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Comparative Study of Signalized Intersection Performance Analysis Methods

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Abstract: At intersections, traffic performance indicators consist of saturation degree, queue length, and delay. There are several methods commonly used to calculate performance indicators at intersections, including the PKJI method (2023) and the RJ method. Salter (1981). Each method produces different performance values. Between the PKJI 2023 method and the RJ method, it is not yet known which method is most representative of field conditions, therefore it is necessary to identify which method produces performance that is most in accordance with real conditions in the field. There are several differences and similarities between the analysis of signalized intersections with the PKJI 2023 and RJ methods. Salter, namely the emp value between the PKJI 2023 method and the RJ Salter method, it can be seen that the PKJI 2023 method divides the emp into 2 (two), namely protected and opposed emp, while RJ Salter does not divide it. The magnitude of the emp value is also different for each type of vehicle, this is likely due to the characteristics of vehicle behavior and the geometry of the intersection. In addition, the saturation current formula between the two methods is different, but in the PKJI 2023 and RJ methods. Salter has a So variable (basic saturation current) in the formula. Calculation of cycle time analysis, green time, and approach capacity of the 2nd intersection method with the same approach. Calculation of traffic behavior in this case the queue length and traffic delay from the 2 methods are different. The results of the Mann-Whitney test between the median on the saturation current value between the survey results and the PKJI 2023 method do not show any significant differences, so it can be concluded that the PKJI 2023 method in calculating the intersection saturation current is more representative.

Keywords: Signalized intersection, emp.

Introduction

Traffic flow has an important role in the sustainability of activities in a region, because transportation is a derivative need in the process of fulfilling the needs of each person. Therefore, traffic flow has a high level of urgency to be maintained by means of control and supervision so that traffic performance remains in optimal condition. The road network is a single unit of road sections that connect and bind growth centers with areas that are under the influence of its services in a hierarchical relationship.

There are several methods that can be used, including Highway capacity manual (HCM) This method was issued by the Transportation Research Board (TRB) in the United States and has become an international standard. HCM assesses intersection performance based on control delay and volume-to-capacity ratio, and produces a LOS (Level of Service) classification from A to F (Transportation Research Board, 2016), the SIDRA intersection method, is software and an analysis method from Australia designed to provide detailed evaluations of signalized and unsignalized intersections. SIDRA considers various factors such as delay, queue length, fuel consumption, and vehicle emissions (Akçelik, 2011), the TRL method, developed by the Transport Research Laboratory in the UK, this method uses an empirical approach in calculating intersection capacity and delay. Kimber (1980) introduced a model that takes into account the level of saturation and the relationship between green time and vehicle queues. This study will discuss the comparison between PKJI (2023) and RJ. Salter (1996).

The road network consists of several interconnected sections and intersections, road sections and intersections have traffic performance indicators that can represent their level of service as a reference for controlling traffic conditions at each location. At intersections, traffic performance indicators consist of saturation level, queue length, and delay. There are several methods commonly used to calculate performance indicators at intersections, including the PKJI method (2023) and the RJ Salter method. (1981). Each method produces different performance values. Based on several studies, there is a deviation between the performance produced by these methods and field data, as written by Eka R. et al (2017), The results of the analysis show that the queue length based on MKJI (1997) is 58.4-235.7 meters and field observations are 32-91 meters. Likewise for the parameter value of

stopped vehicles, which is 0.6-8.8 stops/smp (PKJI 2023), while from field observations there were no vehicles that stopped repeatedly (all passed). in another study written by Satyavita M. and Hidayat N. (2019) stated that there was a difference in the length of the MKJI (1997) calculation queue with the results of the PTV VISSIM 9.0 calibration on the North arm of 51.7 m, the East arm of 107.09, the South arm of 148.04 m, and the West arm of 136.79 m. In the study of Candra F. and Widodo W. (2018) produced the MKJI (1997) method in existing conditions, namely the total traffic flow value (Qtot) = 3101 smp/hour, degree of saturation (DS) = 1.025, queue length (QL) = 326 meters, delay (D) = 271 sec/smp. The results of the PTV VISSIM software modeling of existing conditions are queue length (Qlen) = 143.5 meters, delay (VEHdelay) = 170.0 seconds, and level of service (Level of Service) = LOS F.

Between the PKJI 2023 method and the R.J. Salter method, it is not yet known which method is most representative of field conditions, therefore it is deemed necessary to identify which method produces the most appropriate performance to real conditions in the field. In this study, the calculation results of each method will be compared at 5 signalized intersections in several cities in Indonesia to determine whether there is a difference between the performance produced by each method. To determine whether there is a difference between the survey results with PKJI 2023 and RJ. Salter, a Mann-Whitney test was carried out.

Method

Hobbs (1995) describes a road intersection as a transportation node where vehicle flows from different directions come together and then disperse. Similarly, Jotin Khisty and B. Kent Call (2005) emphasize that intersections are an essential part of the overall road network. In general terms, an intersection refers to the area where two or more roads connect or cross, including the surrounding infrastructure that facilitates traffic movement within it.

For signalized intersections, traffic performance is typically evaluated using measurable indicators. The most commonly used ones include the degree of saturation (DS), delay, and queue length. The degree of saturation compares the traffic demand to the available capacity on each approach. Delay refers to the average amount of time a vehicle is held up when passing through the intersection, while queue length indicates how far vehicles are lined up—from the stop line to the last vehicle in the queue.

1. PKJI 2023 signalized intersection performance

Performance indicators at signalized intersections consist of capacity, degree of saturation, queue length, and delay.

a. Capacity

To calculate the capacity for each approach, the following formula is used:

$C = S \times g/c$

Where:

C = Capacity (smp/hour)

S = Saturation flow, which is the average departure flow from the queue in the approach during the green signal (smp/green hour = smp per green hour)

g = Green time (sec)

c = Cycle time, which is the time interval for a complete sequence of signal changes (i.e. between two consecutive green starts at the same phase)

b. Degree of saturation or DS (Degree of SAturation)

The degree of saturation is the ratio of traffic flow to capacity for an approach.

