
12		28% collector roads	42% collector roads	14% collector roads	29% collector roads
		33% local roads	47% local roads		52% local roads
	the longest width of leg intersection	12-16.8m	8-13.5m	12-21m	10-18m
13	the shortest width of leg intersection	6.15-12m	4-10m	6-12m	5-12m
14	volume capacity ratio of major road	0.615	0.567	0.744	0.751
15	volume capacity ratio of minor road	0.553	0.457	0.79	0.735
16	level of side friction	H=61%; L=39%	H=58%; L=42%	H=71%; L=29%	H=48%; L=52%

Table 2. Observed signalized intersections

Typology	Number of Signalized Intersections	Name of Signalized Intersections
I	8	Lingkar Selatan – Jendral Sudirman Lingkar Selatan – M Ramdan Jendral Sudirman – Gardujati Oto Iskandardinata – Asia Afrika Asia Afrika – Tamblong Cihampelas – Abdul Rivai Merdeka – RE Martadinata Aceh – Merdeka
II	4	Cipaganti – Sampurna Martadinata – Trunojoyo Aceh – R.E. Martadinata Moh Ramdan – Pungkur
III	3	A Yani – RE Martadinata Pasirkoja – Jamika Pajajaran – Pasirkaliki
IV	4	Dipatiukur – Siliwangi Pahlawan – Surapati Abdulrahman Saleh – Pajajaran Talagabodas – Burangrang

Table 3. Observed streams

Roads in Bandung North Region .			Roads in Bandung South Region		
No.	Road Hierarchy	Name	No.	Road Hierarchy	Name
1	Artery	Surapati East to West	1	Artery	Asia Afrika
2	Artery	Surapati West to East	2	Artery	PP 45 North to South
3	Collector	H. Juanda North to South	3	Artery	PP 45 South to North
4	Collector Local	H. Juanda South to North	4	Collector	Kebonjati
5		Cipaganti	5	Local	Oto Iskandardinata

- based on location of observed intersections, application of ATCS is more effective at intersections lie in CBD. This means that areas with high congested traffic need ATCS more than area with lower congested traffic such as residential area.
- based on distance to adjacent intersection, application of ATCS is more effective at intersections closed to adjacent intersections (100 m – 200 m). This means that intersections with closed distance to adjacent intersection need ATCS more than intersections with farer distance to adjacent intersection. Application of ATCS at intersections with

far distance to adjacent intersection is not effective because long stream between intersections can better accommodate number of vehicles, number of traffic movements at streams with the same capacity, higher speed, higher number of queue vehicles, without direct impact to adjacent intersections. In this condition, implementation of ATCS cannot increase traffic performance significantly.

- based on side frictions, application of ATCS is more effective at intersections with high level of side frictions. This means that the intersections lie in the congested area. This result consistence with the previous result, that application of ATCS is more effective in CBD area.
- based on number of phases and number of movements at intersections, throughput per capacity at leg intersections seems similar.

Table 5 shows the following results.

- based on size of intersections, number of phases, and number of movements, number of queue (veh) at leg intersections seems similar.
- number of queue is higher at the intersections with higher number of leg intersections, located in CBD, close distance to adjacent intersection, and higher level of side frictions. This condition occurs since the intersection tent to have traffic congestion.

Table 6 shows that travel time is lower and speed is higher in local roads than those in roads with higher hierarchies (collector roads and arterial roads). This condition occurs since local roads usually have less traffic congestion than roads with higher hierarchies.

Therefore, it is recommended that ATCS is implemented at signalised intersections with the following characteristics.

- higher number of leg intersection.
- located in CBD.
- have closed distance to adjacent intersection.
- have high level of side friction.

The recommendation is very beneficial since implementation of advanced technology ATCS with high cost is only at necessary signalised intersections. The implementation of ATCS is also needs support from road users including drivers and pedestrians to adhere to the traffic regulations, so that good traffic performance can be reached.

