Analysis Of A Signalized Intersection Using The PKJI 2023 Method And PTV Vissim 22 Modeling (Case Study: Jl. Kedung Cowek – Jl. Kenjeran – Jl. Putro Agung)

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Abstract. *Signalized intersections or traffic light control systems (APILL) are important elements in urban road networks that function to regulate vehicle flow to be more orderly and safe. The Kedung Cowek Road, Kenjeran Road, and Putro Agung Road intersection is a signalized intersection with high traffic volume and serves as a strategic junction point in the North Surabaya area. This research aims to analyze the performance of the intersection using the Indonesian Road Capacity Guidelines (PKJI) 2023 method, as well as model and simulate improvement alternatives using PTV Vissim version 22 software. The analysis stages begin with collecting daily traffic volume data, intersection geometric data, and existing signal control data. The data is analyzed using the PKJI 2023 method to obtain capacity values, degree of saturation, delay, and queue length for each approach. The existing condition analysis results show that several approaches experience a degree of saturation exceeding the ideal threshold (>0,85) as well as high delays. As a solution, simulations of several alternatives were conducted, namely signal phase rearrangement, approach widening, and flyover construction from Kedung Cowek Road to Kenjeran Road. The existing condition shows the highest degree of saturation of 1.67 on the eastern approach, with an average intersection delay of 244.56 sec/pcu. Simulation with PTV Vissim shows that flyover construction can significantly reduce the degree of saturation and delays compared to existing conditions and other alternatives. Therefore, the combination of the PKJI 2023 method and microsimulation is considered effective as a planning basis for improving signalized intersection performance.*

Keywords: Degree of Saturation, Flyover, PKJI 2023, PTV Vissim 22, Signalized Intersection

1. Introduction

Surabaya is a densely populated city with high mobility levels. In addition to facing problems of land scarcity and social issues, the city also experiences serious challenges in transportation, particularly traffic congestion. The high demand for transportation to support daily activities has caused traffic volume to increase sharply over time (Utomo 2016). One of the main causes of congestion is the increasing ownership of motor vehicles in various cities, including Surabaya. The continuously growing number of vehicles makes road capacity insufficient, resulting in worsening traffic congestion and saturation. To reduce congestion, intersection management needs to be a primary concern.

An intersection is a meeting point or crossing between two roads, such as roundabouts, grade-separated intersections, and intersections with traffic light signals (APILL) (Kementerian Pekerjaan Umum dan Perumahan Rakyat 2023). The Kedung Cowek-Kenjeran-Putro Agung intersection is particularly critical as it serves as a major access point connecting central Surabaya with the northern coastal areas, including routes toward the Suramadu Bridge, making it a vital transportation hub for both local and regional traffic flows. To assess intersection performance, an approach from the Indonesian Road Capacity Guidelines (PKJI) 2023 is used. Data collection is conducted through traffic volume counting during the morning rush hours. Additionally, queue lengths and geometric conditions of intersections are measured directly in the field, as well as traffic light cycle times, which are observed directly (Kusprasetyo & Irawan 2023). Regular evaluation of intersection efficiency is important to maintain optimal performance. With the implementation of PKJI 2023, which provides the latest methods and parameters, intersection performance assessment can be conducted more accurately. It is expected that this will improve comfort for road users around intersections.

2. Method

Source: Google Maps, 2024

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This research was conducted at the intersection of Kedung Cowek Main Road (north), Kenjeran Main Road (west and east), and Putro Agung Main Road (south), located in Surabaya City. After data collection at the location was completed, the next step was to analyze the data using the Indonesian Road Capacity Guidelines (PKJI) 2023 and PTV Vissim 22 software.

2.1 Determination of Saturation Flow

$$S = S_0 \times F_{SF} \times F_{CS} \times F_G \times F_P \times F_{LT} \times F_{RT}$$

Description:

S_0 = Base saturation flow (pcu/hour)

F_{SF} = A correction factor for S_0 due to side friction around the road

F_{CS} = An adjustment factor for S_0 related to city size

F_G = An adjustment factor for S_0 due to the longitudinal gradient of the approach

F_P = An adjustment factor for S_0 due to parking activities near the intersection arm

F_{LT} = An adjustment factor for S_0 due to left-turn movement

F_{RT} = A correction factor for S_0 due to right-turn movement

2.2 Determination of Cycle Time and Green Time

$$S = \frac{(1{,}5 \times W_{HH} + 5)}{1 - \sum R\frac{q}{j}critical}$$

Description:

