JURNAL TEKNIK SIPIL DAN LINGKUNGAN| EISSN:2549-1407
https://jurnal.ipb.ac.id/index.php/jsil

Vol. 10 No. 01 April 2025
DOI: 10.29244/jsil.10.1.65-76

Design of Gate 4 at IPB University and the Babakan Raya-Dramaga Road intersection to improve traffic performance of the campus's external area

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Abstract: Population growth and increased mobility in the area surrounding IPB University, particularly along Raya Dramaga Road and the Babakan Raya intersection have led to severe congestion. This intersection serves as a critical point where vehicle accumulation frequently occurs due to crossing movements, particularly during morning and evening peak hours. The majority of vehicles involved in these crossings are motorcycles owned by IPB students heading toward the university's main gate. Therefore, effective measures or policies are required to reduce crossing movements during peak hours, such as redirecting a portion of student traffic to alternative gates to alleviate congestion at Babakan Raya intersection. This study aims to identify traffic volume, road and intersection capacity, and the actual intersection performance, design an optimal Gate 4 for IPB, and analyze its impact on traffic performance. The research methodology includes primary and secondary data collection, intersection performance analysis, and the design of a roundabout and intersection improvements based on PKJI 2023 standards and Transportation Ministerial Regulation No. 96 of 2015. The study findings indicate that widening minor approach lanes, constructing traffic islands, and eliminating side friction increase the capacity of Babakan Raya intersection from 2,985.32 PCU/hour to 3,413.88 PCU/hour. The degree of saturation decreases from 1.22 to 0.87, and intersection delay is significantly reduced from 46 seconds/PCU to 14 seconds/PCU, improving the level of service (LoS) from category E (poor) to B (good). The construction of Gate 4 at IPB successfully redirects vehicle flow, particularly motorcycles, which previously traversed Babakan Raya intersection to access Gate 1 of IPB. With a capacity of 2,149 PCU/hour, the Gate 4 roundabout effectively accommodates high vehicle volumes during peak hours. Traffic performance analysis results demonstrate that intersection improvements and the development of Gate 4 at IPB effectively enhance traffic performance in the external area of IPB, mitigate congestion, and improve vehicular movement efficiency.

Submitted: 13 Mar 2025
Revised: 25 Apr 2025
Accepted: 28 Apr 2025

Keywords: delay; intersection; level of service; roundabout; traffic performance

1. Introduction

Rapid population growth has led to an increasing demand for mobility, both for personal and commercial purposes, resulting in a surge in the number of vehicles on the roads, particularly in densely populated urban areas. Road capacity is often insufficient to accommodate the rising traffic volume, leading to prolonged congestion during peak hours, such as in the morning and evening. This phenomenon has become a common issue in many cities, including along Raya Dramaga Road, Bogor, a crucial national road supporting economic activities and national mobility. There are many important and strategic areas along Raya Dramaga Road, including IPB University, residential complexes, and

economic centers, contributing to congestion at multiple points, particularly at the Babakan Raya intersection intersection due to unregulated vehicle crossings. This congestion results in significant economic losses, estimated at IDR 6,693,376,320 per year, due to fuel inefficiency and reduced working hours for drivers [1]. The increasing number of vehicles, without corresponding infrastructure development, has exacerbated traffic flow conflicts, especially at intersections [2].

Babakan Raya intersection is a three-legged intersection of Raya Dramaga Road and Jalan Babakan Raya (Bara) with two lanes on each approach. This intersection is one of the critical points along Raya Dramaga Road near IPB University, frequently experiencing vehicle crossings or traffic flow conflicts, particularly for vehicles traveling from Bara to the main road (Raya Dramaga Road). Traffic flow conflict is defined as a condition in which road users move toward the same location in time and space [3]. The accumulation of vehicles at this intersection worsens during rush hours, when traffic volume becomes unmanageable. The situation is further exacerbated by public transportation vehicles (angkot) stopping indiscriminately, causing long traffic queues. The majority of vehicles crossing at Babakan Raya intersection are motorcycles owned by IPB students heading to the university's main gate. Therefore, effective measures or policies are needed to reduce crossing movements during peak hours, such as redirecting some student vehicles to alternative gates to ease traffic congestion at Babakan Raya intersection.

The increasing traffic flow at Babakan Raya intersection, which contributes to congestion, is closely linked to the commuting activities of IPB University students living in the surrounding area. In 2024, IPB University recorded a total of 36,000 students, an increase of 3.47% from 2023, when the student population was 34,792. The continuous rise in student numbers, coupled with the implementation of a non-mandatory dormitory policy for new students, has led to an increased volume of vehicles entering and exiting the campus. In 2023, the number of vehicles entering the campus tripled compared to the previous year reaching 16,270 vehicles. These consisting of 12,755 motorcycles, 3,504 cars, and 11 shuttle buses [4]. The limited capacity of current three gates of the campus, Gate 1 (main front, active), Gate 2 (front, inactive, for emergency) and Gate 3 (back, active), which are unable to accommodate the surge in vehicles, has resulted in long queues and disrupted traffic flow. Consequently, the construction of Gate 4 at Babakan Raya street is necessary.

