THE DELAYS FOR SIGNALIZED INTERSECTION USING ATCS DATA AND FIELD SURVEY METHOD
(Case Study At Simpang Tiga Kerten, Surakarta)

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THE DELAYS FOR SIGNALIZED INTERSECTION USING ATCS DATA AND FIELD SURVEY METHOD (CASE STUDY AT SIMPANG TIGA KERTEN, SURAKARTA)

TUNDAAN PADA SIMPANG BERSINYAL DENGAN MENGGUNAKAN DATA ATCS DAN METODE SURVAI LAPANGAN (STUDI KASUS SIMPANG TIGA KERTEN, SURAKARTA)

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ABSTRACT
The increasing of traffic flow in Surakarta has caused the increasing of congestion in several road networks. One of traffic jam phenomenon at intersection especially in peak hour can be found at some sigalized intersections and roads especially in Simpang Tiga Kerten. It is located at the meeting between Jl. Slamet Riyadi and Jl. Ahmad Yani, Surakarta. Traffic delay at signalized intersection is used as an indicator to evaluate intersection performance refers to MKJI 1997. This resesarch means to compare the MKJI 1997 delay with the field delay using ATCS. The implementation of manual traffic counts survey carried out for a day mainly at morning peak hour (06:00-07:00 AM) appropiate with traffic counting data of ATCS detector Dishubkominfo Surakarta after converted in passanger cars unit. The datas which is obtained from field observation for calculating delay is the data of waiting vehicle for interval time 15 seconds, stopped (in red and amber time) and not stopped (in green and amber time) vehicles. Based on the comparison result, the field delay is lower than the MKJI 1997 delay. This is caused by the differences in withdrawal traffic flow data that will be used in the delay calculation analysis.
Key words: delay, ATCS, MKJI 1997

ABSTRAK
Meningkatnya arus lalu lintas di Surakarta menyebabkan peningkatan kemacetan di beberapa jaringan jalan. Salah satu fenomena kemacetan lalu lintas di simpang bersinyal dapat dijumpai di Simpang Tiga Kerten, terletak pada pertemuan antara Jl. Slamet Riyadi dengan Jl. Ahmad Yani, Surakarta. Tundaan lalu lintas pada simpang merupakan salah satu tolok ukur dalam menilai kinerja simpang pada MKJI 1997. Penelitian ini mencoba untuk membandingkan tundaan MKJI 1997 dengan tundaan lapangan menggunakan ATCS. Pelaksanaan survai manual arus lalu lintas tundaan MKJI 1997 dan tundaan lapangan dilaksanakan selama 1 hari, yaitu pada h puncak pagi (06.00 – 07.00 WIB) sesuai dari data *traffic counting* detektor ATCS Dishubkominfo Surakarta setelah dikonversikan dalam satuan mobil penumpang. Data yang diperoleh dari pengamatan lapangan untuk perhitungan tundaan lapangan adalah data kendaraan jumlah kendaraan yang menunggu setiap interval waktu 15 detik, kendaraan berhenti (pada saat lampu merah dan amber) dan kendaraan tidak berhenti (pada saat lampu green dan amber). Berdasarkan hasil perbandingan, nilai tundaan lapangan lebih kecil dibandingkan dengan tundaan MKJI 1997. Hal ini disebabkan oleh perbedaan dalam metode pengambilan data arus lalu lintas yang akan digunakan untuk analisis perhitungan tundaan.
Kata kunci: tundaan, ATCS, MKJI 1997

INTRODUCTION

The increasing of traffic volume in Surakarta has caused an increasing of congestion in several road networks. The congestion has caused i.e. driver stress, tired, the waste of fuel costs and the impact on the increasing of air pollution. Such condition can take place in peak hour, which is in the departure toward offices and schools or the return from schools and offices. Traffic jam phenomenon at intersection especially in peak hour can be found at some sigalized intersections and roads especially in Simpang Tiga Kerten, Surakarta. The Local Government through the Communication, Informatics and Transportation Department (Dishubkominfo) Surakarta is developing integrated traffic management control system named Area Traffic Control System (ATCS). This system is equipped at the intersection with high traffic flow. Based on the year, the Government implemented phase I - IV during 2006 - 2009 and phase V in 2010,

they were assisted by the the Ministry of Transportation (Soedrajat, 2013). ATCS technology is a green transport infrastructure that can be used to manage all of the traffic movements at signalized intersection through the central control of ATCS.

