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Management of Unsignalized Intersections (Case Study of Duren Intersection, Ciputat District)

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A B S T R A C T

Traffic congestion leads to significant losses in the form of extended travel times, fuel waste, and environmental degradation. This congestion primarily results from traffic volumes exceeding both highway and intersection capacities. To address these issues and ensure smooth traffic flow, it is crucial to evaluate intersection performance. This study focuses on the Duren Intersection in South Tangerang City, where Merpati Raya Street, Menjangan Raya Street, Cenderawasih Street, and KH. Dewantoro Street converge. The current situation at the Duren Intersection continues to cause congestion, as evidenced by traffic performance data. On weekdays during peak hours, the average vehicle queue length reaches 192.03 meters, with an average traffic delay of 42.153 seconds per vehicle, resulting in a Level of Service (LOS) E. On holidays, the peak hour average queue length is 128.71 meters, with an average delay of 25.126 seconds per vehicle, corresponding to a LOS D. Given these conditions, this study, titled "Arrangement of Unsignalized Intersections: A Case Study of Duren Intersection, Ciputat District," aims to analyze and propose improvements for the intersection's performance. The research will evaluate current traffic patterns, identify bottlenecks, and suggest potential solutions to enhance traffic flow and reduce congestion at this critical junction in South Tangerang City.

1. Introduction

Road transportation is essential in supporting development and plays a pivotal role in the economic, political, social, and security sectors, necessitating a reliable and evolving transportation system to enhance mobility [1], [2]. Urban populations require smooth, safe, comfortable, and environmentally friendly transportation. Many individuals resort to private vehicles as public transportation fails to meet their needs, leading to urban congestion [2], [3].

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Government traffic policies aim to create an integrated urban transportation system that supports the movement of people and goods and fosters economic growth [4]. The strategy involves optimizing and regulating road traffic and transportation [5]. Congestion results in the loss of time, fuel, and environmental degradation [6]. This typically occurs when traffic volume exceeds capacity, especially at intersections, which are critical points of traffic conflict [7], [8]. Effective traffic management at intersections is crucial for efficiency [1].

Duren Intersection is located at 6°17'42"S, 106°44'4"E. According to South Tangerang City Local Regulation No. 9 of 2019, this location falls within the Commercial and Service Area as outlined in the South Tangerang City Spatial Planning for 2011 – 2031. Situated in Sawah Baru, Ciputat District, South Tangerang, this intersection is uncontrolled with four arms, namely Jalan Ki Hajar Dewantoro, Jalan Cendrawasih Raya, Jalan Menjangan Raya, and Jalan Merpati Raya. The Duren Intersection type is 422, indicating four intersection arms with 2 minor road lanes and 2 major road lanes. This study site is a frequent congestion point, especially during peak hours. The vehicle pile-up at this intersection is a primary focus of this research. Thus, the chosen study location provides a clear depiction of the traffic conditions in the area, particularly in terms of frequent congestion [9].

According to the Road Traffic Law No. 22 of 2009 [10] , traffic management involves the design, provision, regulation, and maintenance of road infrastructure to ensure safety and security. To address congestion at Duren Intersection in South Tangerang City, an evaluation of traffic performance and the management of the unsignalized intersection is required. Therefore, this study aims to provide appropriate recommendations for managing the control of the Duren Intersection, with special attention to the implementation of Traffic Management and Engineering (MRLL) at the Duren Intersection, both short-term and long-term.

2. Research Method

This study employed a quantitative method to measure and analyze data related to Traffic Management and Engineering, specifically at the Duren Intersection in South Tangerang City [10], [11]. The primary objective of this research was to provide recommendations for effective traffic control measures, addressing both short-term and long-term solutions.

A. Data Collection

Primary data was collected through direct field surveys at the Duren Intersection. The data collection methods included:

a) Direct observation to count traffic volume during peak hours.
b) Measurement of road and intersection geometry.
c) Recording of traffic light cycle times.
d) Photo and video documentation of traffic conditions.

Secondary data was obtained from relevant authorities, such as the South Tangerang City Transportation Department, including:

a) Historical traffic volume data.
b) Regional development plans.
c) Traffic accident data at the intersection.

B. Data Analysis

Data analysis was conducted using the following methods:

a) Calculation of road capacity and Level of Service (LOS) using the Indonesian Highway Capacity Manual (IHCM).
b) Intersection performance analysis using SIDRA Intersection software.
c) Traffic simulation modeling using PTV VISSIM software to evaluate alternative solutions.

