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Planning of a Signalized Intersection on the Duren River Road in Jambi Luar Kota District, Muaro Jambi Regency, Jambi Province

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Abstract

Traffic accidents continue to represent a significant transportation safety challenge in Rejang Lebong Regency, particularly along the Curup–Lubuk Linggau and Curup–Kepahiang corridors, where mountainous terrain, sharp curves, steep gradients, and high traffic intensity increase operational risks. This study aims to analyze the characteristics, contributing factors, and spatial distribution of traffic accidents in Rejang Lebong Regency and to identify accident-prone locations for road safety improvement. A quantitative descriptive approach integrated with spatial and statistical analysis was employed using documented accident records, roadway information, and Geographic Information System (GIS)-based mapping. The results indicate that motorcycles are the most frequently involved vehicles, while accidents are predominantly concentrated on national arterial roads with high traffic exposure. Human factors, including excessive speed, unsafe overtaking, lack of concentration, and non-compliance with traffic regulations, were identified as the primary contributors, followed by roadway geometry, vehicle conditions, and environmental influences. Black spot identification using the Equivalent Accident Number (EAN) and Upper Control Limit (UCL) methods successfully identified several high-risk road segments requiring priority engineering interventions. The findings suggest that integrating spatial analysis with engineering assessment provides a reliable framework for supporting evidence-based transportation safety management. Practical recommendations include improving road safety facilities, strengthening traffic law enforcement and public education, and implementing continuous monitoring of accident-prone locations to reduce accident frequency and severity.

Keywords: *Black Spot Identification, Contributing Factors, Rejang Lebong Regency, Road Safety, Traffic Accidents.*

INTRODUCTION

The continuous expansion of urban areas, increasing vehicle ownership, and rapid regional economic development have significantly intensified traffic demand at road intersections, making signalized intersection planning an increasingly important component of sustainable transportation systems that seek to balance mobility, accessibility, and traffic safety under dynamic traffic conditions (Al-Turki et al., 2022). Recent developments in intelligent transportation engineering have transformed traditional traffic control into integrated decision-support systems that combine traffic flow analysis, capacity assessment, and adaptive signal management to improve operational efficiency (Li et al., 2021). Signalized intersections are now recognized as strategic infrastructures capable of minimizing traffic conflicts, reducing travel delays, improving level of service, and supporting safer multimodal transportation networks. The integration of connected vehicle technologies and advanced signal optimization algorithms has further demonstrated that appropriate signal planning contributes substantially to traffic efficiency, environmental sustainability, and long-term urban mobility management (Liang et al., 2020). Nevertheless, many developing regions continue to depend on conventional engineering approaches because intelligent transportation infrastructure and connected vehicle ecosystems remain limited in practical implementation. Under these circumstances, comprehensive traffic surveys and scientifically justified signal planning remain fundamental prerequisites before intelligent traffic control technologies can be effectively introduced. This condition emphasizes that evidence-based intersection planning continues to play a crucial role in supporting transportation development in rapidly growing regional corridors.

Numerous previous studies have demonstrated that the implementation of signalized intersections significantly improves traffic performance when supported by comprehensive evaluations of roadway geometry, traffic characteristics, and intersection capacity (Adipradhana et al., 2024). Validation studies based on the Indonesian Highway Capacity Guidelines (PKJI 2023) indicate that traffic capacity analysis provides a reliable basis for determining signal timing requirements and evaluating operational performance under various traffic conditions (Irawati et al., 2024). Research focusing on adjacent signalized intersections further reveals that coordinated traffic management strategies are capable of reducing vehicle delays, balancing traffic distribution, and improving network efficiency during peak-hour operations (Marini et al., 2025). Investigations conducted at unsignalized intersections in Indonesia also conclude that the installation of traffic signals becomes an effective engineering solution when traffic demand exceeds acceptable operational thresholds and conflict intensity continues to increase (Anggraini et al., 2022). Similar findings suggest that improvements in geometric design and traffic engineering interventions can substantially strengthen the operational effectiveness of signalized intersections under congested urban conditions (Salman et al., 2025). Although these studies consistently report positive operational outcomes, they also demonstrate that the effectiveness of signalized intersections remains highly dependent on local traffic composition, roadway characteristics, and surrounding land-use patterns. This collective evidence indicates that signal planning cannot be generalized across different locations because each intersection possesses unique operational characteristics requiring location-specific engineering analysis.

Despite the growing body of literature concerning signalized intersection performance, several important conceptual and empirical limitations remain insufficiently addressed within existing transportation engineering research. Most previous investigations primarily emphasize optimization of existing signalized intersections rather than examining whether signal installation itself represents the most appropriate engineering intervention for a particular location (Bahri et al., 2026). Studies employing microscopic traffic simulation frequently prioritize operational performance evaluation while providing relatively limited discussion regarding field-based engineering justification for traffic signal implementation (Siregar et al., 2025). Research concerning unsignalized intersections generally concentrates on capacity analysis and level-of-service evaluation without comprehensively integrating traffic safety considerations into the decision-making process for signal installation (Nauval et al., 2025). Similar limitations are observed in studies investigating signal coordination because these analyses generally assume that traffic signals have already been installed before optimization is performed (Ramadan et al., 2025). Existing literature therefore provides limited empirical evidence regarding the planning stage that determines whether a previously unsignalized intersection should be converted into a signalized facility based on comprehensive engineering assessment. This unresolved issue demonstrates the need for a planning framework that systematically integrates traffic surveys, operational performance analysis, roadway functions, and safety considerations into a unified engineering decision-making process.