The aim of ATCS is to enable the vehicle movement continuously and minimize the delay in intersection (Risdiyanto, 2014). On the other hand, ATCS also plays a role in producing the best performance for traffic situation at present. According to Alamsyah (2005), the performance of traffic flow can be measured as a delay, the number of stopped, travel time, traffic safety, freedom of movement, and pollution (gas emision and noise).

Traffic delay at signalized intersection is used as an indicator to evaluate the performance of intersection refers to MKJI 1997. The using of MKJI 1997 method for the traffic condition at present needs to be evaluated. The delay value needs to be compared with the result of field survey method using ATCS. According to Noor (2007) the implementation of ATCS at signalized intersection reduced delays up to 40%. Based on the results of the comparison of the delays by using MKJI 1997 method and field survey method, it can be known the most relevant method to analyze the delay according to a real field condition.

This research has purposes i.e.knowing these factors which are considered in calculation analysis of delay for signalized intersection that using ATCS data by using MKJI 1997 and field survey methods, finding the delay value produced by using MKJI 1997 method, finding the delay value produced by using field surveys method and comparing the delay value at signalized intersection uses two methods above.

Delay

Alamsyah (2005) states that delay is an additional time additional time that is required to pass an intersection compared to without pass intersection. In this case is used two methods in delay analysis i.e. MKJI 1997 and field delay methods.

a) MKJI 1997 Method

According to Munawar (2009), MKJI 1997 delay is divided by:

1) Traffic delay (DT), due to traffic interaction with other movements (the influence by other vehicles).

$$DT = c\ x\ A + \frac{NQ_1\ x\ 3600}{C} \quad (1)$$

where:
DT = average traffic delay (sec/pcu).
c = cycle time (sec).

$$A = \frac{0.5\ x\ (1 - GR)^2}{1 - GR\ x\ DS} \quad (2)$$

GR = green ratio (g/c).
DS = degree of saturation.
C = capacity (pcu/h).
NQ_1 = number of pcu that remains from the previous green phase.

2) Geometric delay (DG), due to acceleration and deceleration when making a turn in the intersection and/or when being stopped by traffic light.

$$DG = (1 - P_{SV})\ x\ \rho_T x\ 6 + (P_{SV}\ x\ 4) \quad (3)$$

where:
DG = average geometric delay (sec/pcu).
P_{SV} = vehicles stopped ratio at approach, Min (NS= 1).
P_T = vehicle turn ratio.

3) Delay due to LTOR *(Left Turn On Red)*
Delay due to LTOR (D_{LTOR}) is taken 6 seconds.

4) Average delay (D)

$$D = DT + DG \quad (4)$$

5) Total delay (D_{total})

$$D_{total} = D\ x\ Q \quad (5)$$

6) Average delay for the entire intersection

$$D_I = \frac{\Sigma(QxD_j)}{Q_{TOT}}(\text{sec/pcu}) \quad (6)$$

b) Field Survey Method

Measurements of delay as proposed by Mc Shane and Roses 1990 (in Alamsyah, 2005) in brief i.e:

1. Location observers should be able to reach all queue.
2. The observation periods that can be used are 10, 15 or 20 seconds.
3. Write number of stopped and not stopped vehicles during the observation.
4. Count the number of waiting vehicles before intersection.

The equations that can be used for data analysis according to Risdiyanto (2008) as follows:

1) Number of stopped and not stopped vehicles

$$Q_{total} = Q_{stopped} + Q_{not\ stopped} \quad (7)$$

2) Total delay

$$\Sigma D = Q_{waiting}\ x\ T_{observation} \quad (8)$$

3) Average stopped delay vehicle

$$DT_s = \frac{\Sigma D}{Q_{stopped}} \quad (9)$$

4) The percentage delayed vehicle

$$\%\ QD = \frac{Q_{stopped}}{Q_{total}} x100 \quad (10)$$

5) Average delay for all vehicles

$$DT_{s\ Total} = \frac{\Sigma D}{Q_{total}} \quad (11)$$

where:

Q_{total} = sum of all the volume of stopped and not stopped vehicles (pcu/hours).

