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Evaluation and Performance Improvement of Antasari Intersection Banjarmasin City

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***Abstract*—*The problem of signalized intersection is caused by the traffic volume continually increasing each year, automatically contributing high delay and frequent congestion and One indicator of traffic congestion at the roundabout is a decrease in vehicle speed [1]. Today's operated traffic lights have not yet capable of overcoming congestion which often occurs in the peak hours. The existing condition on intersection has not yet been able to accommodate the populous traffic volume; it can be seen from each of intersection foot while experiencing the vehicles daley. The imprecised existing condition on the Antasari intersection in Banjarmasin, is seen from the 4-phase control with the cycle time at 177 seconds, the degree of saturation is ≥ 0.85, and the delay is ≥ 60 seconds; making it categorized as the intersection with F-level of service (the worst).*

This research aims to analyse the existing condition of the Antasari intersection's performance, and to obtain some handling alternatives of Antasari intersection, with some approaches. To increase the performance of Banjarmasin's Antasari intersection, some handling alternatives are executed, such as: the control of Cycle Time, the control of phase direction (phase simulation), and the phase change by using KAJI program.

Based on the field data, obtained the performance of Banjarmasin's Antasari intersection in existing condition: the cycle time is 177 seconds, degree of saturation is 2,879 or ≥ 0.85, delay is 963 seconds/pcu or ≥ 60 seconds/pcu, and the worst service level (F-level). In some intersection handling alternative results, there comes one alternative that is able to increase the intersection performance: through the phase simulation stages, with the phase adjustment of the north – south of KolonelSugiono streetamd the east – west of PangeranAntasari street, then the acquired results of the Service Level-C are: the delay value (D) is 23.33 seconds/pcu or ≤ 25 seconds/pcu, the degree of saturation (DS) is 0.671 or ≤ 0.85, and the cycle time (CT) is 67 seconds or ≤ 80 seconds.

Keywords*—*Degree of saturation, cycle time, phase, delay, level of service.

I. INTRODUCTION

In accordance with the development of Banjarmasin City, then one of such development aspects –along with its activities—is the increasing of vehicles traffic volume, either of the street capacity side or even of its own traffic characteristic. What is meant by such characteristics are the volume, composition, and velocity. Especially in the peak hours, there can be seen the long queue of vehicles on many intersections causing the vehicles going through the long-enough average delay.

Like any other development countries, today's big cities in Indonesia, especially Banjarmasin, are on the high growth of urbanisation, as the result of its rapid economic growth rate, therefore the population's needs for movement are increasing as well. The private cars keep growing rapidly on their own, as the conveyances which have very big benefits for every individual especially in the movement mobility. Meanwhile, the development of transportation facility supply is very low, thus it is unable to follow.

The problems on the signalized intersection are the high delay and the frequent congestion occurrence. Recent traffic lights control operation have not yet been solving the congestion frequently occurred in the peak hours. The existing condition on intersection has not yet been able to accommodate the heavy traffic volume; this can be seen on each foot of intersection encountering the vehicle delay. The imprecise existing condition of intersection control is seen from the 4-phase control with the Cycle Time at 177 seconds, Degree of Saturation is ≥ 0.85, and Delay is ≥ 60 seconds/pcu, can be categorized as the intersection with the worst service level. According to the condition introduction survey, the volume of vehicles turning right with the vehicles total volume is bigger, compared to the vehicles heading straight and turning left, hence it causes queue and delay on the next green phase.

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To increase the intersection level service in order to decrease the delay value of vehicle/second, this research analyses the recent performance of the intersection of KolonelSugiono street – PangeranAntasari street and PangarenAntasari street – KolonelSugiono street, and giving précised problem solving alternative, either using the cycle time control, phase control, and intersection geometrical control. This research will be devoted to observe the traffic condition on one intersection location which has the traffic lights with the turn left directlysigns. The observed study area is the intersection with the traffic lights on the Antasari section in Banjarmasin. The Antasari intersection in Banjarmasin is located in the district of Central Banjarmasin.

II. THEORITICAL REVIEW

An intersection can be defined as a public area where two or more streets are merged or intersected, including streets and side-street facilities for traffic movement inside; and intersection is divided into two; they are the plot intersection and the non-plot intersection. The plot intersection is an intersection where two or more main streets are merged, with each of the main street heads out of an intersection and forms part of it. The non-plot intersection is an intersection where two streets are intersected each other in different plots, without any relation and adjustment following the plot separator [2].