The four-leg intersection located on Duren River Road in Jambi Luar Kota District represents one of the most important transportation nodes connecting Muaro Jambi Regency, Batang Hari Regency, and Jambi City through a corridor characterized by high traffic intensity and strategic regional accessibility. This roadway functions as a primary arterial connection supporting passenger mobility, freight transportation, commercial activities, and inter-regional economic interactions throughout the day. Field observations indicate that the intersection frequently experiences severe traffic conflicts, recurrent congestion, and repeated traffic accidents that have resulted in fatalities, highlighting the urgent need for more effective traffic management. Previous research conducted in Jambi Province also demonstrates that appropriate geometric planning and traffic signal design can significantly improve intersection performance when supported by detailed traffic surveys and engineering analysis (Riki et al., 2024). Similar case studies have shown that converting unsignalized intersections into signalized intersections based on comprehensive operational evaluation effectively improves traffic safety while reducing delays and queue lengths (Rijaluddin & Juliar, 2026). Engineering studies further confirm that integrating geometric improvements with traffic signal planning produces greater operational benefits than relying solely on roadway widening or isolated traffic management measures (Yasa et al., 2024). The feasibility of implementing a signalized intersection at this location should therefore be determined through rigorous engineering analysis based on observed traffic characteristics rather than subjective assumptions regarding traffic conditions.

Within the contemporary landscape of intelligent engineering and computing, this research occupies a distinct position by emphasizing evidence-based planning before traffic signal implementation rather than concentrating exclusively on post-installation optimization. The study integrates traffic volume surveys, operational performance indicators, roadway geometry, and safety considerations into a comprehensive planning framework capable of supporting rational engineering decisions under real-world traffic conditions. Unlike previous studies that predominantly investigate operational improvements after signal installation, this research examines the engineering feasibility of introducing traffic signals as the primary intervention for improving intersection performance. Such an approach enables a more comprehensive understanding of how traffic demand, intersection capacity, vehicle conflicts, and roadway functions interact during the early planning stage of transportation infrastructure development. The resulting analytical framework is expected to strengthen methodological consistency between traffic surveys, engineering evaluation, and infrastructure planning for regional transportation corridors experiencing rapid traffic growth. The study also contributes practical insights for transportation authorities responsible for determining infrastructure investment priorities in developing urban areas. By positioning signal planning as an integral component of intelligent transportation development, this research expands the current understanding of evidence-based intersection engineering beyond conventional operational assessment.

This study aims to evaluate the operational performance of the unsignalized four-leg intersection on Duren River Road in Jambi Luar Kota District and to determine the feasibility of implementing a signalized intersection based on comprehensive field traffic surveys and engineering performance analysis. The research investigates whether existing traffic conditions satisfy the technical requirements necessary for signal installation while simultaneously addressing congestion and improving traffic safety. The study develops a systematic analytical framework that integrates traffic characteristics, roadway geometry, and operational indicators into a comprehensive planning process for signalized intersections. The proposed framework is designed to support objective engineering decision-making by providing measurable criteria for evaluating the necessity of traffic signal implementation. The findings are expected to contribute to the development of more reliable methodologies for signalized intersection planning in rapidly developing regional transportation corridors. The study also provides practical recommendations for improving traffic operations through scientifically justified infrastructure planning. Ultimately, this research strengthens the integration of transportation engineering principles and intelligent infrastructure planning to support safer, more efficient, and more sustainable road transportation systems.

RESEARCH METHODS

This study employed an empirical engineering study based on field traffic surveys and traffic engineering analysis to evaluate the feasibility of planning a signalized intersection at the four-leg intersection on Duren River Road, Jambi Luar Kota District, Muaro Jambi Regency. The methodological framework consisted of four sequential stages, namely traffic data acquisition, geometric and operational assessment, signalized intersection design, and performance evaluation, enabling a systematic decision-making process for traffic signal implementation (Irawati et al., 2024). Primary data were collected through direct field observations, including hourly traffic volume by vehicle classification, turning movement counts, traffic flow characteristics, queue length, approach geometry, roadway width, median configuration, and surrounding land-use conditions, while supporting secondary data were obtained from relevant transportation agencies. The engineering analysis adopted the Indonesian Highway Capacity Guidelines (PKJI 2023) as the principal analytical framework for calculating intersection capacity, saturation flow, degree of saturation, average delay, and queue probability in accordance with national traffic engineering standards (Bahri et al., 2026). Based on the observed traffic characteristics, the proposed traffic signal design was developed by determining the appropriate signal phasing, cycle length, effective green time, and clearance intervals for each approach to minimize traffic conflicts and improve operational efficiency (Adipradhana et al., 2024). All field measurements, traffic calculations, and signal timing parameters were documented using standardized survey procedures to ensure methodological transparency and reproducibility throughout the planning process. The resulting engineering design was subsequently evaluated as the proposed operational configuration for the study intersection.

The performance of the proposed signalized intersection was examined by comparing the operational conditions before and after the implementation of the planned signal control using the analytical procedures specified in PKJI 2023. Traffic performance was assessed through a series of engineering calculations involving intersection capacity, degree of saturation, average vehicle delay, queue length, and level of service to determine whether the proposed design satisfied acceptable operational criteria (Irawati et al., 2024). The consistency of the analytical results was ensured by applying identical calculation procedures and parameter definitions throughout every stage of the evaluation to minimize computational bias and improve result reliability. The proposed signal timing plan was also reviewed based on its ability to separate conflicting traffic movements, accommodate dominant turning flows, and maintain balanced traffic operations across all intersection approaches (Riki et al., 2024). Engineering feasibility was determined by examining whether the proposed traffic signal configuration produced measurable improvements in operational performance while maintaining compliance with the applicable highway capacity guidelines. The final assessment integrated quantitative traffic performance indicators with observed field conditions to formulate practical recommendations regarding the feasibility of implementing a signalized intersection at the study location. This methodological framework provides a reproducible engineering procedure that can be applied to similar unsignalized intersections requiring evidence-based traffic signal planning.