This degree of saturation can be calculated using the following formula:

DS = Q total/C

Where:

DS = Degree of saturation

Q = Traffic flow (smp/hour)

C = Intersection capacity (smp/hour)

c. Queue Length

The queue length is calculated by multiplying the max NQ by the average area used per smp. The average area used is 20 m^2. The formula used to calculate the queue length is as follows:

$$QL = \frac{NQmax \times 20}{We}$$

Where:
QL = Queue length (m)
NQ max = Number of queue smp (smp) We = Entry width (m)

d. Delay

Each approach average traffic delay is caused by the reciprocal influence of other movements at the intersection. To calculate the average traffic delay can be calculated using the following formulas:

D = DT + DG

Where:
D = Average delay (sec/smp)
DT = Average traffic delay (sec/smp) DG = Average geometric delay (sec/smp)

The average traffic delay on an approach can be determined from the following formula:

$$DT = c \times \frac{0{,}5 \times (1 - GR)^2}{(1 - GR \times DS)} + \frac{NQ_1 \times 3600}{C}$$

Where:
DTj = Average traffic delay on approach j (sec/smp) GR = Green ratio (g/c)
DS = Degree of saturation C = Capacity (smp/hour)
NQ1 = Number of smp left from the previous green phase

The average geometric delay on an approach can be estimated as follows:

DGj = (1-psv) × PT × 6 +(psv × 4)

Where:
DGj = Average geometric delay on approach j (sec/smp) Psv = Ratio of vehicles stalled on an approach
PT = Ratio of vehicles turning on an approach

2. Signalized intersection performance R.J. Salter (1981)

In the analysis of signalized intersections using the RJ. Salter method, the analysis stages are divided into several stages, the following stages in the context of planning new signalized intersections and calculating their performance:

a. Phase Determination
b. Calculating Saturation Flow

1) Unopposed Lane

Saturation Flow/Saturation Flow is the average departure flow in an approach during green conditions (pcu/green hour). In protected flow the formula used is as follows:

$$S_1 = (S_0 - 140 d_n)/(1 + 1.5 f/r) \text{ pcu/h}$$

$$\text{where } S_0 = 2080 - 42\, d_g \times G + 100\,(w - 3.25)$$

Where:
S1 : Protected Saturation Current (pcu/hour)
So : Basic saturation current (smp/hour)
dn : 1 for straight shielded column 0 for opposed column
f : Proportion of vehicles turning
r : Turning radius (m)
dg : 1 for uphill gradient and 0 for downhill gradient
G : Percentage gradient on approach (%)
In : column width (m)

2) Opposed Lane

In the opposite current, the saturated current can be obtained with the following formula:

$S = S_g + S_c$

Where:
S_g : Saturated current in the opposing traffic column during the effective green period
S_c : Saturated flow on the opposing traffic lane after the effective green period

c. Calculating Intersection Performance

1) Degree of Saturation

The degree of saturation can be obtained using the following formula:

DS = Traffic flow x cycle time Saturated flow x green time

2) Delay

Vehicle delays at intersections can be calculated using the following calculation:

$$d = \frac{c(1-\lambda)^2}{2(1-\lambda x)} + \frac{x^2}{2q(1-x)} - 0.65\left(\frac{c}{q^2}\right)^{1/3} x^{(2+5\lambda)}$$

Where d = average delay per vehicle,
c = cycle time,
ʎ = proportion of the cycle that is effectively green for the phase under consideration,
q = flow,
x = degree of saturation

3) Queue Length

The queue length can be calculated using the following formula:

$$N_{in} = qr$$

Where N_{in} = the initial queue at the beginning of an unsaturated green period,
q = flow,
r = length of the effective red period

3. Required data

The data required for this research are as follows:

a. Geometric data of intersection

This data is obtained by means of an intersection inventory survey, the target data obtained in this survey is a complete intersection layout image with dimensions/sizes, and is equipped with road equipment facilities at the intersection. In addition, cycle time, phase form and phase diagram also need to be recorded for use in the intersection performance analysis in the next stage.

b. Intersection saturation current data

Saturated flow can be obtained by surveying with the time slice method, namely recording the number of classified vehicles at an intersection approach per time slice during green time in 1 cycle. The survey was conducted during green time during one cycle during rush hour, recording the number of vehicles was done every 3 seconds/5 seconds/6 seconds/etc. according to the green time on the arm. The target data that must be recorded is the number of classified vehicles (LV, HV, MC).

c. Intersection traffic flow data

Traffic flow at intersections is obtained by classified turning movement counting (CTMC) survey or turning movement survey at intersections. This survey is conducted by counting vehicles originating from each arm of the intersection heading towards the intersection per type of vehicle, per direction of movement, and per 15 minutes. From the results of this survey, the traffic volume from each arm at the intersection will be obtained.

d. Data on the length of vehicle queues at intersections

The length of the vehicle queue on each arm is obtained from a queue survey conducted during peak hours. Every time a queue occurs, the surveyor records the length of the vehicle queue on that arm, the largest queue length is the queue length that represents the intersection arm.

e. Delayed data

Vehicle delays are obtained from delay surveys at each intersection approach for 5 minutes per 15 seconds. From this survey, the average length of time each vehicle is delayed at the approach will be obtained.
City demographic data

After all the required data is obtained, the next step is to analyze the performance of the signalized intersection using the two methods to be compared, namely the PKJI 2023 method and the RJ. Salter method. The following are the analysis stages of the two methods.