A roundabout was chosen as it can minimize waiting times or delays since vehicles do not need to come to a complete stop before entering the intersection. Under moderate traffic conditions, roundabouts can reduce delays and provide safer movement compared to signal-free intersections [5]. However, it is important to note that if the traffic flow from each approach is unbalanced, delays at the roundabout may still occur [6]. A well-designed roundabout can improve traffic performance and reduce congestion [7]. The construction of this new gate is expected to reduce queues at Gate 1 and Gate 3 while also reducing vehicle crossings at Babakan Raya intersection, which is a major source of delays and congestion along Raya Dramaga Road.

2. Method

2.1. Location and equipment

This study was conducted at the unsignalized priority intersection of Babakan Raya–Raya Dramaga Road as shown in **Figure 1**. The Babakan Raya intersection coordinate is: -6.562328, 106.731926, while the planned new gate is -6.559014, 106.731402. Primary data collection was carried out on weekdays, specifically during the morning peak hours from 06:00 to 09:00 WIB and the afternoon peak hours from 14:30 to 17:30 WIB. The equipment used in this study included writing instruments, a camera, a traffic counter application, an auto level, a measuring tape, and a laptop equipped with Microsoft Office, Google Earth, and AutoCAD 2022 software. The primary data collected comprised intersection geometry, vehicle speed, delay, and traffic flow at the intersection. Meanwhile, secondary data used in this study included

map of the Bara Intersection, and relevant regulations such as the 1997 Indonesian Highway Capacity Manual, the 2023 Indonesian Highway Capacity Guidelines, and Ministerial Regulation of Transportation No. 96 of 2015.

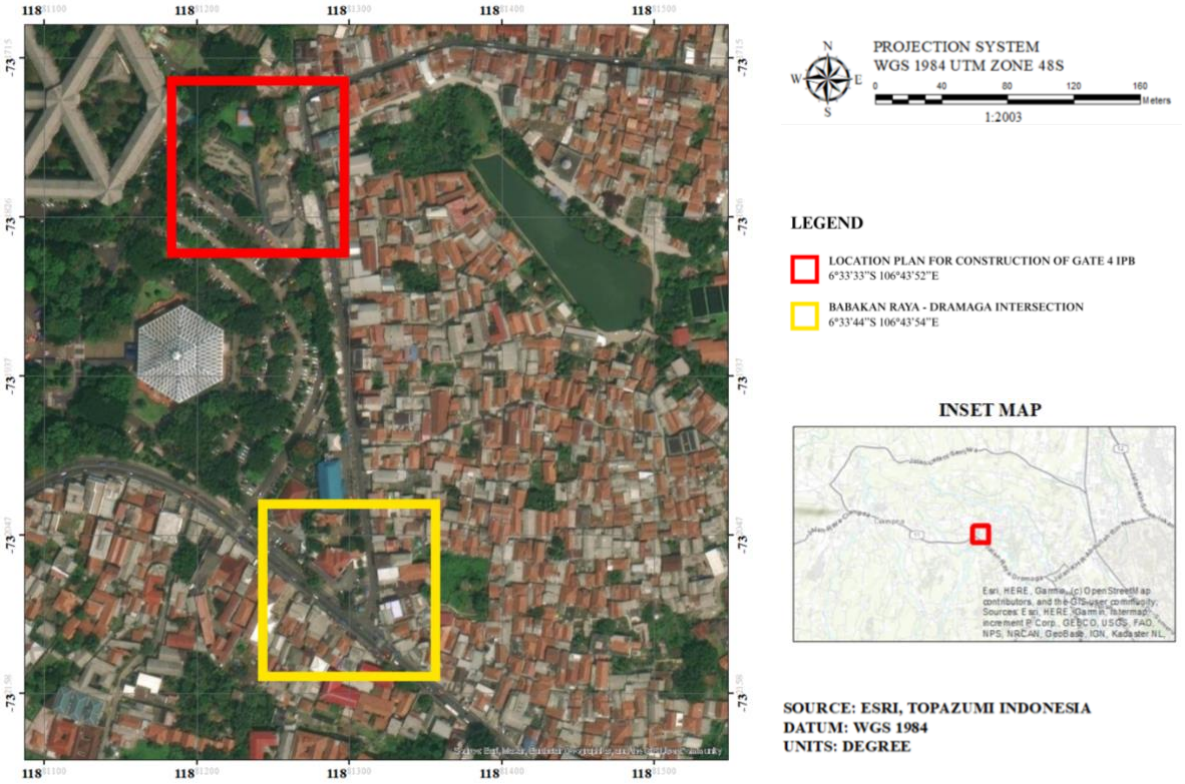

Figure 1. Study location

2.2. Traffic flow analysis

The analysis of the existing intersection conditions begins with a traffic survey. The traffic flow of vehicles entering the intersection, expressed in vehicles per hour (veh/h), must be converted into passenger car units per hour (PCU/h). This conversion is performed using the passenger car equivalent (PCE) factor for each vehicle type. Traffic volume is calculated using **Equation (1)**.

$$q = \sum_{i=1}^{n}(K_i \times E_i) \quad (1)$$

Where:

q = Traffic volume (PCU/h)
K_i = Number of vehicles of type i (veh/h)
E_i = Passenger car equivalent (PCE) factor for vehicle type i
n = Number of vehicle categories surveyed

2.3. Intersection capacity analysis

The intersection capacity analysis is conducted using actual data on intersection geometry, traffic conditions, and environmental factors. The intersection capacity is calculated using **Equation (2)**.

