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SCATS (Sydney Coordinated Adaptive Traffic System) as A Solution to Overcome Traffic Congestion in Big Cities

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Abstract. The development of an urban area should be followed by the arrangement of adequate infrastructure. One of the important needs in an urban area is transportation. An increase in the number of means of transport often creates congestion, especially at intersections. The timing of cycles that do not lead tothe number of vehicles lining up but only based on a balanced division of time is one of the causes of congestion. Based on this background, a system of setting the flame cycle of the lamp u basedon the length of the queue is needed. This study aims to implement the *Sydney Coordinat Adaptive Traffic System* (SCATS) application as a solution to overcome traffic congestion in DKI Jakarta. The method used is to use quantitative methods with the 1997 Indonesian Road Capacity Manual (MKJI) approach. The results obtained include, the SCATS application can adaptively adjust the cycle time of sensor-based traffic lights. Traffic traffic settings can be manually controlled by the operator remotely using an internet communication network and can be conditioned with special cases or emergencies. Based on the results of the study, the SCATS application is expected to be implemented in all major cities in Indonesia.

Keywords: SCATS, Traffic, Big Cities.

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1. Introduction

Transportation problems will always develop following the development of the progress of an area. The development of transportation technology that exists now affects the number of types and number of vehicles which causes congestion on the main roads of each urban area [1].

The majority of congestion occurs on main roads in urban areas, as the main roads become the meeting point of vehicles of various destinations. And congestion often occurs at intersections because the performance of the persimpang arrangement does not run well, one of which is influenced by the slow movement of vehicles which results in congestion [2].

DKI Jakarta is the national capital city whose population level development is very rapid every year. DKI Jakarta itself is a city with the center of government and economy of the Indonesian state, due to the rapid development of the population and the large number of vehicles, there are often traffic jams, especially at intersections [3]. In an effort to reduce traffic congestion at intersections, the DKI Jakarta Transportation Agency implements automatic and remotely controllable settings hammering the implementation of the ATCS (Area Traffic Control System) system which aims to optimize intersection performance, one of which is applied at the Senayan interchange [4].

The application of ATCS (Area Traffic Control System) at the Senayan intersection uses a supporting application, namely SCATS (Sydney Coordinated Adaptive Traffic System), the SCATS setting is adaptive, namely the regulation of traffic light signals is regulated based on the volume of existing vehicles. Interchange vehicle volume data can be adjusted manually by the operator or in real-time using vehicle sensors attached to traffic lights in the field [5].

This research was conducted at Simpang Senayan door one because this intersection has been integrated with SCATS. Through observation and data collection (survey) by researchers at the DKI Jakarta Transportation Agency, precisely at the Traffic Control System Management Unit (UP SPLL), before SCATS was applied at this intersection, it experienced congestion, especially during peak hours when leaving and returning to work [6].

The solution to overcome congestion at intersections is to set the cycle time of these intersections based on the size of capacity, queue length and delay of intersections (MKJI, 1997) [7].

The scope of this study is as follows:

1. The research location is in two places, namely at the DKI Jakarta Technical Office Building, Jl. Abdul muis No.66, 16th Floor (Traffic Control System Management Unit), South Petojo, Gambir district, Central Jakarta and Simpang Senayan Pintu Satu DKI Jakarta.
2. The volume of traffic in the survey at interchange conditions during heavy hours of vehicles.
3. Data processing, analysis and discussion provisions are in the 1997 Indonesian Road Capacity Manual (MKJI).
4. The study used data taken based on surveys conducted directly in the field surveying traffic conditions and surveying road geometric conditions as well as direct observations on the SCATS application in the Traffic Control System Management Unit (UP SPLL) DKI Jakarta.

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2. Method

This study used quantitative research methods with the approach of the Indonesian Road Capacity Manual (MKJI) 1997 method. In conducting a study, a research flowchart is needed that can provide guidance so that the research carried out runs well [8]. Broadly speaking, the following is a research flow chart can be seen in Figure 1.

