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IMPROVING MOBILITY IN KEDIRI CITY WITH MKJI ANALYSIS 1997 AND TIME SLICE AT SIMPANG EMPAT DHOHO PLAZA

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Abstract: The city of Kediri, as the third largest city in East Java, has cultural heritage, history and natural beauty that attracts visitors from various regions. However, population growth and motorized vehicles cause traffic jams. Signalized intersections, which are a solution to control intersection conflicts, require knowledge of intersection saturation flows to plan efficient traffic management. Analysis methods such as MKJI 1997 and Time Slice with Vehicle Operating Cost (BOK) calculations help design effective solutions. This research shows that adjusting cycle times, increasing effective width, and optimizing signals can improve transportation system performance and reduce congestion in Kediri City. Cycle time analysis taking into account factors such as vehicle type, traffic volume, and vehicle speed resulted in a cycle time of 90.7 seconds. The impact can be seen in the Degree of Saturation (DS) at various intersection arms, with service variations from E to F. Research also shows a decrease in waiting time/queuing for signal lights from 135 seconds to 118 seconds, which results in a decrease in the degree of saturation (DS) and changes in time cycle. The use of Smart Traffic Lights and traffic engineering, such as immediate left turns on the east arm and additional signs, is required. Evaluation of congestion cost efficiency shows that changing the value of side barriers can save Rp. 22,679,183 in the next five years.

Keywords: Congestion Costs, MKJI 1997, Signalized Intersections, Time Slice

INTRODUCTION

Kediri, as the third largest city in East Java after Surabaya and Malang, is known for its cultural heritage, history and natural beauty.[1]. With a population reaching 289,418 people (BPS Kediri City 2023),[2]. as well as significant economic growth, the city attracts visitors from various regions[3]. Even though Kediri City provides a variety of shopping centers, the increase in population and motorized vehicles has caused traffic jams, where traffic flows exceed road capacity. This challenge becomes serious in Kediri City because it is caused by population density and lack of an adequate transportation system [4]. Signalized intersections are intersections equipped with traffic lights to regulate intersection conflicts[5]. The placement of traffic lights at intersections affects traffic flow and intersection capacity. Intersection saturation flow and intersection capacity are important parameters in planning and regulating traffic at highway intersections. Knowledge of intersection saturation flow is needed to calculate intersection capacity and plan efficient traffic management[6]. Traffic intersections, as road nodes, are also a major concern because they often cause conflicts between traffic participants [7]. This obstacle is not only a local problem, but reflects transportation problems in developing countries such as Indonesia [8]. With limited resources and suboptimal operation of transportation systems, addressing this problem is increasingly difficult. Congestion not only harms mobility, but also has a negative impact on air pollution and public health [9] [10].

To overcome this problem, comprehensive steps are needed. Analysis methods such as MKJI 1997 and the Time Slice method with calculating Vehicle Operating Costs (BOK) in traffic jams can help design effective solutions. MKJI 1997 is used to analyze the level of saturation and road service, while the Time Slice method for road traffic helps calculate saturation flow by dividing green and yellow periods into certain time slices. This allows the calculation of average traffic flow under saturated conditions that is free from the influence of time loss. This method can be used in conjunction with the Indonesian Road Capacity Manual (MKJI 1997) to analyze the performance of signalized intersections and design effective solutions to overcome traffic congestion on highways. This approach can help optimize traffic signal controllers by reducing congestion, emissions and fuel consumption [11]. Several previous studies [12] using a combination

of the MKJI 1997 and Time Slice methods have shown that changing cycle times, increasing effective width, and signal optimization can improve transportation system performance and reduce congestion [13][14].

This research provides a basis for evaluating and improving the quality of land transportation infrastructure. With a deeper understanding of optimizing road capacity, a comprehensive analysis using simulations of the impact of changes using Time Slice and BOK calculations is expected to produce more effective solutions in overcoming urban congestion in Kediri City. However, further research is needed to fill knowledge gaps and identify innovative strategies in dealing with increasingly complex transportation challenges in Kediri City.