C. Evaluation and Recommendations

Based on the analysis results, evaluations were conducted on:

a) Current intersection performance.
b) Effectiveness of traffic light timing.

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c) Potential for intersection geometry improvements.

Recommendations were formulated considering:

a) Short-term solutions: optimization of traffic light cycle times, improvement of road markings.
b) Medium-term solutions: intersection geometry enhancements, addition of exclusive left-turn lanes.
c) Long-term solutions: construction of flyovers or underpasses.

The quantitative method was chosen as it is most suitable for evaluating field conditions and generating accurate recommendations based on measurable data [12]. This approach enables objective analysis of traffic issues and modeling of solution scenarios that can be empirically tested. This comprehensive methodology ensures a thorough examination of the traffic conditions at the Duren Intersection, providing a solid foundation for evidence-based recommendations to improve traffic flow and safety in both the short and long term.

3. Description and Technical

In this study, the management and engineering of traffic at Duren Intersection were determined through a series of stages, starting from data collection, and analysis, to the development of effective handling scenarios. The following flowchart illustrates the steps in the implementation of this study/research (Figure 1).

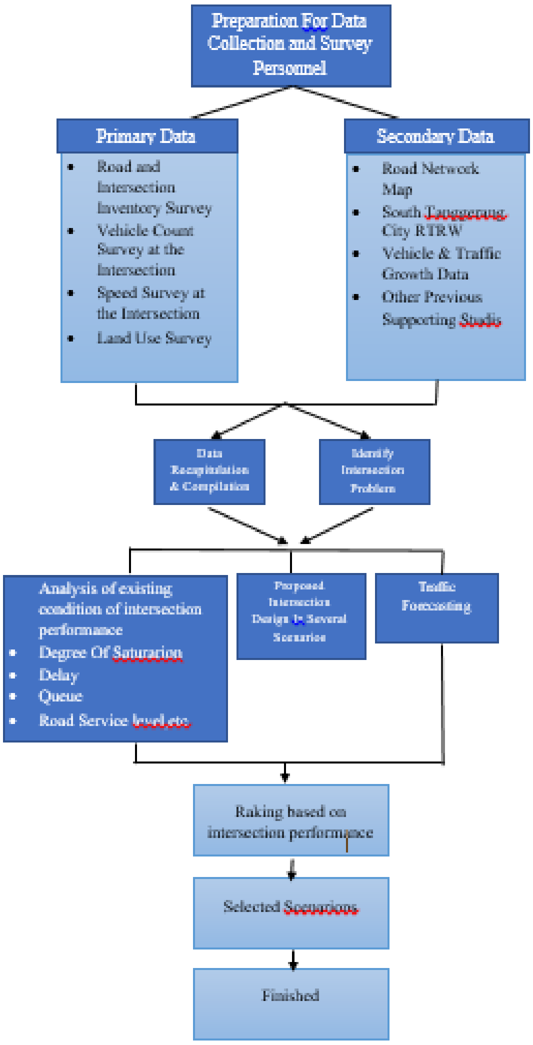

Figure 1. Research Flowchart

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Primary data collection was conducted in the field to gather information on the performance and conditions of traffic and the surrounding road network, complementing the secondary data and providing an overview of the vehicle conditions [11]. Before the field research, preparations were made utilizing secondary data to refine the organization of the primary research [12]. Surveys were conducted over 16 hours (from 05:00 AM to 20:00 PM) on both weekdays and holidays. During the survey, field information was integrated with maps and concepts for analysis, work planning, and detailed mapping. Below is an image showing the conditions at Duren Intersection, South Tangerang City (Figure 2).

(A)

(B)

Source : Google Maps

Figure 2. (A) Research Location at Duren Intersection, (B) Cross Section of Duren Intersection

First, a Road and Intersection Inventory Survey was conducted to obtain maps of the road network and land use, performing detailed inventories of roads and intersections around the Duren Intersection. This survey encompassed roads and intersections involved in administrative and traffic engineering actions related to the developing of the Duren interchange. Measurements focused on road geometry, type of intersection control, and intersection timing with traffic lights, using appropriate equipment to achieve the desired data objectives [13].