Table 1 Comparison of the analysis process in the three methods

method PKJI 2023	method RJ. Salts	Observation
Current & Geometric Survey ↓ Calculating the intersection saturation current ↓ Calculating intersection capacity ↓ Calculating DS ↓ Resolution NQ (NQ1&NQ2) ↓ Calculating the queue length ↓ Calculating the delay	Current & Geometric Survey ↓ Calculating the intersection saturation current ↓ Calculating intersection capacity ↓ Calculating DS ↓ Calculating the queue length ↓ Calculating the delay	CTMC survey, geometry, saturation flow, queue, delay ↓ Calculating intersection capacity ↓ Calculating DS ↓ Calculating the queue length ↓ Calculating the delay

The results of the three methods then compare traffic performance such as saturated flow, queue length and delay obtained from the observation results compared to the PKJI 2023 and RJ Salter models. The analysis method used is using the Mann Whitney U Test with the help of the Minitab 19 device. From the three approaches, namely observation (field survey), PKJI 2023, and RJ Salter, whether the traffic performance of each approach method is the same or different.

Result and Discussion

The comparison of analysis methods between PKJI 2023 and RJ Salter in this study discusses 6 (six) variables, namely: (1) passenger car equivalent; (2) saturated flow; (3) cycle time; (4) green time; (5) approach capacity; (6) traffic behavior, can be seen in the following table.

Table. 2 Comparison Analysis between PKJI 2023 and R.J. Salter

NO	VARIABLES	PKJI 2023	R.J. SALTER
1	Passenger car equivalent	For the type approach**protected:**Light Vehicle (LV): 1; Heavy Vehicle (HV): 1.3; Motorcycle (MC): 0.2. For the type approach**against:**Light Vehicle (LV): 1; Heavy Vehicle (HV): 1.3; Motorcycle (MC): 0.2.	Kendaraan Ringan (LV): 1 Medium good vehicles (vehicles 2 axles with more than 4 wheels): 1,5 Heavy good vehicles (more than 2 axles): 2,3 Buses and coaches: 2 Motor cycles: 0,4

NO	VARIABLES	PKJI 2023	R.J. SALTER
2	Saturated Flow	The saturation current (J) can be expressed as the result of multiplying the basic saturation current (Jo), which is the saturation current at standard conditions, with an adjustment factor (F) for deviations from the actual conditions, from a set of previously determined (ideal) conditions. J **= Jo × F1 × F2 × F3 × F4 ×….× Fn**For a protected approach the basic saturation current is determined as a function of the effective approach width (We): J**o = 600 × We**For the opposed approach, departure from the queue is greatly influenced by the fact that Indonesian drivers do not respect the "right of way rule" from the left, that is, right-turning vehicles force their way into the oncoming straight traffic. Western models of this departure, which are based on the theory of "gap-acceptance", are not applicable.	The average departure flow in an approach during green conditions (pcu/green hour). In protected flow the formula used is as follows:**S1 =(So - 140do)/(1 + 1.5//r) pcu/h** where **So = 2080-42 dg x G + 100 (w- 3.25)**S1: Protected Saturation Current (pcu/hour) So: Basic saturation current (smp/hour) dn: 1 for straight shielded column 0 for opposed column f : Proportion of vehicles turning r : Turning radius (m) dg: 1 for uphill gradient and 0 for downhill gradient G : Percentage gradient on approach (%) w : column width (m)
3	Cycle time	**C = (1.5 x LTI + 5) / (1 - ΣFRcrit)**If the field cycle time is less than this value then there is a serious risk of oversaturation at the intersection. Too long a cycle time will cause an increase in the average delay. If the value of E(FRcrit) is close to or more than 1 then the intersection is oversaturated and the formula will produce a very high or negative cycle time value.	**Co= (1,5L + 5)/(1 - Y)** where L is the total lost time per cycle Y is the sum of the maximum y values for all the phases comprising the cycle.
4	Green Time	**gi = (c - LTI) x FRcrit, / L(FRCrit)**	To calculate the green time for each phase, the first thing to do is to calculate the green time in one cycle, namely using the formula: **Total Green Time = Cycle Time - Total Lost Time** After that, calculate the green time for each phase using the following formula: **Green Time per phase = Total green time x (y max per phase/Σ y max)**
5	Intersection approach capacity	**C = S x g/c**	**C = S x g/c**

NO	VARIABLES	PKJI 2023	R.J. SALTER
6	Long queues and traffic delays	**Long queue**: The average number of smp queues at the start of the green signal (NQ) is calculated as the number of smps remaining from the previous green phase (NQ1) plus the number of smps arriving during the red phase (NQ2) **NQ = NQ1 + NQ2**The queue length (QL) is obtained by multiplying (NQ) by the average area used per smp (20 square meters) and dividing by the entrance width.	**Queue length: Nu =qr (45.1)** where Nu is the initial queue at the beginning of an unsaturated green period, q is the flow, r is the length of the effective red period; the effective red period is equal to the cycle time minus the effective green period.
		Stop Number: Stopping number (NS), which is the average number of stops per vehicle (including repeated stops in the queue) before passing an intersection, is calculated as:**NS=0.9x(NQ/Qxc)x3600**	
		Delay: Delay at an intersection can occur due to two things: 1) TRAFFIC DELAY (DT) due to traffic interaction with other movements at an intersection. 2) GEOMETRIC DELAY (DG) due to deceleration and acceleration when turning at an intersection and/or stopping for a red light. The average delay for an approach j is calculated as: **Dj=DTj+DGj**	**Delay:d= c(1- "11.)2 + x2 -0.65(.£..)1/3 x<2 + s?..)** $d = \frac{c(1-\lambda)^2}{2(1-\lambda x)} + \frac{x^2}{2q(1-x)} - 0.65\left(\frac{c}{q^2}\right)^{1/3} x^{(2+5\lambda)}$ d =average delay per vehicle, c = cycle time, Λ= proportion of the cycle that is effectively green for the phase under consideration (that is, effective green time/cycle time), q =flow, s = saturation flow, x =degree of saturation, which is the ratio of actual flow to the maximum flow that can be passed through the approach (that is q(A.s).

