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Analysis of Traffic Performance on the Sapta Marga Road Section South Curup Subdistrict, Rejang Lebong Regency

Jaka Malis Irawan[1*], M. Wisridani P.[2]
[1-2] Universitas Ratu Samban Bengkulu Utara, Indonesia
email: jakamalis@gmail.com[1]

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Abstract

Sapta Marga Road is an important urban collector road that connects residential areas, government offices, schools, and commercial centers in South Curup Subdistrict, Rejang Lebong Regency. Increasing community activities have resulted in higher traffic demand, particularly during peak hours, potentially affecting roadway operational performance. This study aimed to analyze traffic flow characteristics, roadway capacity, degree of saturation, and Level of Service (LOS), as well as to formulate traffic engineering recommendations for improving traffic operations. An empirical field survey was conducted over three consecutive days during morning, midday, and afternoon peak periods. Primary data included traffic volume, vehicle speed, roadway geometric characteristics, side-friction conditions, and surrounding land-use activities, while the analysis was performed using the 2023 Indonesian Road Capacity Guidelines (PKJI 2023). The results indicate that Sapta Marga Road currently operates at LOS C–D, suggesting that traffic flow remains stable despite increasing operational pressure during peak periods. Moderate to high side friction caused by on-street parking, roadside commercial activities, pedestrian movements, and vehicles entering and exiting adjacent properties was identified as the primary factor reducing operational efficiency and travel speed. The study recommends improving parking management, traffic signs, pavement markings, pedestrian facilities, and road safety infrastructure to enhance roadway performance and support sustainable urban traffic management.

Keywords: *Degree of Saturation, Level of Service, PKJI 2023, Road Capacity, Traffic Engineering.*

INTRODUCTION

Road transportation plays a fundamental role in supporting economic growth, social interaction, educational accessibility, and public services because it provides the primary infrastructure for the movement of people and goods within urban and regional areas. As urbanization and motorization continue to accelerate, many cities experience traffic demand that grows faster than the expansion of road infrastructure, creating operational problems such as congestion, reduced travel speed, increased travel time uncertainty, and higher accident risk. These challenges have encouraged transportation engineers to move beyond conventional road construction toward performance-based traffic management that emphasizes continuous monitoring and data-driven decision-making. Contemporary traffic engineering considers roadway performance as an essential indicator for evaluating the operational quality of transportation systems because it reflects the interaction between traffic demand, road capacity, and roadside environmental conditions (Mannering & Washburn, 2013). In Indonesia, roadway performance assessment has become increasingly important following the implementation of the latest Indonesian Road Capacity Guidelines (PKJI 2023), which provide updated analytical procedures for evaluating traffic flow under existing roadway characteristics (Direktorat Jenderal Bina Marga, 2023). Improving road performance is not merely a technical objective but also a strategic effort to ensure safer, more efficient, and more sustainable transportation systems capable of supporting regional development.

Previous studies have consistently shown that traffic performance is strongly influenced by traffic volume, roadway geometry, side friction, and surrounding land-use activities, indicating that roadway operation cannot be evaluated solely from vehicle flow characteristics. Investigations conducted on several urban road corridors reported that roadside activities such as on-street parking,

commercial operations, pedestrian movements, and public transport stopping behavior substantially reduce effective roadway capacity and consequently deteriorate the level of service (Misbah & Hendrizal, 2023). Other researchers demonstrated that increasing traffic demand during peak hours directly increases the degree of saturation, leading to unstable traffic conditions and lower operational efficiency, particularly on urban collector roads with mixed traffic composition (Ramadani & Sari, 2023). Recent studies have also highlighted that changes in surrounding land use, including industrial and commercial development, generate additional traffic that may significantly alter the operational characteristics of adjacent road segments if appropriate traffic engineering measures are not implemented (Antoro et al., 2024). Although these studies provide valuable empirical evidence, most of them focus on highly urbanized corridors where traffic characteristics differ considerably from collector roads serving residential and local service functions. Such differences indicate that traffic performance should always be interpreted within its specific spatial and functional context rather than generalized across different roadway classifications.

