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Performance Analysis of Two Unsignalized Intersections

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Abstract: The escalating traffic volumes driven by population growth and increasing vehicle ownership within the IPB University educational area in Dramaga, Bogor leads to transportation challenges. This study aims to evaluate the operational performance of the Babakan Raya Intersection and Duta Berlian Intersection in IPB Dramaga campus area, by integrating the analysis of the two intersections using Indonesian Road Capacity Manual (PKJI 2023). The analysis of existing conditions in 2026 indicates that the Babakan Raya Intersection operates at Level of Service (LOS) C, with a degree of saturation (DS) of 0.96, while the Duta Berlian Intersection operates at LOS B, with a DS of 0.86. Despite improved performance compared with previous-year studies, attributed to route redistribution and a reduction in observed traffic volumes, both intersections remain vulnerable to high delays and significant side friction. To optimize traffic flow, various traffic engineering scenarios were evaluated. The results indicate that a combined strategy involving the installation of traffic signal control (APILL) and geometric widening constitutes the most effective solution. Implementation of a 32-second signal phase at the Babakan Raya Intersection reduced the DS to 0.55, with a delay of 6.39 seconds/passenger car unit (PCU), corresponding to LOS B. Similarly, implementation of a 42-second signal phase accompanied by roadway widening at the Duta Berlian Intersection reduced the DS to 0.71, with a delay of 13.14 seconds/PCU (LOS B). This comprehensive traffic engineering strategy demonstrates its effectiveness in systematically increasing intersection capacity, minimizing traffic conflicts, and meeting the minimum service standards stipulated by national transportation regulations for strategically important educational areas.

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1. Introduction

Road infrastructure development plays a strategic role in supporting an efficient transportation system, particularly in educational areas such as IPB University. In recent years, the Dramaga area, especially along Babakan Raya Road and the IPB Dramaga campus ring road, has experienced a substantial increase in traffic volume. This growth is closely associated with the rapid expansion of IPB University as a major center for education, research, and other academic activities, accompanied by population growth and increasing motor vehicle ownership in the surrounding area. Two intersections that play a critical role in facilitating traffic movement within this area are the three-leg Babakan Raya Intersection, which provides a primary connection between Babakan Raya Road and Dramaga Road, and the four-leg Duta Berlian Intersection, which serves as a major link between the IPB Campus Ring Road and Dramaga Road. Both intersections constitute vital transportation nodes supporting the daily mobility of local communities and the IPB academic community in the Dramaga area.

Based on data from Statistics Indonesia (BPS) (2024), the population of Bogor Regency reached approximately 5,664,537 in 2024, making it one of the most populous regencies in Indonesia. The increasing population has been accompanied by growing transportation activity, with traffic congestion particularly pronounced during morning and afternoon peak hours. This condition is largely associated with the high mobility of residents commuting to workplaces and educational institutions outside the regency, particularly in Jakarta and its surrounding areas [1]. Furthermore, rapid population growth has been accompanied by a 7.51% annual increase in the number of motor vehicles, reaching 1,666,859 units in 2023 [2].

Traffic congestion in Bogor Regency results from a combination of interrelated factors, including traffic demand exceeding road capacity, undisciplined road-user behavior, and limitations in transportation infrastructure and traffic-control facilities. Previous studies have identified additional contributing factors, such as the limited implementation of effective traffic signal systems, illegal roadside parking, and the lack of alternative routes [3,4]. In addition, low public awareness of the importance of traffic discipline further exacerbates traffic conditions in urban areas [5]. In the vicinity of the IPB Dramaga campus, increasing congestion is driven not only by academic activities but also by surrounding community activities, including commercial activities, public transportation operations, and social activities within adjacent residential areas. These activities generate substantial traffic conflicts at nearby intersections, particularly at the Babakan Raya (Bara) and Duta Berlian (Duber) intersections, both of which currently operate as unsignalized intersections. According to the 2023 Indonesian Road Capacity Guidelines (PKJI), unsignalized intersections of this type are generally associated with considerable delay and a high potential for traffic conflicts, particularly in areas characterized by intensive educational and residential activities [6]. Previous studies have also indicated that geometric improvements and the implementation of traffic signal control systems (APILL) can improve intersection efficiency and traffic flow conditions [7].