Second, a Vehicle Count Survey at the Intersection was carried out to obtain information on turning movements, traffic distribution, and peak hour planning, involving traffic counts at intersections. Counts were performed separately for each branch and direction of traffic, as well as vehicle type. The collection of traffic volume and density data at intersections required tools such as counters, stopwatches, and digital clocks [14], [15].

Third, a Spot Speed Survey in front of the Study Location was conducted where the link speed method was used by placing two measuring devices at a certain distance (e.g., 50 meters) to record the travel time of vehicles between these two points. Speeds studied included private vehicles, public transport, and motorcycles [16]. The values taken represent the average for each road segment with different physical characteristics in the research area.

Secondary Data Collection was carried out to facilitate and support the analysis process [17], [18]. Secondary data were collected from various relevant agencies such as Bappeda, the Transportation Agency, the Central Bureau of Statistics, and other departments in South Tangerang City, with consultants initiating the data collection stage. The collected data includes:

a. Road network and land use data around the study area;
b. Traffic data from previous surveys;
c. DRK data (incident locations);
d. Information about public transport routes in the study area;
e. Information on traffic growth and volume in the study area;
f. South Tangerang Regional Plan (RTRW)[19].

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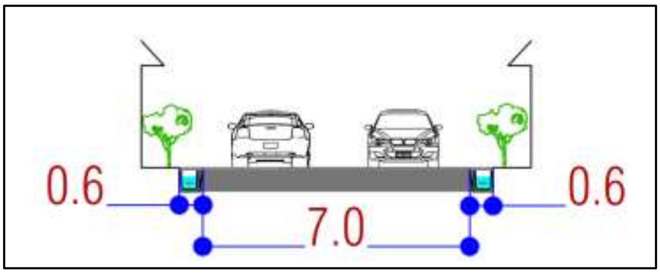
4. Results and Discussions

4.1 Results

1. KH. Dewantoro Street converge

KH. Dewantoro Street is part of the Duren Intersection that connects the Duren Intersection with Ir. H. Juanda street, classified as a city road with a secondary collector function. This road has a 2/2 UD type, with a total width of 9 meters, a drainage width of 0.6 meters on each side, and an effective lane width of 7 meters. The road is in good condition, using flexible pavement made of asphalt, with soil shoulders. The area surrounding this road is commercial, consisting of shops, with high side constraints. Visualization and the capacity of KH. Dewantoro Street , based on the calculations from PKJI 2023[20], is shown in Figure 3 and Table 1.

(A)



(B)

Source : Google Maps

Figure 3. (A) Visualization of KH. Dewantoro Street, (B) Cross Section of KH. Dewantoro Segment Street

Table 1. Capacity of KH. Dewantoro Street

Road Name	Correction Factor					Total Capacity
	C_0	FC_{LJ}	FC_{PA}	FC_{HS}	FC_{UK}	
KH. Dewantoro Street	2760	0.87	1.00	0.92	1.00	2.472

Source: Analysis Results, 2024.

2. Cenderawasih Segment Street

Cenderawasih Street, a part of the Duren Intersection, connects Tegal Rotan Raya Street, classified as a city road with a secondary collector function. This road has a 2/2 UD configuration (2 lanes, 2 directions without a median separator), with a total width of 9 meters and a drainage width of 0.6 meters on each side. The effective lane width is 8 meters. The current condition of the road is good, using flexible asphalt pavement, with soil shoulders. This area is a commercial zone, dominated by shops, with high side constraints. Visualization and the capacity of Cenderawasih Street, based on calculations from PKJI 2023, are shown in Figure 4 and Table 2.

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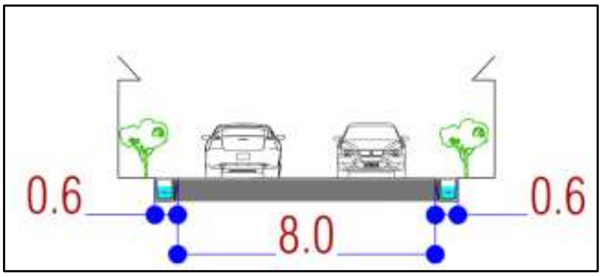


(B)

(A)

Source: Google Maps.
Figure 4. (A) Visualization of Cenderawasih Street, (B) Cross Section of Cenderawasih Segment Street