$Q_{stopped}$ = sum of all the volume of stopped vehicles at intersection (pcu/hours).

$Q_{not\ stopped}$ = sum of all the volume of not stopped vehicles at intersection (pcu/hours).

$Q_{waiting}$ = sum of all the volume of waiting vehicles volume in *range* 15 seconds (pcu/hours).

$T_{observation}$ = observation duration (seconds).

ΣD = total delay (seconds).

DTs = average delay all vehicles (sec/pcu).

%QD = percentage delayed vehicle (%)

$DT_{s\ Total}$ = average delay all vehicles (sec/pcu)

RESEARCH METHODS

This research is located at Simpang Tiga Kerten at Jl. Slamet Riyadi and Jl. Ahmad Yani Surakarta. This location has been equipped with the first ATCS installation in 2006, and it can be used for visually observation although traffic volume at intersection is crowded.

Data collection

There are two types of data i.e primary and secondary datas.

1. Secondary Data

Secondary data is obtained data from the related institution or transportation department, in this case is Communication, Informatics and Transportation Department (Dishubkominfo) Surakarta authorized in the availablity of processed data. Data sourced from Communication, Informatics and Transportation Department (Dishubkominfo) Surakarta consist of:

a) Research location map.
b) ATCS data at all aproaches of Simpang Tiga Kerten i.e. cycle (green time, amber and allred), recording video of monitoring and controlling intersection and traffic counting data every 15 minutes in veh/hour from 06:00 AM - 18:00 PM from ATCS detector.
c) Data of population.

2. Primary Data

Primary data is obtained data from direct observation in the field. Obtained data from the field is as follows:

a) Geometric and environmental condtion
Geometric and environmental conditions data are obtained data by measuring road width, approach width, the number of lanes, and also observing the activities around intersection.
b) Traffic flow
This data are number of each type of vehicle and each type of movement.
c) Waiting vehicles data
It is obtained data by counting the number of queued or waiting vehicles every 15 seconds when red and amber time.
d) Stopped vehicles data
It is obtained data by counting the number of stopped vehicles when red and amber time.
e) Not stopped vehicles data
It is obtained data by counting the number of not stopped vehicles when green and amber time.

After preparing, determining the time of survey from Dishubkominfo Surakarta and preliminary survey, then the next step is to conduct the main survey. The total demand of suveyor is 44 surveyors distributed at West and North approaches around 12 surveyors, and at East around 20 surveyors. This survey conduct on Thursday, June 5th, 2014 mainly at morning peak hour (06:00-07:00 AM).

RESULT AND DISCUSSION

a. Empirical delay by using MKJI method

1. Traffic signal condition

Traffic signal in the location of reseach is arranged into 3 stages / 3 phases, as shown in Figure 1, it is obtained by counting the average signal time setting plan of Dishubkominfo Surakarta, it can be seen in Table 1.

Table 1. Signal time setting plan in 3 phases

Phase	Approach	Cycle time setting plan			
		Green	Yellow	Allred	Cycle
A	East (RT) East (ST_1)	17	3	3	102
B	East (ST_2) West	33	3	3	
C	Nortt	34	3	3	

(Source: Dishubkominfo Surakarta)

Signal phase diagram can be seen in Figure 1.

2. Geometric data

Result of the effective width measurement (W_e) for each phase can be seen in Table 2.

Table 2. Result of of the effective witdh measurement (W_e)

Phase	Approach	W_A (m)	W_{ENTRY} (m)	W_{LTOR} (m)	W_{EXIT} (m)	W_e (m)
A	E-RT E-ST_1	6	3 3	0 0	5,9 5,9	3 3
B	E-ST_2 W	3 10,7	3 6,5	0 4,2	5,9 6	3 6,5
C	N	7	3,2	3,8	5,9	3,2

(Source : Hasil pengukuran lapangan)

3. The environmental condition data

There are some public facilities (i.e. Panti Waluyo Hospital, Solo Square Mall, schools, BST bus stops and office buildings) around the intersection, so generally the activities around the intersectioncan be classified as commercial area. The side friction in Simpang Tiga Kerten is fairly high based on visual observation. It is due to the increasing activities of pedestrians, bicycles and pedicabs. This conditionhas caused an increasing of defection activity, loading and unloading proccess of public transport.