RESEARCH METHOD

The research subject in this article is the signalized intersection on Jalan Dhoho Plaza, Kediri City, which is one of the connecting routes between Kediri City and the cities of Tulungagung, Blitar and Trenggalek. This road often experiences traffic jams on the west (Jl. Brigjen Ngalim) and south (Jl. Urip Sumoharjo). This intersection is categorized as an intersection with phase 411, has a protected road type, and is located in a Commercial Complex (COM). The survey was conducted over three days, namely Monday, Friday and Saturday, considering that the majority of workers in Kediri have holidays on Saturday and Sunday. Data collection was carried out for 14 hours, starting from 06:00 to 20:00 WIB. This research chose this time period with the assumption that it could reflect traffic flow conditions on weekdays, weekends, and when activities occur.

Figure 1. Location Roads

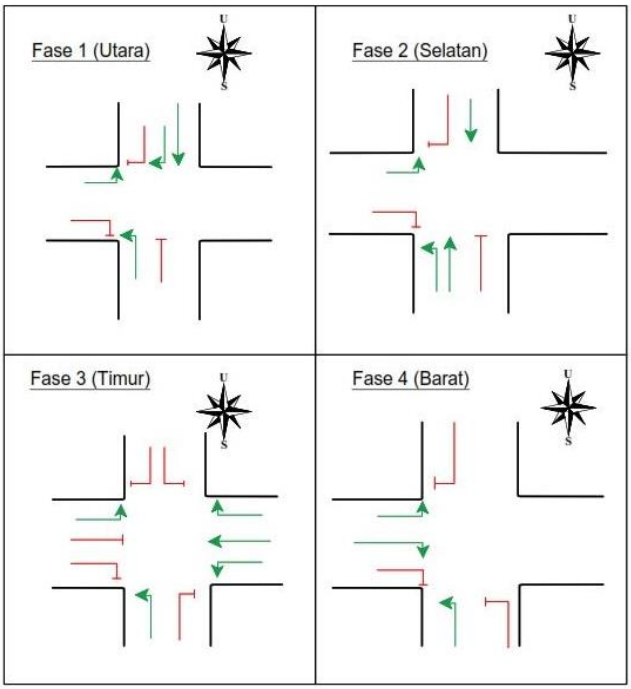

Figure 2. Phase Details on 4-way intersection Dhoho Plaza Kediri

This research uses two types of data, namely primary data and secondary data:

1. Data Primer

In the analysis of the Jalan Dhoho Plaza intersection in Kediri City, the main information obtained directly involved vehicle traffic volume, road geometry, speed, capacity, degree of saturation, and signal timing [15]. Traffic volume was collected through manual surveys based on the 1997 MKJI vehicle classification. Road geometric parameters, such as lane width, shoulders and medians, were measured directly in the field. To understand the movement aspects, information regarding vehicle speed and slowness is identified. Determining signal timing, using the MKJI method, involves collecting data on the duration of red, green and yellow lights for 3 days at the Jalan Dhoho Plaza Kediri intersection. Although these steps provide insight, there is still room for further research to develop innovative strategies to overcome the complexity of transportation in Kediri City [16].

2. Data Secondary

Secondary data used to complete the analysis includes a map of Kediri City, information regarding the function and class of roads, population, and statistics on the number of vehicles. The source of this data comes from the Level I Kimpraswil Service, the Central Statistics Agency, and the Kediri City Transportation Department. By collecting this information, it is hoped that it can provide a broader context and support a more comprehensive understanding of city conditions and other factors that can influence the transportation system in Kediri City.