The integration analysis of two intersections by using the Indonesian Road Capacity Guidelines (PKJI 2023) provides a quantitative approach for evaluating traffic performance, in accordance to Minister of Transportation Regulation No. 96 of 2015. A case study at the three-leg intersection of Jl. Gusti Situt Mahmud in Pontianak projected an increase in the degree of saturation (DS) from 0.95 to 1.07, accompanied by a decline in the Level of Service (LOS) from C to D over a five-year period [9]. Meanwhile, a study in Bekasi demonstrated that geometric optimization reduced the DS from 1.23 to 0.87 [10]. Intersection performance assessment commonly refers to Minister of Transportation Regulation No. 96 of 2015, which classifies LOS from A, representing an average delay of less than 5 seconds per vehicle, to F, representing a delay exceeding 60 seconds per vehicle [11]. For Bogor Regency, particularly along the Babakan Raya Road, IPB Campus Ring Road, and Dramaga Road corridors, the technical analysis is aligned with the Bogor Regency Spatial Plan (RTRW) 2024–2044, established through Regional Regulation No. 1 of 2024, and Minister of Public Works and Housing Regulation No. 5 of 2023. This alignment is intended to support the management of the volume-to-capacity (V/C) ratio and maintain traffic flow efficiency in an area characterized by intensive academic and logistics activities [12,13]. This study covers assessment both on existing conditions and proposed improvement scenarios, with particular emphasis on Level of Service (LOS), Degree of Saturation (DS), and average vehicle delay. The findings are expected to provide a technical basis for identifying appropriate intersection improvement strategies, including geometric optimization, coordinated traffic signal control, and other traffic engineering measures, with the broader objective of improving traffic efficiency and safety in the IPB University Dramaga area.

2. Method

2.1. Tools and location

The study was conducted at the Babakan Raya (Bara) and Duta Berlian (Duber) intersections as shown in **Figure 1**. Primary data were collected on Tuesday, 18 November 2025, during the morning peak period from 06:00 to 09:00 Western Indonesia Time (WIB) and the afternoon peak period from

15:00 to 18:00 WIB. The equipment and software used in the study included smartphones, manual counting devices, measuring tapes, laptops, stationery, the Traffic Counter application, Google Earth, Microsoft Excel, AutoCAD 2024. The primary data consisted of intersection geometric characteristics, vehicle speeds, and traffic volume at the study intersections. Secondary data included environmental characteristics and maps of the Bara and Duber intersections.