S = Cycle time (Seconds)

W_{HH} = Minimum green time in each cycle (Seconds)

R_{qj} = Ratio for saturation flow when divided by $^{q}/_{S}$

$Rq_{/j}$ critical = Maximum $^{q}/_{S}$ value when equivalent phase begins

$$W_{Hi} = (S - W_{HH}) \times \left(1 - \sum R\frac{R\frac{q}{j}critical}{\sum\left(R\frac{q}{j}critical\right)i}\right)$$

Description:

W_{Hi} = Green time duration (Seconds)

i = Phase i indicator

2.3 Determination of Capacity

$$C = S\frac{G}{c}$$

Description:

C = Capacity (pcu/hour)

S = Saturation flow (pcu/hour)

G = Total green cycle time in one rotation (seconds)

c = Cycle time (seconds)

2.4 Degree of Saturation Analysis

The degree of saturation is obtained from the relationship between traffic volume and road capacity based on vehicle survey results in the field. This value serves as an important indicator in assessing traffic performance on a road segment.

$$D_S = \frac{q}{C}$$

Description:

D_S = Degree of Saturation

q = Traffic flow on that approach (pcu/hour)

C = Capacity (pcu/hour)

2.5 Queue Analysis

Queue analysis is conducted by calculating the number of vehicles (pcu) that stop during the red light (N_{q^2}) and the remaining vehicles from the previous green period (N_{q^1}). The result is the average number of vehicles in the queue ($\mathrm{N_q}$) at the beginning of the green light.

$$\mathrm{N_q} = \mathrm{N}_{q^1} + \mathrm{N}_{q^2}$$

If $\mathrm{D_S} \leq 0{,}5$, then $\mathrm{N_{q^1}} = 0$ and if $\mathrm{D_S} \geq 0{,}5$, then

$$\mathrm{N}_{q^1} = 0{,}25 \times C \times (D_S - 1) + \sqrt{\frac{\big((D_S - 1) \times 2\big) + (8 \times (D_S - 0{,}5))}{C}}$$

$$\mathrm{N}_{q^2} = S \times \frac{(1 - R_H)^2}{(1 - R_H \times D_S)} + {}^{q}\!/_{3600}$$

Description:

$\mathrm{N_{q^1}}$ = Number of vehicles stopped before green time

Queue length is calculated using the equation:

$$P_A = N_{q_{max}} + \frac{20}{LM}$$

2.6 Delay Analysis

Delay analysis aims to determine the additional time required by drivers to cross the intersection compared to a path without traffic light signals (APILL). There are two types of delays: traffic delay ($\mathrm{T_L}$) and delay due to road geometry ($\mathrm{T_G}$).

Average delay is calculated using the equation:

$$T_i = T_{LLi} + T_{Gi}$$

Description:

T_i = Average stopping delay for approach I (sec/pcu)

T_{LL} = Traffic transition delay (sec/pcu)

T_G = Geometric delay (sec/pcu)

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Average traffic delay is calculated using the equation:

$$T_L = s \times \frac{0{,}5 \times (1 - R_H)^2}{(1 - R_H \times D_S)} + \frac{N_{q^1} \times 3600}{C}$$

Description:

s = Cycle time (seconds)

R_H = Green time ratio

C = Capacity (pcu/hour)

Average geometric delay is calculated using the equation:

$$T_G = (1 - R_{KH}) \times P_B \times 6 + (R_{KH} \times 4)$$

$$R_{KH} = 0{,}9 \times \left(\frac{N_q}{q \times s}\right) \times 3600$$

Description:

P_B = Vehicle value at an approach

R_{KH} = Proportion of vehicles that must stop at the intersection before the green light turns on

2.7 Modeling Using PTV Vissim 22

The modeling process was conducted through several stages. First, the background was uploaded from Google Earth to provide an accurate geographical reference. Next, a road network was created by adding links and connectors according to real field conditions. Vehicle types were then input based on actual field observations to ensure a realistic representation. The traffic volume data obtained from the survey were subsequently entered into the model. Finally, the simulation was executed using the continuous simulation feature to analyze the traffic flow patterns and intersection performance.

3. Results and Analysis

3.1 Data Analysis Using PKJI 2023 Method

Traffic Flow

Data was obtained from survey results at each peak hour, then converted to pcu units using passenger car equivalent (pce) for each vehicle type. The following is the ADT data on Tuesday, October 1, 2024, taken during morning peak hour periods (06.00–10.00 WIB).