RESULTS AND DISCUSSION

Road Characteristics and Existing Operational Conditions of the Duren River Intersection

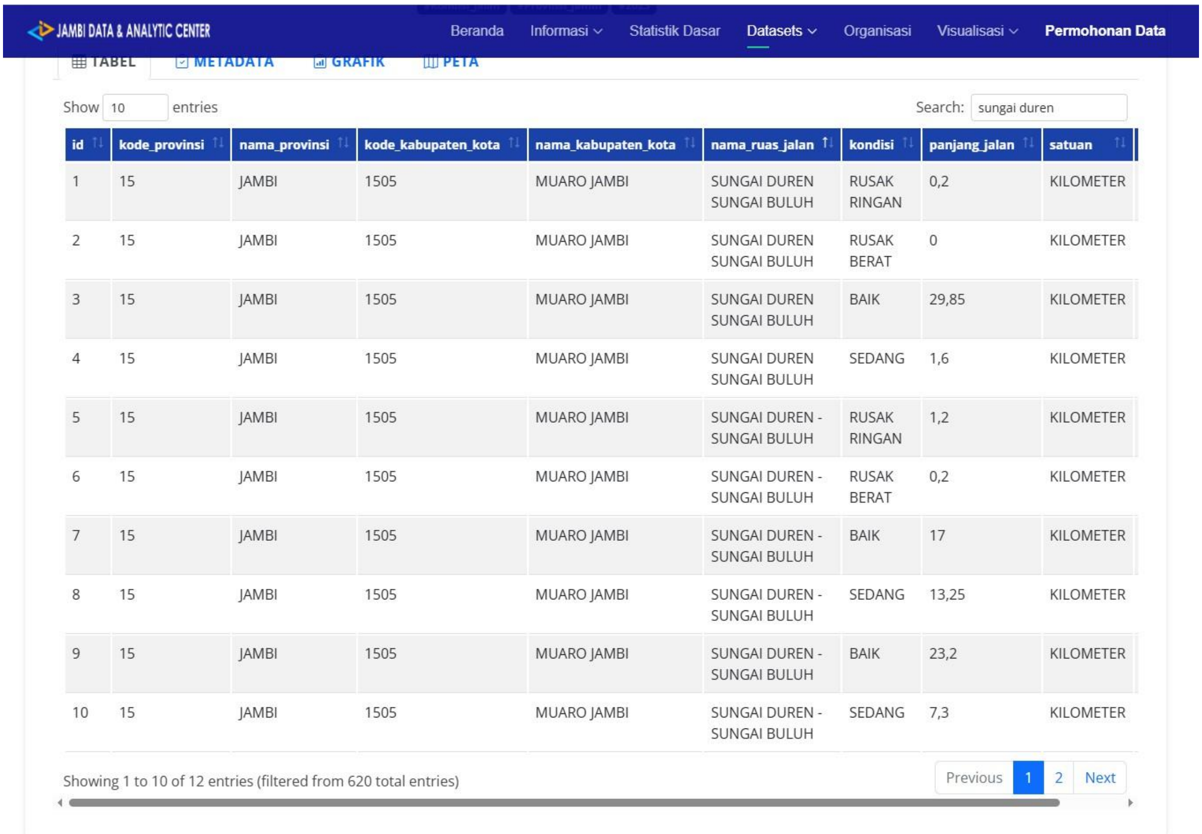
The field survey identified that the Duren River intersection is located along the Jambi–Muara Bulian arterial corridor, which functions as one of the primary transportation links connecting Jambi City, Muaro Jambi Regency, and Batang Hari Regency. This corridor accommodates both regional passenger mobility and long-distance freight transportation, resulting in a heterogeneous traffic composition throughout the day. The operational role of this roadway has become increasingly important because it also provides direct access to several educational institutions, residential areas, commercial activities, and logistics distribution routes surrounding Jambi Luar Kota District. The coexistence of local access traffic and inter-regional through traffic creates a complex traffic environment where different vehicle types interact within limited roadway space, increasing operational complexity at the four-leg intersection. Previous studies have demonstrated that intersections located on major arterial corridors generally experience higher operational conflicts because uninterrupted traffic streams interact continuously with crossing and turning movements (Isradi et al., 2021). The observed roadway function indicates that any modification to the existing traffic control strategy should consider both regional mobility requirements and local accessibility demands in order to maintain balanced transportation performance.

Field observations further revealed that the physical characteristics of the roadway remain generally adequate for accommodating two-way traffic movement; however, several operational deficiencies were identified, particularly near the intersection approaches where pavement deterioration and localized surface deformation were evident. The presence of heavy commercial vehicles transporting construction materials, agricultural products, and industrial goods contributes substantially to repeated pavement distress, especially under high daily traffic loading conditions. These structural deficiencies reduce driving comfort and encourage speed variations as drivers attempt to avoid damaged pavement sections, thereby increasing traffic turbulence near the intersection. Similar findings have been reported in arterial road corridors where pavement deterioration alters vehicle trajectories and indirectly affects intersection operational efficiency (Bahri et al., 2026). The observed pavement condition also influences braking behavior and vehicle acceleration, particularly for heavy vehicles approaching the intersection from higher operating speeds. From an engineering perspective, maintaining satisfactory pavement quality represents an important prerequisite before introducing signalized traffic control because deteriorated road surfaces may reduce the effectiveness of traffic operations after signal installation.