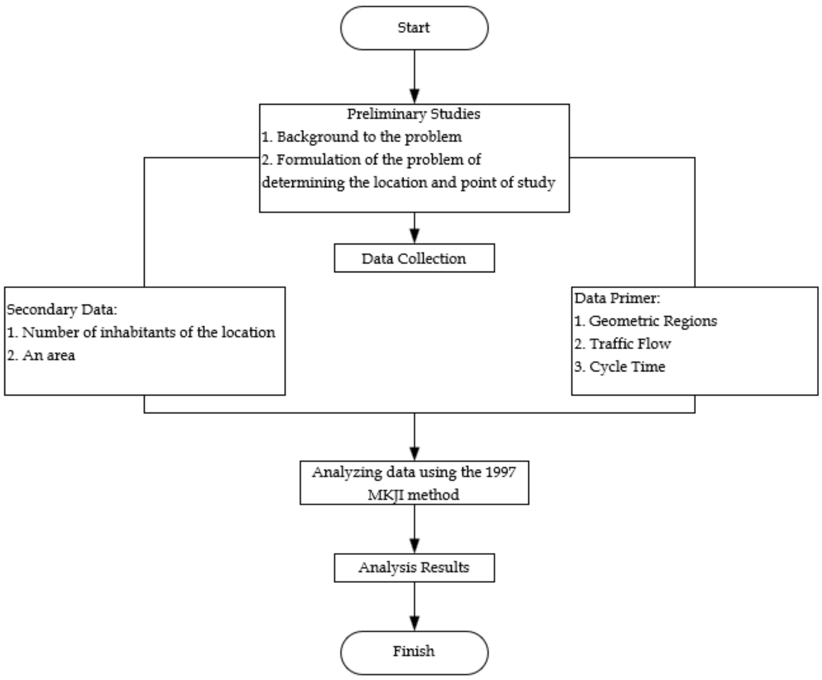

Figure 1. Research Methods

The research site is in two places, namely at the DKI Jakarta Technical Office Building, Jl. Abdul muis No.66, 16th Floor (Traffic Control System Management Unit), South Petojo, Gambir district, Central Jakarta and at the Senayan Pintu Satu intersection, Kebayoran Baru, South Jakarta[9]. This intersection is a junction between Jalan Asia-Afrika and Jalan Pintu Satu Senayan [10].

Data retrieval to count the number of vehicles passing by at the intersection is done manually. Data collection is carried out at the DKI Jakarta Technical Office Building, 16th floor through a CCTV monitor (Jl. Asia - Afrika, Jl. Pintu Satu Senayan) so that the view is wide and clear. Furthermore, the researcher recorded each vehicle based on its type that crossed the specified limit using a hand counter application on the researcher's cell phone, after which the data was transferred to fill out the survey form [11].

Data on the volume of vehicles on interchange traffic is taken for 5 days (weekdays i.e. Monday to Friday), survei is divided into 2 parts, namely at peak hours when commuting to work hours (07:00 – 09:00) and returning home from work (16:00 – 18:00), data is taken once every 15 minutes [12].

The vehicles surveyed were divided into three groups of vehicles, namely as follows:

1. Light Vehicle (LV).
2. Heavy Vehicle (HV).

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3. Motorcycle (Motor Cycle / MC)

The data collection of vehicle volume is taken from different directions on each interchange arm, that is, there are those who turn right, turn left and go straight [13]. The form of data is collected into two, namely secondary data and primary data [14]. Secondary data were obtainedthrough literature studies conducted by researchers from various sources including related agencies in this study [15]. While primary data is a data obtained directly by researchers at a predetermined survey location. The data taken in this study are geometric data on roads such as the middle line and the stop line[16]. Distances are measured using a length measuring instrument (in meters) [17]. The geometric data measured were the width of the lane and the width of the arm of the road where the vehicle stopped before passing the stop line. Meanwhile, the traffic flow data taken includes the volume of vehicles and the cycle time at the intersection [15, 18-19].