4. Gradient

Based on visual observation in the field, this location can be classified as an area on flat condition with 0% of gradient

5. Total population of Surakarta

The total population according to data from Communication, Informatics and Transportation Department (Dishubkominfo) Surakarta in 2013 is approximately around 570,000 persons.

6. Traffic flow condition

Traffic flow recapitulation at Simpang Tiga Kerten in passenger car units can be seen in Table 3.

7. Saturation flow

Saturation flow calculation result can be seen in Table 4.

8. Capacity and degree of saturation

Cycle time that will be used in capacity calculation is obtained by counting the average cycle time setting plan data from Dishubkominfo Surakarta, that is 102 seconds. Calculation result of capacity and degree of saturation are in Table 5.

Table 5. Calculation result of capacity (C) and degree of saturation (DS)

Phase	Approach	Q (pcu/h)	S (pcu/h green)	G (sec)	C (pcu/h)	DS
A	E-RT	310	1837,57	17	306,26	1,012
	E-ST_1	190,7	1584,81	17	264,13	0,722
B	E-ST_2	370,3	1582,74	33	512,06	0,723
	W	880,6	3315,40	33	1072,63	0,821
C	N	516,2	1941,67	34	647,22	0,798

Based on the calculation result above shows that DS oversaturated in phase A at East approach right turn direction (T-RT) is 1.012. It has exceed the ideal DS required by MKJI 1997 (DS < 0.85). To reduce the DS value, it is needed to recalculate the signal time, so it can be used to anticipate long queue and delay values that too high by using MKJI 1997 method.

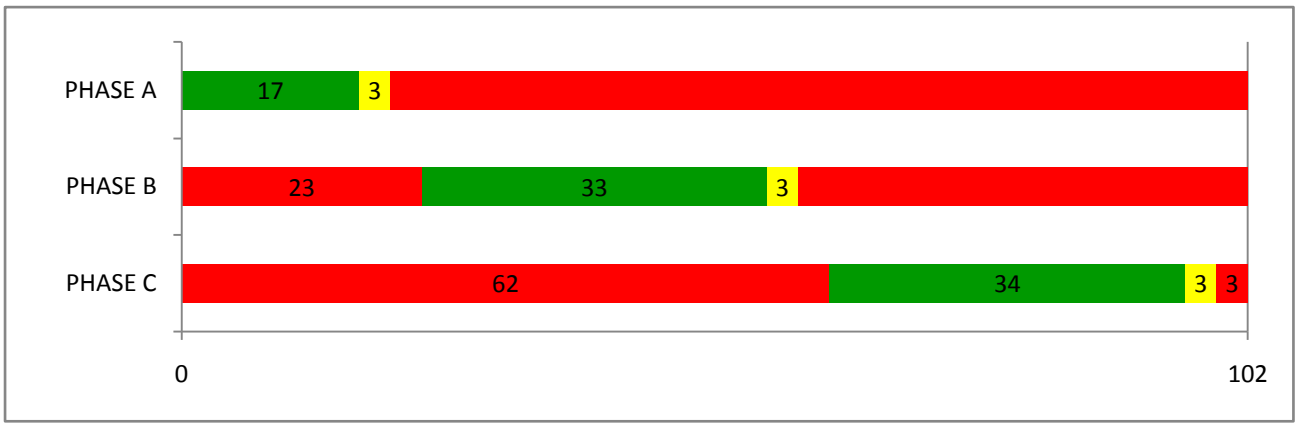

Figure 1. Signal phase diagram

Table 3. Traffic flow recapitulation Simpang Tiga Kerten (Thursday, June 5th, 2014 : 06:00-07:00 AM)