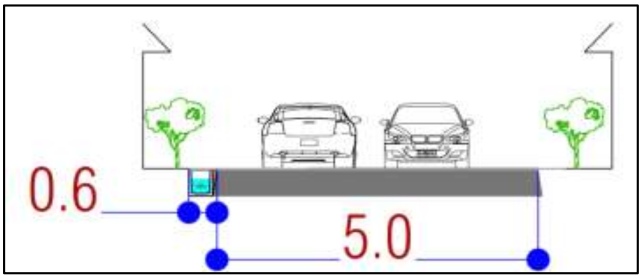
Table 2. Capacity of Cenderawasih Street

Road Name	Correction Factor					Total Capacity
	C_0	FC_{LJ}	FC_{PA}	FC_{HS}	FC_{UK}	
Cenderawasih Street	2760	1.25	1.00	0.92	1.00	2.512

Source: Analysis Results, 2024.

3. Menjangan Raya Segment Street

Menjangan Raya Street is part of the Duren Intersection, connecting with Kompas Raya Street. As a city road with a secondary collector function, it features a 2/2 UD configuration, consisting of 2 lanes and 2 directions without a median separator. The total width of the road is 7 meters, with a drainage width of 0.6 meters on the left side, and an effective lane width of 7 meters. The current condition of the road is good, utilizing flexible asphalt pavement, while the road shoulders are composed of soil. The surrounding area is a commercial zone, predominantly filled with shops, and features high-side constraints. Visualization and the capacity of Menjangan Raya Street, based on calculations from PKJI 2023, are shown in Figure 5 and Table 3.



(A)

(B)

Source: Google Maps.
Figure 5. (A) Visualization of Menjangan Raya Street , (B) Cross Section of Menjangan Raya Segment Street

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Table 3. Capacity of Menjangan Raya Street

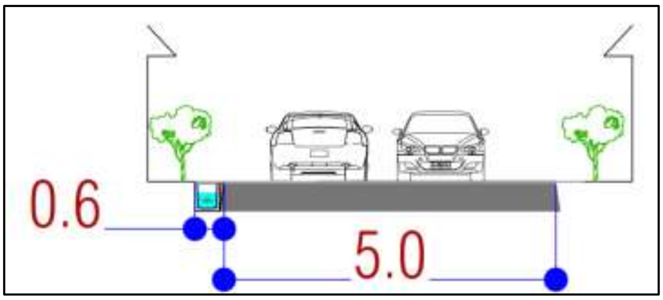
Road Name	Correction Factor					Total Capacity
	C_0	FC_{LJ}	FC_{PA}	FC_{HS}	FC_{UK}	
Menjangan Raya Street	2760	1.13	1.00	0.88	1.00	2.382

Source: Analysis Results, 2024.

4. Merpati Raya Segment Street

Merpati Raya Street, part of Duren Intersection, connects with Jombang Raya Street. This road is classified as a city road and serves as a secondary collector. With a 2/2 UD configuration, Merpati Raya Stret has a total width of 8 meters, a drainage width of 0.6 meters, and an effective lane width of 7 meters. The road is currently in good condition, utilizing flexible asphalt pavement, with soil road shoulders. The surrounding area is a commercial zone, dominated by shops, with high side constraints. Visualization and the capacity of Merpati Raya Street, based on calculations from PKJI 2023, are shown in Figure 6 and Table 4.

(A)



(B)

Figure 6. (A) Visualization of Merpati Raya Street, (B) Cross Section of Merpati Raya Segment Street

Table 4. Capacity of Merpati Raya Street

Road Name	Correction Factor					Total Capacity
	C_0	FC_{LJ}	FC_{PA}	FC_{HS}	FC_{UK}	
Merpati Raya Street	2760	0.78	1.00	0.85	1.00	3.081

Source: Analysis Results, 2024.

5. Performance of Duren Intersection in 2023, 2026, and 2028 (Planned Years)

Analysis reveals that the performance of the Duren Intersection in 2023 during peak hours is quite poor, characterized by a saturation degree > 0.80, indicating that the intersection reaches a saturation point. The worst performance on weekdays occurs during the evening rush hour with a saturation degree of 0.99, a queue of 39.51%, a delay of 18.65 seconds, and a service level of C. This indicates that intervention at the intersection is necessary to improve its performance.