An intersection usually has four types of basic pattern of vehicle traffic movement which potentially causes conflicts of merging (merging with the main street), diverging (separating direction from the main street), weaving (shifting street occurs), and crossing (intersecting with vehicles from other streets) [3].

There are methods to decrease the traffic movement conflict on intersection [4]:

1. Time sharing (involving the utilization control of the body of the street for each direction of traffic movement in certain periods)
2. Space sharing (using the principle of changing the movement conflict, from crossing to braid or combination of diverging or merging)

In broad outline, the basic characteristics of traffic current are divided into three parameters [5]:

1. Traffic volume
2. Traffic velocity
3. Traffic density

The traffic volume data is calculated to get the value which represents the vehicles as many as 85% [6], velocity is the average speed in a space, density is the total vehicles of each main street length unit, and current is the total vehicles which pass through certain spots on the main street per time unit [7]. The headway can be seen on two sides: the time headway and the distance headway. Time Headway is the time interval between the moment where the front part of a vehicle passes a point until the moment where the front part of the next vehicle passes the same point, and the Distance Headway is the distance between the front part of one vehicle with the part of the next vehicle in a certain time [8].

The capacity of signalized intersection is based on the concept and the level of saturation degree [5]. Indeed that the junction capacity tabulation in all conditions is impossible to do, and the capacity on the thorough part of track is more needed than the capacity in the closed area. However, most street assembly will determine the limits of capacity and security from all tracks. The difficulty is to decide the total unit, either pedestrians or vehicles, that will use the facilities, and along with the level of safety and comfort. In the point of social view, in certain level, we have to be ready to be able to accept bigger traffic slowness to add its security level. However in most calculation which recovers traffic current, will be able to reduce the accident potential [9].

There are two types of main system in the traffic signal operation: the fixed-time signal system and the traffic responsive. Fixed-time signal system is a signal operating system which uses fixed cycle time, the modification of this fixed cycle time can be set for a certain time period, such as for daily or weekly simulation, or to peak hour from off-peak hour. Meanwhile the traffic responsive signal system is a signal operating system which uses the changeable cycle time setting, in line with the existed traffic current condition [10].

The intersection performance is to evaluate the performance of an intersection commonly can be seen from the following parameters [5]:

1. The Delay
2. The Number of Stop Vehicle
3. The Queue Length

The Intersection Delay is the total time of average barrier experienced by vehicles when passing through an intersection [11]. The average traffic delay in *j* approach can be determined based on the following formula [12]:

$$DT_j = c \times \frac{0.5\times(1-GR)^2}{(1-GR\times DS)} + \frac{NQ_1 \times 3600}{c}$$

whereas:

DT_j = Average traffic delay for the *j* approach (seconds/pcu)

GR = Green ratio (g/c)

DS = Degree of saturation

C = Capacity (pcu/hour)

NQ_1 = Total amount of the left pcu from the previous green phase

Number of Stop *(NS)*, is the average total of each vehicle (including continued stop in queueing) before passing through intersection, the following formula is calculated:

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$$NS = 0.9 \times \frac{NQ}{Q \times c} \times 3600$$

whereas c is the cycle time, and Q is the traffic current (pcu/hour) from the explored approach.

The total of pcu queue average in the first green signal (NQ) is counted as the total of remaining pcu from the previous green phase (NQ_1) added by the total of incoming pcu during the red phase (NQ_2).

$$NQ = NQ_1 + NQ_2$$

$$NQ_1 = 0.25 \times c \times \left[\left\{ (DS-1) + \sqrt{(DS-1)^2 + \frac{8 \times (DS-0.5)}{c}} \right] \right.$$

if $DS > 0.5$; otherwise, $NQ_1 = 0$

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

whereas**:**

NQ_1 = total of remaining pcu from previous green phase.

NQ_2 =total of incoming pcu during red phase.

DS = degree of saturation

GR = green ratio

C = cycle time (sec)

C = capacity (pcu/hour) = degree of saturation times green ratio ($S \times GR$)

Q = traffic current in such approach (pcu/sec)

The queue length (QL) is acquired by the multiplication (NQ) with the used average area per pcu (20 m^2) and the division with the entrance width.

$$QL = NQ_{max} \times \frac{20}{W_{ENTRANCE}}$$

Technically, the intersection controls with Traffic Signal Device (APILL) are as follow [13]:

1. The traffic current is bigger than the approach width.
2. *Degree of Saturation*.
3. *Cycle Time*.

The traffic current calculation data is acquired based on the traffic survey result on the field (Traffic Counting); that traffic current data is then changed from vehicle/hour to pcu/hour by using the passenger car equivalent (pce), on Table-1 below.