Phase	Approach	Direction	Motorised vehicle								Unmotorised (UM) veh/h
			Light vehicle (LV)		Heavy vehicle (HV)		Motorcycle (MC)		Total motor vehicle (MV)		
			veh/h	pcu/h emp = 1,0	veh/h	pcu/h emp = 1,3	veh/h	pcu/h emp = 0,2	veh/h	pcu/h	
A	E	RT	189	189	22	28,6	462	92,4	673	310	4
		ST_1	108	108	2	2,6	400	80	510	189,3	5
		Total	**297**	**297**	**24**	**31,2**	**862**	**172,4**	**1183**	**500,6**	**9**
B	W	ST	523	523	6	7,8	1749	349,8	2278	880.6	15
		LTOR	128	128	3	3,9	602	120,4	733	252.3	31
		Total	**651**	**651**	**9**	**11,7**	**2351**	**470,2**	**3011**	**1132,9**	**46**
	E	**ST_2**	**211**	**211**	**3**	**3,9**	**777**	**155,4**	**991**	**370,3**	**10**
C	N	LT	151	151	7	9,1	215	43	373	203,1	8
		RT	201	201	176	228,8	432	86,4	809	516,2	2
		Total	**352**	**352**	**183**	**237,9**	**647**	**129,4**	**1182**	**719,3**	**10**

Table 4. Saturation flow

Phase	Approach	Base saturation flow pcu/h green S_o	Adjustment factors						Saturation flow S pcu/h green
			All approach type				P type		
			City size F_{cs}	Side Friction F_{SF}	Gradient F_G	Parking F_P	Rght turn F_{RT}	Left turn F_{LT}	
A	E-RT_1	1800	0,94	0,94	1,00	1,00	1,16	1,00	1837,57
	E-ST_1	1800	0,94	0,94	1,00	1,00	1,00	1,00	1584,81
B	E-ST_2	1800	0,94	0,94	1,00	1,00	1,00	1,00	1582,74
	W	3900	0,94	0,92	1,00	1,00	1,00	0,98	3315,40
C	N	1920	0,94	0,93	1,00	1,00	1,19	0,97	1941,67

9. Queue length

Queue length calculation uses MKJI 1997 method is influenced by traffic volume, capacity, green ratio, degree of saturation and effective width. Queue length (QL) calculation result can be seen in Table 6.

From the calculation in Table 6 the biggest queue length at north approach in phase C, so the queue is the longest in red light.

Table 6**.** Queue length (QL)

Phase	Approach	NQ_{MAX} (pcu)	QL (m)
A	E-RT	27	83
	E-ST_1	10	67
B	E-ST_2	16	107
	W	34	105
C	N	22	138

10. Delay

Delay calculation result can be seen in Table 7.

Delay due to LTOR (6 seconds):

$$D_{LTOR} = 252{,}3 \times 6 = 1513{,}80 \text{ sec/pcu}$$

Average delay for the entire intersection can be calculated as follows:

$$D_I = \frac{134447{,}2}{22670} = 59{,}29 \text{ sec/pcu}$$

Based on the average delay value for the entire intersection above, itcan be classified that the level of service according to the regulations KM No. 14 Tahun 2006 is at the E level (very poor). Therefore, it is needed to improve the traffic signals and the existing geometric condition.

Table 7. MKJI 1997 delay recapitulation

Phase	Approach	Delay			
		Average traffic delay (sec/pcu)	Average geometric delay (sec/pcu)	Average delay (sec/pcu)	Total delay (sec/pcu)
A	T-RT	158,27	4	162,27	50303,80
	$T\text{-}ST_1$	50,88	4	54,88	10460,51
B	$T\text{-}ST_2$	36,07	4	40,07	14837,92
	B	37,69	4	41,69	36710,48
C	U	38,87	4	42,87	22132,00

b. Field delay

Field delay calculation method at each intersection approach is obtained by counting waiting vehicles volume first or queued in range 15 seconds, not stopped and stopped vehicles in passenger cars unit. The number of delays is obtained by multiplying the number of vehicles queues / waiting with time duration of observation that is 15 seconds. Then, the number of delay is divided by the sum of not stopped and not stopping vehicles, so it can be obtained the average delay for all vehicles. The count of field delay can be seen in this example:

West Approach :

