

ANALYSIS OF THE PERFORMANCE EFFECTIVENESS OF THE KARYA WISATA INTERNATIONAL SYSTEM USING THE PTV VISSIM SIMULATION APPROACH AND THE 2023 PKJI STANDARDS

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Abstract

Karya Wisata intersection in Medan Johor District experiences declining traffic performance due to high vehicle volumes and side friction from commercial activities. This study evaluates existing intersection performance using the 2023 Indonesian Road Capacity Manual (PKJI 2023) and PTV VISSIM and identifies the most effective improvement scenario. Traffic volume, road geometry, and side friction were obtained through field surveys. The existing condition had a degree of saturation of 0.81, an average simulated delay of 31.80 seconds/vehicle, a maximum queue length of 35.75 meters, and Level of Service (LOS) D. Five improvement scenarios were evaluated: a separating median, U-turn relocation, traffic signal control (APILL), combined APILL and median treatment, and a flyover. APILL was selected as the most practical tactical intervention, achieving LOS B with an average delay of 19.71 seconds/vehicle and a maximum queue length of 73.13 meters. The flyover achieved LOS A but was positioned as a secondary long-term alternative. The study recommends APILL supported by side-friction control to optimize intersection performance and maintain traffic-flow stability.

Keywords: *Intersection Performance; PKJI 2023; PTV VISSIM; Side Friction; Traffic Signal Control (APILL).*

INTRODUCTION

Intersections are a critical part of the road network because they connect vehicle flows from various directions. At unsignalized intersections, smooth movement is influenced by the acceptance of gaps and prioritization among road users. Increasing traffic volumes approaching capacity can reduce speeds and increase delays and queues. Roads, as transportation infrastructure, play a role in supporting the mobility of people and goods, as explained in Law Number 2 of 2022 (Indonesia, Republic of, 2022).

The development of residential and commercial activities in Medan Johor District has increased the traffic load on Jalan Karya Wisata. The J.City area, the Citra Wisata Complex, and Johor Indah Permai areas serve as sources of traffic, while commercial activities around the intersection create side obstacles. Data from the Medan City Statistics Agency (BPS) (2026) used in this study recorded a population of approximately 2,540,120. This condition underpins the evaluation of the intersection's capacity to serve traffic during peak hours.

This study aims to analyze the performance of the Karya Wisata intersection using PKJI 2023 and PTV VISSIM, compare performance parameters, and determine alternative management options. The analysis includes volume, capacity, degree of saturation, delays, queues, and service levels. The results are used to formulate intersection management strategies appropriate to the traffic conditions and side obstacles at the study site.

LITERATURE REVIEW

Intersection capacity and performance

An intersection is an area where two or more roads meet to facilitate a change in direction. Its capacity is influenced by the number of arms, lanes, approach width, median, environmental conditions, and traffic composition. The 2023 PKJI defines intersection capacity as the multiplication of the base capacity by a correction factor reflecting

differences in field conditions from ideal conditions (Directorate General of Highways, 2023). Intersection performance is then assessed through the degree of saturation, delays, and queuing opportunities.

Side obstructions are disruptions to traffic flow caused by activities on the side of the road. These include pedestrians, stopped or parked vehicles, vehicles entering and exiting a site, and slow-moving vehicles. In commercial environments, these activities can reduce the effective width and disrupt the flow of people leaving on approach roads. Therefore, performance assessments consider not only vehicle volume but also the characteristics of the activity around the intersection (Directorate General of Highways, 2023).

Previous research findings

Lubis et al. (2021) studied the Raja–Pelangi–Turi Intersection in Medan City and obtained a peak flow of 6,059 smp/hour and a degree of saturation of 0.87. At an unsignalized intersection, Afni et al. (2023) reported a capacity of 2,169 smp/hour and a degree of saturation of 1.05 on Jalan Ahmad Yani–Raden Intan, Gadingrejo. Simanjuntak et al. (2022) found a degree of saturation of 1.1238 at the Deli Tua Pamah–Besar Deli Tua Intersection, with on-road parking as the cause of the reduction in effective width. These three studies demonstrate the importance of the relationship between traffic load, capacity, and roadside conditions.

Intersection management can be done through traffic management, geometric changes, or signal control. Zulkarnaen et al. (2024) evaluated the coordinated intersection at Kapuas II Bridge and Kapur Village with saturation degrees of 1.08 and 1.15 and delays reaching 273 seconds. Proposed improvements include widening the approach and optimizing the signal cycle. Madani and Supriyanto (2024) used SIDRA INTERSECTION 8.0 at the Tlogomas Intersection and reported an alternative right-turn prohibition that improved service to LOS B. Putri et al. (2021) showed that widening the approach at the Setia Darma 2–Kalimalang Inspection Intersection can improve service from LOS F to LOS D.