Further analysis for 2026 shows that the intersection's performance during peak hours worsens, marked by a saturation degree > 0.80, indicating that the intersection reaches a saturation point. The worst performance on weekdays occurs during the evening rush hour with a saturation degree exceeding 1, a queue of 42.51%, a delay of 20.40 seconds, and a service

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level of C. This performance in the planned year 2026 is worse compared to 2023, highlighting the need for intervention.

As previously mentioned, the traffic condition in 2028 represents the scenario without any intervention in the planned years. This condition is based on a five-year traffic forecast using the growth rate of vehicles/traffic in South Tangerang. Analysis for 2028 shows that the worst intersection performance on weekdays occurs during the evening rush hour with a saturation degree exceeding 1, a queue of 44.64%, a delay of 21.84 seconds, and a service level of C. This indicates that the performance in the planned year 2028 will continue to deteriorate compared to both 2023 and 2026.

6. Performance of Duren Intersection with Interventions in 2023, 2026, and 2028 (Planned Years)

The most significant change at Duren Intersection with intervention in 2023 was the control upgrade from uncontrolled to APILL (Traffic Signaling Device) with two and four phases. Based on the above performance, it can be explained that the improvement in intersection performance was not very significant, with a level of service of F, characterized by delays of more than 60 seconds per vehicle, indicating the need for further interventions. The four-phase APILL configuration performed better compared to the two-phase setup. Generally, installing APILL has reduced conflict points, enhanced safety, and improved intersection performance compared to previous conditions.

The analysis results indicate that the improvement in intersection performance was still not very significant, with a level of service of F, characterized by delays of more than 60 seconds per vehicle. This condition is better compared to without the implementation of an SSA (One-Way System). However, traffic performance with SSA implementation should not only be viewed from the performance at one traffic node but also from the performance of other road segments as part of the SSA application. Therefore, considering that this MRLL study focuses only on the Duren Intersection, the proposed short-term intervention is the implementation of APILL without SSA. However, further studies on the broader application of SSA may be necessary.

The most significant change at Duren Intersection with intervention in 2026 involved land acquisition and road widening by 1 - 2.5 meters at each leg of the intersection. Proposals include two-phase and four-phase APILL settings. The analysis suggests that the improvement in intersection performance remained limited, with a level of service of F, characterized by delays of more than 60 seconds per vehicle, hence the necessity for additional interventions. Generally, installing APILL has proven effective in reducing conflict points, enhancing safety, and improving intersection performance. Below are tables summarizing the intersection's performance without interventions during each peak hour (Tables 5-7).

Table 5. Recapitulation of Intersection Performance without Interventions for 2023

No	Peak Hour	Volume	DS	Queue (%)	Delay (sec/veh)	LOS
1	Morning	2527	0.92	33.6	15.9	C
2	Midday	2083	0.76	23.3	12.4	B
3	Evening	2752	0.99	39.5	18.7	C

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Table 6. Recapitulation of Intersection Performance without Interventions for 2026

No.	Peak Hour	Volume	Average DS	Queue (%)	Delay (sec/veh)	LOS
1	Morning	2619	0.95	36.1	17.0	C
2	Midday	2159	0.75	24.9	12.9	B
3	Evening	2852	1.03	42.5	20.4	C

Table 7. Recapitulation of Intersection Performance without Interventions for 2028

No.	Peak Hour	Volume	Average DS	Queue (%)	Delay (sec/veh)	LOS
1	Morning	2683	0.97	37.9	17.8	C
2	Midday	2211	0.80	26.1	13.2	B
3	Evening	2921	1.05	44.6	21.8	C

The most significant change at Duren Intersection with intervention in 2028 was the redesign of the intersection's geometric layout and the widening of roads for all approach legs. The analysis indicates that the improvement in intersection performance remained modest, with a level of service of E, characterized by delays between 40 - 60 seconds per vehicle, suggesting the need for further interventions. The four-phase APILL configuration proved to be more effective than the two-phase setup. Generally, installing APILL has helped reduce conflict points, enhance safety, and improve intersection performance compared to previous conditions. Below are tables summarizing the intersection's performance without interventions during each peak hour (Tables 8-13).