Table 4. *Throughput* per capacity based on classification of signalized intersections

Classification		Throughput/capacity (%)			
		7:00-8:00 am	10:00-11:00 am	4:30-5:30 pm	Average
Size of Intersection	Large > 9 m	24,12	23,32	20,34	22,59
	Medium 6 m - 9 m	20,53	19,94	22,67	21,04
	Smalll 3 m - 6 m	22,21	23,34	28,13	24,56
Number of leg intersections	5	45,30	29,79	32,71	35,93
	4	19,95	19,94	21,52	20,47
	3	16,10	17,54	18,31	17,32
Location of intersection	CBD	22,33	21,39	23,45	22,39
	Residential area	15,53	16,67	19,75	17,32
Distance to adjacent intersection	100 m - 200 m	28,49	29,44	32,53	30,15
	200 m - 300 m	18,23	18,38	17,26	17,96
	300 m - 400 m	21,23	20,98	25,62	22,61
	> 400 m	19,78	18,45	20,69	19,64
Side friction	High	23,59	22,35	24,87	23,60
	Low	15,73	16,65	18,38	16,92
Number of phases	2	22,97	21,96	24,80	23,24
	3	19,20	19,16	20,94	19,77
	5	20,70	20,08	22,13	20,97
Number of Movements	1 - 5	20,13	21,17	22,37	21,22
	6 - 10	20,41	20,68	24,14	21,74
	11 - 15	21,82	19,88	22,00	21,23

Table 5. Number of queue based on classification of signalized intersections

Classification		Number of queue (veh)			
		7:00-8:00 am	10:00-11:00 am	4:30-5:30 pm	Average
Size of Intersection	Large > 9 m	3	3	3	3
	Medium 6 m - 9 m	4	4	5	4
	Smalll 3 m - 6 m	2	2	2	2
Number of leg intersections	5	7	6	7	6
	4	4	4	5	4
	3	1	2	2	2
Location of intersection	CBD	4	4	5	5
	Residential area	2	2	2	2
Distance to adjacent intersection	100 m - 200 m	6	7	8	7
	200 m - 300 m	4	4	4	4
	300 m - 400 m	3	3	4	4
	> 400 m	3	3	4	3
Side friction	High	5	5	6	5
	Low	2	2	2	2
Number of phases	2	3	3	4	3
	3	4	4	5	4
	5	5	5	6	5
Number of Movements	1 - 5	3	3	3	3
	6 - 10	3	4	4	4
	11 - 15	5	5	5	5

Table 6. Travel time based on road hierarchy

Road hierarchy	Travel Time (hh:mm:ss)				Speed (km/h)			
	7:00-8:00 am	10:00-11:00 am	4:30-5:30 pm	Average	7:00-8:00 am	10:00-11:00 am	4:30-5:30 pm	Average
Artery	0:06:19	0:06:19	0:07:19	0:06:39	19,49	19,10	15,91	18,17
Collector	0:07:08	0:05:41	0:07:25	0:06:45	15,18	19,92	13,77	16,29
Local	0:04:34	0:04:49	0:07:48	0:05:44	23,83	22,67	14,20	20,23
Average	0:06:13	0:05:50	0:07:26	0:06:30	19,07	20,06	14,93	18,02

CONCLUSIONS

This study evaluated characteristics of signalized intersection which need to be under ATCS. Data collection was carried out at 19 signalized intersections under ATCS 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). Observed intersections are classified based on existing geometric and traffic conditions.

The results show that ATCS implementation are recommended to signalised intersections with the characteristics of higher number of leg intersection, located in CBD, have closed distance to adjacent intersection, and have high level of side friction.

The recommendation is very beneficial since implementation of advanced technology ATCS with high cost is only at necessary signalised intersections needed. The implementation of ATCS is also needs support from road users including drivers and pedestrians to adhere to the traffic regulations, so that good traffic performance can be reached. The findings of this study are very beneficial not only for Bandung but also for other large cities in Indonesia that have similar local conditions.

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