U-turns also affect traffic flow. Febriyani et al. (2024) showed that U-turns on Jalan HZ Mustofa, Tasikmalaya, were associated with reduced speeds and increased queues. Nababan et al. (2024) identified a limited turning radius at the median opening on Jalan Trikora, Manokwari, which lengthened maneuvers and triggered conflicts. These findings are relevant to the Karya Wisata Intersection because the U-turn facility is located close to the intersection entrance.

Simulation approach and research position

PTV VISSIM models individual vehicle movements, including interactions, braking, acceleration, and lane selection. The network is formed through links and connectors, while priority settings are used to represent conflicts at unsignalized intersections. The model requires calibration and validation to ensure that the simulation output matches observed conditions. In this study, volume suitability was tested using GEH and MAPE before the model was used to evaluate improvement alternatives.

The research's distinctive feature lies in its evaluation of the Karya Wisata corridor, which has commercial activity and local side obstacles, and its integration of the 2023 PKJI analysis with microscopic simulations. The focus is not solely on determining existing conditions but also on comparing five management scenarios at the same location. Thus, recommendations are formulated based on operational testing results and intersection problem characteristics.

METHOD

Location, data, and research stages

The study was conducted at the Karya Wisata–Jalan Jenderal Besar AH Nasution intersection, Medan Johor District, Medan City, near the commercial area of the Chykes Supermarket. Primary data included road geometry, vehicle volume, and side obstacles. In accordance with the survey implementation presented in the research results section, observations took place over seven days, covering weekdays and weekends, with 15-minute recording intervals at 6:00–9:00, 11:00–14:00, and 16:00–19:00 WIB. Volume was obtained through manual traffic counts by vehicle type. Geometric traffic was measured directly using a meter, while side obstacles were observed and recorded on survey forms. Stopwatches, mobile phone cameras, and a traffic counter app supported the recording and documentation. Secondary data, including Medan's population, was used to determine the city size adjustment factor. The research flow is presented in Figure 1.

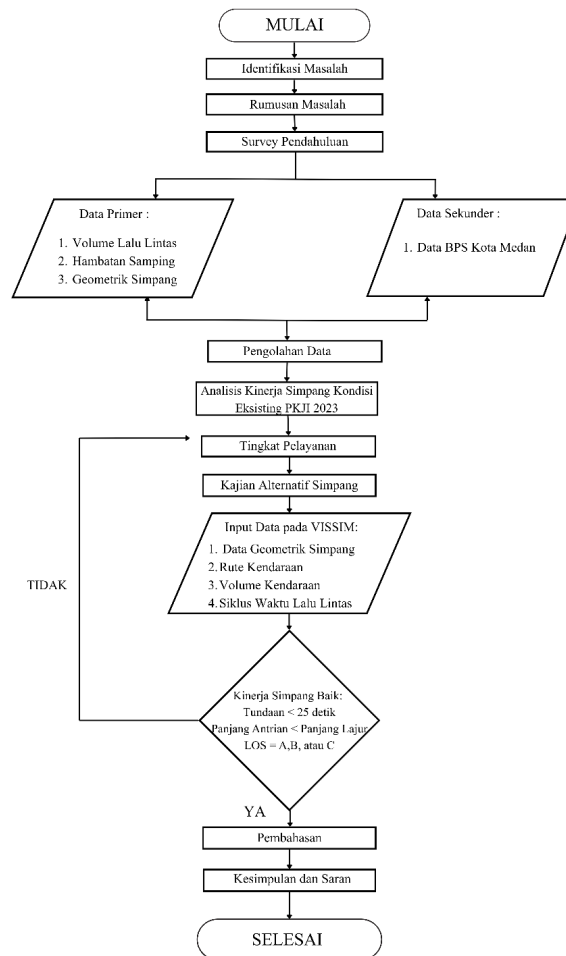


Figure 1. Research flow diagram

Source: Flowchart in research manuscript.

Data was processed using PKJI 2023 and input into PTV VISSIM. The existing model was validated by comparing observed and simulated volumes. Furthermore, five improvement scenarios were tested and compared based on delays, queue lengths, and service levels. The study did not include detailed geometric designs, cost budgets, or in-depth analysis of macro-transportation policies and land-use changes.