1. Tabanan Rindam Intersection

The data collection and processing process that has been carried out at Simpang Rindam has produced the data needed for further analysis.

Table 3. Data of Tabanan Rindam Intersection

DATA	Unit	Arm			
		North	South	East	West
Traffic Flow	smp/hour	463	697	73	595
Green Time	second	25	25	12	25
Cycle Time	second	107			
Effective width (We)	meter	3,6	5	2,75	5,5
Proportion of vehicles turning	%	0,42	0,71	0,72	0,95
Turning radius	meter	30	35	10	35

Traffic performance calculations are carried out in 3 methods. Namely by using the survey method in obtaining data on saturated flows, queues and delays, the PKJI 2023 method, and the RJ. Salter method. The following is the intersection performance using the survey method in obtaining intersection saturated flows, queues and delays

Table 4 Performance of the Tabanan Rindam Intersection (Survey)

Survey

Variabel	Unit	Lengan			
		Utara	Selatan	Timur	Barat
Arus jenuh	smp/jam	2205	2912	1705	3195
Kapasitas	smp/jam	690	1144	215	1110
Derajat Kejenuhan	-	0,67	0,61	0,34	0,54
Antrian	meter	50	60	10	55
Tundaan	detik	30,2	25,8	48,2	26,6

From the data above, it is known that the intersection saturation current has a value of 2952 pcu/hour on the North arm, 4896 pcu/hour on the South arm, 1920 pcu/hour on the East arm, and 4752 pcu/hour on the West arm. The queue on the North arm is 50 m long, 60 m on the South arm, 10 m on the East arm, and 55 m on the West arm. The delay on the North arm is 30.2 sec, 25.8 sec on the South arm, 48.2 sec on the East arm, and 26.6 sec on the West arm.

Table 5 Performance of the Tabanan Rindam Intersection (PKJI 2023)

PKJI 2023 (KAJI)

Variables	Unit	Arm			
		North	South	East	West
Saturated current	smp/hour	2160	3000	1650	3300
Capacity	smp/hour	505	701	185	771
Degree of Saturation	-	0,92	0,99	0,39	0,77
Queue	meter	133	184	22	91
Delay	second	73,8	107,5	48,2	47,9

Based on the analysis using the PKJI 2023 method, the data in the table above is obtained. The intersection saturation flow on the North arm is 2160 pcu/hour, 3000 pcu/hour on the South arm, 1650 pcu/hour on the East arm, and 3300 pcu/hour on the West arm. The queue on the North arm is 133cm long, 184 m on the South arm, 22 m on the East arm, and 91 m on the West arm. The delay on the North arm is 73.8 sec, 107.5 sec on the South arm, 48.2 sec on the East arm, and 47.9 sec on the West arm.

Table.6 Performance of the Rindam Tabanan Intersection (RJ. Salter)

R.J. SALTER

Variables	Unit	Arm			
		North	South	East	West
Basic saturation current	smp/hour	2115	2255	2030	2305
Saturated current	smp/hour	1934	2053	1706	2080
Capacity	smp/hour	452	480	191	486
Degree of Saturation	-	1,02	1,45	0,38	1,22
Queue	meter	92,6	139,4	14,6	119
Delay	second	66,39	76,45	55,18	70,75

Based on the analysis using the RJ. Salter method, the intersection saturation current on the North arm is 1934 smp/hour, 2053 smp/hour on the South arm, 1706 smp/hour on the East arm, and 2080 smp/hour on the West arm. The queue on the North arm is 92.6 cm long, 139.4 m on the South arm, 14.6 m on the East arm, and 119 m on the West arm. The delay on the North arm is 66.4 s, 76.5 s on the South arm, 55.2 s on the East arm, and 70.8 s on the West arm.

2. Veterans Junction

The data collection and processing process that has been carried out at Simpang Veteran has produced the data needed for further analysis.

Table.8 Veteran Intersection Data

DATA	Unit	Arm		
		North	South	West
Traffic Flow	smp/hour	373	486	407
Green Time	second	14	14	14
Cycle Time	second		54	
Effective width (We)	meter	4	4	6
Proportion of vehicles turning	%	0,64	0,56	0,52
Turning radius	meter	13	30	40

The following is the performance of the intersection using the survey method in obtaining intersection saturation flows, queues and delays.

Table.8 Veteran Intersection Performance (Survey)

Survey

Variabel	Unit	Lengan		
		Utara	Selatan	Barat
Arus jenuh	smp/jam	1812	1974	2875
Kapasitas	smp/jam	902	840	1027
Derajat Kejenuhan	-	0,41	0,58	0,40
Antrian	meter	19	24	20
Tundaan	detik	16,0	17,1	15,8

From the data above, it is known that the intersection saturation flow has a value of 3480 smp/hour on the North arm, 3240 smp/hour on the South arm, and 3960 smp/hour on the West arm. The queue on the North arm is 19 m long, 24 m on the South arm, and 20 m on the West arm. The delay on the North arm is 16 sec, 17.1 sec on the South arm, and 15.8 sec on the West arm.

Table 9 Veteran Intersection Performance (PKJI 2023)

PKJI 2023 (KAJI)

Variables	Unit	Arm		
		North	South	West
Saturated current	smp/hour	1866	2023	2934
Capacity	smp/hour	484	524	761
Degree of Saturation	-	0,77	0,93	0,53
Queue	meter	45	80	23
Delay	second	31,11	55,94	21,38

Based on the analysis using the PKJI 2023 method, the data in the table above is obtained. The intersection saturation flow on the North arm is 1866 pcu/hour, 2023 pcu/hour on the South arm, and 2934 pcu/hour on the West arm. The queue on the North arm is 45 cm long, 80 m on the South arm, and 23 m on the West arm. The delay on the North arm is 31.1 sec, 55.9 sec on the South arm, and 21.4 sec on the West arm.