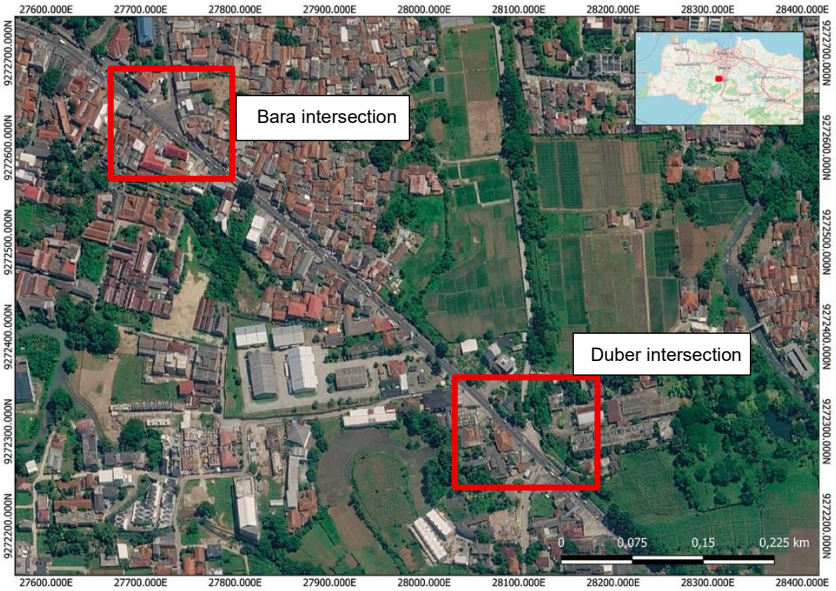


Figure 1. Study location

2.2. Traffic flow analysis

The traffic flow entering the intersections, initially recorded in vehicles per hour (veh/h), was converted into passenger car units per hour (PCU/h). This conversion was performed by applying the passenger car equivalent (PCE) factor corresponding to each vehicle type. The traffic volume was subsequently calculated using **Equation (1)**:

$$Q = \sum (n_i \times PCE_i) \quad (1)$$

where Q is the traffic volume expressed in PCU/h, n_i is the number of vehicles of type i (veh/h), and PCE_i is the passenger car equivalent factor for vehicle type i.

2.3. Intersection Capacity Analysis

Intersection capacity was evaluated based on the actual geometric characteristics of the intersection, prevailing traffic conditions, and environmental factors, by using **Equation (2)**.

$$C = C_0 \times F_{LP} \times F_M \times F_{UK} \times F_{HS} \times F_{BKi} \times F_{BKa} \times F_{Rmi} \quad (2)$$

Where:

C = Intersection capacity (PCU/h)
Co = Basic intersection capacity (PCU/h)
FLP = Correction factor for average approach width
FM = Correction factor for lane separator (median) type
FUK = Correction factor for city size
FHS = Correction factor for side friction
FBKi = Correction factor for left-turn flow ratio
FBKa = Correction factor for right-turn flow ratio

Frmi = Correction factor for minor-road flow ratio

2.4. Level of Service (LOS)

Intersection performance was evaluated based on the Degree of Saturation (DS) and intersection delay (T). The DS was determined by comparing the traffic volume (q) with the intersection capacity (C). Total intersection delay was calculated as the sum of traffic delay (TLL) and geometric delay (TG). Traffic delay TLL was calculated using **Equation (3)**, while geometric delay (TG) was determined using **Equation (4).** The intersection Level of Service (LOS) was subsequently determined based on the calculated delay values, referring to Minister of Transportation Regulation No. 96 of 2015 [14].

$$TLL = \frac{1{,}0504}{(0{,}2742-0{,}2042\ \mathrm{D_J})} - \left(1-\mathrm{D_J}\right)^2 \quad (3)$$

$$TG = \left(1-\mathrm{D_J}\right) \times \{6\mathrm{R_B} + 3(1-\mathrm{R_B})\} + 4\mathrm{D_J} \quad (4)$$

3. Result and discussion

3.1. Geometry of the Babakan Raya and Duta Berlian Intersections

The Bara Intersection is an unsignalized three-leg intersection comprising Dramaga Road (IPB-bound), Babakan Raya Road, and Dramaga Road (Duta Berlian-bound). These three approaches are designated as Approaches A, B, and C, respectively, which categorized as UD or undivided. The Duber Intersection is an unsignalized four-leg intersection comprising Dramaga Road (IPB-bound), the IPB Dramaga Campus Ring Road, Dramaga Road (Bubulak-bound), and the Dramaga Ring Road. These four approaches are designated as Approaches A, B, C, and D, respectively. The geometric characteristics of the Bara and Duber intersections are presented in **Tables 1** and **2**, respectively.

Table 1. Geometric Characteristics of Babakan Raya Intersection

Road segment	Approach	Width (m)	Road type	Lane width (m)	Side friction
Dramaga Road (IPB-bound)	A (West)	8	2/2 UD	4	High
Babakan Raya	B (North)	5,5	2/2 UD	2.75	High
Dramaga Road (Duta Berlian-bound)	C (East)	8	2/2 UD	4	High

Based on its geometric classification, the Bara Intersection is categorized as a 322 intersection, consisting of three legs, with two lanes on the major road and two lanes on the minor road. The intersection is characterized by a high level of side friction, as traffic entering and exiting the intersection is frequently disrupted by vehicles accessing adjacent road segments, public-transport passenger loading and unloading activities, and commercial activities or roadside shops. These activities generate frequent vehicle entry and exit movements and consequently interfere with traffic flow.