Table-1.Passenger Car Equivalent [13]

Vehicle Type	PCE	
	Protected approach	Provoked approach
LV	1.0	1.0
HV	1.3	1.3
MC	0.2	0.4

Degree of saturation (S) can be stated as multiplication result of the primary degree of saturation (So), that is the degree of saturation in standard condition, with the adjustment factor (F) for the distortion of actual condition, from a group of conditions (ideal) previously stated.

$$S = So \times F_1 \times F_2 \times F_3 \times F_4 \times Fn$$

The protected approach of primary degree of saturation as the function of approach effective width (We).

$$So = 600 \times W_e$$

Whereas:

S_o = Primary saturation traffic current (pcu/hour)

W_e = Street width (meter)

According from several researches in several cities in Indonesia, the degree of saturation value on the field turns out to be bigger which is 1.3 times with the empirical formula corrected as follows [14]:

$$So = 780 \times W_e$$

The calculation of degree of saturation as follows:.

$$DS = Q/C = (Q \times c) / (S \times g)$$

Whereas:

DS= Degree of Saturation

Q= Total Traffic Current (pcu/sec)

C= Capacity (pcu/jam)

The signal time definition for the time control condition is still executed to minimize the total delay of an intersection [15]. The equation of Cycle Time as follows [13]"

$$C = (1{,}5 \times LTI + 5) / (1 - \sum FR_{crit})$$

whereas:

C = Cycle time signal (second)

LTI = Total of lost time per cycle (second)

FR =Current divided with degree of saturation (Q/S)

FR_{crit} = Highest FR value from all approaches leaving for a signal phase.

$\sum(FRcrit)$ = Ratio of intersection current = total of FRcrit from all phases on that cycle.

The recommended cycle time to be used depends on its control type. The phase control type and the suitable cycle time can be seen on Table-2.

Table-2.Phase Control and Cycle Time [13]

Control Type	Cycle Time (second)
Two-phase control	40-80
Three-phase control	50-100
Four-phase control	80-130

The size level of service of a signalized intersection can be seen on Table-3 and Table-4 as follow.

Table-3. Service Level on Intersection [16]

Level of Service	Delay(sec/pcu)	Information
A	<5	Very good
B	5.1 – 15	Good
C	15.1 – 25	Moderate

D	25.1 – 40	Less
E	40.1 – 60	Bad
F	>60	Very bad

Table-4.Service Level Criterion of the Intersection with Traffic Light [17]

Level of Service (LOS)	**Control Delayper Vehicle (sec/vech)**
A	≤ 10
B	>10 – 20
C	>20 – 35
D	>35 – 55
E	>55 – 80
F	>80

III. RESEARCH METHOD

There are two steps in analysing this research:

1. Data collecting.
2. Data analysis.

This research step is commonly elaborated as follows:

1. Problem Identification
   Identifying the problems on Antasari intersection as seen on the cycle time and phase control.
2. Determining the goal of research
   The goal of this research is done based on the acquired problems.
3. Data collecting
   The data collecting is based on two steps which are the secondary data collecting and the primary data collecting; the secondary data collecting is done by requesting data in the related agencies, and the primary data is done by the direct observation survey on the field.
4. Existing Condition Analysis
   The existing condition analysis is based on the result of existing condition data analysis using the KAJI program.
5. Evaluation and Improvement of Intersection Performance
   It is done based on the result of existing condition analysis, then the alternative handling is done using the KAJI program and based on existed theoretical approach.
6. Suggestion and conclusion
   The suggestion and conclusion is Kesimpulan dan saran achieved based on data analysis and whether it has been in line with the purpose and goal of the research.

IV. DISCUSSION AND RESULT

Based on the result of inventory survey and traffic survey been carried out, the intersection geometrical data can be obtained, along with the cycle time control, and the peak-hour vehicles volume data which are seen on Table-5, Table-6, Table-7, Figure-1 andFigure-2.