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

Where:

C = Capacity of the observed road segment (PCU/h)
C_0 = Basic capacity of the segment (PCU/h)
F_{LP} = Adjustment factor for the average approach width
F_M = Adjustment factor for median type

F_{UK} = Adjustment factor for city size impact on capacity
F_{HS} = Adjustment factor for capacity due to side friction
F_{BKi} = Adjustment factor for the left-turn flow ratio
F_{BKa} = Adjustment factor for the right-turn flow ratio
F_{Rmi} = Adjustment factor for the minor road flow ratio

2.4. Level of Service

Intersection performance is evaluated based on the degree of saturation, delay, and queue probability. The degree of saturation (Dj) is calculated by comparing the traffic volume (q) with the intersection capacity (C). The total delay at the intersection is determined by summing the traffic delay (T_{LL}) and the geometric delay (T_G). T_{LL} can be calculated using **Equation (3)**, while T_G can be determined using **Equation (4)**.

$$T_{LL} = \frac{1{,}0504}{(0{,}2742 - 0{,}2042\ Dj)} - (1 - Dj)^2 \quad (3)$$

$$T_G = (1 - Dj) \times \left(6\ R_B + 3\ (1 - R_B)\right) + 4\ Dj \quad (4)$$

The Level of Service (LoS) of the intersection is determined based on the delay (T) analysis results, referring to Transportation Ministerial Regulation No. 96 of 2015.

2.4. Roundabout capacity

Roundabout is analysed by using traffic weaving principle. The capacity of the weaving section is obtained by multiplying the basic capacity (C_0) by its corresponding adjustment factors. These adjustment factors include the city size factor (F_{UK}), the road environment type factor (F_{RSU}), side friction, and the non-motorized vehicle ratio factor. The capacity of the weaving section can be calculated using **Equation (5)**.

$$C = 135 \times {W_W}^{1.3} \times \left(1 + \frac{W_E}{W_W}\right)^{1.5} \times \left(1 - \frac{P_W}{3}\right)^{0.5} \times \left(1 + \frac{W_W}{L_W}\right)^{-1.8} \times F_{UK} \times F_{RSU} \quad (5)$$

Where:
W_W = Weaving section width (m)
W_E = Average entry width (m)
P_W = Weaving ratio
L_W = Weaving section length (m)
F_{UK} = City size adjustment factor
F_{RSU} = Road environment type adjustment factor, including side friction

3. Result and discussion

3.1. Intersection geometric of Babakan Raya intersection

Babakan Raya intersection is an unsignalized three-leg intersection consisting of Raya Dramaga Road (Duta Berlian direction), Raya Dramaga Road (IPB direction), and Jalan Babakan Raya. These roads are sequentially categorized as Approach 1, Approach 2, and Approach 3. The geometric data of the intersection is presented in **Table 1**.

Table 1 Geometric data for each approach at Babakan Raya intersection

Approach	Road width (m)	Road type	Lane width (m)	Shoulder width (m)	Side friction
Approach 1	9	2/2 UD	4	±0.5	Medium
Approach 2	9	2/2 UD	4	±0.5	Medium
Approach 3	5.5	2/2 UD	±2.7	-	High

Approach 1: Raya Dramaga Road (Duta Berlian direction) is a major road with a 2/2 undivided configuration and a total roadway width of 900 cm for both directions. Approach 2: Raya Dramaga Road (IPB direction) is also a major road with a 2/2 undivided configuration, with a total roadway width of 900 cm for both directions. Approach 3: Jalan Babakan Raya is a minor road with a 2/2 undivided configuration, having a functional roadway width of 550 cm for both directions. The average approach width for Approaches 1, 2, and 3 is 980 cm, 960 cm, and 850 cm, respectively. Based on its geometry Babakan Raya intersection is classified in to 322 intersection type, which refers to an intersection with three legs, two lanes on the minor road, and two lanes on the major road. The geometric illustration of the intersection is depicted in **Figure 2**.