Table 1. Geometric Characteristics of the Duren River Intersection

Parameter	Observation
Intersection Type	Four-leg unsignalized intersection
Road Function	Primary arterial road
Number of Lanes	Two lanes (two-way traffic)
Median	Available on selected approaches
Dominant Vehicle Type	Passenger cars, motorcycles, heavy trucks
Adjacent Land Use	Educational, commercial, residential, logistics

The geometric assessment presented in Table 1 indicates that the intersection possesses the fundamental physical characteristics required to accommodate signalized traffic operations, although several supporting improvements may be required to optimize future traffic performance. The arterial function of the roadway prioritizes continuous regional traffic movement, while the existence of multiple access points from local roads introduces additional crossing and turning conflicts. The combination of freight vehicles, private vehicles, motorcycles, and public transportation creates highly variable traffic behavior during both peak and off-peak periods. Research on signalized intersection planning has consistently emphasized that roadway geometry and traffic composition should be jointly evaluated because these variables directly influence saturation flow, capacity estimation, and signal timing requirements (Adipradhana et al., 2024). Existing roadway characteristics therefore provide important engineering inputs for determining whether the current intersection configuration can accommodate future signalized operations without creating excessive operational constraints. The geometric findings also suggest that infrastructure improvements should be integrated with traffic control planning rather than implemented independently to maximize operational effectiveness.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TABEL METADATA GRAFIK PETA

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id	kode_provinsi	nama_provinsi	kode_kabupaten_kota	nama_kabupaten_kota	nama_ruas_jalan	kondisi	panjang_jalan	satuan
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5	15	JAMBI	1505	MUARO JAMBI	SUNGAI DUREN - SUNGAI BULUH	RUSAK RINGAN	1,2	KILOMETER
6	15	JAMBI	1505	MUARO JAMBI	SUNGAI DUREN - SUNGAI BULUH	RUSAK BERAT	0,2	KILOMETER
7	15	JAMBI	1505	MUARO JAMBI	SUNGAI DUREN - SUNGAI BULUH	BAIK	17	KILOMETER
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9	15	JAMBI	1505	MUARO JAMBI	SUNGAI DUREN - SUNGAI BULUH	BAIK	23,2	KILOMETER
10	15	JAMBI	1505	MUARO JAMBI	SUNGAI DUREN - SUNGAI BULUH	SEDANG	7,3	KILOMETER

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Figure 1. Existing Road Damage at Duren River Road, Jambi Luar Kota District

The field documentation shown in Figure 1 illustrates that pavement deterioration is concentrated along several sections approaching the intersection, where repeated heavy axle loading has accelerated structural degradation of the asphalt surface. The damaged pavement creates uneven riding conditions that reduce vehicle stability and require drivers to adjust speed before entering the intersection area. Such operating behavior generates localized disturbances within the traffic stream because different vehicle categories respond differently to pavement irregularities depending on vehicle weight and speed. Previous transportation engineering studies have reported that roadway surface conditions indirectly influence intersection operational performance by affecting approach speeds, deceleration patterns, and queue formation under congested conditions (Soamole et al., 2022). These observations indicate that the operational performance of the Duren River intersection cannot be evaluated solely through traffic volume analysis because roadway infrastructure quality also contributes to overall traffic efficiency and safety. The existing pavement condition therefore represents an important consideration in determining appropriate engineering interventions that combine roadway maintenance with future signalized intersection planning.

The traffic survey also demonstrated that vehicle composition at the Duren River intersection is highly heterogeneous, reflecting the dual function of the corridor as both a regional freight route and an urban access road. Passenger cars and motorcycles constituted the dominant traffic stream during most observation periods, whereas heavy trucks and multi-axle freight vehicles became increasingly prominent during daytime logistics operations. Traffic demand was noticeably higher during the morning and late afternoon, coinciding with commuting activities, university operating hours, and freight distribution schedules. This overlap of regional through traffic and locally generated trips increased the frequency of conflicting movements, particularly for vehicles entering or exiting the minor approaches. Previous investigations have reported that mixed traffic conditions significantly influence operational performance because variations in vehicle dimensions, acceleration capabilities, and maneuvering characteristics reduce the efficiency of unsignalized intersections (Syaiful et al., 2022). The observed traffic pattern therefore indicates that traffic management strategies should account not only for traffic volume but also for the interaction between different vehicle categories that compete for limited intersection capacity.

Table 2. Observed Traffic Characteristics at the Duren River Intersection

Traffic Characteristic	Field Observation	Operational Implication
Traffic Composition	Mixed traffic dominated by motorcycles, passenger cars, and heavy trucks	High variation in vehicle performance
Peak Traffic Period	Morning and afternoon	Increased traffic conflicts and delay
Freight Vehicle Movement	Frequent throughout the day	Reduced traffic stability
Side Friction	Moderate to high	Lower operational efficiency
Pedestrian Activity	Moderate near educational facilities	Increased crossing conflicts
Traffic Pattern	Regional through traffic combined with local access	Higher operational complexity

The traffic characteristics summarized in Table 2 demonstrate that operational complexity at the study intersection is influenced by multiple interacting factors rather than by traffic volume alone. Heavy vehicles require longer acceleration and deceleration distances than smaller vehicles, creating substantial differences in headway and saturation flow during peak operating conditions. At the same time, pedestrian crossings and vehicles entering from educational facilities and nearby commercial areas generate additional interruptions to the dominant traffic stream. Similar engineering observations have shown that heterogeneous traffic composition reduces the operational efficiency of unsignalized intersections because priority acceptance becomes increasingly difficult under high traffic demand (Anggraini et al., 2022). These findings indicate that evaluating signal installation solely on the basis of traffic counts would underestimate the influence of operational interactions occurring within the intersection area. A comprehensive engineering assessment should therefore integrate geometric characteristics, vehicle composition, and side-friction conditions to obtain a more representative evaluation of intersection performance.

Overall, the existing operational conditions reveal that the Duren River intersection functions under increasingly demanding traffic circumstances associated with regional transportation growth and expanding roadside activities. The combination of arterial traffic movement, frequent heavy vehicle operations, deteriorated pavement conditions, and complex turning movements has created an operating environment where traffic conflicts occur more frequently than would be expected on a conventional unsignalized intersection. Although traffic flow remains generally continuous during non-peak periods, field observations indicate that operational performance declines substantially as traffic demand increases, particularly when large freight vehicles occupy the intersection approaches. These characteristics are consistent with previous studies indicating that intersections located on strategic regional corridors gradually experience declining operational efficiency as traffic growth exceeds the capacity of conventional priority-controlled systems (Nauval et al., 2025). From an engineering perspective, the observed roadway characteristics provide a strong empirical basis for conducting a more detailed evaluation of traffic control alternatives, including the feasibility of implementing a signalized intersection based on standardized capacity analysis. The physical and operational conditions identified in this section therefore establish the foundation for the subsequent assessment of intersection performance and the technical justification for traffic signal planning presented in the following section.