Table-5. Geometrical Data of Antasari Intersection

Location	Approach	Approach width		
		W_A (m)	W_{enter} (m)	W_{exit} (m)
Intersection Antasari - Sugiono	North	12.6	7.38	14.46
	East	15.5	10.24	13.5
	South	12	7.1	6.63
	West	11	11	10.22

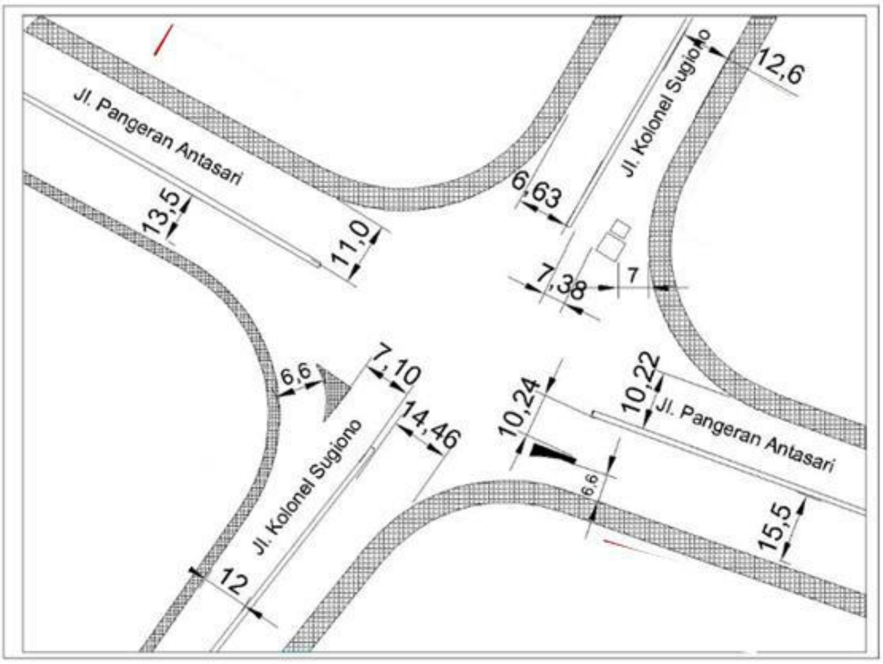

Fig.1: Intersection Geometry

Table-6.Existing Cycle Time

Location	Approach	Signal Time			All Red	Cycle Time (second)
		Red	Yellow	Green		
Intersection	North	144	3	28	2	177
P.Antasari –	South	154	3	18	2	177
K.Sugiono	East	141	3	30	3	177
	West	92	3	80	2	177

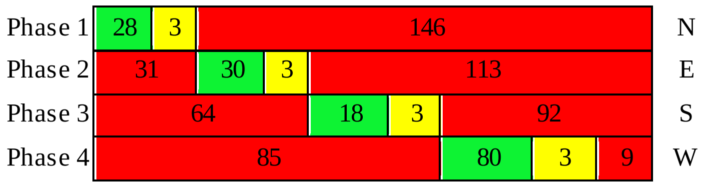

Fig.2: Diagram of Existing Condition Cycle Time

Table-7.Recapitulation ofTraffic Volume

Period	Location	Peak Hour	MC	LV	HV	UM	AMOUNT
Morning 06.00 - 10.00	K. SugionoSt. (N)	07.10 – 08.10	1168	201	5	28	1374
	P. AntasariSt. (E)		3297	603	0	76	3900
	K. SugionoSt. (S)		2650	225	0	110	2875
	P. AntasariSt. (W)		1280	131	0	23	1411
						AMOUNT	9560
Noon 10.00-14.00	K. SugionoSt. (N)	13.50 - 14.50	1198	487	29	15	1714
	P. AntasariSt. (E)		2422	721	2	63	3145
	K. SugionoSt. (S)		2050	499	56	57	2605
	P. AntasariSt. (W)		1510	183	0	29	1693
						AMOUNT	9157
Afternoon 14.00-18.00	K. SugionoSt. (N)	16.30 - 17.30	1815	389	11	20	2215
	P. AntasariSt. (E)		3196	592	1	58	3789
	K. SugionoSt. (S)		2201	234	1	66	2436
	P. AntasariSt. (W)		2443	253	0	66	2696
						AMOUNT	11136

Based on Table-7 above, it can be seen that the condition of existing traffic volume can be ranked: the first rank is the afternoon peak hour at 16.30 – 17.30 (Central Indonesian Time) with the volume of 11,136 vehicles/hour; the second rank is the morning peak hour at 07.10 – 08.10 (Central Indonesian Time) with the volume of 9,560 vehicles/hour; and the third rank is the noon peak hour at 13.50 – 14.50 (Central Indonesian Time). As the data in analysing the intersection performance, the used data is the highest peak hour which is the afternoon peak hour at 16.30 – 17.30 (Central Indonesian Time).