Table 1. Morning Peak Hour Traffic Flow (pcu/hour)

Approach Code	Direction	MOTOR VEHICLES							
		Passenger Car (PC)		Heavy Vehicle (HV)		Motorcycle (MC)		Total Motor Vehicles	
		Protected EMP =1,00		Protected EMP =1,30		Protected EMP = 0,15			
		Vehicles/hour	Protected PCU/hour	Vehicles/hour	Protected PCU/hour	Vehicles/hour	Protected PCU/hour	Vehicles/hour	Protected PCU/hour
(1)	(2)	(3)	(4)	(6)	(7)	(9)	(10)	(12)	(13)
N	BKiJT	256	256	99	128,7	3214	482,1	3569	866,8
	Straight	376	376	6	7,8	4359	653,85	4741	1037,65
	BKa	321	321	125	162,5	1719	257,85	2165	741,35
	Total	**953**	**953**	**230**	**299**	**9292**	**1393,8**	**10475**	**2645,8**
E	BKiJT	437	437	22	28,6	922	138,3	1381	603,9
	Straight	739	739	23	29,9	727	109,05	1489	877,95
	BKa	217	217	12	15,6	457	68,55	686	301,15
	Total	**1393**	**1393**	**57**	**74,1**	**2106**	**315,9**	**3556**	**1783**

Approach Code	Direction	MOTOR VEHICLES							
		Passenger Car (PC)		Heavy Vehicle (HV)		Motorcycle (MC)		Total Motor Vehicles	
		Protected EMP =1,00		Protected EMP =1,30		Protected EMP = 0,15			
		Vehicles/hour	Protected PCU/hour	Vehicles/hour	Protected PCU/hour	Vehicles/hour	Protected PCU/hour	Vehicles/hour	Protected PCU/hour
S	BKiJT	104	104	11	14,3	994	149,1	1109	267,4
	Straight	219	219	10	13	1631	244,65	1860	476,65
	BKa	203	203	6	7,8	1038	155,7	1247	366,5
	Total	**526**	**526**	**27**	**35,1**	**3663**	**549,45**	**4216**	**1110,55**
W	BKiJT	286	286	152	197,6	885	132,75	1323	616,35
	Straight	255	255	28	36,4	2599	389,85	2882	681,25
	BKa	32	32	1	1,3	764	114,6	797	147,9
	Total	**573**	**573**	**181**	**235,3**	**4248**	**637,2**	**5002**	**1445,5**

Saturation Flow and Flow Ratio

Table 2. Calculation of Flow Ratio for Morning Peak Hour

Approach Code	Saturation Flow, S (pcu/hour)	Traffic Volume, q (veh/hour)	Flow Ratio	Phase Ratio
N	7440,93	2645,80	0,356	0,289
E	4335,66	1783,00	0,411	0,335
S	5155,92	1110,55	0,215	0,175
W	5859,00	1445,50	0,247	0,201

Capacity (C) & Degree of Saturation (D_S)

Table 3. Calculation of Capacity and Degree of Saturation for Morning Peak Hour

Approach Code	Traffic Volume, q (pcu/hour)	Capacity, C (pcu/hour)	Degree of Saturation, D_S
N	2645,80	2383,42	1,11
E	1783,00	1066,98	1,67
S	1110,55	1107,72	1,00
W	1445,50	1007,02	1,44

Traffic Performance at Signalized Intersections (APILL)

Number of Queued Vehicles

Table 4. Calculation of Queued Vehicle Count for Morning Peak Hour

Approach Code	q (pcu/hour)	C (pcu/hour)	D_S	R_H	Number of Queued Vehicles (pcu)			
					N_{q^1}	N_{q^2}	N_Q	N_{qmax}
N	2645,80	2383,42	1,11	0,32	18,32	198,44		80
E	1783,00	1066,98	1,67	0,25	87,61	162,36		80
S	1110,55	1107,72	1,00	0,21	8,19	79,03		80
W	1445,50	1007,02	1,44	0,17	57,81	113,00		80

Number of Stopped Vehicles Value

Table 5. Calculation of Stopped Vehicles for Morning Peak Hour

Approach Code	Queue Length P_A	Stopped Vehicle Ratio R_{KH} (stop/pcu)	Number of Stopped Vehicles N_{KH} (pcu)
N	341,40	1,04	2743,72
E	675,58	1,77	3163,61
S	198,21	0,99	1103,80