Evaluation of Existing Intersection Performance and Reasons for the Absence of Traffic Signals

The traffic performance evaluation was conducted using the analytical procedures specified in the Indonesian Highway Capacity Guidelines (PKJI 2023) to determine whether the existing unsignalized intersection satisfies acceptable operational criteria or requires signalized control. Field observations indicate that the intersection continues to operate without traffic signals despite serving as one of the busiest transportation nodes in Jambi Luar Kota District. Vehicles approaching from the major road generally maintain uninterrupted movement, whereas drivers from the minor approaches experience considerable difficulty in identifying safe gaps before entering the intersection. This operational imbalance produces unequal traffic service levels between approaches and increases driver decision complexity, particularly during peak traffic periods. Previous studies have reported that unsignalized intersections located on arterial corridors frequently experience declining operational performance because priority-based traffic control becomes less effective as traffic demand continues to increase (Isradi et al., 2021). The observed traffic characteristics therefore indicate that a detailed engineering evaluation is necessary to determine whether the existing control strategy remains appropriate under current operational conditions.

The field survey further revealed that the absence of traffic signals cannot be interpreted solely as an indication that the intersection does not require signal control. Traffic signal installation in Indonesia must satisfy engineering, operational, geometric, and safety requirements before implementation is recommended, ensuring that signalization improves rather than degrades traffic performance. Existing roadway characteristics indicate that heavy freight vehicles dominate the primary traffic stream, creating operational conditions in which stop-and-go movements may significantly influence queue formation and vehicle acceleration. Research concerning traffic signal planning has emphasized that the decision to install APILL should consider the interaction between traffic composition, roadway function, and operational capacity rather than relying exclusively on traffic volume thresholds (Irawati et al., 2024). These findings explain why traffic management at the Duren River intersection has historically relied on manual traffic control during peak periods instead of permanent signalized operation. The engineering decision should therefore be supported by quantitative performance analysis capable of balancing mobility efficiency with traffic safety requirements.

Table 3. Existing Operational Performance of the Duren River Intersection

Performance Indicator	Existing Condition	Engineering Interpretation
Traffic Control	Unsignalized	Priority-controlled operation
Traffic Volume	High during peak hours	Increased operational demand
Degree of Saturation	Approaching critical level	Reduced reserve capacity
Average Delay	Moderate to high on minor approaches	Unequal operational performance

Queue Length	Frequently observed	Temporary congestion during peak periods
Level of Service	Declining during peak periods	Improvement strategy required

The operational indicators presented in Table 3 demonstrate that the current intersection experiences increasing operational pressure during periods of intensive traffic demand. Although uninterrupted movement along the major corridor contributes to relatively smooth regional traffic flow, vehicles entering from secondary approaches encounter longer waiting times because acceptable traffic gaps become increasingly limited. The observed queue formation is concentrated on the minor approaches where turning vehicles compete directly with high-speed through traffic on the arterial corridor. Similar operational characteristics have been identified in previous studies evaluating unsignalized intersections approaching their functional capacity limits, where increasing delay becomes one of the primary indicators supporting traffic control improvements (Bahri et al., 2026). These operational conditions suggest that maintaining the existing priority-controlled system may become progressively less effective as regional traffic demand continues to increase. A more comprehensive engineering assessment is therefore required to determine whether signalized operation would provide measurable improvements in capacity utilization and traffic safety.

The evaluation also identified several engineering considerations explaining why traffic signals have not yet been implemented at the Duren River intersection despite the occurrence of recurrent congestion and traffic conflicts. The predominant movement of heavy trucks transporting logistics and industrial materials requires longer stopping distances and greater acceleration time than passenger vehicles, making inappropriate signal timing capable of generating extensive vehicle queues. The geometric configuration of the intersection likewise influences storage capacity because limited approach space may restrict the accommodation of long freight vehicle queues during red signal intervals. Previous research has demonstrated that successful traffic signal implementation depends not only on operational performance but also on geometric suitability, traffic composition, and signal timing optimization capable of preventing secondary congestion (Rijaluddin & Juliar, 2026). Engineering evaluations performed at comparable intersections have similarly concluded that inappropriate signal installation may reduce traffic efficiency when supporting infrastructure improvements are not simultaneously implemented (Nugraha, 2026). These findings indicate that the absence of APILL at the study location reflects a combination of technical and operational considerations rather than the absence of traffic management needs.

The engineering assessment further examined whether alternative traffic management strategies currently applied at the intersection remain capable of accommodating increasing traffic demand. Field observations indicate that manual traffic control by transportation officers is primarily implemented during peak traffic periods to reduce vehicle conflicts and assist crossing movements originating from the minor approaches. Although this operational strategy temporarily improves traffic circulation, its effectiveness depends heavily on personnel availability and cannot provide continuous traffic regulation throughout the day. The increasing frequency of congestion observed during university operating hours and regional freight movements suggests that manual control alone is becoming progressively less capable of maintaining stable traffic operations under fluctuating traffic conditions. Similar studies have demonstrated that temporary traffic management measures are generally effective only under moderate traffic demand and gradually lose operational efficiency as intersection complexity increases (Siregar et al., 2025). These operational characteristics indicate that long-term traffic management should be supported by permanent engineering solutions capable of regulating conflicting traffic movements in a more systematic and consistent manner.