Using the 1997 KAJI program ver. 1.10, the existing condition analysis is done based on the most peak hour traffic volume data; the F can be seen on Table-8.

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Table-8. Analysis ofExisting Condition

Peak Hour	Approach	Time Cycle (second)	Degree of Saturation (DS)	Delay(second /pcu)	ITP
Morning 07.10 – 08.10	K. SugionoSt. (N)	177	0.707	472	F
	P. AntasariSt. (E)		1.033		
	K. SugionoSt. (S)		2.018		
	P. AntasariSt. (W)		0.143		
Noon 13.50 - 14.50	K. SugionoSt. (N)	177	1.180	963	F
	P. AntasariSt. (E)		1.142		
	K. SugionoSt. (S)		2.879		
	P. AntasariSt. (W)		0.189		
Afternoon 16.30 - 17.30	K. SugionoSt. (N)	177	1.228	352	F
	P. AntasariSt. (E)		1.019		
	K. SugionoSt. (S)		1.801		
	P. AntasariSt. (W)		0.284		

According to the existing condition analysis, the condition of Antasari intersection has the F-level of service, means it is very bad; the worst condition is in the noon peak hour with the Delay (D) value of 963 seconds/pcu, and the Degree of Saturation of 2,879. From the result of existing condition analysis, there are some steps of intersection scenario control need to be done in order to increase the performance and service as follow:

1. Cycle time recovery
2. Phase simulation (4 phases)
3. Phase change

1. Cycle Time Recovery

In cycle time existing condition of 177 seconds, the ideal cycle time control on 4-phase control is 80 – 130 seconds, with such condition needs cycle time recovery; after changing the cycle time, the new cycle time is 113 seconds. Based on the result of cycle time recovery analysis, there is an increasing of intersection service, which changes F to E, with the analysis result on Table-9.

Table-9.Result of Cycle Time Recovery Analysis

Performance Stage	Approach	Cycle Time (second)	Degree of Saturation *(DS)*	*Delay* (second/ pcu)	ITP
Cycle Time Recovery	K. SugionoSt. (N)	113	0.834	41.65	E
	P. AntasariSt. (E)		0.840		
	K. SugionoSt. (S)		0.819		
	P. AntasariSt. (W)		0.796		

On the stage of cycle time change, there is change on the service level but not too significant from the existing condition, F at first, changes to E, with Degree of Saturation value at 0.840 or ≤ 0.85.

2. Phase Simulation (4 Phases)

Phase simulation is done in 3 steps:

a. Controlling the phase on the foot of intersection on the north and south of KolonelSugionostreet.
b. Controlling the phase on the foot of intersection on the east and west of PangeranAntasaristreet.
c. Controlling the phase on the foot of intersection on the north – south intersection of KolonelSugiono street, dan the east – west of PangeranAntasaristreet.

On this stage of phase simulation, the analysis result of the intersection performance enhancement can be seen on Table-10.

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Table-10.Phase Simulation is Done Using Intersection Performance Analysis Result.

Performance Level	Approach	CT (second)	Degree of Saturation *(DS)*	Delay (second/ pcu)	ITP
Control of Foot of Intersection Phase of K.SugionoStreet North - South	Jl. K. Sugiono (N) Jl. P. Antasari (E) Jl. K. Sugiono (S) Jl. P. Antasari (W)	78	0.700 0.711 0.724 0.714	27.69	**D**
Control of Foot of Intersection Phase of P.AntasariStreet East – West	Jl. K. Sugiono (N) Jl. P. Antasari (E) Jl. K. Sugiono (S) Jl. P. Antasari (W)	89	0.785 0.763 0.776 0.513	31.63	**D**
K.Sugiono street North – South and P.Antsari Street East - West	Jl. K. Sugiono (N) Jl. P. Antasari (E) Jl. K. Sugiono (S) Jl. P. Antasari (W)	67	0.647 0.663 0.671 0.386	23.33	**C**