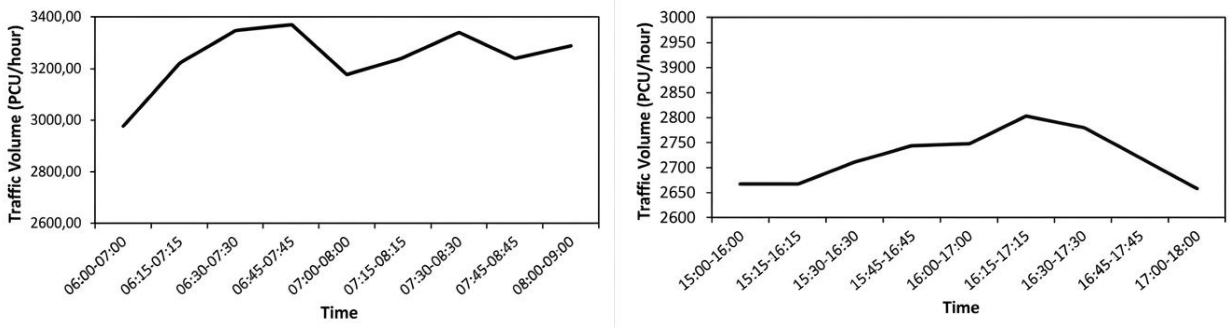
Table 2. Geometric Characteristics of the Duta Berlian Intersection

Road segment	Approach	Width (m)	Road type	Lane width (m)	Side friction
Dramaga Road (IPB-bound)	A (West)	8	2/2 UD	4	High
IPB Dramaga campus ring road	B (North)	6	2/2 UD	3	High
Dramaga Road (Bubulak-bound)	C (East)	8	2/2 UD	4	High
Dramaga ring road	D (South)	7	2/2 UD	3.5	High

Based on its geometric classification, the Duber Intersection is categorized as a 422 intersection, consisting of four legs, with two lanes on the major road and two lanes on the minor road. Similar to the Bara Intersection, the Duber Intersection experiences a high level of side friction due to vehicles entering and exiting adjacent road segments, public-transport passenger loading and unloading activities, and roadside commercial activities. These conditions contribute to frequent disturbances to traffic flow at the intersection. In addition, the Duber Intersection is equipped with a traffic signal system that is currently non-operational. The intersection also has faded pavement markings and inadequate traffic signage. These conditions indicate deficiencies in traffic-control and road-safety facilities that may further affect traffic operations and road-user safety, particularly given the strategic function of the corridor as a national road.

3.2. Traffic Volume at the Babakan Raya and Duta Berlian Intersections

Traffic volume surveys at the Bara and Duber intersections were conducted using the Classified Turning Movement Counting (CTMC) method. Observations were carried out for three hours during the morning peak period (06:00–09:00 WIB) and the afternoon peak period (15:00–18:00 WIB). The recorded vehicle counts were subsequently converted into passenger car units (PCU/h) for each vehicle type. The traffic volume data for the Bara and Duber intersections are presented graphically in **Figures 2** and **3**, respectively.