$Q_{stopped}$ = 649.7 pcu/h

$Q_{not\ stopped}$ = 598.4 pcu/h

$Q_{waiting}$ = 1351.8 pcu/h

Q_{total} = 649.7 + 598.4 = 1248.1 pcu/h

1) Total delay

$\Sigma D = 1351.8 \times 15 = 20277$ pcu sec

2) Average stopped delay vehicle

$DT_s = 20277 / 649.7 = 31.21$ sec/pcu

3) The percentage delayed vehicle

$\%QD = 649.7 / 1248.1 \times 100\% = 52.1\ \%$

4) Average delay for all vehicles

$DT_{sTotal} = 20277 / 1248, 1 = 16.25$ sec/pcu

The result above shows that the value of average delay of all vehicles in the West Approach Simpang Tiga Kerten of 16.25 seconds/pcu, so it is at C level of service or good enough according to the regulations KM No. 14 Tahun 2006.

Field delay calculation result at all approach can be seen in Table 9.

The recapitulation results in Table 9, shows that the empirical delay (MKJI 1997 method) is higher than the field delay. It can be seen from the difference of the delay value at each approach with the largest difference at east approach turn right (phase A) that is 126.24 sec/pcu . This is caused by:

1. The traffic flow data from survey will be used in this analysis needs to be converted in the passenger cars unit. This is in accordance with MKJI 1997 stipulation. Inaccurate of conversion value used (in this case is pce) will cause an inaccurate in the traffic flow value.
2. The delay value calculation by MKJI 1997 method is greater than field delay, this is due to MKJI delay consists of traffic delay and geometric delay. Traffic delay is very influenced by cycle time, green ratio, degree of saturation and capacity. The acquisition of capacity itself is influenced by saturation flow and adjustment values, which consists of: geometric road condition to determine effective width, city size, side friction and turning movement. While, for geometric delay is influenced by vehicles stopped ratio and turn at each approach. Nevertheless, Inaccurate of determining the adjustment values (which are: effective width, city size, side friction, turning movement, vehicles stopped ratio and turn at each approach will also cause inaccurate in the delay value.

The comparison between MKJI 1997 and field delays diagram can be seen in Figure 2.

Table 8. Field delay recapitulation

Phase	Approach	$Q_{stopped}$ (pcu/h)	$Q_{not\ stopped}$ (pcu/h)	$Q_{waiting}$ (pcu/h)	Q_{total} (pcu/h)	ΣD (pcu /sec)	DTs (sec/pcu)	%QD	DTs_{Total} (sec/pcu)	LOS
		(1)	(2)	(3)	(1) + (2)					
A	E-RT E-ST_1	175,7 228	253,4 81,2	1030,7 195,8	429,1 309,2	15460,5 2937	87,99 12,88	40,9 73,7	36,03 9,50	D B
B	E-ST_2 W	184 649,7	161,5 598,4	158,3 1351,8	346,1 1248,1	2374,50 20277	12,86 31,21	53,3 52,1	6,86 16,25	B C
C	N	625,6	651,2	1369,3	1276,8	20539,5	32,83	49,0	16,09	C

Table 9. Empirical delay (MKJI 1997 method) and field delay recapitulation

Phase	Approach	MKJI 1997 Delay (sec/pcu)	Field delay (sec/pcu)	The difference MKJI 1997 delay and Field delay (sec/pcu)
A	E-RT E-ST_1	162,27 54,88	36,03 9,50	126,24 45,38
B	E-ST_2 W	40,07 41,69	6,86 16,25	33,21 25,44
C	N	42,87	16,09	26,78