Based on phase simulation result, there is change in intersection performance enhancement, which are: the first existing condition is F on the control of foot of intersection phase of the north – south of KolonelSugiono street, turns to D with the Degree of Saturation value of 0.724;on the control of foot of intersection phase of the east – west of PangeranAntasari street, turns to D with the Degree of Saturation value of 0.785;and on the control of foot of intersection phase of the north – south of KolonelSugiono street, and the east – west of PangeranAntasari street, turns to C with the Degree of Saturation value of 0.671. Of those three results, the best intersection performance is the control of foot of intersection phase of the north – south of KolonelSugiono street and the east – west of PangeranAntasari street, with the C-level of intersection service, and the Delay (D) value of 23.33, and the Degree of Saturation (DS) value of 0.671 or ≤ 0.85, meaning that the current on that intersection is smooth.

3. Phase Change

The phase change stage is done by changing from 4 phases to 3 phases, with the adjustments as follow:

1. Change of 3 phases (merging of direction current of east – west)
2. Change of 3 phases (merging of direction current ofnorth – south)

The analysis result is acquired from phase change, as seen on Table-11.

Table-11.Intersection Performance Analysis Result after Phase Change is Done

Performance Level	Approach	Cycle Time (Second)	Degreeof Saturation (DS)	Delay(second/ pcu)	ITP
Change of 3 phases (merging of direction current of east – west)	K. SugionoSt. (N) P. AntasariSt. (E) K. SugionoSt. (S) P. AntasariSt. (W)	72	0.735 0.732 0.732 0.543	24.07	C
Change of 3 phases (merging of direction current of east – west)	K. SugionoSt. (N) P. AntasariSt. (E) K. SugionoSt. (S) P. AntasariSt. (W)	64	0.691 0.691 0.649 0.684	21.52	C

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As seen on the phase change analysis, there are changes in intersection performance; on the change of 3 phases (merging of direction current of east – west), the existing condition F has changed to C; and on the change of 3 phases (merging of direction current of north – south), it has changed to C. it cannot be done in this analysis, considering the result of merging the traffic current which needs an access to make a U-turn, meanwhile there is no access to make a U-turn on the streets of KolonelSugiono street and PangeranAntasari street.

From several handling alternatives, the best chosen one is the phase control of foot of intersection of the north – south of KolonelSugiono Street and the east – west of PangeranAntasari Street, with the C-level of intersection service, with the delay (D) value of 23.33, and the degree of saturation value (DS) value of 0.671 or ≤ 0.85, which means that the current on that intersection is smooth. The cycle time diagram is seen on Figure-3:

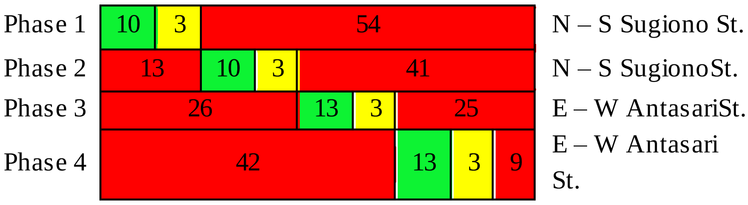

Fig.3: Phase Control Cycle Time Diagram of Kolonel Sugiono Street North – Southand Pangeran Antasari Street East – West.

V. CONCLUSION

There are many things to conclude based on the accomplished intersection handling scenario analysis, and to answer the problem statement, all at once; it is concluded that:

1. Based on the existing condition analysis, it is seen that the worst condition of Antasari intersection service level occurs in the noon with the F-level of service, the delay (D) value of 960 seconds/pcu, the degree of saturation value of 2,879 or ≥ 0.80, which shows the congestion on the intersection, and the cycle time of 177 seconds or ≥ 130 seconds meaning that the control of existing condition cycle time is not ideal.
2. From the accomplished control alternatives, the 4th alternative is the best for increasing the intersection level of service. In the 4th alternative, the phase on the foot of intersection of Kolonel Sugiono street north – south, and Pangeran Antasari street east – west, is adjusted and the intersection level of service has increased to C, with the delay (D) value of 23.33 seconds/pcu or ≤ 25 seconds/pcu, the degree of saturation (DS) value of 0,671 or ≤ 0.85, and the cycle time (CT) is 67 seconds or ≤ 80 seconds.

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