RESULTS AND DISCUSSION

Location and geometric characteristics of intersections

The Karya Wisata intersection is located at the intersection of the main corridor of Jalan AH Nasution and the Jalan Karya Wisata corridor. The study location was chosen because it serves residential and commercial areas with high traffic density. Direct access to shophouses, supermarkets, and businesses near the approach is a crucial factor in the observed operational conditions. A map of the study location is shown in Figure 2.



Figure 2. Map of research location

Source: Google Earth, 2026.

The geometric inventory provides the physical parameters as the basis for capacity calculations and model development. Major roads serve as primary arteries with national road status, while minor roads serve as secondary collectors with city road status. Both corridors are 4/2 T type. Details of the intersection geometric measurement results are presented in Table 1.

Table 1. Geometric Data of the Field Trip Intersection

No	Information	Mayor Street	Minor Road
1	Location	Karya Wisata Intersection, Medan Johor District, Medan City	Karya Wisata Road, Medan Johor District, Medan City
2	Road Function	Primary Arterial Road	Secondary Collector Road
3	Road Status	National Road	City Road
4	Road Type	4/2 T (four lanes, two directions, divided)	4/2 T (four lanes, two directions, divided)
5	Road Body	7 meters	6 meters
6	Lane Width	3.5 meters per lane	3 meters
7	Shoulder Width	1.7 meters	0.75 meters
8	Median Width	7 meters	0.4 meters
9	Median Amount	1 unit	1 unit

Source: Results of research analysis.

Traffic volume processing

Vehicle count data at 15-minute intervals was accumulated into hourly traffic. Traffic in vehicles/hour was converted to passenger car units using the EMP values used in the study, namely 1.0 for passenger cars, 1.8 for medium-sized vehicles, and 0.2 for motorcycles. This determination follows the traffic group of $\geq 1,000$ vehicles/hour in the 2023 PKJI (Directorate General of Highways, 2023). A seven-day summary served as the basis for determining critical conditions for the analysis.

Traffic volume and peak hour determination

The summary in Table 2 shows the variation in current according to the time and day of observation. Based on this summary, the weekday peak hour is set on Wednesday at 4:30–5:30 PM WIB with a flow of 4,933.2 smp/hour. The weekend peak occurs on Saturday at 6:00–7:00 PM WIB with a flow of 3,908.6 smp/hour. Weekday conditions are used as the primary reference for analysis and simulation.

Table 2. Recapitulation of LHR Traffic smp/hour

time	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday
06.00-07.00	3594	3204.6	3250.8	3337	2221.8	1614.6	2971.2
06.15-07.15	3849.8	3605.4	3681.8	3697	2502	1675.4	3547
06.30-07.30	4273.2	4018.8	4047.2	3954	2656.8	1811.8	4067.6
06.45-07.45	4423.8	4203.8	4133	3982	2943.6	1811.8	4534.8
07.00-08.00	4211.6	4196.4	3904.6	3738.2	2972.2	1898.6	4896.8
07.15-08.15	3954.8	4046	3551.8	3377	2910.2	2109.8	4714.6
07.30-08.30	3421	3669.8	3071.4	2913.4	2788	2072.6	4348.4
07.45-08.45	3102.8	3289	2675	2503	2370.4	2011.4	3656.8
08.00-09.00	2801	2939.8	2280	2098.2	2017.4	1822.6	2862
11.00-12.00	2874.6	3086.8	2538.4	2772	3274.8	2055.8	2548.2
11.15-12.15	3147.8	3435.4	2796.6	3448	3542	2193	2892
11.30-12.30	3311.2	3584	2903	3494.2	3647	2225.6	3187.6
11.45-12.45	3306.4	3507.2	2796.6	3439.6	3689	2142.8	3337.2
12.00-13.00	3115.2	3275.8	2674	3370.6	3511	1982	3245
12.15-13.15	2825.4	2941.6	2438.8	3155.8	3238	1782.2	3109.6
12.30-13.30	2560.8	2615	2275.4	3086.2	2982.4	1605.6	2786.6
12.45-13.45	2350.2	2329.4	2113	3041.8	2653.6	1447.8	2384.6
1:00-2:00 PM	2212.2	2210.6	1973.2	3154.4	2411.8	1317.2	2056.4
16.00-17.00	3626	4541.4	3971	4183.2	2909	2342.6	2694.4
4:15 PM - 5:15 PM	3838	4814.8	4117.4	4309.6	3070.4	2889.4	3074.2
4:30-5:30 PM	4006.2	4933.2	4051	4371	3143.4	3231.8	3456
4:45-5:45 PM	4450.8	4743.6	3962.6	4263.6	3224.4	3570.4	3629.2
17.00-18.00	4831.2	4428.4	3880.8	4220.8	3305.4	3835.8	3739.4
17.15-18.15	4861.2	4083.8	3840.4	4129.4	3493.6	3890.8	3772
17.30-18.30	4737.6	3881.2	3796.4	4061.6	3676.4	3861.6	3695.2
17.45-18.45	4077	4011	3732.2	3967.6	3781.6	3599.4	3628
18.00-19.00	3283.8	4019.2	3641.4	3978.2	3908.6	3186.8	3373.8