Despite the increasing number of studies on roadway performance evaluation, several limitations remain evident in the existing literature. Many previous investigations were conducted using earlier analytical frameworks or focused primarily on describing traffic conditions without critically examining how updated capacity standards influence the interpretation of roadway performance. Recent studies adopting the PKJI 2023 approach have generally concentrated on arterial roads in metropolitan areas, while empirical evidence concerning collector roads in medium-sized regional cities remains relatively limited (Putri et al., 2025). Existing research also tends to emphasize quantitative traffic indicators individually, whereas the interaction between traffic volume, roadway capacity, degree of saturation, and side friction has not been comprehensively discussed within a unified analytical framework. This limitation reduces the ability of transportation authorities to formulate engineering recommendations that accurately reflect actual field conditions, particularly in road segments experiencing rapid changes in daily traffic activities. Consequently, further investigation is required to provide a more comprehensive evaluation of roadway performance on collector roads using the latest national guidelines while considering the operational characteristics that distinguish regional urban environments from larger metropolitan networks.

The Sapta Marga Road section in South Curup Subdistrict, Rejang Lebong Regency, represents one of the important collector roads connecting residential areas with educational facilities, commercial activities, government offices, and other public service centers. Daily traffic on this road consists of motorcycles, passenger cars, freight vehicles, and public transportation operating simultaneously, creating substantial fluctuations in traffic demand during morning and afternoon peak periods. The increasing concentration of roadside activities, including on-street parking, commercial transactions, pedestrian crossings, and vehicles stopping to load or unload passengers, further reduces the effective operating space available for moving traffic. Similar operational conditions have been reported on several urban collector roads where side friction significantly affected road capacity and level of service, emphasizing the need for systematic traffic engineering evaluation before implementing improvement measures (Ayunaning et al., 2023). Current traffic management policies also recommend that roadway performance evaluation should become an integral component of traffic engineering and management to ensure that operational improvements are based on measurable traffic characteristics rather than temporary observations (Kementerian Perhubungan Republik Indonesia, 2015). A comprehensive assessment of the existing traffic conditions on Sapta Marga Road is therefore essential to identify operational deficiencies and to formulate engineering recommendations that can improve both mobility and traffic safety.

From a scientific perspective, evaluating collector-road performance using the latest analytical framework is increasingly important because transportation characteristics continue to evolve alongside regional development and changing travel behavior. Existing studies have demonstrated that roadway performance indicators such as capacity, degree of saturation, and level of service provide reliable information for identifying operational constraints and prioritizing infrastructure improvements when they are evaluated using standardized procedures (Arief et al., 2025). At the practical level, accurate traffic performance analysis enables local governments to allocate transportation resources more effectively while supporting evidence-based planning for future road network development. Nevertheless, the operational characteristics of Sapta Marga Road have not yet been comprehensively evaluated using the PKJI 2023 framework despite its strategic role in serving daily community mobility.

This condition creates an important opportunity to generate empirical evidence that reflects actual traffic conditions in a regional urban environment rather than relying on findings obtained from metropolitan road networks. The present study is positioned to complement previous research by providing a context-specific assessment that integrates traffic volume, roadway capacity, degree of saturation, and level of service within a single analytical framework for an urban collector road.

This study aims to analyze the traffic performance of the Sapta Marga Road section in South Curup Subdistrict by determining traffic volume, roadway capacity, degree of saturation, and level of service based on the latest Indonesian road capacity standards. The analysis is intended to provide a comprehensive representation of existing traffic conditions and identify the principal operational factors influencing roadway performance during daily traffic activities. The findings are expected to support the formulation of appropriate traffic engineering strategies that improve traffic flow efficiency while enhancing road safety for all users. From a theoretical perspective, this research extends the application of contemporary roadway performance assessment to collector roads in regional urban areas that have received relatively limited scholarly attention. Methodologically, the study demonstrates the application of a standardized analytical framework capable of producing objective and comparable performance indicators for transportation planning and management. The results are expected to contribute not only to the development of transportation engineering knowledge but also to assist local authorities in designing more effective and sustainable traffic management policies.