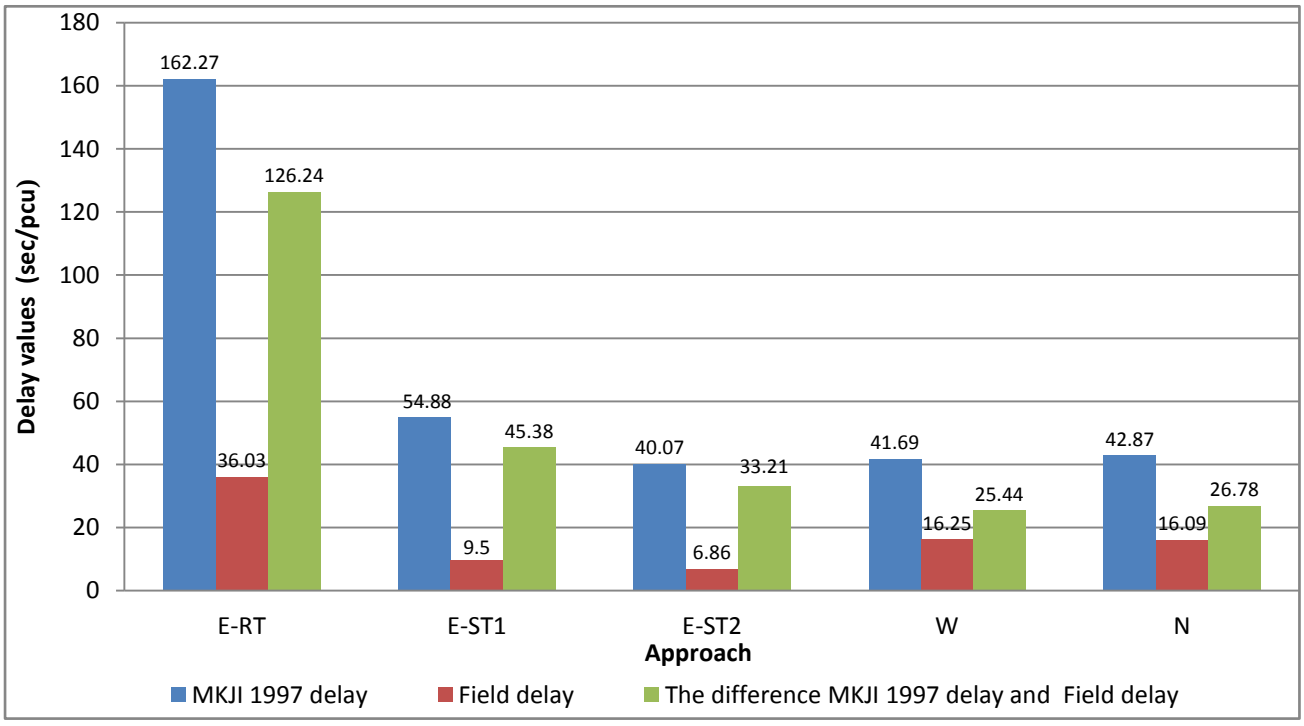

Figure 2. The comparison between MKJI 1997 and field delays diagram

CONCLUSION

Based on the analysis, it can be concluded several things as follows.:

1. Factors considered in the analysis of delay using MKJI 1997 method are road geometric condition, city size, side friction,turning movement and time signal. While for field delay, the factors are waiting vehicle in 15 seconds, not stopped and stopped vehicles.
2. The delay of MKJI 1997 method at Simpang Tiga Kerten, Surakarta are: a) 162.27 sec/pcu at East approach phase A (E-RT), 54.88 sec/pcu at East approach phase A (E-ST_1), 40.07 sec/pcu at East approach phase B (E-ST_2), 41.69 sec/pcu at West approach phase B, and 42.87 sec/pcu at North approach phase C, b) the delay of entire intersection is 105.50 sec/pcu.

3. The field delay are: a) 36.03 sec/pcu at East approach phase A (E-RT), 9.50 sec/pcu at East approach phase ($E\text{-}ST_1$), 6.86 sec/pcu at East approach phase B ($E\text{-}ST_2$), 16.25 sec/pcu at West approach phase B, and 16.09 sec/pcu at North approach phase C, b) the delay of entire intersection is 16.19 sec/pcu.
4. Based on the comparison , it can be known that the field delay is lower than MKJI 1997 delay. It is caused by the differences in withdrawal traffic flow data that will be used in delay calculation analysis.

Some recommendations to maximize the result are written as follows:

1. A Study of passenger cars equivalent value of field delay with all types ofvehicle is needed.
2. In order to anticipate overestimate delay using MKJI 1997 method, it is necessary to recalculate the cycle time and the saturation flow.
3. Field survey method combined with recording video (from Dishubkominfo) can be used as an alternative to find the queue length in the field.
4. In the implementation of reseach, it is needed to prepare an additional surveyors, equipments and research forms to anticipate lack of surveyors, equipments and research forms so that the research results can be more accurate.

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