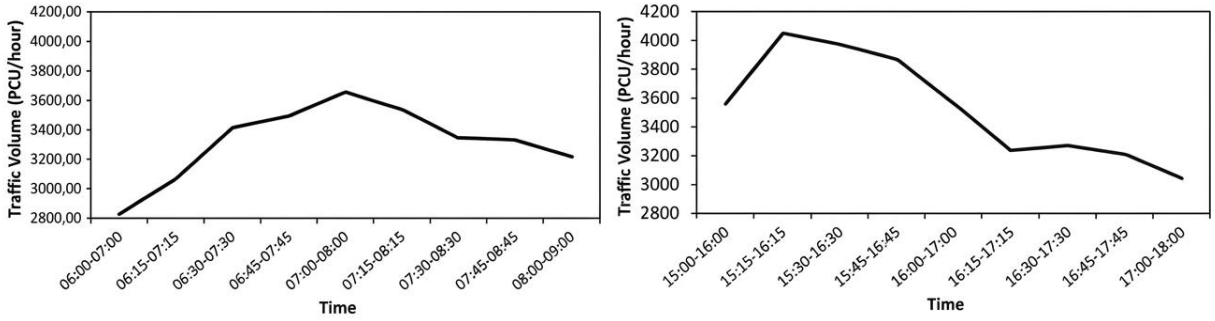


(a) **(b)**

Figure 2. Traffic volume at the Babakan Raya Intersection during **(a)** morning, **(b)** afternoon

As shown in Figure 1, the morning traffic volume at the Bara Intersection reached its peak during 06:45–07:45 WIB, with a volume of 3,369.4 PCU/h. This increase reflects the high level of travel activity during the morning peak, including commuting and school trips. Following this peak, the traffic volume decreased to 3,178 PCU/h during 07:00–08:00 WIB. This decline may be associated with traffic congestion, which causes vehicle accumulation and limits the number of vehicles that can pass through the intersection efficiently. Subsequently, traffic volume fluctuated until 09:00 WIB, indicating the gradual end of the morning peak period.

In the afternoon, the traffic volume at the Bara Intersection reached its peak during 16:15–17:15 WIB, at 2,936.8 PCU/h. The lower volume compared with the morning peak indicates a different traffic demand pattern during the afternoon period. Following the peak, the volume decreased to 2,898.4 PCU/h during 16:30–17:30 WIB. This reduction may be attributed to traffic congestion, which results in vehicle accumulation and constrains the effective discharge of traffic through the intersection. The traffic volume subsequently continued to fluctuate and decline toward 18:00 WIB, indicating the end of the afternoon peak period.



(a) **(b)**

Figure 3. Traffic volume at the Duta Berlian Intersection during **(a)** morning, **(b)** afternoon

At the Duber Intersection, the morning traffic volume reached its peak during 07:00–08:00 WIB, with a volume of 3,652 PCU/h. The increase reflects intensive travel activity during the morning peak, particularly work- and school-related trips. Following this peak, the traffic volume decreased to 3,531 PCU/h during 07:15–08:15 WIB. This decrease may be associated with traffic congestion, which causes vehicle accumulation and reduces the effective traffic discharge rate at the intersection. The traffic volume subsequently declined toward 09:00 WIB, indicating the end of the morning peak period.

During the afternoon period, the Duber Intersection recorded its highest traffic volume between 15:15 and 16:15 WIB, reaching 4,053.2 PCU/h. The higher volume compared with the morning period indicates greater traffic demand during the afternoon peak, particularly from returning work and school trips. Following this peak, the volume decreased to 3,977.2 PCU/h during 15:30–16:30 WIB. Similar to the morning period, this reduction may be associated with congestion-induced vehicle accumulation and restricted traffic discharge. The traffic volume then gradually declined until 18:00 WIB, indicating the end of the afternoon peak period.

The differences in peak periods between the Bara and Duber intersections along this corridor indicate variations in traffic demand associated with the distribution of commercial, academic, and residential activities. The morning peak at the Bara Intersection may be related to its function as an access point for local activities and commuter movements, whereas the higher afternoon peak at the Duber Intersection reflects increased travel demand associated with return trips and other afternoon activities [13]. Intersection performance is also strongly influenced by side-friction factors, including stopping and illegal parking activities, which reduce the effective roadway width and consequently decrease the capacity of unsignalized intersections [15]. The relatively short distance between the two intersections may further contribute to spillback, whereby queues forming on the minor approach of the Duber Intersection interfere with through traffic originating from the Bara Intersection [16]. Under high main-road traffic volumes, reduced opportunities for drivers to identify and accept adequate gaps (gap acceptance) may further increase vehicle queues and delay during the afternoon peak period [6].