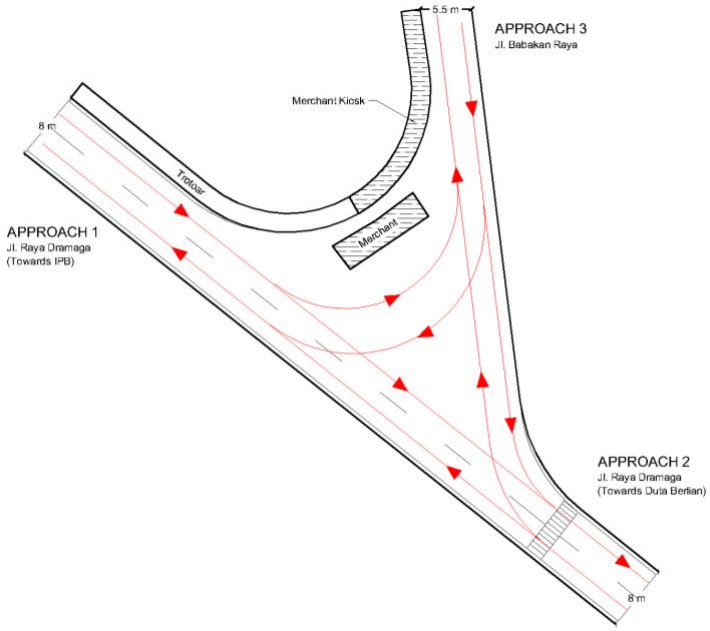

Figure 2. The geometry of Babakan Raya intersection

3.2. Existing traffic flow at Babakan Raya intersection

The traffic volume or traffic flow survey at the intersection was conducted using the Classified Turning Movement Counting (CTMC) method. Observations were carried out for three hours during peak hours in the morning (06:00–09:00 WIB) and afternoon (14:30–17:30 WIB). The recorded vehicle counts were then converted into passenger car units (PCU/hour) for each vehicle type. The traffic flow data is illustrated in the graph shown in **Figure 3**.

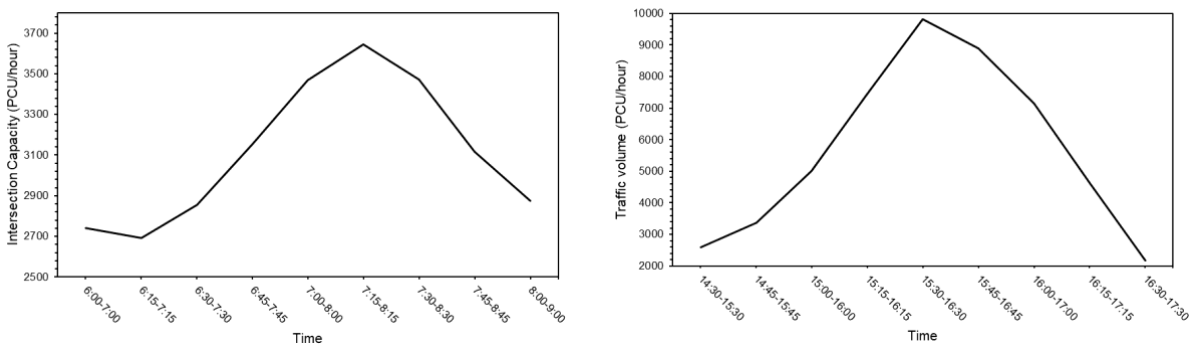

Figure 3. Traffic flow at Babakan Raya intersection (a) morning period, (b) afternoon period

Based on the presented curve, the morning traffic volume reaches its peak between 07:15–08:15, with a volume of 3,643 PCU/hour. This increase reflects the high mobility activity of the community during the morning rush hour. However, after reaching its peak, the traffic volume declines to 3,114 PCU/hour between 07:30–08:30. This reduction is caused by congestion, which results in vehicle accumulation and limits the number of vehicles that can pass smoothly. After this period, the traffic volume continues to decline significantly until 09:00, marking the end of the morning rush hour. In contrast, during the afternoon period, the traffic volume reaches its highest point between 15:50–16:30, with a value of 9,827 PCU/hour. This considerably higher volume compared to the morning period reflects the intense vehicle movement during after-work and school hours. However, after reaching its maximum, a significant decrease in traffic flow occurs until 16:00–17:00, indicating congestion. The accumulation of vehicles reduces travel speed, allowing fewer vehicles to pass. Traffic flow improves again between 16:30–17:30, with a volume of 2,164 PCU/hour, signaling the end of the afternoon rush hour.

3.3. Existing Capacity of Babakan Raya intersection

The capacity of an intersection is calculated by multiplying the base capacity of the intersection by various correction factors. The base capacity (C_0) is set at 2,700 PCU for a type 322 intersection (three legs, two lanes on the minor road, two lanes on the major road). Using the calculations, the correction factor for average approach width (FLP) is determined to be 1.098. The median correction factor (FM) for the major road is set at 1.00, as there is no median on the major road. According to the Badan Pusat Statistik (BPS) of Bogor Regency, which reports a population of 5,682,303, the city size correction factor (FUK) is set at 1.05. The road environment correction factor (FHS) due to activities around the intersection is determined to be 0.93. The correction factors for the left-turn flow ratio (FBKi) and right-turn flow ratio (FBKa) are calculated, yielding values of 0.983 and 1.008, respectively. The correction factor for the flow ratio from the minor road (FRmi) is calculated at 1.89. Based on the capacity calculations and the correction factors mentioned above, the intersection capacity for Babakan Raya intersection is determined to be 2,985.32 PCU/hour

3.4. Traffic performance and Level of Service of the intersection

The traffic performance at the intersection is assessed based on the degree of saturation (Dj), delay, and queue probability. Delay consists of both traffic delay and geometric delay, which are subsequently used to determine the Level of Service (LoS) of the intersection. By dividing the total traffic volume by the known intersection capacity, the degree of saturation of the intersection during the morning and evening peak hours are found to be 1.22 and 1.3, respectively. The detailed traffic performance calculations are shown in **Table 2**.