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Approach Code	Queue Length P_A	Stopped Vehicle Ratio R_{KH} (stop/pcu)	Number of Stopped Vehicles N_{KH} (pcu)
W	341,62	1,50	2161,81
		Total Stopped Vehicles	**9172,94**
		Average Stopped Vehicle Ratio	1,31

Delay Analysis (T_L, T_G, T)

Table 6. Recapitulation of Delay Calculation

Approach Code	Average Traffic Delay T_L(sec)	Average Geometric Delay T_G(sec)	Average Delay $T = T_L + T_G$	Total Delay $T \times q$
N	119,47	4,01	123,49	326717,97
E	419,16	7,10	426,26	760016,88
S	127,17	4,00	131,17	145672,84
W	323,18	5,98	329,17	475809,79
			Total Average Delay	**1.708.217,47**
			Average Intersection Delay (sec/pcu)	244,560

3.2 Modeling Using PTV Vissim 22 on Existing

Source: Personal Documentation, 2025

The simulation results show the occurrence of long queues on the northern arm of Kedung Cowek Road due to high traffic density and poor vehicle flow. This condition reduces intersection performance and has the potential to cause conflicts between vehicles. Therefore, alternative scenario modeling was conducted to test the effectiveness of solutions, such as flyover construction in reducing congestion at that point.

3.3 Alternative Intersection Performance Solutions

Alternative 1: Cycle Time Engineering

Table 7. Green Time and Capacity Evaluation Alternative 1

Approach Code	q $\left(\frac{pcu}{hour}\right)$	R_q/J	R_F	C Exist. $\left(\frac{pcu}{hour}\right)$	D_S Exist.	W_{Hi} (sec)	C Plan. $\left(\frac{pcu}{hour}\right)$	D_S Plan.
N	2645,80	0,289	82	2383,42	1,11	69	2005,56	1,32
E	1783,00	0,335	63	1066,98	1,67	79	1439,15	1,24
S	1110,55	0,175	55	1107,72	1,00	42	909,87	1,22
W	1445,50	0,201	44	1007,02	1,44	48	1181,65	1,22

Based on the simulation results, the implementation of signal timing engineering through green time redistribution shows mixed results in intersection performance improvement. While some approaches show marginal improvement, the degree of saturation values in Table 7 indicate that most approaches still exceed the ideal threshold (D_S > 0.85), with several approaches actually showing increased saturation levels compared to existing conditions. This demonstrates that signal timing optimization alone is insufficient to address the severe congestion at this intersection.

Alternative 2: Geometric Engineering (Flyover Construction Plan)

Free Flow Speed on Flyover

Table 8. Recapitulation of Free Flow Speed Calculation

Approach Code	Free Flow Speed Base (km/hour)	Correction Factor for Lane (km/hour)	Free Flow Speed MP (km/hour)
North	88	0	88
South	88	0	88

Lane Segment Capacity per Hour

Table 9. Recapitulation of Lane Segment Capacity Calculation

Approach Code	Number of Lanes Being Reviewed	Base Capacity C_0 (pcu/hour)	Correction Factor for Lane Width F_{CLE}	Capacity C (pcu/hour)
North	2	2200	1	4400
South	2	2200	1	4400

Mixed Traffic Speed (VMP) and Mixed Traffic Travel Time (WT)

Table 10. Recapitulation of Lane Segment Capacity Calculation

Approach Code	Mixed Traffic Volume per Hour J (pcu/hour)	Degree of Saturation, D_S	Mixed Traffic Speed V_{MP} (km/hour)	Lane Segment Length P	Travel Time (hour)	Travel Time (seconds)
North	933,89	0,21	84	0,3	0,003571	12,86
South	428,99	0,10	**87**	0,3	0,003448	12,41

The degree of saturation (D_S) values on all approaches and peak hours are below 0,75. This indicates that alternative 2 is able to maintain smooth intersection performance and has not reached saturation conditions.

APILL Intersection Traffic Flow under Flyover

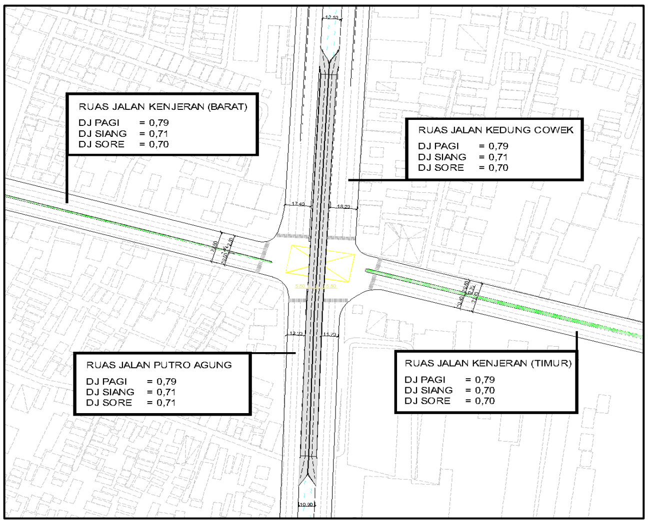
Table 11. Green Time and Capacity Evaluation Alternative 2