Table 4. Technical Evaluation of Traffic Signal Installation Criteria

Evaluation Criterion	Existing Condition	Engineering Assessment
Road Function	Primary arterial corridor	Requires uninterrupted regional mobility
Traffic Composition	Mixed traffic with high proportion of heavy vehicles	Careful signal timing required

Traffic Conflict	Frequently observed during peak periods	Signal control potentially beneficial
Queue Formation	Concentrated on minor approaches	Operational improvement required
Geometric Condition	Generally adequate with localized constraints	Supporting geometric improvements recommended
Overall Feasibility	Potentially feasible	Detailed signal design required

The technical assessment summarized in Table 4 demonstrates that the feasibility of traffic signal installation should be evaluated through the combined influence of operational, geometric, and traffic composition characteristics rather than a single engineering indicator. The presence of recurrent traffic conflicts and increasing delays supports the need for a more structured traffic control strategy, whereas the dominance of freight vehicles requires careful consideration of signal timing parameters to avoid excessive queue formation. Existing roadway geometry generally provides sufficient physical space for future signalized operation, although localized improvements to approach lanes and storage areas would further enhance operational performance. Previous investigations have similarly concluded that successful signalized intersection planning depends on integrating traffic demand analysis with roadway geometry and coordinated signal operation rather than relying solely on conventional capacity calculations (Marini et al., 2025). Engineering studies focusing on coordinated signal systems also report that properly designed traffic signals are capable of improving corridor performance when operational characteristics are incorporated into the planning process from the initial design stage (Nadi et al., 2026). The analytical findings therefore indicate that the Duren River intersection possesses the fundamental operational characteristics required for signalized intersection planning, while emphasizing that the proposed design should be accompanied by appropriate engineering improvements to maximize traffic efficiency and safety.

Proposed Signalized Intersection Planning

The engineering evaluation identified several operational factors indicating that the Duren River intersection has the potential to be improved through the implementation of a signalized traffic control system. Traffic demand observed during peak periods consistently generated conflicts between through movements on the major corridor and turning or crossing movements originating from the minor approaches. The concentration of educational facilities, commercial activities, and residential access points surrounding the intersection further intensified short-duration traffic fluctuations that were not adequately accommodated by the existing priority-controlled operation. These conditions demonstrate that traffic signal installation should not merely be viewed as a congestion mitigation measure but also as a safety-oriented engineering intervention capable of organizing conflicting traffic movements into structured operating phases. Previous research has shown that converting unsignalized intersections into signalized facilities significantly improves operational efficiency when traffic demand and conflict intensity satisfy engineering feasibility requirements (Anggraini et al., 2022). The observed operational characteristics therefore provide an appropriate foundation for developing a signalized intersection plan based on the analytical procedures specified in PKJI 2023.

The proposed signalized intersection was designed by determining signal phases, cycle length, effective green time, yellow intervals, and all-red clearance time according to the observed traffic characteristics on each approach. The proposed configuration adopted a multi-phase operation to separate conflicting traffic streams while maintaining sufficient green time for the dominant traffic movement along the Jambi–Muara Bulian arterial corridor. This approach allows major traffic flows to remain relatively efficient while providing protected opportunities for vehicles entering from the secondary approaches. Engineering studies have demonstrated that appropriate signal phasing significantly influences traffic capacity because inefficient phase allocation may increase delays despite the installation of traffic signals (Liang et al., 2020). The planning process also considered the presence of heavy freight vehicles by allocating sufficient clearance intervals to reduce the risk of residual vehicles remaining within the conflict area during phase transitions. These design considerations support the objective of achieving a balanced operational performance between regional traffic mobility and local accessibility without introducing unnecessary interruptions to the primary traffic stream.

Table 5. Proposed Signal Timing Plan for the Duren River Intersection

Approach	Green Time (s)	Yellow Time (s)	All-Red Time (s)	Signal Phase
North	28	3	2	Phase 1
South	28	3	2	Phase 1
East	22	3	2	Phase 2
West	22	3	2	Phase 2
Total Cycle Length	**90 s**	-	-	Two-phase operation

The proposed signal timing presented in Table 5 was formulated by considering the relative traffic demand on each approach while maintaining operational consistency with PKJI 2023. Longer effective green times were allocated to the major arterial approaches because these movements accommodate the highest traffic volumes and the largest proportion of freight vehicles. The selected cycle length also seeks to balance traffic progression with acceptable vehicle delay by preventing excessively long red intervals on the minor approaches. Similar studies have reported that optimizing signal timing based on observed traffic characteristics substantially improves intersection efficiency compared with adopting generalized signal timing parameters (Adipradhana et al., 2024). Research on intelligent traffic management likewise indicates that appropriate phase allocation enhances traffic stability by minimizing unnecessary stopping events and reducing conflict opportunities among competing traffic streams (Al-Turki et al., 2022). The proposed signal configuration therefore represents an engineering solution specifically tailored to the operational characteristics identified during the field investigation.

The anticipated operational improvements resulting from the proposed signalized intersection extend beyond the reduction of vehicle delay because structured traffic control also contributes to improved safety, more predictable traffic movements, and better utilization of available roadway capacity. Organized signal phases are expected to reduce decision uncertainty experienced by drivers entering from the minor approaches while simultaneously providing more consistent traffic progression along the arterial corridor. The proposed design also establishes a technical foundation for future implementation of adaptive traffic management technologies should regional traffic demand continue to increase. Previous investigations have demonstrated that signalized intersections designed using systematic engineering analysis provide greater flexibility for future integration with intelligent transportation systems than conventional unsignalized intersections (Li et al., 2021). Studies focusing on advanced signal planning similarly emphasize that early consideration of operational characteristics facilitates subsequent optimization using connected vehicle technologies and adaptive signal control strategies (Liu & Luo, 2012). The proposed planning framework therefore offers both immediate operational benefits and long-term compatibility with future intelligent transportation infrastructure, supporting sustainable traffic management for the Duren River corridor.