RESEARCH METHODS

This study employed an empirical field survey to evaluate the traffic performance of the Sapta Marga Road section located in South Curup Subdistrict, Rejang Lebong Regency. The research architecture consisted of four sequential stages, namely literature review, preliminary site observation, field data acquisition, and traffic performance analysis to ensure a systematic and reproducible workflow. Primary data were collected through direct field observations, including traffic volume, vehicle speed, roadway geometric characteristics, and side-friction activities occurring along the observed road segment. Secondary data comprised the study area map, demographic information, and technical references related to traffic engineering and roadway performance analysis. Traffic performance was evaluated using the 2023 Indonesian Road Capacity Guidelines (PKJI 2023), which provide standardized procedures for estimating roadway capacity, degree of saturation, and level of service under prevailing roadway and traffic conditions (Direktorat Jenderal Bina Marga, 2023). The analytical framework adopted in this study follows the principles of traffic engineering that emphasize quantitative evaluation of traffic flow characteristics to support evidence-based traffic management and roadway operation (Kementerian Perhubungan Republik Indonesia, 2015).

The collected traffic data were processed by calculating traffic volume, roadway capacity, degree of saturation, and level of service based on the PKJI 2023 methodology. Traffic volume was determined using Equation (1), roadway capacity was estimated using Equation (2), and the degree of saturation was calculated using Equation (3):

$$Q = \frac{N}{T}$$

where $Q$is the traffic volume (veh/h), $N$is the total number of observed vehicles, and $T$is the observation period (h).

$$C = C_0 \times FC$$

where $C$is the roadway capacity (pcu/h), $C_0$is the basic capacity, and FCrepresents the adjustment factors accounting for roadway geometry, lane width, roadside environment, and side-friction conditions.

$$DS = \frac{Q}{C}$$

where DSdenotes the degree of saturation, which was subsequently used to classify the Level of Service (LOS) according to the PKJI 2023 criteria. The validity of the analysis was ensured through

standardized field observation procedures and the application of nationally recognized capacity estimation methods, allowing the calculated performance indicators to accurately represent existing traffic conditions (Permana & Mukhlis, 2026). The resulting traffic performance indicators were finally interpreted by comparing the calculated degree of saturation and level of service with established roadway performance criteria to identify operational deficiencies and formulate appropriate traffic engineering recommendations (Putri et al., 2025).

RESULTS AND DISCUSSION

Existing Road Characteristics and Existing Traffic Conditions

The Sapta Marga Road section functions as an urban collector road that accommodates daily traffic movements between residential neighborhoods and various public activity centers in South Curup Subdistrict, Rejang Lebong Regency. Its strategic location causes the roadway to serve heterogeneous traffic consisting of motorcycles, passenger cars, freight vehicles, and public transportation operating within the same traffic stream throughout the day. Unlike arterial roads that primarily facilitate through traffic, collector roads are characterized by frequent interactions between moving vehicles and roadside activities, creating operational conditions that fluctuate according to surrounding land use and travel demand. Traffic engineering theory recognizes that the operational quality of collector roads is determined not only by geometric design but also by the interaction between traffic demand and roadside environmental characteristics (Khisty & Lall). This operational complexity makes field-based performance evaluation essential because traffic conditions observed under actual circumstances provide more representative information than theoretical capacity assumptions alone. The existing characteristics of Sapta Marga Road were therefore examined as the initial basis for understanding the factors influencing subsequent traffic performance analysis.