3.3. Capacity of Babakan Raya and Duta Berlian Intersections

Intersection capacity was determined by multiplying the basic intersection capacity by the relevant adjustment factors. The detailed capacity calculations for the Bara and Duber intersections are presented in **Table 3**.

Table 3. Capacity of Babakan Raya and Duta Berlian Intersections

Intersection	Period	Co (PCU/h)	FLP	C (PCU/h)
Babakan Raya	Morning	2700	1.186	3229.70
Babakan Raya	Afternoon	2700	1.186	3365.60
Duta Berlian	Morning	2900	1.2196	3966.02
Duta Berlian	Afternoon	2900	1.2196	3839.30

The calculated capacity of the Bara Intersection presented in Table 3 was 3,229.70 PCU/h during the morning period and 3,365.60 PCU/h during the afternoon period. Although the calculated capacity was lower during the morning period, the morning peak period was selected for the subsequent improvement analysis because it represented the critical traffic condition, with the highest observed traffic demand occurring between 06:45 and 07:45 WIB.

At the Duber Intersection, the calculated capacity was 3,966.02 PCU/h during the morning period and 3,839.30 PCU/h during the afternoon period. The afternoon period was selected for the subsequent improvement analysis because it represented the critical operating condition, with the highest observed traffic volume occurring between 15:15 and 16:15 WIB. Accordingly, the subsequent intersection performance and improvement analyses focus on the 06:45–07:45 WIB period for the Bara Intersection and the 15:15–16:15 WIB period for the Duber Intersection.

3.4. Performance of Babakan Raya and Duta Berlian Intersections

Intersection traffic performance was evaluated based on the Degree of Saturation (DS) and delay (T). Total delay consists of traffic delay (TLL) and geometric delay (TG), which are subsequently used to determine the intersection Level of Service (LOS). Traffic delay is further divided into major-road traffic delay (TLLma) and minor-road traffic delay (TLLmi). The DS was calculated as the ratio of total traffic volume to intersection capacity. The resulting DS values for the Bara Intersection during the morning and afternoon peak periods were 0.96 and 0.80, respectively. At the Duber Intersection, the corresponding DS values were 0.72 and 0.86. Detailed results of the intersection performance analysis are presented in **Table 4**.

Table 4. Performance of Babakan Raya and Duta Berlian Intersections

Intersection	Period	DS	TLL (s/PCU)	TG (s/PCU)	T (s/PCU)	LOS
Babakan Raya	Morning	0.96	13.43	3.96	17.39	C
Babakan Raya	Afternoon	0.80	9.51	3.83	13.34	B
Duta Berlian	Morning	0.72	8.19	3.85	12.04	B
Duta Berlian	Afternoon	0.86	10.68	3.92	14.59	B

As shown in Table 4, the total delay at the Bara Intersection was 17.39 s/PCU during the morning peak period and 13.34 s/PCU during the afternoon peak period. At the Duber Intersection, the corresponding delay values were 12.04 s/PCU in the morning and 14.59 s/PCU in the afternoon. Intersection delay is affected by several factors, including traffic volume, intersection capacity, traffic-flow distribution, and driver behavior [6,11,17]. The resulting delay values were used to determine the intersection LOS in accordance with Minister of Transportation Regulation No. 96 of 2015. Based on the values presented in Table 4, the Bara Intersection operates at LOS C during the morning peak period and LOS B during the afternoon peak period. Meanwhile, the Duber Intersection operates at LOS B during both the morning and afternoon peak periods.

The results differ from those reported in previous studies. Ikram (2025) reported LOS E and F for the Bara Intersection during the morning and afternoon peak periods, respectively, whereas the present study obtained LOS C and B. Similarly, Fatoni (2025) reported LOS C for the Duber Intersection during both peak periods, compared with LOS B obtained in the present study. These differences may be associated with variations in observed traffic volumes between the study periods. A reduction in traffic demand in the more recent observation period may reflect traffic-flow redistribution, whereby road users dynamically select alternative routes to avoid previously identified congested locations [18].