2.1. Secondary Data

The survey was conducted at the Senayan interchange, precisely the Senayan one-door intersection. This interchange is located in the new Kebayoran district, the city of south Jakarta. Through data from the Central Statistics Agency (BPS) of south Jakarta, it is known that the total population in 2019 was recorded at 2.265 million. The area of the survey location is located in the city of south Jakarta, recorded at BPS South Jakarta, which is 154.3 km^2.

2.2. Primary Data

Survey data at the observation site are obtained in the form of vehicle units per hour. Then the data will be converted into the same unit, namely smp (passenger car unit) per hour according to their respective shorts.

Traffic volume data at a certain peak hour will be the main data in analyzing how the interchange performs. The data will then be used in calculations in accordance with the 1997 MKJI regarding road capacity, vehicle delays, number and length of intersection queues. The main data is said to be the highest traffic volume data if the traffic flow data is the most dense compared to other data [20-22].

In its arrangement, the SCATS system divides the cycle time into several plans, where this plan is divided into 5 (five) according to several time divisions. The following is the SCATS plan signal time data for settings at the survey location.

1) Short type
2) Effective short width
3) Basic saturated current
4) Current/current-saturated ratio
5) Cycle time and green time

Observation tools, observation needs are needed, including:

1) Hand counter application, used to shelter many vehicles passing by the field of observation. calculated by type.

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2) Media to record data on survey results.
3) Meter, used to calculate the geometric size of the location.
4) Stationery.

The procedure for calculating the capacity and performance level of the intersection according to the 1997 Indonesian Road Capacity Manual (MKJI) is carried out in the following order:

First step: Input data
- a) Geometric data, environmental conditions of the survey site and traffic arrangements.
- b) Traffic conditions

Step two: Process input data
- a) The width of the short is effectively interchangeable.
- b) The saturated current of the interchange base.
- c) Adjustment factor.

Third step: Capacity
- a) Interchange capacity.
- b) Degree of saturation.

Fourth step: Interchange Performance Level
- a) The length of the interchange queue.
- b) The number of vehicles stalled.
- c) The number of interchange delays.

3. Results and Discussion

The SCATS (Sydney Coordinated Adaptive Traffic System) application at the Senayan DKI Jakarta interchange works in flexilink operating mode, which is a contiguous signal synchronized based on the unit-electricity frequency or by an accurate clock determined by the existing plan based on the clock time of each duration, for example according to daily data and hours. Daily and clock data on flexilink mode are collected manually. The SCATS architecture can be seen in Figure 2.

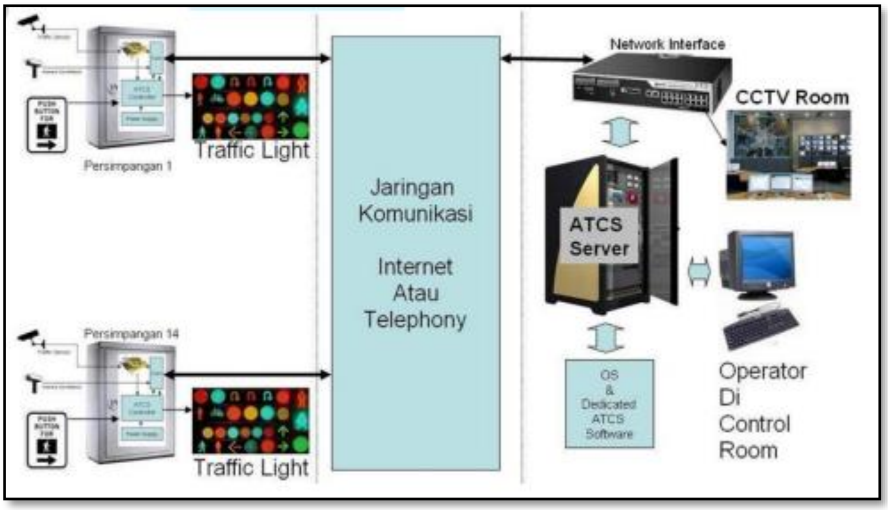

Figure 2. Architecture of ATCS DKI Jakarta (Mitra et al, 2020)