Table.10 Veterans Junction Performance (RJ. Salter)

R.J. SALTER

Variables	Unit	Arm		
		North	South	West
Basic saturation current	smp/hour	2155	2155	2355
Saturated current	smp/hour	1876	1960	2173
Capacity	smp/hour	486	508	563
Degree of Saturation	-	0,77	0,96	0,72
Queue	meter	35,2	45,9	38,4
Delay	second	31,42	33,48	30,98

Based on the analysis using the RJ. Salter method, the intersection saturation current on the North arm is 1876 smp/hour, 1960 smp/hour on the South arm, and 2173 smp/hour on the West arm. The queue on the North arm is 35.2 cm long, 45.9 m on the South arm, and 38.4 m on the West arm. The delay on the North arm is 31.4 sec, 33.5 sec on the South arm, and 30.9 sec on the West arm.

3. Simpang Degung

The data collection and processing process that has been carried out at Simpang Degung has produced the data needed for further analysis.

Table 11 Degung Intersection Data

DATA	Unit	Arm			
		North	South	East	West
Traffic Flow	smp/hour	510	447	406	489
Green Time	second	26	18	13	19
Cycle Time	second	96			
Effective width (We)	meter	4	4,5	5,5	5,5
Proportion of vehicles turning	%	1	0,69	0,39	0,51
Turning radius	meter	35	35	35	35

The following is the performance of the intersection using the survey method in obtaining intersection saturation flows, queues and delays.

Table 12 Degung Intersection Performance (Survey)

Survey

Variabel	Unit	Lengan			
		Utara	Selatan	Timur	Barat
Arus jenuh	smp/jam	1998	2155	2890	2420
Kapasitas	smp/jam	1398	1215	595	1116
Derajat Kejenuhan	-	0,36	0,37	0,68	0,44
Antrian	meter	50	55	50	60
Tundaan	detik	29,3	29,4	23,4	30,7

From the data above, it is known that the intersection saturation current has a value of 5160 smp/hour on the North arm, 6480 smp/hour on the South arm, 4392 smp/hour on the East arm, and 5640 smp/hour on the West arm. The queue on the North arm is 50 m long, 55 m on the South arm, 50 m on the East arm, and 60 m on the West arm. The delay on the North arm is 29.3 s, 29.4 s on the South arm, 23.4 s on the East arm, and 30.7 s on the West arm.

Table 13 Degung Intersection Performance (PKJI 2023)

PKJI 2023 (KAJI)

Variables	Unit	Arm			
		North	South	East	West
Saturated current	smp/hour	1938	2078	3006	2504
Capacity	smp/hour	525	390	407	496
Degree of Saturation	-	0,97	1,15	1,00	0,99
Queue	meter	150	276	105	113
Delay	second	63,4	63,3	61,3	61,3

Based on the analysis using the PKJI 2023 method, the data in the table above is obtained. The intersection saturation flow on the North arm is 1938 pcu/hour, 2078 pcu/hour on the South arm, 3006 pcu/hour on the East arm, and 2504 pcu/hour on the West arm. The queue on the North arm is 150 cm long, 276 m on the South arm, 105 m on the East arm, and 113 m on the West arm. The delay on the North arm is 63.4 sec, 63.3 sec on the South arm, 61.3 sec on the East arm, and 61.3 sec on the West arm.

Table 14 Degung Intersection Performance (RJ. Salter)

R.J. SALTER

Variables	Unit	Arm			
		North	South	East	West
Basic saturation current	smp/hour	2155	2205	2305	2305
Saturated current	smp/hour	1932	2006	2129	2119
Capacity	smp/hour	523	376	288	419
Degree of Saturation	-	0,97	1,19	1,41	1,17
Queue	meter	85,0	74,5	67,7	81,5
Delay	second	60,42	59,50	58,08	59,87

Based on the analysis using the RJ. Salter method, the intersection saturation current on the North arm is 1932 smp/hour, 2006 smp/hour on the South arm, 2129 smp/hour on the East arm, and 2119 smp/hour on the West arm. The queue on the North arm is 85 cm long, 74.5 m on the South arm, 67.7 m on the East arm, and 81.5 m on the West arm. The delay on the North arm is 60.4 s, 59.5 s on the South arm, 58.1 s on the East arm, and 59.9 s on the West arm.

4. Denpasar Intersection

The data collection and processing process that has been carried out at Simpang Denpasar Raya has produced the data needed for further analysis.

Table 15 Denpasar Intersection Data

DATA	Unit	Arm			
		North	South	East	West
Traffic Flow	smp/hour	600	217	256	451
Green Time	second	16	6	7	13
Cycle Time	second	58			
Effective width (We)	meter	4	4,5	5,5	5,5
Proportion of vehicles turning	%	1	0,69	0,39	0,51
Turning radius	meter	30	19	10	15

The following is the performance of the intersection using the survey method in obtaining intersection saturation flows, queues and delays.

Table 16 Denpasar Intersection Performance (Survey)

Survey

Variabel	Unit	Lengan			
		Utara	Selatan	Timur	Barat
Arus jenuh	smp/jam	2023	1942	1980	2110
Kapasitas	smp/jam	968	354	434	834
Derajat Kejenuhan	-	0,62	0,61	0,59	0,54
Antrian	meter	30	11	13	23
Tundaan	detik	19,9	16,4	16,4	18,0

From the data above, it is known that the intersection saturation current has a value of 3510 smp/hour on the North arm, 3420 smp/hour on the South arm, 3600 smp/hour on the East arm, and 3720 smp/hour on the West arm. The queue on the North arm is 30 m long, 11 m on the South arm, 13 m on the East arm, and 23 m on the West arm. The delay on the North arm is 19.9 sec, 16.4 sec on the South arm, 16.4 sec on the East arm, and 18 sec on the West arm.