In addition to traffic volume, changes in roadside environmental conditions may also influence intersection performance. A reduction in side-friction activities can increase the effective capacity of the roadway [15]. This interpretation is consistent with PKJI (2023), which indicates that, at unsignalized intersections, lower major-road traffic volumes increase the opportunity for minor-road vehicles to identify and accept adequate gaps in the main traffic stream (gap acceptance) [6]. Therefore, the differences in LOS between the present study and previous studies can reasonably be associated with changes in traffic demand, traffic-flow distribution, and roadside conditions during the respective observation periods. Although vehicle ownership may continue to increase over time, the operational performance of an intersection at a particular observation period is determined by the traffic demand and prevailing roadway conditions recorded during that period.

3.5. Improvement Design

According to PKJI (2023), intersection performance can be improved through several engineering measures, including increasing approach width at approaches with critical DS values and restricting right-turn movements, as eliminating one or more right-turn movements can increase intersection capacity [6]. Capacity can also be improved by reducing side friction, such as illegal parking, pedestrian activities within the roadway, and slow-moving vehicles [19].

The first improvement scenario involved widening the approaches at both the Bara and Duber intersections while maintaining their existing unsignalized configurations. The proposed geometric modification consisted of increasing the major-road approach width to 12 m and the minor-road approach width to 10 m, while reducing the side-friction level to low. The results of the proposed widening scenario compared with the existing conditions are presented in **Table 5**.

As shown in Table 5, the existing Bara Intersection had a relatively high DS of 0.96 and a total delay of 17.39 s/PCU, corresponding to LOS C. Under the widening scenario combined with reduced side friction, the DS decreased to 0.79, and total delay decreased to 13.04 s/PCU, resulting in LOS B. These changes indicate that geometric modification and side-friction management can improve the operational performance of the unsignalized intersection.

Table 5. Results of the Road-Widening Analysis at the Babakan Raya and Duta Berlian Intersections

Intersection	Scenario	DJ	T (s/PCU)	LOS
Babakan Raya	Existing	0.96	17.39	C
Babakan Raya	Widening	0.79	13.04	B
Duta Berlian	Existing	0.86	14.59	B
Duta Berlian	Widening	0.70	11.67	B

At the Duber Intersection, the existing condition produced a DS of 0.86 and a total delay of 14.59 s/PCU, corresponding to LOS B. Under the widening and side-friction reduction scenario, the DS decreased to 0.70, and total delay decreased to 11.67 s/PCU, while the LOS remained B. Although the LOS category did not change, the reduction in DS, delay, and queue probability indicates an improvement in the operational characteristics of the intersection.

The second improvement scenario involved converting the existing unsignalized intersections into signalized intersections without modifying the existing intersection geometry. Different signal-phase configurations were evaluated, including two- and three-phase arrangements for the Bara Intersection and two-, three-, and four-phase arrangements for the Duber Intersection. The analysis considered configurations that allow right-turn movements without restriction. Where the resulting performance required additional geometric capacity, road widening was considered as part of the subsequent improvement scenario. The results of the signal-phase analysis are presented in **Table 6**.

Table 6. Results of Signal-phase analysis

Intersection	Type	Intersection Flow Ratio	Cycle (s)	DS	Delay (s/PCU)
Babakan Raya	32	0.58	44	0.73	11.38
Babakan Raya	33	0.79	86	0.88	34.78
Duta Berlian	42	0.80	101	0.89	32.05
Duta Berlian	43A	1.07	-369	1.03	-
Duta Berlian	43B	0.89	213	0.94	65.89
Duta Berlian	43C	1.00	-5966	1.00	-
Duta Berlian	43D	0.93	355	0.97	151.73
Duta Berlian	44A	1.13	-231	1.05	-
Duta Berlian	44B	1.54	-53	1.16	-
Duta Berlian	44C	1.06	-460	1.03	-