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The working principle of ATCS is that LC (*Local Control*) instructs TL (*Traffic Light*) based on input data from the detector, then TraffiCam inputs traffic data, CCTV to monitor intersection density, and TL (*Traffic Light*) receives data from LC (*Local Control)* and inform red and green time. The equipment used such as sensor detectors, CCTV cameras, SCATS controllers, servers, SCATS software, computers, and telephones. The use of SCATS is divided into 5 (five) operators on duty on each shift. The task of the operator is to be responsible for 5-7 corridors, check whether there is a vehicle queue tail in the corridor with the help of google maps, then check on CCTV to ensure congestion in the corridor, then immediately execute the interchange arrangements on the SCATS application.

Each coordinated intersection has traffic light control, becoming a system that is connected to each other (Mitra et al, 2020). The screen display on the SCATS application for the Senayan DKI Jakarta interchange is as follows in Figure 3.

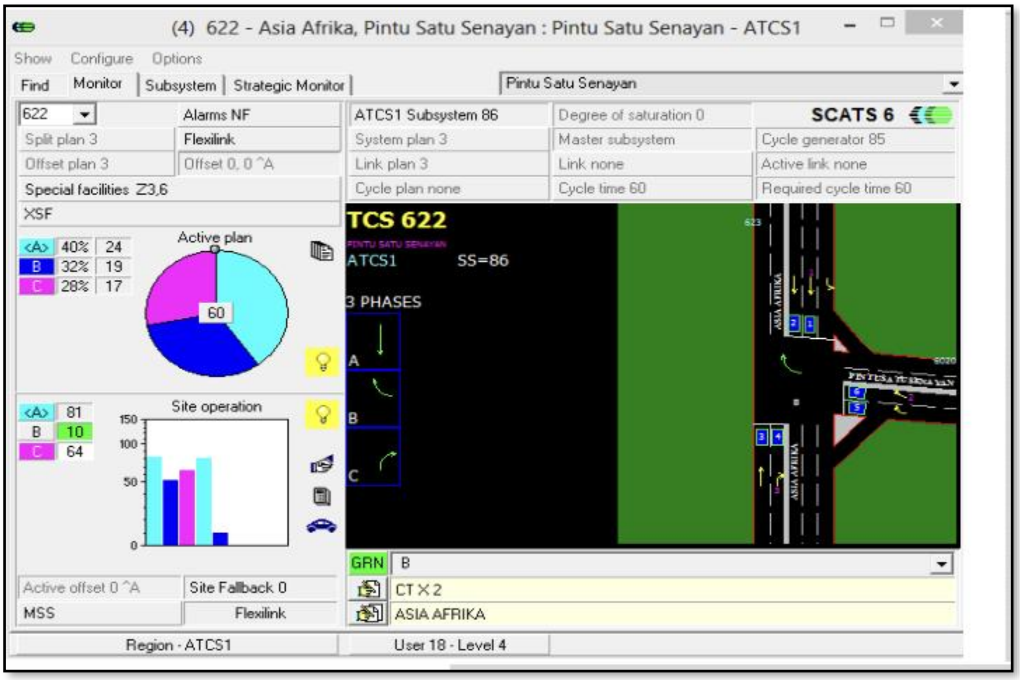

Figure 3. SCATS Application View

2.3. Geometric Data Interchange

The data taken was carried out manually in the field, along with the data from observations at the interchange survey location at the door one intersection.

Table 1. Geometric Observation Data

Code	Type	Side Bariers	Median (Y/T)	LTOR	Parkir Distance (m)	Approach width			
						Wa	W In	W out	LTOR
U	COM	R	Y	Y	0	6	5	7	2
S	COM	R	Y	T	0	6	4	4	-
T	COM	R	Y	Y	0	6	4	6	2

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2.4. State of Traffic Flow

In taking data on the number of vehicles, it is divided into several types of vehicles, namely light vehicles, heavy vehicles and motorcycles. The data used are two peak hour data, namely vehicle volume data on Monday morning at 07:00-09:00 and afternoon at 16:00-18:00. The intersection is included in the protected short type because everyone phase there is only one short that gets a green time signal.