Jl. Urip Sumoharjo (South)

Jl. Bandar Ngalim (West)

Jl. Commander Sudirman (North)

Jl. Brigadier General Katamso (East)

Figure 3. Geometric Road Conditions at Dhoho Plaza Signaled Interchange

Data Analysis

To calculate Vehicle Operational Costs (BOK) during traffic jams in the next 5 years, this can be done using a quantitative approach and the road capacity method (MKJI 1997) and Time Slice. The data analysis steps involve collecting data on traffic volume, average speed, and road capacity on the section to be analyzed. Road capacity is calculated using the 1997 MKJI method, taking into account road width, number of lanes and type of vehicle. Time slice analysis is carried out by calculating the time it takes for a vehicle to cross a road section. Calculation of BOK during traffic jams involves the formula BOK = (base rate + congestion rate) x distance traveled, with congestion rates calculated based on additional time during heavy traffic. Finally, BOK projections for the next 5 years are carried out by considering traffic volume growth

and changes in congestion rates. Through this analysis technique, accurate BOK calculations can be produced to anticipate future congestion conditions.

The formulas used are as follows:

1. Traffic Volume
   The number of vehicles passing an observation point in a certain time period is known as traffic volume [17]. Traffic volume calculations can be done using the following formula:

$$Q = \frac{n}{t} \quad (1)$$

   Where:
   Q = volume of traffic passing through a point
   n = number of vehicles passing that point in the observation time interval
   t = observation time interval

2. Basic Saturated Current (So) and Intersection Saturated Current (S)
   Saturated Flow occurs when a traffic light has a green signal for a long time at an intersection. The amount of Saturated Flow is calculated by taking into account the width of the road and applying a correction factor to take into account elements that can reduce the smoothness of the ideal flow. These factors include grade, vehicle composition, turning traffic maneuvers, pedestrian activity, and parked vehicles. Determination of the amount of Saturated Current is carried out using the following formula:

$$So = 600 \times We \quad (2)$$

   Information:
   We = Entrance width of an Approach

   Intersection Saturated Flow (S) is the maximum capacity before congestion occurs [15]. The S value is calculated from the vehicle volume and a certain time duration with a formula involving basic saturation current (So), standard saturation current (with adjustment factor F), and a set of previously established ideal conditions. The formula for intersection saturated current [18] can be presented as follows:

$$S = So \times F1 \times F2 \times F3 \times F4 \times \ldots \times Fn\ (smp/jam) \quad (3)$$

   Information:
   So = Basic Saturated Current
   F = Adjustment Factor

   Adjustments are then made for the following conditions:

1. City Size	CS, millions of people	
2. Side Obstacles	SF, side resistance class of the environment and non-motorized vehicles	street
3. Smoothness	G, % up (+) or down (-)	
4. Parking	P, stop line distance – first parked vehicle	
5. Turning Movement	RT, % right-turns LT, % turn-left	

   So the formula for Intersection Saturated Current (S) is as follows:

$$S = So \times Fcs \times Fsf \times FG \times FP \times FRT \times FLT\ (smp/jam) \quad (4)$$

3. Capacity (C) and Degree of Saturation (DS)
   Road capacity (C) is a quantity that shows the maximum number of vehicles that can be served by a road section in one unit of time, generally in one hour [19]. Road capacity is expressed in units pcu/hour (motor vehicle units per hour). In general, road capacity does not change throughout the day, but can vary based on traffic conditions. Increasing road capacity can help solve congestion problems. The amount of road capacity is influenced by various factors such as road width, number of lanes, and type of vehicles passing

$$C = S \times \frac{gi}{co} \quad (5)$$

   Information:
   S = Saturated Current of Intersection (pcu/hour)
   gi = Cycle Time

The degree of saturation (DS) is a comparison between traffic volume (V) and road capacity (C). The theoretical value is between 0 - 1, where if the value is close to 1, the road condition is approaching saturation

[20]. The degree of saturation is used as an indicator of traffic performance and shows whether a road segment has capacity problems or not.