Table 8. Recapitulation of Intersection Performance with Interventions (2 Phases) for 2023

No.	Peak Hour	Volume	Average Density	Queue (%)	Delay (sec/veh)	LOS
1	Morning	2683	0.97	37.9	17.8	C
2	Midday	2211	0.80	26.1	13.2	B
3	Evening	2921	1.05	44.6	21.8	C

Table 9. Recapitulation of Intersection Performance with Interventions (4 Phases) for 2023

No.	Peak Hour	Cycle Time (sec)	Volume	DS	Average Queue (m)	Average Delay (sec/veh)	Average Vehicle Stops (stop/veh)	LOS
1	Morning	132	1816	0.87	166	72	1.01	F
2	Midday	84	1487	0.77	92	44	0.97	E
3	Evening	145	1926	0.88	186	77	1.00	F

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Table 10. Recapitulation of Intersection Performance with Interventions (2 Phases) for 2026

No.	Peak Hour	Cycle Time (sec)	Volume	DS	Queue (m)	Average Delay (sec/veh)	Vehicle Stops (stop/veh)	LOS
1	Morning	89	1882	0.82	107	61	1.11	F
2	Midday	82	1542	0.68	75	43	0.95	E
3	Evening	97	1996	0.83	144	95	1.37	F

Table 11. Recapitulation of Intersection Performance with Interventions (4 Phases) for 2026

No.	Peak Hour	Cycle Time (sec)	Volume	DS	Queue (m)	Average Delay (sec/veh)	Vehicle Stops (stop/veh)	LOS
1	Morning	93	1882	0.79	98	47	0.96	E
2	Midday	70	1542	0.70	65	35	0.92	D
3	Evening	100	1996	0.81	110	51	0.96	E

Table 12. Recapitulation of Intersection Performance with Interventions (2 Phases) for 2028

No.	Peak Hour	Cycle Time (sec)	Volume	DS	Queue (m)	Average Delay (sec/veh)	Vehicle Stops (stop/veh)	LOS
1	Morning	96	2063	0.88	152	92	1.32	F
2	Midday	87	1678	0.72	89	49	0.96	F
3	Evening	104	2175	0.88	213	151	1.70	F

Table 13. Recapitulation of Intersection Performance with Interventions (4 Phases) for 2028

NO	PEAK HOUR	CYCLE TIME (sec)	VOLUME	DS	QUEUE (m)	DELAY (sec/veh)	VEHICLE STOPS (stop/veh)	LOS
1	Morning	104	2063	0.82	118	51	0.91	E
2	Midday	75	1678	0.73	74	36	0.88	D
3	Evening	111	2175	0.84	128	54	0.91	E

5. Conclusion and Suggestion

5.1 Conclusion

Based on the analysis conducted, the traffic performance at Duren Intersection during peak hours is quite poor. In 2023, the intersection performance reached a saturation point with a saturation degree over 0.80, a queue length of 39.5%, a delay of 18.7 seconds, and a Level of Service (LOS) C. By 2026, this condition worsens with a saturation degree over 1, a queue length of 42.51%, a delay of 20.40 seconds, and a level of service C. In 2028, the situation becomes even more severe with a saturation degree over 1, a queue length of 44.64%, a delay of 21.84 seconds, and a level of service C. To address this congestion, several intervention proposals are suggested. In the short term, the installation and activation of APILL (Traffic Signaling Device), renewal of road markings and traffic signs, and installation of CCTV are necessary.

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In the medium term, evaluation of APILL cycle times, renewal of road markings, traffic signs, and CCTV, along with relocation of utility poles and electrical substations, a road widening of 1.5 meters, and adjustments to the turning radius are required. Meanwhile, in the long term, adjustments to the geometric design of the intersection are needed, including widening Jalan Menjangan Raya to 7.5 meters, and Merpati Raya to 14 meters, KH. Dewantoro to 11 meters, and Cendrawasih Raya to 12 meters, along with the addition of traffic islands, renewal of road markings, traffic signs, and CCTV. Although a four-phase setting is implemented, the intersection's performance is predicted to continue deteriorating annually.

5.2 Suggestion

Several measures have been identified to address the increase in traffic flow and manage unsignalized intersections. These measures include enhancing road capacity, installing clear traffic signs, and improving coordination among stakeholders involved in traffic management. The proposed suggestions are as follows: a. Coordinate with relevant parties in implementing Traffic Management and Engineering at Duren Intersection; b. Regular monitoring and evaluation of the Traffic Management and Engineering implementation, including the evaluation of APILL cycle times; c. Land acquisition to support the implementation of Traffic Management and Engineering.

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