Source: Results of research analysis.

The overall graph in Figure 3 shows traffic fluctuations during the observation period. The flow pattern shows differences between morning, afternoon, and evening periods.

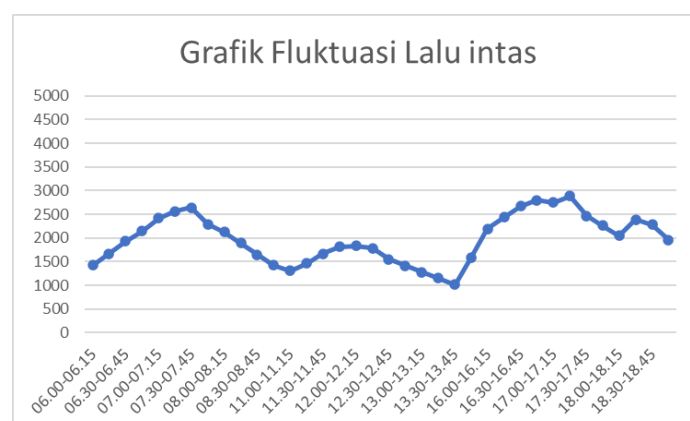


Figure 3. Overall Traffic Fluctuation Graph

Source: Results of researcher analysis.

Traffic fluctuations according to observation period

During the morning period, volume increases gradually as people move towards work, school, and other routine activities, then decreases towards the end of the observation period. This pattern is shown in Figure 4.

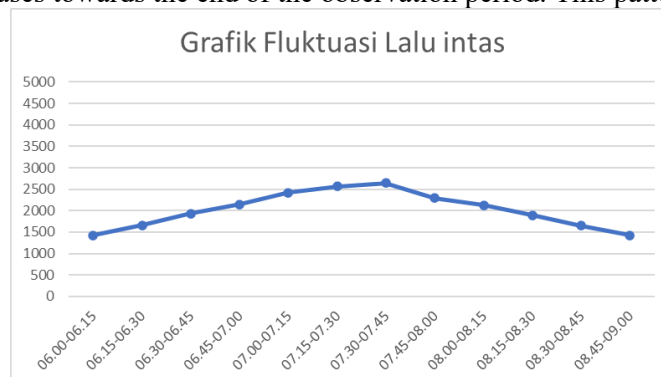


Figure 4. Morning Traffic Fluctuation Graph

Source: Results of researcher analysis.

The afternoon period shows relatively lower volumes compared to the morning and afternoon periods. Observations indicate that this period is not peak travel time at the study location, as seen in Figure 5.

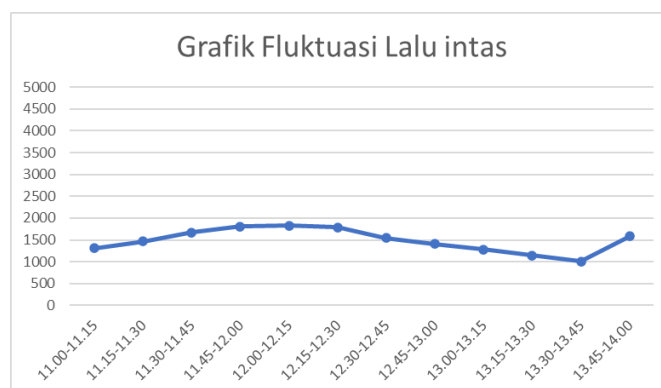


Figure 5. Traffic Fluctuation Graph for the Afternoon Period

Source: Results of researcher analysis.

In the afternoon, the increase in traffic is related to the return to work and school activities. Wednesday's observations determined 4:30–5:30 PM WIB as the peak hour used to assess intersection performance. The afternoon period graph is presented in Figure 6.