$$DS = \frac{Q}{C} \qquad (6)$$

Information:
Q = Traffic flow (pcu/hour)

4. Calculation of Vehicle Operating Costs (BOK)
   Calculation of Vehicle Operational Costs (BOK) is a calculation of the costs of all factors related to the operation of one vehicle in normal conditions and in traffic jam conditions. Vehicle operating costs consist of two parts, namely direct costs and indirect costs. Direct cost components include depreciation costs, capital interest, vehicle crew, fuel, tire usage, vehicle maintenance/repair, terminal fees, administration, insurance and vehicle KIR.

$$BOK = 0.4937V^2 - 60.218V + 2991.9 \qquad (7)$$

RESULT AND DISCUSSION

Analysis and Calculations Using the 1997 MKJI Method

1. Daily Traffic Volume Results (LHR)

Research evaluating the performance of roads at Simpang Empat Dhoho Plaza was carried out by taking traffic flow data from various types of vehicles, such as motorbikes, light vehicles, medium heavy vehicles and non-motorized vehicles. From the data obtained, it can be seen that heavy traffic volume occurs on Saturdays. Apart from that, existing geometric data at the intersection of four Dhoho Plaza Kediri can be seen in Figure 1, and the results of traffic volume can be seen in the following graph.

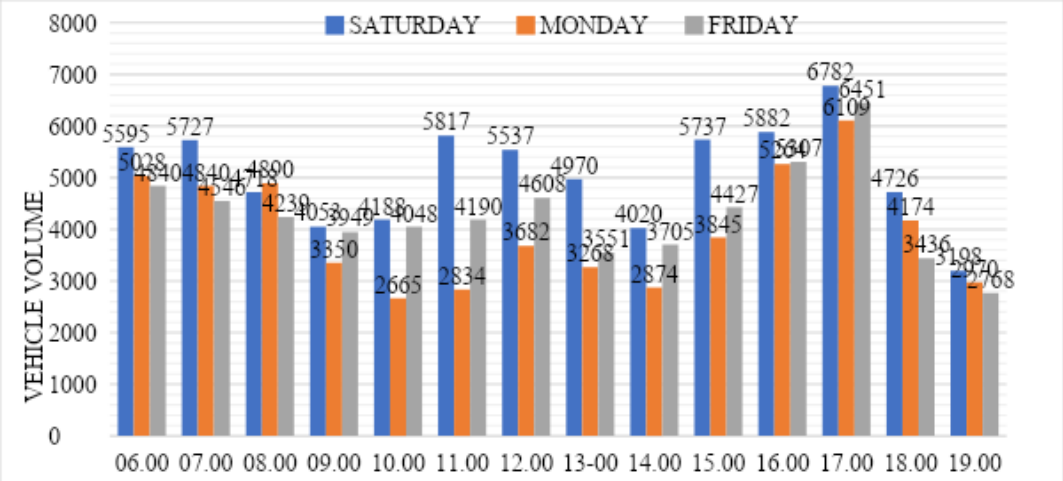

Figure 4. Graph of Time Interval Relationship with Vehicle Volume

Peak hour volume (VJP) is known to occur on Saturdays at 17:00 – 18:00 with a total vehicle volume of 6782 kend/hour. Result

Table 1. Traffic Flow Conditions at Peak Hours 17:00 – 18:00 WIB (Combined)

Street Direction	Street Name	Traffic FLow (smp/hour)		
		Left	Right	Straight
North	Panglima Sudirman	474	490	589
East	Brigjen Katamso	465	467	459
South	Urip Sumoharjo	453	266	598
West	Bandar Ngalim	536	649	336

In the table above is the peak current condition that occurs. From the peak current, it is presented according to the direction of the vehicle's destination. The current above is a combination of inlet current and outflow on the arm of that direction.