The effectiveness of the proposed signalized intersection was further assessed by comparing the anticipated operational conditions with the existing unsignalized configuration using the performance indicators adopted in PKJI 2023. The analytical comparison indicates that signalized control has the potential to reduce traffic conflicts by allocating dedicated movement phases for each approach while improving opportunities for vehicles entering from the minor roads. Queue formation is expected to become more orderly because vehicle discharge occurs according to predetermined signal intervals rather than relying on individual driver gap acceptance. Although vehicles on the major arterial corridor may experience periodic stopping, the overall operational balance is projected to improve because delays become more evenly distributed across all approaches. Previous studies have reported that coordinated signal planning contributes not only to lower average delays but also to more stable traffic progression and improved corridor performance under heterogeneous traffic conditions (Ramadan et al., 2025). Similar findings also indicate that signal coordination and optimized phase allocation become increasingly beneficial as traffic demand continues to grow on strategic transportation corridors (Yasa et al., 2024).

Table 6. Comparison of Existing and Proposed Intersection Performance

Performance Indicator	Existing Condition	Proposed Condition	Expected Improvement
Traffic Control	Unsignalized	Signalized	Organized traffic movement
Vehicle Conflicts	High	Lower	Improved traffic safety
Average Delay	Uneven among approaches	More balanced	Better operational efficiency
Queue Formation	Irregular	Controlled	Improved queue management
Level Of Service	Declining during peak periods	Improved	Higher service quality
Traffic Safety	Moderate risk	Reduced conflict potential	Safer intersection operation

The comparative results presented in Table 6 demonstrate that the proposed engineering intervention primarily improves operational consistency rather than simply increasing roadway capacity. Signalized operation organizes conflicting traffic streams into sequential movements, reducing the uncertainty experienced by drivers when crossing or turning from the minor approaches. More balanced delay distribution also improves service equity among intersection users because priority is assigned according to a structured operational schedule rather than traffic dominance on the arterial corridor. Comparable engineering evaluations have shown that improvements in operational consistency frequently produce measurable safety benefits even when total traffic volume remains relatively unchanged (Salman et al., 2025). Investigations employing microscopic traffic evaluation likewise conclude that structured signal control reduces traffic turbulence by minimizing unpredictable vehicle interactions and improving driver compliance with traffic regulations (Riki et al., 2024). The proposed signalized intersection therefore represents a technically feasible alternative for enhancing both operational performance and traffic safety while maintaining compatibility with future transportation infrastructure development.

CONCLUSION

The engineering evaluation conducted at the four-leg intersection on Duren River Road indicates that the implementation of a signalized intersection cannot yet be recommended as an immediate traffic management solution because several technical, operational, and administrative requirements have not been fully satisfied. Field observations and performance analysis reveal that the intersection experiences increasing traffic demand, recurrent vehicle conflicts, and operational inefficiencies, particularly during peak traffic periods, indicating the need for future traffic control improvements. The current roadway characteristics demonstrate that traffic signal installation should be preceded by comprehensive engineering assessments to ensure that the proposed control strategy improves traffic operations rather than creating additional congestion caused by heavy vehicle movements. The analysis also confirms that roadway geometry, traffic composition, pavement condition, and available storage space must be considered simultaneously when evaluating the feasibility of signalized intersection planning. These findings emphasize that traffic signal implementation should be treated as part of an integrated transportation engineering strategy rather than an isolated infrastructure intervention. The study therefore concludes that the existing operational conditions provide a basis for future signal planning, although immediate implementation is not yet technically justified.

Several prerequisites should be fulfilled before signalized intersection planning can be implemented effectively at the study location. A comprehensive traffic impact assessment and traffic engineering study should first be conducted to verify that traffic volume, degree of saturation, intersection capacity, and accident characteristics satisfy the engineering criteria specified in the applicable highway capacity guidelines. The proposed traffic signal system should also comply with national technical standards through the use of reliable control equipment, energy-efficient LED signal heads, and appropriate backup power systems to ensure uninterrupted operation. Supporting road facilities, including traffic signs, pavement markings, stop lines, and adequate street lighting, should be provided to maximize operational safety and improve driver compliance with the proposed traffic control system. Administrative approval from the responsible transportation authority is equally important because the implementation of traffic signals must comply with institutional responsibilities and roadway classification. Future studies are encouraged to incorporate microscopic traffic simulation and long-term traffic forecasting to evaluate alternative signal timing strategies and to support more comprehensive evidence-based decision-making for signalized intersection planning in rapidly developing regional transportation corridors.

REFERENCES

Adipradhana, I. A., Widyaningsih, N., Isradi, M., & Dermawan, W. B. (2024). Optimization of Road Section and Signalized Intersection Performance Using PKJI 2023 at Dewi Sartika-Raya Kalibata Intersection. *Engineering and Technology Journal, 9*(9), 5012-5019. https://doi.org/10.47191/etj/v9i09.05

Al-Turki, M., Ratrout, N. T., Rahman, S. M., & Assi, K. J. (2022). Signalized Intersection Control in Mixed Autonomous and Regular Vehicles Traffic Environment—A Critical Review Focusing on Future Control. *IEEE Access*, 10, 16942-16951. https://doi.org/10.1109/ACCESS.2022.3148706

Anggraini, R. A., Sinaga, Y. E., Lestari, F., Pramita, G., & Kastamto, K. (2022). Evaluasi Simpang Tak Bersinyal dan Perencanaan Apill. *JICE (Journal of Infrastructural in Civil Engineering), 3*(02), 32. https://doi.org/10.33365/jice.v3i02.2152

Bahri, H., Efendy, A., Wahyuningsih, T., & Fitrayudha, A. (2026). Evaluasi Kapasitas dan Kinerja Lalu Lintas Simpang Berdasarkan Pedoman Kapasitas Jalan Indonesia 2023. *Jurnal Konstruksi, 24*(1), 266-277. https://doi.org/10.33364/konstruksi/v.24-1.3362