Table 2. Traffic Flow Data on Monday at 07:00-09:00 WIB

Approach Code	Direction	MOTOR VEHICLE TRAFFIC FLOW (MV)									
		Light Vehicles (LV) sheltered emp = 1,0		Heavy Vehicles (HV) sheltered emp = 1,3		Motorcycles (MC) sheltered = 0,2		Motor Vehicle (MV) Total		Rasio Berbelok	
		Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour RMS	PLT RMS	PRT RMS
North	LT/LTOR	217	217	19	24,7	826	165,2	1062	406,9	0,17	
	ST	1307	1307	44	57,2	2825	565	4176	1929,2		
	RT	-	-	-	-	-	-	-	-		0
	LT/LTOR	-	-	-	-	-	-	-	-	0	
South	ST	1649	1649	53	68,9	5927	1185,4	7629	2903,3		
	RT	904	904	20	26	1910	382	2834	1312		0,31
	LT/LTOR	71	71	5	6,5	162	32,4	238	109,9	0,20	
East	ST	-	-	-	-	-	-	-	-		
	RT	275	275	16	20,8	680	136	917	431,8		
Total		4423	4423	157	204,1	12330	2466	16856	7093,1	0,37	1,11

2.5. Traffic Flow (Q)

Because, the traffic flow on the LTOR is considered unobtrusive and is not included in the Q calculation. $W_{LTOR} \geq 2m$.

2.6. Signal Cycle

The signal cycle obtained through the SCATS application, plan that will be taken as time cycle data is cycle time data that is in accordance with the maximum vehicle volume data at peak hours, namely plan 1 and plan 3.

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Table 3. Traffic Flow Data on Monday at 16:00-18:00 WIB

Approach Code	Direction	MOTOR VEHICLE TRAFFIC FLOW (MV)									
		Light Vehicles (LV) sheltered emp = 1,0		Heavy Vehicles (HV) sheltered emp = 1,3		Motorccles (MC) sheltered = 0,2		Motor Vehicle (MV) Total		Rasio Berbelok	
		Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour	Vehicle/hour RMS	PLTRMS	PRTRMS
North	LT/LTOR	938	938	33	42	679	135,8	1650	1116,7	0,26	
	ST	846	846	81	105,31	4221	844,2	6477	1795,5		
	RT	-	-	-	-	-	-	-	-		0
	LT/LTOR	-	-	-	-	-	-	-	-	0	
South	ST	1495	1495	38	49,4	3150	630	4683	2174,4		
	RT	284	284	16	20,8	1102	220,4	1402	252,2		0,19
	LT/LTOR	191	191	7	9,1	709	141,8	907	341,9	0,25	
East	ST	-	-	-	-	-	-	-	-		
	RT	590	590	23	29,9	1954	2567	1010,7	1010,7		0,75
Total		4344	4344	198	256,5	11815	16357	6964,4	69964,4	0,51	0,94

Table 4. Traffic Flow at each Peak Hour

Approach Code	Traffic Flow (Q) pcu/hour	
	Morning peak hours (07:00-09:00)	Afternoon peak hours (16:00-18:00)
North	1929,2	1795,5
South	1312	525,5
East	431,8	1010,7

Table 5. Data on signal time PLAN 1 am at 07:00-09:00 WIB

Approach	Turn-on Time (Second)				Cyle time (second)
	Green	Yellow	Red	All Red	
North	60	3	140	0	203
East	40	3	160	0	203
South	100	3	100	0	203

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Table 6. **Plan signal time data 1 pm at 16:00-18:00 WIB**

Approach	Turn-on Time (Second)				Cyle time (second)
	Green	Yellow	Red	All Red	
North	96	3	124	0	223
East	70	3	150	0	223
South	54	3	166	0	223