Field observations indicated that Sapta Marga Road is a two-lane, two-way undivided roadway with an asphalt pavement, a total length of approximately 2,280 m, a carriageway width of 6 m, and shoulders measuring approximately 1 m on each side. The surrounding environment is dominated by residential areas, schools, small commercial establishments, government offices, and automotive workshops, producing continuous access movements and diverse roadside activities throughout the observation period. Such land-use characteristics increase the frequency of vehicle stopping, parking maneuvers, pedestrian crossings, and turning movements that interrupt traffic flow and reduce the effective operating space available for moving vehicles. The PKJI 2023 emphasizes that roadway geometry and roadside conditions constitute important adjustment factors affecting practical roadway capacity because they directly influence driver behavior and traffic stream stability (Direktorat Jenderal Bina Marga, 2023). The observed physical characteristics and roadside environment are summarized in Table 1, which provides the baseline conditions used in the subsequent traffic performance evaluation. These characteristics demonstrate that roadway operation on Sapta Marga Road cannot be interpreted solely from its geometric dimensions because surrounding activities substantially contribute to the overall traffic environment.

Table 1. Existing Characteristics of the Sapta Marga Road Section

Parameter	Value
Road Classification	Two-lane Two-way Undivided (2/2 UD)
Road Length	2,280 m
Carriageway Width	6 m
Shoulder Width	1 m
Pavement Type	Asphalt
Adjacent Land Use	Residential areas, schools, shops, government offices, workshops
Side Friction Category	Moderate–High

The characteristics presented in Table 1 indicate that the operational environment of Sapta Marga Road is influenced by both its physical configuration and the intensity of surrounding activities. Although the roadway width generally satisfies the geometric requirements for a two-lane two-way collector road, the available traffic space is frequently reduced by roadside activities occurring during daily operational periods. Field observations revealed that on-street parking, vehicles entering and

exiting residential access points, pedestrian crossings, and short-duration stopping near commercial facilities constituted the dominant sources of side friction. Previous studies have reported that moderate to high side friction can substantially reduce effective roadway capacity even when the geometric characteristics of a road segment remain unchanged, because these disturbances interrupt traffic continuity and increase driver response time (Misbah & Hendrizal, 2023). Similar operational behavior was observed along the Sapta Marga Road section, where traffic flow remained relatively stable under normal conditions but became increasingly sensitive to disturbances during peak travel periods. These findings indicate that roadway performance on urban collector roads should be interpreted from the interaction between infrastructure characteristics and surrounding land-use activities rather than from geometric dimensions alone.

The observed roadside environment also reflects the functional role of Sapta Marga Road as an urban connector serving multiple community activities within a relatively short corridor. Educational facilities generate concentrated traffic during school arrival and dismissal periods, while commercial establishments and workshops produce intermittent stopping and parking activities throughout the day. Residential access further contributes to repeated turning movements that interrupt the continuity of traffic flow, particularly when traffic demand begins to increase during commuting hours. Comparable conditions have been identified on collector roads adjacent to traditional commercial areas, where roadside activities significantly altered traffic stream characteristics and reduced operational efficiency despite moderate traffic volumes (Maulana et al., 2024). From a traffic engineering perspective, these recurring interactions increase traffic turbulence and create localized bottlenecks that cannot be adequately represented through geometric evaluation alone (Mannering & Washburn, 2013). The operational characteristics identified in this study therefore provide a logical explanation for why subsequent analyses of traffic volume, roadway capacity, and degree of saturation are required to accurately assess the actual level of service of the Sapta Marga Road section.

The existing roadway conditions identified through field observations establish the foundation for evaluating the operational performance of Sapta Marga Road using the PKJI 2023 analytical framework. The combination of moderate-to-high side friction, mixed traffic composition, and intensive roadside activities suggests that the roadway operates under dynamic conditions in which traffic performance may vary considerably between peak and off-peak periods. These characteristics emphasize the importance of integrating field survey data with standardized traffic performance indicators so that the evaluation reflects actual operational conditions rather than theoretical roadway capacity. The following section presents the analysis of traffic volume, roadway capacity, degree of saturation, and level of service to quantify how the observed physical and environmental characteristics influence the operational performance of the study corridor. Such an approach enables the interpretation of traffic conditions to be supported by measurable engineering indicators while providing an objective basis for formulating traffic management recommendations. The transition from physical characterization to quantitative performance assessment also ensures consistency between the empirical observations and the analytical procedures adopted in this study.