Tabel 2 Capacity of Babakan Raya intersection

Time	Dj	T_{LL} (sec/PCU)	T_{LLma} (sec/PCU)	T_{LLmi} (sec/PCU)	T_G (sec/PCU)	T (sec/PCU)	Pa (%)	LoS
Morning	1.22	41.96	22.89	227.92	4.12	46.08	124	E
Afternoon	1.30	120.09	40.00	990.05	4.12	124.2	144	F

The delay at the intersection during the morning and evening peak hours are 46.08 sec/PCU and 124.22 sec/PCU, respectively. The magnitude of delay is influenced by various factors, including vehicle volume, intersection capacity, traffic distribution patterns, and driver behavior [8, 9, 10]. These delay values are used as parameters to determine the Level of Service (LoS) according to the Transportation Ministerial Regulation No. 96 of 2015. Based on the delay in Table 2, the Level of Service at the intersection is classified as E during the morning peak hour and F during the evening peak hour. The intersection's service level is poor due to the high delays, which indicate a potential for severe congestion.

3.5. Exsisting condition of Jalan Raya Bara

Jalan Babakan Raya is a local road of type 2/2 UD (undivided) with an effective width of 5 meters, without a shoulder or median. High side obstacles, such as street vendors, illegal parking, pedestrians, and angkot (minibus) frequently stopping to pick up and drop off passengers, impact the smooth flow of traffic. Jalan Babakan Raya has a capacity of 1,337.19 PCU/hour. The traffic flow on Babakan Raya street is depicted in **Figure 4**.

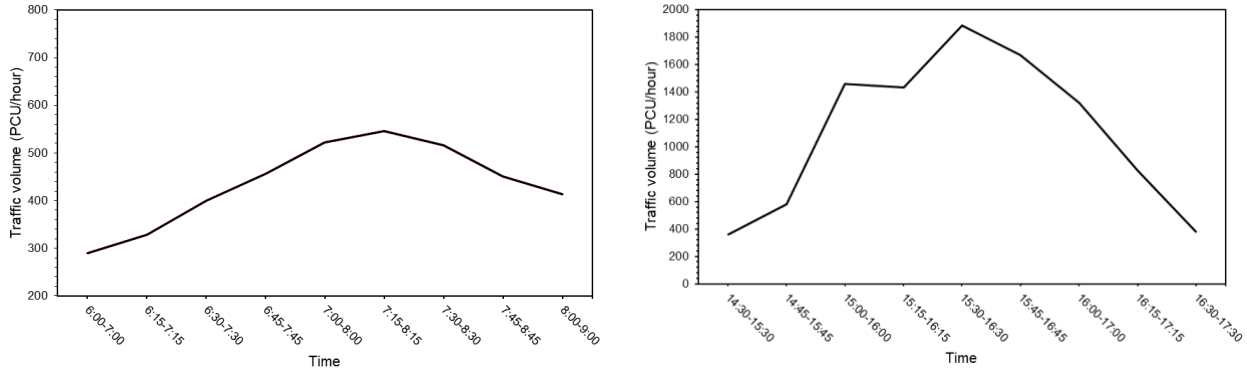

Figure 4. Traffic flow of Jalan Babakan Raya (a) morning period, (b) afternoon period

Based on the collected data, the traffic flow curve for Jalan Babakan Raya shows a significant difference between the morning and evening peak hours. In the morning, traffic volume is relatively light, with a peak volume of 554.2 PCU/hour, an average vehicle speed of 16 km/h, and a degree of saturation of 0.4. In contrast, during the evening, traffic volume increases dramatically to 1,883.3 PCU/hour, with the vehicle speed dropping to 8 km/h and the degree of saturation reaching 1.4. This indicates that the road section has exceeded its capacity, leading to severe congestion. According to Transportation Ministerial Regulation No. 96 of 2015, the Level of Service for Jalan Babakan Raya in both the morning and evening falls into category F, signifying a congested road with long vehicle queues and very low speeds.

3.6. Design of improvements

The high delays and congestion occurring at the Babakan Raya intersection intersection are caused by the intersection's capacity being unable to accommodate the high vehicle flow during peak traffic hours, both in the morning and in the evening. Improvements are required to improve the performance of the intersection. These improvements include widening Babakan Raya street, modifying the geometry of Babakan Raya intersection, and diverting some of the traffic flow through the construction of Gate 4 IPB, located in the Bara area. To achieve a good level of service, road geometry changes, i.e. road widening, are among the supporting measures. Widening the road reduces delay (congestion), which contributes to improving the level of service [11, 12, 13, 14]. This widening will be carried out along Babakan Raya street-Duta Berlian, including the removal of side obstacles to significantly increase road capacity. In addition, the road widening will include a drainage system to prevent water pooling during and after rain, as well as the construction of a 1.5-meter-wide sidewalk along Babakan Raya street. The parameters for the improvement of Jalan Babakan Raya can be seen in **Table 3**.