2. Results of Basic Jenus Current (So) and Intersection Saturated Current (S)

To calculate the basic saturation current, a calculation is carried out by calculating the effective width of the intersection gate and the number of vehicle flows passing through the intersection, based on survey data that has been obtained using the Eq.2 formula. Previously, saturation current calculations were carried out to determine the factors that influence the capacitance value. The following are the results of saturated flow calculations for the Jalan Panglima Sudirman (North) section.

$So = 600 \times We$

So = 600 ×10 meter

So = 6.000 Smp/Hour

After getting the results of the Basic Saturation Current (So) calculation, you will then calculate the Intersection Saturation Current (S) value using equation 3. The following is the calculation of intersection saturation flow (S) on the Jalan Panglima Sudirman (North) section:

$S = So \times Fcs \times Fsf \times FG \times FP \times FRT \times FLT$

$S = 6000 \times 0{,}83 \times 0{,}94 \times 1 \times 1 \times 1 \times 1$

S = 4681 pcu/hour

The following are the results of the Basic Jenus Current (So) and Intersection Saturated Current (S):

Table 2. Results of Basic Saturation Current and Signaled Simpang empat Dhoho Plaza Kediri

Direction	Effective width	Basic Saturated Current	City Size Factor	Side Resistance Factors	Factor Kelandsan	Factor Parking	Factor Turn Right	Factor Turn Left	Interchange Saturation Current
	We	So	Fcs	Fsf	FG	FP	FRT	FLT	S
North	10	6000	0,83	0,94	1,00	1,00	1,00	1,00	4681
East	7	2850	0,83	0,94	1,00	0,74	1,00	1,00	1645
South	4,5	4200	0,83	0,94	1,00	0,74	1,00	1,00	2425
West	5	3000	0,83	0,94	1,00	0,74	1,00	1,00	1732

The results above will obtain intersection saturation flow results which will be used to calculate the traffic capacity of the intersection.

3. Cycle Time Results

At the four-way intersection with the Dhoho Plaza signal, phase 411 results are obtained with green time, All Red Time and Yellow Time.

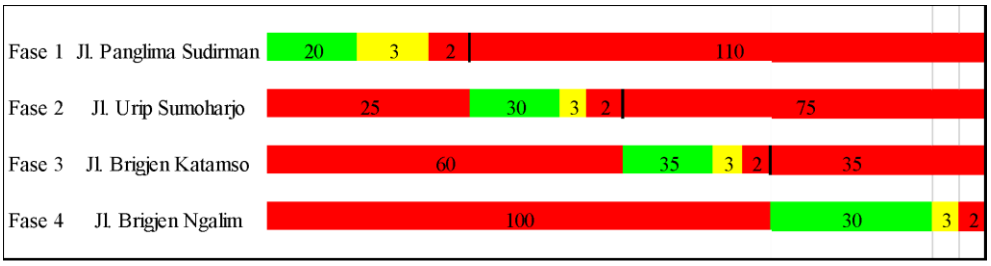

Figure 5. Dhoho Plaza Signaled Four-Junction Phase Diagram

From the results of the Dhoho Plaza intersection phase, the following cycle time calculations will be obtained:

Table 3. Cycle Time for each Phase at Simpang Dhoho Plaza

Direction	Street Name	Green Time (gi) (seconds)	Total Time Lost (LTI) (seconds)	Current divided by Saturated Current (FR)	Signal Cycle Time (co)
North	Panglima Sudirman	20	20	0,213	90,7
East	Brigjen Katamso	35	20	0,614	90,7
South	Urip Sumoharjo	30	20	0,229	90,7
West	Bandar Ngalim	30	20	0,591	90,7

The Dhoho Plaza intersection, with 4 phases, has a cycle time of 90.7 seconds. These results form the basis for improving traffic efficiency and designing better management strategies around the area. Careful cycle time analysis opens up opportunities for improving the quality of the traffic experience and the efficiency of the transportation system as a whole.