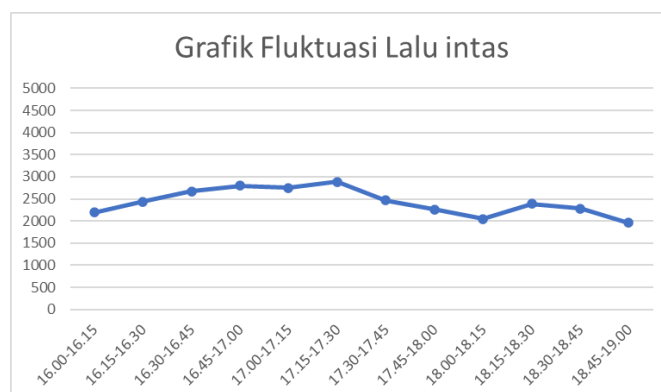


Figure 6. Traffic Fluctuation Graph for the Afternoon Period

Source: Results of researcher analysis.

Side effects and performance based on PKJI 2023

Side obstruction observations focused on the Jalan Karya Wisata approach due to its high commercial activity. The recapitulation in Table 3 recorded a weighted frequency of 201.6 incidents per hour during Wednesday's peak hour, 4:30–5:30 PM WIB. Qualitatively, the location was classified as having high side obstructions because stopping activities, pedestrians, and vehicles entering and exiting the area disrupted the departure flow.

Table 3. Recapitulation of Weighted Frequency of Side Obstacles at the Field Trip Intersection

time	PED	PSV	EE	SMV	total
06.00-07.00	21.6	15.6	69	69.6	175.8
06.15-07.15	27.6	18.6	88.8	85.8	220.8
06.30-07.30	28.8	19.2	94.2	89.4	231.6
06.45-07.45	26.4	17.4	88.2	82.8	214.8
07.00-08.00	18.6	12.6	69	64.2	164.4
07.15-08.15	12.6	9	50.4	48	120
07.30-08.30	9.6	7.2	40.2	36.6	93.6
07.45-08.45	7.2	6.6	31.8	29.4	75
08.00-09.00	5.4	6	26.4	24.6	62.4
11.00-12.00	11.4	10.2	67.2	58.2	147
11.15-12.15	12	15	86.4	75	188.4
11.30-12.30	13.8	17.4	101.4	81.6	214.2
11.45-12.45	19.8	18.6	108	78.6	225
12.00-13.00	21	18.6	103.2	69.6	212.4
12.15-13.15	22.2	14.4	87	53.4	177
12.30-13.30	19.2	10.2	67.2	40.8	137.4
12.45-13.45	10.8	7.8	48.6	33	100.2
1:45-2:00 PM	7.8	6.6	36.6	27	78
16.00-17.00	21	13.8	76.2	55.8	166.8
4:15 PM - 5:15 PM	20.4	15.6	83.4	66.6	186
4:30-5:30 PM	21	15.6	86.4	78.6	201.6
4:45-5:45 PM	19.8	15.6	88.2	82.8	206.4
17.00-18.00	21	18	95.4	90	224.4
17.15-18.15	22.8	21.6	106.2	97.8	248.4
17.30-18.30	21	21	106.2	93.6	241.8
17.45-18.45	22.8	22.2	114.6	97.8	257.4
18.00-19.00	16.8	17.4	97.8	86.4	218.4

Source: Results of research analysis.

PED = pedestrian; PSV = parked/stopped vehicle; EE = entering/exiting vehicle; SMV = slow vehicle.

The road environment is designated as a commercial area. The non-motorized vehicle ratio of 0.003 is rounded to 0.00 in determining the lateral resistance correction factor. With a basic capacity of 3,200 smp/h for intersection type 344, the correction factors are used to obtain the following existing capacity (Directorate General of Highways, 2023).

$$C = C_0 \times F_{LP} \times F_M \times F_{UK} \times F_{HS} \times F_{BK_i} \times F_{BK_a} \times F_{mi} \quad (1)$$

Calculations at peak hours yield $C = 3,200 \times 1.0399 \times 1.2 \times 1.00 \times 0.93 \times 1.35514 \times 1.09 \times 1.1034293 = 6,098$ smp/hour. The degree of saturation is obtained from the ratio of flow to capacity.

$$D_J = q/C = 4,933.2/6,098 = 0.81 \quad (2)$$

Intersection traffic delays were reported at 9.60 seconds/pcu, major road delays at 7.09 seconds/pcu, and minor road delays at 23.01 seconds/pcu. With a geometric delay of 4.00 seconds/pcu, intersection delays were 13.60 seconds/pcu. The probability of queuing was in the range of 26.37%–52.34%.