Approach Code	q $\left(\frac{pcu}{hour}\right)$	R_q/J	R_F	C Exist. $\left(\frac{pcu}{hour}\right)$	D_S Exist.	W_{Hi} (sec)	C Plan. $\left(\frac{pcu}{hour}\right)$	D_S Plan.
N	1711,92	0,230	0,314			75	2179,96	0,79
E	992,85	0,229	0,312			74	1253,28	0,79
S	681,57	0,132	0,180			43	866,03	0,79
W	832,38	0,142	0,194			46	1052,79	0,79

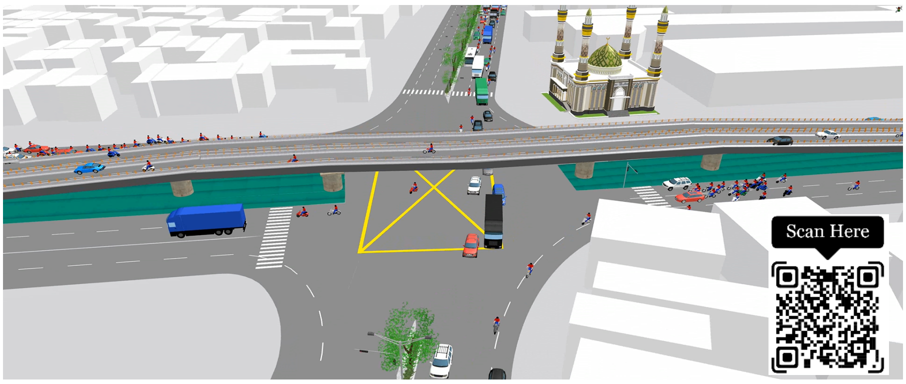
The degree of saturation analysis for the at-grade intersection after flyover construction (Table 11) shows significantly improved performance with all approaches achieving D_S = 0.79. It should be noted that these calculations reflect the reduced traffic volumes at the intersection level, as the straight-through traffic from the North (Kedung Cowek) to South (Putro Agung) directions, and vice versa, has been diverted to use the flyover structure. The traffic volumes (q) shown in Table 11 represent only the remaining turning movements and local traffic that continue to use the signalized intersection below the flyover.

Modeling Using PTV Vissim 22 on Alternatives

The traffic condition modeling for alternative 2 was conducted to illustrate the changes in intersection performance following the implementation of geometric engineering in the form of a flyover construction. This modeling utilized PTV Vissim 22 software to simulate traffic dynamics and AutoCAD to depict the geometric layout of the proposed design.



Source: Personal Documentation, 2025



Source: Personal Documentation, 2025

The model provides a comprehensive overview of the impact of the proposed engineering measures on actual traffic conditions and serves as a basis for evaluating future intersection performance.

4. Conclusion

Current intersection performance is considered suboptimal. Based on calculation results using PKJI 2023, the average delay reaches 244,56 sec/pcu, with the highest degree of saturation of 1,67 on the eastern approach. The proposed solutions include optimizing signal cycle time from 256 seconds to 238 seconds, as well as redistributing green time for each phase. This adjustment considers the highest traffic volume occurring on the northern approach, which is 2645,80 pcu/hour. However, the analysis demonstrates that signal retiming alone (Alternative 1) proves insufficient to achieve acceptable performance levels, as degree of saturation values remain above the ideal threshold of 0.85 for most approaches. Simulation results for alternative conditions involving flyover construction and phase time rearrangement show improved intersection performance. Average delay decreased to 97,02 sec/pcu, degree of saturation reduced to 0,79, and average queue length dropped to 0,86 meters. Given the inadequacy of simple signal optimization measures and the substantial traffic demand at this critical intersection, the capital-intensive flyover project emerges as a necessary infrastructure solution to achieve acceptable service levels. These findings indicate that the alternative scenario with a flyover is more effective than existing conditions in reducing congestion and improving traffic efficiency.

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