4. Capacity Results (C), Degree of Saturation (DS)

Approach capacity is calculated by multiplying saturation current by green time, resulting in the following calculation:

- Capacity (C)
  North = S $\times\frac{gi}{co}$ = 4681 $\times \frac{20}{90,7}$ = 1031,8 Smp/Hour
- Degree of Saturation (DS) North Direction
  DS (north) =$\frac{Q}{C}$ = $\frac{998}{1031,8}$ = 0,97

Table 4. Analysis of Capacity (C) and Degree of Saturation (DS) at the Dhoho Plaza signalized intersection

Direction	Street Name	Interchange Saturation Current (S)	Capacity (C)	Traffic Flow (Q)	Degree of Saturation (DS)
		Smp/Hour	Smp/Hour	Smp/Hour	
North	Panglima Sudirman	4681	1031,8	998	0,97
East	Brigjen Katamso	1645	544,0	1011	1,86
South	Urip Sumoharjo	2425	935,3	555	0,59
West	Bandar Ngalim	1732	572,7	1211	2,11

Based on the analysis results listed in the table above, it can be concluded that the Dhoho Plaza signalized intersection has a Degree of Saturation (DS) value of 1.4, which is classified as category F. This conclusion indicates that there is a significant level of traffic density. Therefore, it is recommended to make improvements to the intersection signal lights to reduce the level of congestion and increase the level of service provided. Efforts to improve the light signal system can be a critical step in increasing the efficiency and smooth flow of traffic at the Dhoho Plaza signalized intersection.

Handling Signalized Intersections using Time Slice

1. Alternative Signalized Intersection

From the improvements it was found that the DS value dropped and affected the calculated cycle time. The following is the calculation and comparison of cycle times before and after reconstruction.

Table 5. Cycle Time for each Phase at Simpang Dhoho Plaza

Direction	Green Time (gi) (seconds)	Total Time Lost (LTI) (seconds)	Current divided by Saturated Current (FR)	Signal Cycle Time (c)	Traffic Flow (Q) (Smp/Hour)
North	15	18	0,200	40,0	898
East	30	18	0,427	55,9	951
South	15	18	0,159	38,1	525
West	40	18	0,486	62,3	1089

The data above was obtained from prediction data from passenger data at the terminal and daily visitors to the city of Kediri.

Table 6. Analysis of the Degree of Saturation at the Dhoho Plaza Signalized Intersection

Direction	Intersection Saturated Current (S)	Capacity (C)	Traffic Flow (Q)	Degree of boredom he(DS)
	junior high school/Hr	junior high school/Hr	junior high school/Hr	
North	4980	1866,8	898	0,47

Direction	Intersection Saturated Current (S)	Capacity (C)	Traffic Flow (Q)	Degree of boredom he(DS)
	junior high school/Hr	junior high school/Hr	junior high school/Hr	
East	2366	1270,1	951	0,72
South	3486	1374,1	525	0,38
West	2490	1598,9	1089	0,62

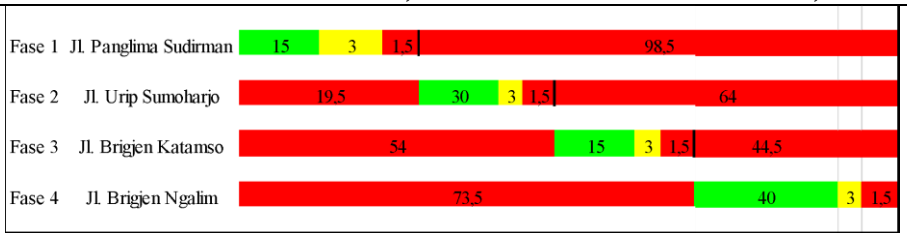

Figure 6. Current Level at Each Approach to Reconstruction Conditions

From the results of the reconstruction calculations above, it can be seen that travel time efficiency has decreased from 135 seconds to 118 seconds, or a decrease of 17 seconds.