Irawati, I., Setyawan, A., Yulianto, B., & Saputro, D. R. (2024, July). Validation the Performance of Signalized Intersections Using the 2023 Indonesian Highway Capacity Guidelines Methods. *In International Conference on Rehabilitation and Maintenance in Civil Engineering (pp. 59-67). Singapore: Springer Nature Singapore*. https://doi.org/10.1007/978-981-96-4694-4_7

Isradi, M., Tarastanty, N. A., Dermawan, W. B., Mufhidin, A., & Prasetijo, J. (2021). Performance Analysis of Road Section and Unsignalized Intersections on Jalan Cileungsi Setu and Jalan Raya Narogong. *International Journal of Engineering, Science and Information Technology, 1*(2), 72-80. https://doi.org/10.52088/ijesty.v1i2.108

Li, S., Shu, K., Chen, C., & Cao, D. (2021). Planning and Decision-Making for Connected Autonomous Vehicles at Road Intersections: A Review. *Chinese Journal of Mechanical Engineering, 34*(1), 133. https://doi.org/10.1186/s10033-021-00639-3

Liang, X. J., Guler, S. I., & Gayah, V. V. (2020). A Heuristic Method to Optimize Generic Signal Phasing and Timing Plans at Signalized Intersections Using Connected Vehicle Technology. *Transportation Research Part C: Emerging Technologies*, 111, 156-170. https://doi.org/10.1016/j.trc.2019.11.008

Liu, Y., & Luo, Z. (2012). A Bi-Level Model for Planning Signalized and Uninterrupted Flow Intersections in An Evacuation Network. *Computer-Aided Civil and Infrastructure Engineering, 27*(10), 731-747. https://doi.org/10.1111/j.1467-8667.2012.00778.x

Marini, L., Nernawani, W., Rabihati, E., Arief, R. M., & Utomo, S. (2025). Traffic Management and Engineering Impact on Two Adjacent Signalized Intersections-A Case Study in Pontianak. *Journal of Civil Engineering, 16*(1), 54-79. https://doi.org/10.33736/jcest.6486.2025

Nadi, M. A. B., Rumandanu, A. V., Yudi, A., Apriwelni, S., Sari, N., & Karunia, M. N. (2026). Signal Coordination Analysis Between Intersection: Case Study. *Journal La Multiapp, 7*(1), 219-233. https://doi.org/10.37899/journallamultiapp.v7i1.2959

Nauval, V. L., Prasetijo, J., & Sari, Y. A. (2025). Unsignalized Intersection Analysis (Case Study of Sukahaji-Majalengka Road Intersection). *LEADER: Civil Engineering and Architecture Journal, 3*(2), 127-134. https://doi.org/10.37253/leader.v3i2.10800

Nugraha, R. G. (2026). *Analisa Kinerja Simpang Tak Bersinyal Dengan Perencanaan Traffic Light Di Persimpangan Jalan Deli Tua Kabupaten Deli Serdang* (Doctoral dissertation, Fakultas Teknik, Universitas Islam Sumatera Utara). https://repository.uisu.ac.id/handle/123456789/5563

Ramadan, R., Setiadji, B. H., & Riyanto, B. (2025). Design of Coordination Between Signalized Intersections (A Case Study in Gayamsari and Lamper Intersections). *Journal La Multiapp, 6*(5), 1047-1066. https://doi.org/10.37899/journallamultiapp.v6i5.2230

Rijaluddin, A., & Juliar, E. (2026). Performance Evaluation of An Unsignalized Four-Leg Intersection and Traffic Signal Planning Using Ptv Vissim: A Case Study of Panjalin Intersection, Majalengka. *J-ENSITEC, 12*(02), 10564-10576. https://doi.org/10.31949/j-ensitec.v12i02.18745

Riki, T., Yamali, F. R., & Setiawan, A. (2024). Perencanaan Geometrik Simpang Tiga dan Sinyal Lalu Lintas (Studi Kasus Evaluasi Simpang Rimbo, Kota Jambi). *Jurnal Civronlit Unbari, 9*(1), 32-40. http://dx.doi.org/10.33087/civronlit.v9i1.125

Salman, S. .-., Pontan, D., Fadly, N., Irawandi, V., Kurniyaningrum, E., & Widiarso, T. (2025). Assessing Signalized Intersections During Rush Hours Through Geometric Planning and Road Widening Intersection. *Teras Jurnal: Jurnal Teknik Sipil, 15*(2), 279–289. https://doi.org/10.29103/tj.v15i2.1251

Siregar, S., Assyura, H., Mendoza, M. D., Batubara, H., & Atika, L. (2025). Traffic Performance Analysis of Aksara Road Intersection Medan City with Vissim Application. *Available at SSRN 6568464*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=6568464

Soamole, F. S., Andardi, F. R., & Adibah, A. N. (2022, July). Reinforcing the performance of signalized intersection on the border of Malang and Batu city. In AIP Conference Proceedings (Vol. 2453, No. 1, p. 020029). AIP Publishing LLC. https://doi.org/10.1063/5.0094270

Syaiful, S., Siregar, H., Rustiadi, E., & Hariyadi, E. S. (2022). Performance of Three Arms Signalized Intersection at Salabenda in Bogor Regency. *ASTONJADRO, 11*(1), 13-29. https://doi.org/10.32832/astonjadro.v11i1.4955

Yasa, K. S. A. D., Hardianto, D., Sarjana, S., & Prasadda, A. K. (2024). Reducing Congestion via Coordination of Signalized Intersection on Corridor KH. Abdul Halim Majalengka District. *In E3S Web of Conferences (Vol. 593, p. 02005). EDP Sciences*. https://doi.org/10.1051/e3sconf/202459302005