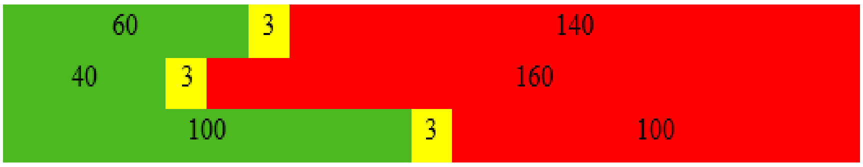

Figure 4. Plan 1 Interchange Cycle Time

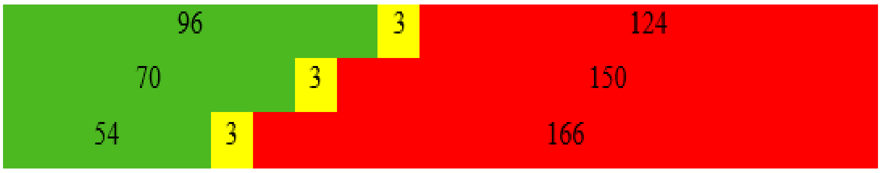

Figure 5. Plan 3 Interchange Cycle Time

2.7. Calculation of Interchange Performance with the 1997 MKJI Method

i) Saturated Current (S), The formula of the basic saturated current under the conditions of protected current MKJI 1997 in the equation :$S_o = 600\ x\ effective\ width\ (W_e)$

$$S \;= S_o \times F_{cs} \times F_{SF} \times F_G \times F_P \times F_{RT}(morning) \times F_{LT}(morning)$$
$$= 2400 \times 1 \times 0{,}95 \times 1 \times 1 \times 1 \times 1 = 2280 \text{ pcu/hour}$$

Table 7. **Calculation of The Saturated Current of the Peak Hour of each Short**

Approach	We (m)	So (pcu/hour)	Adjusment Factors						S(pcu/hour)
			Fcs	FSF	FG	FP	FRT	FLT	
North	4	2400	1,05	0,95	1	1	1	1	2280
South	4	2400	1,05	0,95	1	1	1	1	2280
East	4	2400		0,95	1	1	1	1	2280

ii) Capacity and Degree of Saturation, through data processing using the 1997 MKJI equation formula: and $C = S \times \frac{g}{c}$ $DS = \frac{Q}{C}$

Capacity (C) is the result of the multiplication of the ratio of saturated current (S) and the ratio between green time (g) and cycle time (c). While DS is the traffic flow value (Q) compared to the capacity value (C).

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Table 8. Calculation of Capacity and Degree of Saturation at Peak Hours

Fase	Capacity (Pcu/hour)		Degree of Saturation (DS)	
	Morning peak (07:00-09:00)	Afternoon peak (16:00-18:00)	Morning peak (07:00-09:00)	Morning peak (07:00-09:00)
North	2245,8	2250,4	0,85	0,79
South	2245,8	2250,4	0,58	0,23
East	2245,8	2250,4	0,19	0,44

iii) Vehicle Queue Length (QL), to find out how long the vehicle queue is can be calculated using the following equation, if the DS value < 0.5 then the value, while if the DS > 0.5 is calculated by: $NQ_1 = 0$

$$NQ_1 = 0{,}25 \times C \left[(DS-1) + \sqrt{(DS-1)^2 + \frac{8 \times (DS - 0{,}5)}{c}} \right]$$

$$NQ_2 = c \times \frac{1 - GR}{1 - GR \times DS} \times \frac{Q}{3600}$$

Table 9. Vehicle Queue Length at Peak Morning and Evening Hours

Fase	$NQ = NQ_1 + NQ_2$		Vehicle Queue Length (m)	
	Morning peak	Afternoon peak	Morning peak	Morning peak
North	35,6	20,75	142,2	83
South	5,11	0,87	25,6	4,35
East	0,609	2,21	3,045	11,05

iv) $N_{SV} = Q \times NS$ Number of Stalled Vehicles (smp/hour) with $NS = 0{,}9 \times \frac{NQ}{Q \times c} \times 3600$