Table 17 Denpasar Intersection Performance (PKJI 2023)

PKJI 2023 (KAJI)

Variables	Unit	Arm			
		North	South	East	West
Saturated current	smp/hour	2016	1953	2001	2053
Capacity	smp/hour	556	202	242	460
Degree of Saturation	-	1,08	1,07	1,06	0,98
Queue	meter	260	110	115	110
Delay	second	201,61	244,34	210,62	88,9

Based on the analysis using the PKJI 2023 method, the data in the table above is obtained. The intersection saturation flow on the North arm is 2016 smp/hour, 1953 smp/hour on the South arm, 2001 smp/hour on the East arm, and 2053 smp/hour on the West arm. The queue on the North arm is 260 cm long, 110 m on the South arm, 115 m on the East arm, and 110 m on the West arm. The delay on the North arm is 201.6 s, 244.3 s on the South arm, 210.6 s on the East arm, and 88.9 s on the West arm.

Table.18 Denpasar Intersection Performance (RJ. Salter)

R.J. SALTER

Variables	Unit	Arm			
		North	South	East	West
Basic saturation current	smp/hour	2155	2205	2305	2305
Saturated current	smp/hour	1919	1958	2045	2060
Capacity	smp/hour	529	203	247	462
Degree of Saturation	-	1,13	1,07	1,04	0,98
Queue	meter	56,7	20,5	24,2	42,6
Delay	second	38,92	32,14	32,54	35,27

Based on the analysis using the RJ. Salter method, the intersection saturation current on the North arm is 1919 smp/hour, 1958 smp/hour on the South arm, 2045 smp/hour on the East arm, and 2060 smp/hour on the West arm. The queue on the North arm is 56.7 cm long, 20.5 m on the South arm, 24.2 m on the East arm, and 42.6 m on the West arm. The delay on the North arm is 38.9 s, 32.1 s on the South arm, 32.5 s on the East arm, and 35.3 s on the West arm.

5. Univet Junction

The data collection and processing process that has been carried out at Simpang Univet has produced the data needed for further analysis.

Table 19 Univet Intersection Data

DATA	Unit	Arm			
		North	South	East	West
Traffic Flow	smp/hour	523	409	262	117
Green Time	second	23	28	10	
Cycle Time	second	115			
Effective width (We)	meter	5	5	7	7
Proportion of vehicles turning	%	1	0,69	0,39	0,51
Turning radius	meter	30	31	32	33

The following is the performance of the intersection using the survey method in obtaining intersection saturation flows, queues and delays.

Table.20 Univet Intersection Performance (Survey)

Survey

Variabel	Unit	Lengan			
		Utara	Selatan	Timur	Barat
Saturation flow	smp/jam	2495	2703	3290	3155
Capacity	smp/jam	1252	1302	714	689
Degree of Saturation	-	0,42	0,31	0,37	0,17
Queue	meter	60	47	30	13
Delay	detik	34,8	32,2	32,2	30,0

From the data above, it is known that the intersection saturation flow has a value of 3600 pcu/hour on the North arm, 3744 pcu/hour on the South arm, 4104 pcu/hour on the East arm, and 3960 pcu/hour on the West arm. The queue on the North arm is 60 m long, 47 m on the South arm, 30 m on the East arm, and 13 m on the West arm. The delay on the North arm is 34.8 sec, 32.2 sec on the South arm, 32.2 sec on the East arm, and 30 sec on the West arm.

Table 21 Univet Simpang Performance (PKJI 2023)

PKJI 2023 (KAJI)

Variables	Unit	Arm			
		North	South	East	West
Saturated current	smp/hour	2545	2776	3358	3197
Capacity	smp/hour	770	1023	442	421
Degree of Saturation	-	0,68	0,40	0,59	0,28
Queue	meter	56	36	23	9
Delay	second	29,5	20,8	36,84	33,84

Based on the analysis using the PKJI 2023 method, the data in the table above is obtained. The intersection saturation flow on the North arm is 2545 pcu/hour, 2776 pcu/hour on the South arm, 3358 pcu/hour on the East arm, and 3197 pcu/hour on the West arm. The queue on the North arm is 56 cm long, 36 m on the South arm, 23 m on the East arm, and 9 m on the West arm. The delay on the North arm is 29.5 sec, 20.8 sec on the South arm, 36.8 sec on the East arm, and 33.8 sec on the West arm.

Table.22 Univet Intersection Performance (RJ. Salter)

R.J. SALTER

Variables	Unit	Arm			
		North	South	East	West
Basic saturation current	smp/hour	2255	2255	2455	2455
Saturated current	smp/hour	2014	2047	2273	2263
Capacity	smp/hour	403	498	198	197
Degree of Saturation	-	1,30	0,82	1,33	0,59
Queue	meter	94,4	73,8	47,3	21,1
Delay	second	74,45	67,57	64,33	57,46