Calculation of Vehicle Operating Costs (BOK)

With the results obtained from time and cost calculations and with the assumption that in the next 5 years the growth of road facility users, especially the Dhoho Plaza intersection, will not experience significant growth, the final results obtained are as in table 7.

Table 7. Congestion Costs at Simpang Empat Dhoho Plaza Kediri After Reconstruction

Direction	Vehicle Type an	Number of Vehicles (N)		BOK Rp.Kend/km (G)		Congestion Fee (Rp/Kend.Hour)	
		Exciting conditio n	Alternati ve Conditio ns	Excitin g conditio n	Alternati ve Conditio ns	Exciting condition	Alternative Conditions
North	H.V	17	12	Rp1.758	Rp1.758	IDR 29,715	Rp. 21,099
	LV	83	75	Rp1.758	Rp1.758	Rp145.937	IDR 131,871
	MC	97	89	Rp1.758	Rp1.758	Rp170.553	Rp156.487
	ONE	1	1	Rp1.758	Rp1.758	Rp1.407	Rp1.758
East	H.V	4	4	Rp1.742	Rp1.742	Rp6.969	Rp6.969
	LV	324	297	Rp1.742	Rp1.742	Rp517.438	Rp517.438
	MC	144	124	Rp1.742	Rp1.742	Rp216.035	Rp216.035
	ONE	0	0	Rp1.742	Rp1.742	Rp0	Rp0
South	H.V	39	23	Rp1.762	Rp1.762	Rp68.701	Rp40.516
	LV	186	125	Rp1.762	Rp1.762	Rp327.652	₹220.196
	MC	134	110	Rp1.762	Rp1.762	Rp236.491	Rp193,773
	ONE	4	2	Rp1.762	Rp1.762	Rp7.751	Rp3.523
West	H.V	62	34	Rp1.756	Rp1.756	Rp109.573	Rp59.703
	LV	284	235	Rp1.756	Rp1.756	Rp498.696	Rp412.653
	MC	129	119	Rp1.756	Rp1.756	Rp226.081	Rp208,960
	ONE	5	2	Rp1.756	Rp1.756	Rp9.482	Rp3.512
TOTAL						**₹2.572.480**	**Rp2.194.494**
TOTAL COSTS FOR 1 YEAR						**Rp30.869.765**	**Rp26,333,928**
TOTAL COSTS 5 YEARS						**Rp154.348.824**	**Rp131.669.641**
Rp22,679,183							

From the results of Table 7 it is clear that there is a fairly large cost comparison between the existing condition and the alternative condition, where in the existing condition the level of use of congestion charges that must be paid by road users within 5 years is IDR 154,348,824,- while in the alternative condition the congestion charge must be paid. incurred by road users within 5 years amounting to Rp. 131,669,641,- The difference in costs within 5 years from the existing condition and alternative conditions is Rp. 22,679,183,-.

CONCLUSION

After analyzing the cycle time by taking into account various factors such as vehicle type, traffic volume, and vehicle speed, it was found that the cycle time (co) was 90.7 seconds. These results will have an impact on the Degree of Saturation (DS) at various intersection arms, where the northern arm reaches 0.97 with service level E, the eastern arm reaches 1.86 with service level F, the southern arm reaches 0.58 with service level C, and the west arm reached 2.11 with a service level of F. Apart from that, the analysis also shows that the waiting/queuing time for signal lights can be reduced from 135 seconds to 118 seconds. Therefore, these improvements will have a significant impact on the degree of saturation (DS) and cycle time. Apart from using Smart Traffic Lights, engineering by implementing direct left turns on the east arm and adding adequate signs is also needed. The results of the efficiency level of congestion costs for users of the Pahing Market intersection in the next 5 years from the alternative of changing the value of side barriers are able to influence the value of waiting/queue time and fuel/congestion costs by IDR. 22,679,183.

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