Modeling and validation of existing conditions of PTV VISSIM

The model is built with links for each approach and connectors to connect vehicle movements. Medians and separation islands are modeled as the physical boundaries of the network. Vehicle Input uses the volume per approach in vehicles/hour, while Vehicle Composition defines the desired proportion of vehicle types and speed distribution. The free speeds used in the modeling are 30 km/h for heavy vehicles, 40 km/h for cars, and 50 km/h for motorcycles. The average standstill distance and safety distance parameters are adjusted to represent dense vehicle movement. Vehicle Routing Decisions regulate the distribution of movement, while Priority Rules represent priority at conflict points. Data Collection Points are placed at intersection arms to record passing vehicles, and Queue Counters are used to record queue characteristics. Simulation output is extracted and processed to evaluate its agreement with observations. Validation was performed using GEH and Mean Absolute Percentage Error (MAPE) statistics. In model testing, $GEH < 5$ was the volume suitability criterion, while MAPE was used as a supporting measure of percentage deviation. The results of the existing condition testing are presented in Table 4.

Table 4. Existing GEH and MAPE Test Results

Origin	1 Hour Observation	VISSIM 10 Minutes	VISSIM 1 Hour	Deviation	GEH	MAPE	Information
	Vehicle/Watch	Vehicle/Watch	Vehicle/Watch				
East	2051	339	2034	-17	0.3762	0.8289	Accepted
South	9051	1474	8844	-207	2.1884	2,287	Accepted

Source: Results of research analysis.

The GEH value for the East direction is 0.3762 and the South direction is 2.1884, fulfilling the criteria of $GEH < 5$. The MAPE values are 0.8289% and 2.287%, respectively. Based on these tests, the model is declared suitable for use in evaluating existing conditions and testing improvement scenarios. The visualization of existing conditions is shown in Figure 7.



Figure 7. Simulation of Existing Intersection Conditions

Source: VISSIM simulation results, 2026.

The existing simulation results show an average delay of 31.80 seconds/vehicle, a maximum queue of 35.75 meters, and a LOS service level of D. This figure is the simulation output, while the delay of 13.60 seconds/smp in the previous section comes from the 2023 PKJI calculation. Both results are presented according to their respective approaches and units, without replacing one with the results of the other method.

Evaluation of median arrangement and U-turn relocation scenarios

Scenario 1: geometric arrangement with dividing median

A dividing median was implemented on the approach to Jalan AH Nasution to organize turning and straight-through vehicles. The goal was to reduce conflicts at the intersection entrance and irregular maneuvers. The scenario model is shown in Figure 8, while the results for each route are presented in Table 5.



Figure 8. Simulation of Median Separator Recommendation

Source: VISSIM simulation results, 2026.

Table 5. Intersection Performance Evaluation Results Scenario 1

Movement Route	Queue Length (m)	Delay (sec/kend)	Level of Service (LOS)
East - North	74.33	44.88	D
South - East	29.08	30.74	E
South – North	40.73	5.99	A

Source: VISSIM simulation results, 2026.

The results between routes differ: the East–North route has a delay of 44.88 seconds per vehicle, while the South–North route has a delay of 5.99 seconds per vehicle. The overall recapitulation places the median scenario at LOS D, with an average delay of 33.62 seconds per vehicle and a maximum queue of 74.33 meters.

Scenario 2: U-turn location reversal

The U-turn point was relocated 150 meters from its original location, with a median opening width of 10 meters. This scenario aims to provide maneuvering space and reduce weaving conflicts caused by the U-turn being too close to the intersection entrance. The U-turn handling and location are shown in Figures 9 and 10.

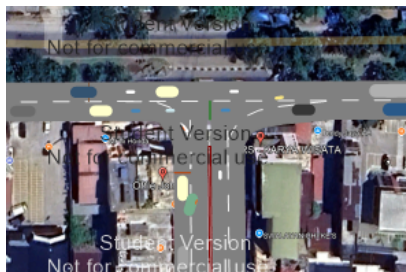


Figure 9. U-turn location reversal

Source: VISSIM simulation results, 2026.