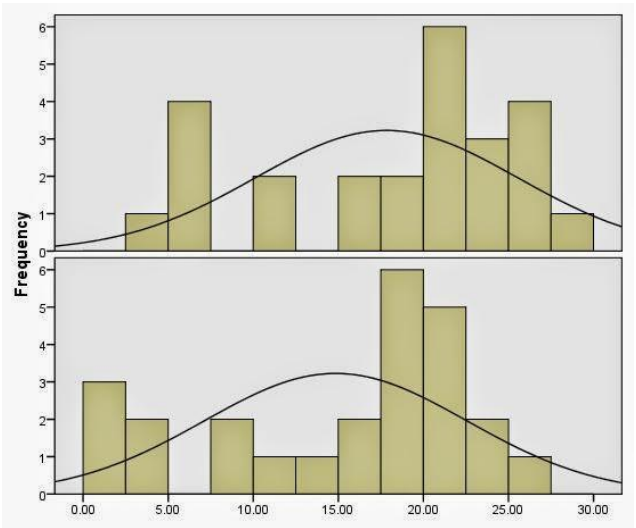
Based on the analysis using the RJ. Salter method, the intersection saturation current on the North arm is 2014 smp/hour, 2047 smp/hour on the South arm, 2273 smp/hour on the East arm, and 2263 smp/hour on the West arm. The queue on the North arm is 94.4 cm long, 73.8 m on the South arm, 47.3 m on the East arm, and 21.1 m on the West arm. The delay on the North arm is 74.5 s, 67.6 s on the South arm, 64.3 s on the East arm, and 57.5 s on the West arm.

6. Mann Whitney U Test

The Mann-Whitney U Test is a non-parametric statistical test used to determine whether there's a significant difference between two independent groups—especially when the data are not normally distributed. It works with ordinal, interval, or ratio data, but is most useful when the data don't meet the assumptions required for a parametric test like the Independent Samples T-Test. For example, you might use this test to compare two different classes—Class A and Class B—where each group consists of different individuals.

Also known as the Wilcoxon Rank Sum Test, the Mann-Whitney U Test is often chosen when the normality assumption for a T-Test isn't met. However, unlike the T-Test, which focuses on comparing group means, this test is mainly used to compare the medians of the two groups. That said, some researchers argue that it doesn't just test medians—there are cases where the medians of both groups are the same, but the test still produces a significant p-value (typically < 0.05). This usually suggests a difference in means or distribution shapes, not just medians.

In essence, the Mann-Whitney U Test is useful when you suspect there are differences between two groups—perhaps in their central tendency or the overall spread of their values—but you're not sure whether those differences are statistically meaningful. It helps confirm whether those patterns you're seeing in the data are likely due to real differences or just random chance.



Gambar.1 Histogram Mann Whitney U Test (MWU)

Look at the two histograms above, where the width and height are the same, which means the shape and distribution of the data for both groups are the same, but the medians are different. See that the histogram above is more to the right than the one below, with a median of 18 while the one below has a median of 15. The purpose of the researcher in conducting the Mann Whitney U Test is to test whether the difference in the median is significant or not, if the shape and distribution of the histogram are not the same, the Mann Whitney U Test can still be done, but it no longer tests the difference in the median and mean, but only tests the difference in the mean.

7. Mann Whitney U Test Sensitivity

So it can be interpreted that the Mann Whitney U Test (MWU) is very sensitive to changes in the median. Another option is the Kolmogorov Smirnov Z Test (KS-Z) for the two-sample independent test. This KS-Z test is different from the MWU, where KS-Z not only tests the difference in Median and Mean, but also the difference in Variances. Therefore, if the assumption of homogeneity in the MWU test is not met, then KS-Z can be an alternative. The advantage of the KS-Z test is that it is not so sensitive to the median, but is sensitive to the mean and variance.

8. Mann Whitney Assumptions

Based on the description above, it can be concluded that the assumptions that must be met in the Mann Whitney U Test are:

The scale of the dependent variable data is ordinal, interval or ratio. If the scale is interval or ratio, the assumption of normality is not met. (Normality can be known afternormality test).

The data comes from 2 groups. (If the data comes from 3 or more groups, then it is better to use the testKruskall Wallis).

The variables are independent of each other, meaning that the data comes from different groups or is not paired.

The variance of both groups is the same or homogeneous. (Because the distribution is not normal, thenhomogeneity testThe right thing to do is the Levene's Test. Where the testFisher Fis intended if the normality assumption is met). Assumptions of points 1, 2 and 3 do not require separate tests. While point 4 clearly requires a test that can determine whether the two groups have the same variance or not, which is called the homogeneity test.

9. Comparison traffic performance of the three methods

As described in the analysis method chapter, one of the objectives of this study is to compare traffic performance, such as saturated flow, queue length and traffic delay obtained from observation data compared to the PKJI 2023 method and the RJ Salter method. Are the results of field observations with both PKJI 2023 and RJ Salter methods similar or different, as well as the PKJI 2023 and RJ Salter methods, are they the same or different.

Comparative analysis of traffic performance (saturated flow, queue length, and traffic delay) was obtained by taking data from 5 (five) intersections, namely: Simpang 4 Rindam, Simpang 4 Denpasar Raya, Simpang 4 Degung, Simpang 3 Veteran, and Simpang 4 Univet. Data on saturated flow, queue length, and traffic delay from each intersection leg at the five intersections are presented in Appendix 1.

The following is a recapitulation of the Mann Whitney Test for the 3 approaches, namely observation (survey), PKJI 2023 and RJ Salter as in the table below.

Table 23 Recapitulation of the 3rd Mann Whitney Test approach

No	Test	P-Value	Results
1	Mann-Whitney Analysis between Survey Saturation Flow Data and PKJI 2023 Saturation Flow Data	0,08	P-value > alpha (0.05), then Ho is rejected (there is no difference)
2	Mann-Whitney Analysis between Survey Saturation Flow Data and R.J. Salter Saturation Flow Data	0,00	P-value < alpha (0.05), then Ho is rejected (there is a difference)
3	Mann-Whitney Analysis between R.J. Salter Saturation Flow Data and PKJI 2023 Saturation Flow Data	0,06	P-value > alpha (0.05), then Ho is accepted (there is no difference)