Gate 4 IPB is to be constructed directly connecting Babakan Raya street with the road near campus' main auditorium, Graha Widya Wisuda (GWW). The straight road leading to this gate will be designed to connect with the rear road of GWW to ensure that vehicle queues do not disrupt the main traffic flow at IPB. The design of this gate uses a roundabout type to minimize vehicle crossing and extend the entry lanes, aiming to prevent congestion on Babakan Raya street, particularly during vehicle buildup. The roundabout geometry design for Gate 4 IPB can be seen in **Figure 5**.

Tabel 3. Road Widening Parameters for Jalan Babakan Raya

Parameter	Existing	Improvement
Effective Width	Local	Class II Collector
Effective Width	5 m	7 m
Capacity (C)	1337,19 PCU/hour	2697 PCU/hour
Speed (v)	16 km/hour	50-60 km/hour
Side friction	High	Low
Level of Service (LoS)	F	C-D

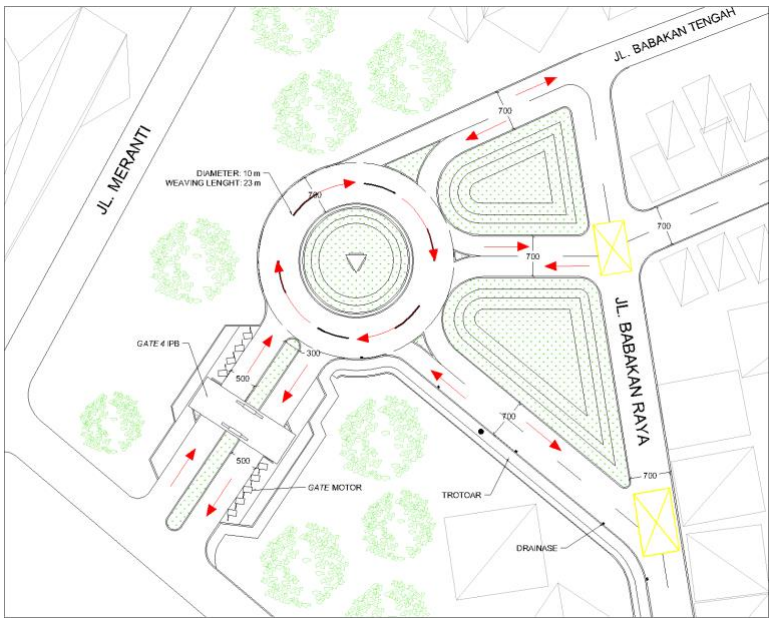

Figure 5. Roundabout Design at Gate 4 IPB

The roundabout at Gate 4 IPB uses a R 10-11 type with a radius of 10 meters, designed to accommodate medium-sized vehicles. It is equipped with a single entry lane of 3.5 meters wide and a weaving section spanning 23 meters in length and 7 meters in width. With a capacity of 2,149 PCU/hour, this roundabout is expected to handle high vehicle flow, especially during peak times, such as when students commute to and from campus. Gate 4 IPB Bara is designed to reduce vehicle density at Babakan Raya intersection by diverting traffic to Gate 1 IPB without passing through the intersection. Based on surveys during the morning peak (07:15-08:15), approximately 700 motorcycles per hour pass through Babakan Raya intersection from Babakan Raya to Gate 1 IPB. To improve efficiency, Gate 4 will have 5 dedicated motorcycle entry and exit lanes, capable of serving 35 motorcycles per minute, allowing approximately 700 motorcycles to be served in 20 minutes. Based on the distribution of medium vehicle groups such as cars, motorcycles, and medium-loaded trucks, the pavement design must be adjusted to ensure its service life aligns with the planned duration and reduce the likelihood of delays (congestion) caused by damage that can reduce road capacity [15].

Intersection improvements are necessary to enhance its capacity, ensuring that it performs more optimally. These improvements include the separation of traffic flows through the construction of traffic islands, widening the minor lanes, and removing side obstacles that contribute to increased intersection capacity. The intersection will be designed in a Y-shape, utilizing a priority non-signalized intersection type. Traffic islands will be constructed to avoid congestion at a single point and also serve as traffic flow separators, ensuring more even traffic distribution. The post-improvement intersection geometry design is shown in **Figure 6**. The improvement parameters for Babakan Raya intersection are presented in

Table 4. Hipothetically the new Gate 4 opening will divert incoming traffic to the campus, which will considerably higher in the morning. Therefore, the improvements were planned based on this scenario.