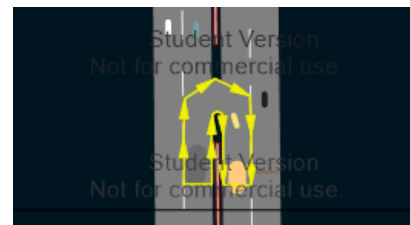


Figure 10. Relocation of the U-turn by 150 m

Table 6. Intersection Performance Evaluation Results Scenario 2

Movement Route	Queue Length (m)	Delay (sec/kend)	Level of Service (LOS)
East - North	135.84	170.73	F
South - East	21.20	69.30	C
South – North	21.20	69.30	D

Source: VISSIM simulation results, 2026.

Evaluation of signal phase management scenarios

Scenario 3: signal phase management (APILL)

The APILL scenario was implemented without changing the existing U-turn position. Controls separate green time allocations for the main traffic flow and U-turn traffic to regulate vehicle movement at the conflict point. The model and evaluation results are shown in Figure 11 and Table 7.



Figure 11. APILL Recommendation Simulation

Source: VISSIM simulation results, 2026.

Table 7. Evaluation Results of Scenario 3

Movement Route	Queue Length (m)	Delay (sec/kend)	Level of Service (LOS)
East - North	73.13	38.18	D
South - East	40.78	7.81	A
South – North	46.44	16.36	B

Source: VISSIM simulation results, 2026.

The South–East route reaches LOS A and the South–North route LOS B, while the East–North route is at LOS D. The overall recapitulation results in LOS B, an average delay of 19.71 seconds/vehicle, and a maximum queue of 73.13 meters. This scenario is determined as the most applicable tactical handling for the current intersection performance improvement needs.

Scenario 4: combination of APILL and dividing median

The combined scenario combines physical separation of left-turn traffic with signal management. A median separates turning vehicles from the straight-through queue, while the APILL regulates the turnaround. The results show different service levels for each route, as shown in Figure 12 and Table 8.



Figure 12. Combined Recommendation Simulation

Source: VISSIM simulation results, 2026.

Table 8. Results of Analysis of Recommendation 4

Movement Route	Queue Length (m)	Delay (sec/kend)	Level of Service (LOS)
East - North	62.74	60.65	E
South - East	37.80	13.49	B
South – North	64.03	5.88	A

Source: VISSIM simulation results, 2026.

Non-level intersection scenarios and comparison of results

Scenario 5: flyover construction with U-turn relocation

A flyover is planned in the median of Jalan AH Nasution to separate through traffic from local traffic and turning traffic. Utilizing the median space is intended to reduce land acquisition requirements. The scenario also includes relocating the U-turn to provide more adequate maneuvering space. A visualization of the simulation results is shown in Figure 13.

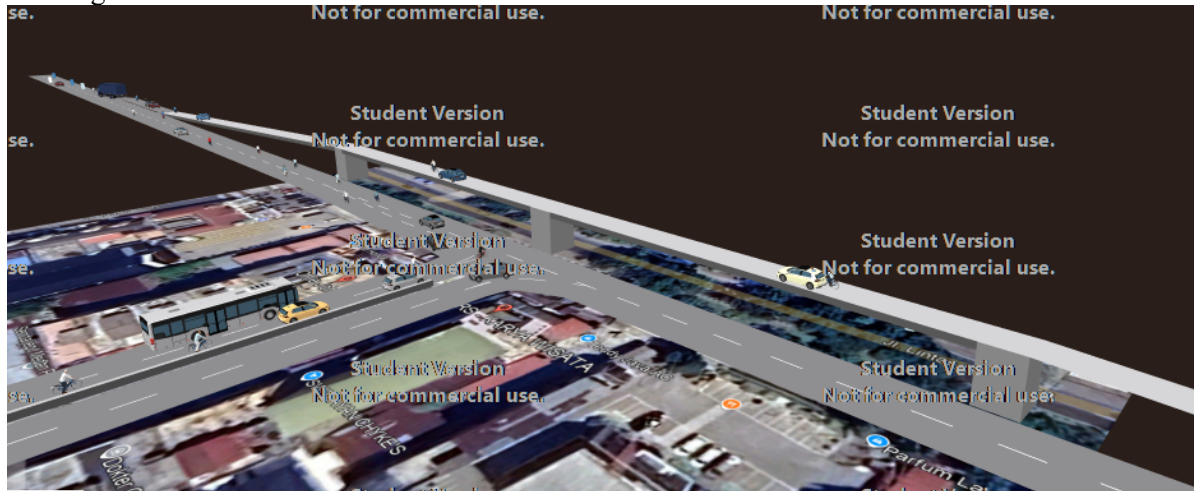


Figure 13. Simulation of Recommendations for Non-Level Intersections (Flyovers) with U-turn Relocation

Source: VISSIM simulation results, 2026.