The results in Table 6 indicate that both two-phase and three-phase signal configurations can be considered for traffic control at the Bara Intersection. The intersection flow ratio (IFR) must not exceed the maximum allowable value of 1.0 [6]. Among the evaluated configurations, phase configuration 32 produced an IFR of 0.58 with a cycle length of 44 s, resulting in a DS of 0.73 and an average delay of 11.38 s/PCU. The corresponding LOS was B, with the maximum queue length occurring on the western approach at 50.88 m. This configuration therefore provides an operational condition within the specified IFR limit and meets the performance criterion of maintaining LOS A or, at minimum, LOS B based on the LOS classification adopted in this study.

For the Duber Intersection, the evaluated four-phase configurations generally produced IFR values exceeding the applicable limit or operational characteristics that were not feasible. Therefore, additional engineering measures are required to obtain an acceptable signalized-intersection configuration. According to PKJI (2023), potential measures include increasing approach width, modifying signal phases, and restricting right-turn movements [6].

Among the two- and three-phase configurations evaluated for the Duber Intersection, configurations 42, 43B, and 43D produced IFR values below or close to the maximum allowable value. Configuration 42 resulted in an IFR of 0.80, a cycle length of 101 s, a DS of 0.89, and an average delay of 32.05 s/PCU, corresponding to LOS D. The maximum queue length occurred on the eastern approach and reached 175.31 m. This result indicates that signalization without geometric widening does not provide the same level of operational improvement as the geometric and signal-control combination considered in the subsequent scenario.

The third improvement scenario combined the conversion of the intersections to signalized control with road widening at each approach. The results of the combined signal-phase and geometric improvement analysis are presented in **Table 7.**

Table 7. Results of the Combined Signalization and Road-Widening Analysis

Intersection	Intersection Flow Ratio	Cycle (s)	DS	Delay (s/PCU)
Babakan Raya	0,38	29	0,55	6,39
Duta Berlian	0,54	43	0,71	13,14

As shown in Table 7, the combination of phase configuration 32 and road widening at the Bara Intersection produced an IFR of 0.38 with a cycle length of 29 s, resulting in a DS of 0.55 and an average delay of 6.39 s/PCU, corresponding to LOS B. The substantial reduction in DS and delay indicates that combining signal control with increased intersection capacity provides a greater improvement in operating conditions than either measure considered independently.

At the Duber Intersection, the combination of phase configuration 42 and road widening resulted in an IFR of 0.54, a cycle length of 43 s, a DS of 0.71, and an average delay of 13.14 s/PCU, corresponding to LOS B. These results indicate that the combined application of signal control and geometric widening can substantially improve the operational performance of the intersection while maintaining an IFR below the allowable limit.

4. Conclusion

The traffic performance analysis indicates that, under the existing conditions in 2026, the Babakan Raya Intersection operates at LOS C during the morning peak period and LOS B during the afternoon peak period, while the Duta Berlian Intersection consistently operates at LOS B. This represents a substantial improvement compared with the 2025 study, which may be associated with reduced traffic volumes and route redistribution. Nevertheless, the Babakan Raya Intersection remains critical during the morning peak period, with a degree of saturation (DS) of 0.96.

To address the potential for saturation, the evaluation of various improvement scenarios indicates that a combination of traffic signal control and road widening provides the most effective improvement among the scenarios examined. At the Babakan Raya Intersection, the implementation of traffic signal phase 32 combined with road widening reduced the DS to 0.55 and total delay (T) to 6.39 s/PCU, corresponding to LOS B. At the Duta Berlian Intersection, the combination of traffic signal phase 42 and road widening reduced the DS to 0.71, with a total delay of 13.14 s/PCU (LOS B). These improvements demonstrate the potential of integrated signalization and geometric modification to increase intersection capacity and provide more controlled traffic flow in the surrounding commercial area compared with relying solely on geometric improvements or partial signal control.

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