No	Test	P-Value	Results
4	Mann-Whitney Analysis between Survey Queue Data and PKJI 2023 Queue Data	0,001	P-value < alpha (0.05), then Ho is rejected (there is a difference)
5	Mann-Whitney Analysis between Survey Queue Data and R.J. Salter Queue Data	0,011	P-value < alpha (0.05), then Ho is rejected (there is a difference)
6	Mann-Whitney Analysis between R.J. Salter Queue Data and PKJI 2023 Queue Data	0,096	P-value > alpha (0.05), then Ho is accepted (there is no difference)
7	Mann-Whitney Analysis between Survey Delay Data and PKJI 2023 Delay Data	0,00	P-value < alpha (0.05), then Ho is rejected (there is a difference)
8	Mann-Whitney Analysis between Survey Delay Data and R.J. Salter Delay Data	0,00	P-value < alpha (0.05), then Ho is rejected (there is a difference)
9	Mann-Whitney Analysis between R.J. Salter Delay Data and PKJI 2023 Delay Data	0,35	P-value > alpha (0.05), then Ho is accepted (there is no difference)

The Mann Whitney test shows that there is no difference between the saturation current values from the survey results and the PKJI 2023 method and there is a difference between the RJ method. Salt and supervision. There are several things that cause these differences, including when collecting data, the investigator or supervisor may make several errors such as accuracy, precision, fatigue so that they are less precise in making calculations. Meanwhile, the Mann Whitney test between the PKJI 2023 and RJ Salter methods on each traffic performance shows no difference, meaning that the analysis between using PKJI 2023 and RJ Salter does not show a significant difference.

Conclusions

There are several differences and similarities between the analysis of signalized intersections using the PKJI 2023 and RJ. Salter methods, namely 1) emp between the PKJI 2023 method and the RJ Salter method, it can be seen that the PKJI 2023 method divides emp into 2 (two), namely protected and opposed emp, while RJ Salter does not divide it. The magnitude of the emp value is also different for each type of vehicle, this is likely due to the characteristics of vehicle behavior and the geometry of the intersection; 2) The saturation current formula between the two methods is different, but in the PKJI 2023 and RJ. Salter methods there is a So variable (basic saturation current) in the formula; 3) Calculation of cycle time analysis, green time, and approach capacity of the 2nd intersection method with the same approach, meaning the formula used is the same; 4) Calculation of traffic behavior in this case the length of the queue and traffic delay from the 2 methods is different; 5) The queue length, delay and saturation current of each approach from each analysis method show different results; 6) The results of the Mann-Whitney test between the median on the saturation current value between the survey results and the PKJI 2023 method do not show any significant differences, so it can be concluded that the PKJI 2023 method in calculating the intersection saturation current is more representative.

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References

Akçelik, R. (2011). *SIDRA Intersection User Guide (Version 5)*. Akçelik & Associates Pty Ltd.

Candra, F., & Widodo, W. (2018). *Analisis Kinerja Simpang Bersinyal Menggunakan metode PKJI 2023 Dan Ptv Vissim (Studi Kasus Simpang Empat Bersinyal Gemangan, Sinduadi, Sleman, Yogyakarta*.

Direktorat Jenderal Bina Marga, K. P. U. dan P. R. (2023). *Pedoman Kapasitas Jalan Indonesia*.

Eka, I., Seundhar, P., Yulipriono, E., & Kusuma, I. (2017). Perbandingan Hasil Analisis Kinerja Operasional Simpang Bersinyal Dengan PKJI 2023 Terhadap Hasil Pengamatan Langsung. *Jurnal Karya Teknik Sipil*, *6*(1), 246–262.

Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics* (4th ed.). Sage Publications.

Hauer, E. (1982). Traffic conflicts and exposure. *Accident Analysis & Prevention*, *14*(5), 359–364.

Herinaldi. (2002). *Prinsip prinsip Statistik untuk Teknik dan Sains*. Erlangga.

Irawan, M. Z., & Putri, N. H. (2015). *Kalibrasi Vissim Untuk Microsimulasi Arus Lalu Lintas Tercampur Pada Simpang Bersinyal (Studi Kasus: Simpang Tugu, Yogyakarta)*. Universitas Gadjah Mada.

Irawan, N., & Astuti, S. P. (2006). *Mengolah data Statistik dengan Mudah Menggunakan Minitab 14*. Penerbit Andi.

Khisty, C., Jolin, & Lall, B. K. (2005). *Dasar-dasar Rekayasa Transportasi: Vol. Jilid 1* (E. P. Sutjipto, Ed.; Edisi ke-3). Penerbit Erlangga.

Kimber, R. M. (1980). *The Traffic Capacity of Priority Junctions*.

McGraw-Hill Education. (2016). *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using IBM SPSS* (6th ed.).

Nachar, N. (2008). The Mann-Whitney U: A Test for Assessing Whether Two Independent Samples Come from the Same Distribution. In *Tutorials in Quantitative Methods for Psychology* (Vol. 4, Issue 1).

Roess, R. P., Prassas, E. S., & McShane, W. R. (2011). *Traffic Engineering* (4th ed.). Pearson.

Salter, R. J. (1989). *Traffic Engineering Worked Examples*. Macmillan Education Ltd.

Satyavita M., & Hidayat N. (2019). *Analisis Perbandingan Kinerja Simpang KM 0 Yogyakarta pada Jam Puncak dengan metode PKJI 2023 dan PTV VISSIM 9.0*. Universitas Gadjah Mada.

Sugiyono. (2015). *Metode Penelitian Pendidikan: Pendekatan Kuantitatif, Kualitatif, dan R&D*. CV Alfabeta.

Transportation Research Board. (2010). *Highway Capacity Manual (HCM) 2010*. National Academies Press.

Transportation Research Board. (2016). *Highway Capacity Manual* (6th ed.). National Academies of Sciences, Engineering, and Medicine.

Zegeer, C. V., & Deen, R. C. (1978). *Traffic conflict techniques for safety and operations – Engineers guide*.