Table 9. Results of Analysis of Recommendation 5

Movement Route	Queue Length (m)	Delay (sec/kend)	Level of Service (LOS)
East - East	22.57	1.07	A
East - North	22.57	9.08	A
South - East	0	6.89	A
South – North	0	0	A

Source: VISSIM simulation results, 2026.

All routes in the flyover scenario achieved LOS A. Although it provided the best operational results in the simulation, its construction was positioned as a long-term alternative. Determining development needs requires considering traffic developments through further assessments, and this study did not calculate detailed construction costs.

Performance comparison across scenarios

The summary of simulation results in Table 10 serves as the basis for comparing the effectiveness of alternatives. The comparison includes the maximum queue length, average delay, and service level for each scenario.

Table 10. Comparison of Intersection Performance Evaluation Results

Condition	Max Queue Length (m)	Average Delay (sec/kend)	Level of Service (LOS)
Existing	35.75	31.80	D
Median Separator	74.33	33.62	D
U-turn Location Reversal	170.73	40.81	E
Signal Phase Management (APILL)	73.13	19.71	B
Combined (APILL and Median Separator)	64.03	24.31	C
Construction of a Non-Level Intersection (Flyover)	22.57	5.01	A

Source: VISSIM simulation results, 2026.

Discussion of results and handling priorities

The results of the study show that the operational problems of the Karya Wisata Intersection are influenced by a combination of high volume, traffic conflicts, and commercial activities on the approach. The degree of saturation of 0.81 describes the large capacity utilization during peak hours, while the VISSIM output indicates the condition of LOS D service. Observations of side obstacles explain the disruption of departure flow due to stopped vehicles, pedestrian activities, and vehicles entering and exiting the land. Therefore, the handling of the intersection is not only directed at changing infrastructure, but also at regulating movement and regulating the roadside.

This finding is related to Simanjuntak et al. (2022), who emphasized the impact of reduced effective width due to parking, as well as Febriyani et al. (2024) and Nababan et al. (2024), who discussed U-turn maneuver conflicts. However, the results of the Karya Wisata test indicate that relocating the U-turn alone is not the primary option. The recapitulation of the scenarios still shows a LOS of E. The dividing median also does not change the overall service category from LOS D. Therefore, the suitability of the treatment needs to be assessed through evaluation results at the research location, not solely based on the initial objectives of each scenario.

The APILL provides an average delay of 19.71 seconds/vehicle and a LOS of B, compared to the existing condition of 31.80 seconds/vehicle and a LOS of D. However, the APILL maximum queue of 73.13 meters is longer than the existing value of 35.75 meters. Therefore, the reported improvement should be read primarily on the delay and level of service parameters, not as a decrease in all indicators simultaneously. The APILL and median combined result in a maximum queue of 64.03 meters, but an average delay of 24.31 seconds/vehicle and a level of service of LOS C. The APILL priority aligns with the discussion of intersection control through signal optimization in Zulkarnaen et al. (2024). The flyover resulted in a LOS of A, an average delay of 5.01 seconds per vehicle, and a maximum queue length of 22.57 meters. Nevertheless, the research recommendation still prioritizes APILL as a tactical solution and positions the flyover as a long-term alternative. These practical considerations are research recommendations, not the results of economic feasibility calculations, as cost analysis was not included in the study's limitations.

CONCLUSION

The existing condition of the Karya Wisata Intersection based on PKJI 2023 obtained a saturation degree of 0.81. The PTV VISSIM simulation resulted in an average delay of 31.80 seconds/vehicle, a maximum queue of 35.75 meters, and a LOS of D. This performance was influenced by the high volume of vehicles and the activity of entering and exiting commercial areas as dominant side obstacles. GEH and MAPE tests in the evaluated direction met the validation criteria used in the study. Of the five scenarios, signal phase management (APILL) is recommended as the most applicable tactical solution, with a LOS of B, an average delay of 19.71 seconds per vehicle, and a maximum queue of 73.13 meters. Its implementation needs to be supported by the regulation of side obstacles, especially vehicle access to commercial areas. Flyovers can be considered as a long-term alternative after further assessment using annual daily traffic data. Future research is recommended to deepen the calibration of driver behavior to make the model more closely align with field conditions.

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