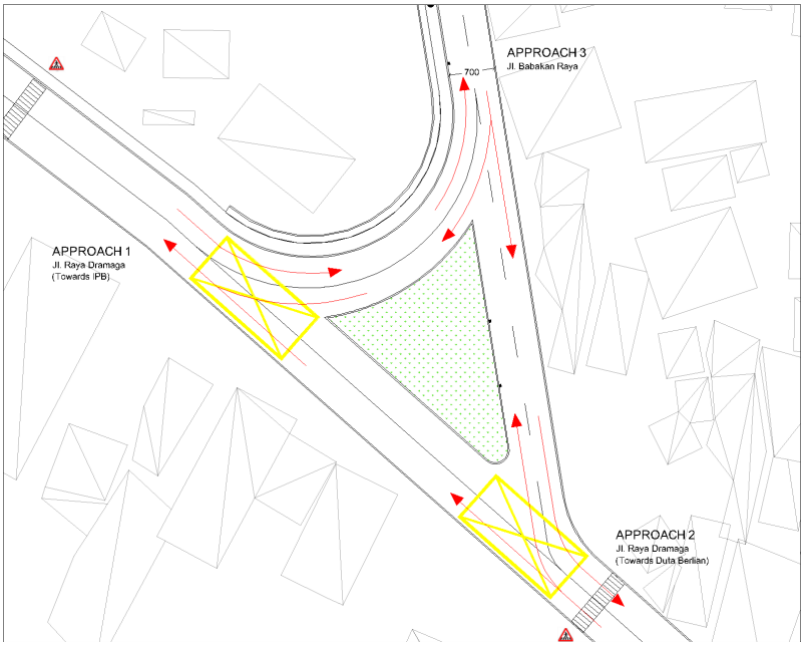

Figure 6. Improvement Design for Babakan Raya intersection-Dramaga

Tabel 4. Improvement Parameters for Babakan Raya intersection

Parameter	Existing	Improvement
Capacity (C)	2985.32 PCU/hour	3413.88 PCU/hour
Degree of Saturation (D_J)	1.22	0.87
Traffic Delay (T_{LL})	41.96 sec/PCU	10.93 sec/PCU
Geometric Delay (T_G)	4.12 sec/PCU	3.92 sec/PCU
Intersection Delay (T)	46.08 sec/PCU	14.85 sec/PCU
Level of Service (LoS)	E	B

As shown in **Table 4**, the intersection's performance has significantly improved. The capacity has increased from 2,985.32 PCU/hour to 3,413.88 PCU/hour, while the degree of saturation has decreased from 1.22 to 0.87, indicating that the intersection no longer experiences overcapacity and now operates at more optimal conditions. Furthermore, intersection delay has been drastically reduced from 46 sec/PCU to only 14 sec/PCU, meaning vehicle waiting times at the intersection have shortened considerably, resulting in an improved Level of Service (LoS) from E to B.

Based on the traffic flow curve and intersection capacity illustrated in Figure 7, three capacity lines are identified: existing capacity, optimal capacity, and design capacity. The existing capacity represents the actual intersection conditions, considering side frictions (obstacles). The optimal capacity is the capacity value without side frictions, while the design capacity refers to the capacity after improvements, such as the removal of side frictions, widening of minor approaches, and diversion of motorcycle traffic towards Gate 1 IPB. Following these improvements, the capacity of Babakan Raya intersection increased by 14% to 3,413.88 PCU/hour. Although this design capacity has not fully accommodated the peak morning traffic surge, which reaches 3,643.11 PCU/hour, the improvements have successfully reduced delays and congestion, resulting in significantly better traffic conditions.

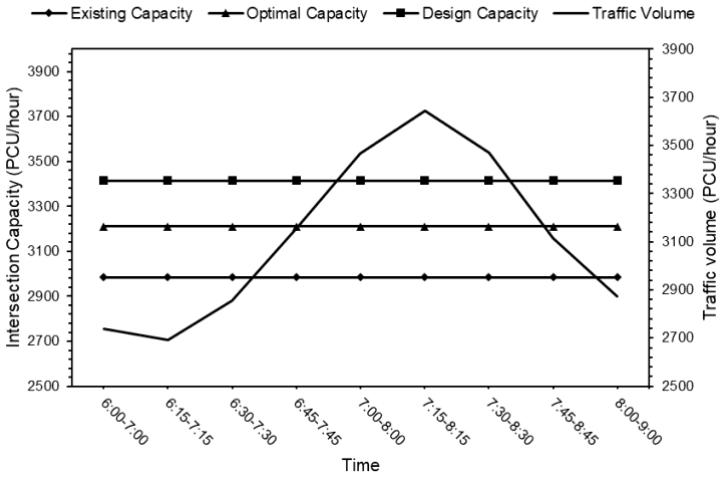

Figure 7. Traffic flow curve and capacity of Babakan Raya street

4. Conclusion

Babakan Raya intersection experiences extremely high traffic flows, particularly during peak hours, reaching 3,643 PCU/hour in the morning and 9,827 PCU/hour in the evening, exceeding the intersection's existing capacity of 2,983 PCU/hour. This situation has led to severe congestion and high delays, with 46 sec/PCU in the morning and 124 sec/PCU in the evening, corresponding to an existing Level of Service (LoS) of F (poor).