Table 10. Calculation Results of Stop Numbers and Number of Stalled Vehicles

Approach	NQ (pcu)		Q (pcu)		C (second)		NS (stop/pcu)		Nsy (q x NS) (pcu/hour)	
	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
North	36,5	20,75	1929,2	1795,5	203	223	0,29	0,17	599,4	305,24
South	5,11	0,87	1312	525,2	203	223	0,06	0,024	78,72	12,6
South	0,609	2,21	431,8	1010,7	203	223	0,02	0,032	8,63	32,34
Total			3673	3331,4					686,75	350,18

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v) Average delay, the average delay of each short can be calculated by the formula in the 1997 MKJI: As for the whole intersection using the equation: Based on the 1997 MKJI to calculate the delay of traffic flow (DT), using the equation $D = DT + DGD_1 = \frac{\Sigma(Q \times D)}{Q_{total}}$: $DT = c\ \times A + \frac{NQ \times 3600}{c}$ with $A = \frac{0,5 \times (1-GR)^2}{(1-GR \times DS)}$

Table 11. Average Delay Calculation Results for each Simpang Shortat

Approach	Q (pcu)		DT (second/pcu)		DG (second/pcu)		D = DT + DG		D x Q (second/pcu)	
	Morning	Afternoon	Morning	After noon	Morning	After noon	Morning	After noon	Morning	After noon
North	1929,2	1795,5	13,7	6,43	1,33	0,88	15,03	7,31	28995,8	13125,1
South	1312	525,2	0,78	0,081	0,47	0,33	1,25	0,41	1640	215,5
South	431,8	1010,7	0,049	0,28	0,32	0,36	0,37	0,64	159,8	646,8
Total	3673	3331,4						Total	30795,6	13984,7

vi) Simpang Service Level, known the level of interchange performance by calculating the average delay time at each short or average delay of the entire intersection. Where the relationship of the delay time with the service level index according to the 1997 MKJI can be seen in Table 13 and Table 14.

Table 12. Service Level Index Standardization

No.	Service level	Delays stalled (second/pcu)
1.	A	≤ 5
2.	B	5,1 - 15
3.	C	15,1 – 25
4.	D	25,1 – 40
5.	E	40,1 – 60
6.	F	> 60

Table 13. Service Level Index of each Short

Approach Code	Average delay (D)		Service Level Index	
	Morning peak hours	Afternoon peak hours	Morning peak hours	Afternoon peak hours
North	15,03	7,31	B	B
South	1,25	0,41	A	A
East	0,37	0,64	A	A

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Table 14. Service Level Index of the Entire Pendekat

Delay the whole approach (D1) second/pcu		Service Level Index	
Morning peak hours	Afternoon peak hour	Morning peak hours	Afternoon peak hour
8,38	4,19	B	A

4. Conclusion

Based on the findings and discussions, it can be concluded that according to calculations using the Indonesian Road Capacity Manual method (MKJI 1997). The application of the SCATS application resulted in a delay value and an Interchange Service Index, for each of them, the highest delay value was at the northern peak of 15.03 seconds/passenger car unit (pcu) for the morning peak and 7.31 seconds/passenger car unit (pcu) for the afternoon peak.
The lowest delay was at the eastern peak for the morning peak of 0.37 seconds/passenger car unit (pcu) and the southern short for the afternoon peak of 0.41 seconds/ passenger car unit (pcu). Furthermore, from the results of calculating the delay data on each short, a delay was obtained for the entire short at the morning peak of 8.38 seconds/passenger car unit (pcu) with the Service Level Index value according to MKJI 1997 is B and for the peak of afternoon delay of the entire short of 4.19 seconds/passenger car unit (pcu) with the Service Level Index value according to MKJI 1997 is A. So that the application of the SCATS application in overcoming congestion that has been implemented in DKI Jakarta provides good index results, namely B in the morning and A in the afternoon. SCATS applications can adaptively set the cycle time of sensor-based traffic lights. Traffic management can be manually controlled by the operator remotely using an internet communication network and can be conditioned with special cases and emergencies. Furthermore, researchers believe that the application of SCATS can be implemented in all major cities in the country in overcoming congestion problems.

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