The construction of Gate 4 IPB was designed as a roundabout with a 10-meter radius, 3.5-meter entry lane, and 23-meter weaving section, capable of handling up to 2,149 PCU/hour. It is also equipped with five dedicated motorcycle entry/exit lanes, successfully diverting a significant portion of traffic—especially motorcycles—away from Babakan Raya intersection to Gate 1 IPB.

Improvements at Babakan Raya intersection were implemented through widening of minor lanes, the construction of traffic islands, and the removal of side obstacles, utilizing a Y-shaped design with an unsignalized priority intersection. These modifications resulted in an increase in intersection capacity from 2,985.32 PCU/hour to 3,413.88 PCU/hour, a reduction in the degree of saturation from 1.22 to 0.87, and a decrease in intersection delay from 46 sec/PCU to 14 sec/PCU. Consequently, the Level of Service (LoS) improved from category E (poor) to B (good). However, it is important to be noted that the improvements were planned based on morning data, since the main incoming traffic diversion will occurs considerably higher in the morning. A further deeper analysis can be done for actual traffic origin and destination changes due to the new gate, and the optimal improvements of Babakan Raya intersection for other daily peak hours.

References

[1] Wulandari DA. 2023. Estimasi nilai kerugian pengguna jalan akibat kemacetan lalu lintas di jalan Raya Dramaga Kabupaten Bogor [SKRIPSI]. Bogor: IPB University.

[2] Afni DN, Juwita F, Prikurnia AK, Putri IY. 2023. Analisis Simpang Tak Bersinyal di Jalan Ahmad Yani-Jalan Raden Intan Gadingrejo Menggunakan PKJI 2023. Tek. Sains J. Ilmu Tek. 8(2):135–142.

[3] Shahdah U, Saccomanno F, Persaud B. 2015. Application of traffic microsimulation for evaluating safety performance of urban signalized intersections. Transp. Res. Part C Emerg. Technol. 60:96–104.

[4] [BPKB] Badan Pengembangan Kampus Berkelanjutan IPB. 2023. Achieving Sustainability. IPB University Sustainability Report.

[5] Sugiarto S, Faisal R, Reyhan M. 2019. Pengaruh sepeda motor terhadap kapasitas bagian jalinan pada perencanaan bundaran di Simpang Tujuh Ulee Kareng. Teras J. J. Tek. Sipil. 8(2):416.

[6] Putra AD, Purwanti O. 2019. Analisis Kinerja Bundaran Leuwigajah Kota Cimahi. J. Tek. Sipil. 5(2):50–60.
[7] Sudibyo T, Mahardi P, Fauzan M, Putra H. 2019. Analisis Kinerja Rencana Bundaran dengan Pendekatan Simulasi Mikro. J. Tek. Sipil Dan Lingkung. 4(3):177–186.
[8] Keke CI, Siswoyo S. 2021. Analisa kinerja simpang tak bersinyal jalan eltari ende, Nusa Tenggara Timur. Axial J. Rekayasa Dan Manaj. Konstr. 9(2):119.
[9] [Dirjen BM] Direktorat Jenderal Bina Marga. 2023. Pedoman Kapasitas Jalan Indonesia (PKJI) 2023. Jakarta (ID): Dirjen Bina Marga.
[10] [KEMENHUB] Kementrian Perhubungan Republik Indonesia. 2015. Pedoman Pelaksanaan Kegiatan Manajemen dan Rekayasa Lalu Lintas. Peraturan Menteri Perhubungan No. 96 Tahun 2015. Jakarta (ID): KemenHub.
[11] Novitasari N, Sudibyo T. 2020. Analisis Perkiraan Tingkat Pelayanan Jalan (Studi Kasus Rencana Tol Dalam Kota Jakarta Ruas Bekasi Raya). J. Tek. Sipil Dan Lingkung. 5(1):1–16.
[12] Sudibyo T. 2016. Pengaruh Bottleneck dalam Variabel Komposisi Kendaraan Berat Terhadap Level of Service (LOS) Jalan. Journal Industrial Services. 2(1):107-113.
[13] Irfan DK, Sutoyo S, Sudibyo T. 2020. Evaluasi Geometri Jalan Menggunakan Uav Dengan Aplikasi Agisoft Photoscanner Pada Jalan Meranti Kampus IPB Dramaga. J. Tek. Sipil Dan Lingkung. 5(2):101-114.
[14] Sudibyo T. 2023. Pengaruh Pembatasan Jenis Kendaraan Terhadap Kinerja Ruas Jalan. J. Tek. Sipil Dan Lingkung. 8(3):177-182.
[15] Ardiansyah R, Sudibyo T. 2020. Analisis Perencanaan Tebal Perkerasan Kaku Lajur Pengganti pada Proyek Pembangunan Jalan Tol Jakarta-Cikampek II Elevated. J. Tek. Sipil Dan Lingkung. 5(1):17–30.