The existing characteristics identified through field observations indicate that the operational performance of the Sapta Marga Road section cannot be explained solely by its geometric dimensions, since roadway operation is continuously influenced by the interaction between traffic demand and roadside activities. Although the physical condition of the pavement remains adequate for accommodating two-way traffic, the moderate to high level of side friction reduces the effective capacity available for uninterrupted vehicle movement during busy periods. This observation is consistent with the principles of traffic engineering, which emphasize that roadway performance depends on the combined effects of infrastructure characteristics, traffic composition, and environmental conditions rather than on roadway geometry alone (Oglesby & Hicks). The existing condition also reflects the functional characteristics of urban collector roads that frequently experience localized disturbances generated by access movements, commercial activities, and pedestrian interactions. Understanding these baseline conditions is essential because they provide the engineering context required to interpret subsequent calculations of traffic volume, roadway capacity, degree of saturation, and level of service using the PKJI 2023 framework. The following section therefore focuses on the quantitative evaluation of traffic flow characteristics to determine how the observed roadway conditions influence the operational performance of the Sapta Marga Road section under actual traffic conditions.

Traffic Volume and Road Performance Analysis

Traffic volume constitutes the primary parameter for assessing roadway operational performance because it reflects the magnitude of traffic demand imposed on the available roadway capacity during a specific observation period. In this study, traffic observations were conducted for three consecutive days, namely Sunday, Monday, and Tuesday, to capture variations in travel characteristics between weekend and weekday conditions. Vehicle counts were recorded during the identified peak periods of 07:00–08:00 WIB, 12:00–13:00 WIB, and 16:00–17:00 WIB, representing the highest intensity of daily community activities. The selected observation periods are considered capable of describing temporal variations in traffic demand and are commonly applied in traffic engineering studies to evaluate roadway operational conditions under peak-hour traffic (Hafram & Asrib, 2022). The collected traffic data subsequently became the basis for calculating roadway capacity, degree of saturation, and level of service using the PKJI 2023 analytical procedure. This sequential analytical approach ensures that roadway performance is evaluated using observed traffic conditions rather than estimated travel demand.

The traffic survey results indicate that motorcycles dominated the traffic stream on the Sapta Marga Road section, followed by passenger cars, while freight vehicles and buses contributed a considerably smaller proportion of the total traffic volume. Such a traffic composition reflects the mobility pattern commonly observed in regional urban areas, where motorcycles remain the preferred travel mode because of their operational flexibility and accessibility. Passenger cars also represented a substantial component of traffic demand, particularly during commuting hours associated with work and educational activities. Although pickups, trucks, and buses were observed less frequently, these vehicle categories occupy greater roadway space and generate a proportionally larger influence on traffic flow characteristics than their numerical frequency alone would suggest. Differences in vehicle composition therefore become an important consideration in evaluating roadway capacity because each vehicle category contributes differently to the equivalent passenger car unit calculation required by PKJI 2023 (Direktorat Jenderal Bina Marga, 2023). The observed traffic composition is summarized in Table 2.

Table 2. Traffic Volume Survey Results on the Sapta Marga Road Section

Vehicle Type	Traffic Volume (veh/h)
Motorcycle	977
Passenger Car	452
Pickup	52
Truck	70
Bus	10

The distribution presented in Table 2 demonstrates that motorcycles accounted for the largest proportion of observed traffic, representing more than half of the total recorded vehicle movements during the survey period. This condition indicates that roadway operation is primarily influenced by mixed traffic interactions dominated by small vehicles with relatively high maneuverability, while larger vehicles intermittently affect traffic stability because of their lower operating speeds and greater space requirements. Similar traffic compositions have been reported on Indonesian collector roads, where motorcycle dominance contributed to relatively stable traffic flow under normal conditions but became increasingly sensitive to roadside disturbances during peak travel periods (Ramadani & Sari, 2023). Comparable findings were also identified by Andrian et al. (2021), who observed that variations in traffic composition significantly influenced operational performance and travel speed despite relatively unchanged roadway geometry. These similarities suggest that vehicle composition should be evaluated together with roadway capacity because traffic volume alone cannot adequately explain fluctuations in operational performance. The traffic characteristics identified in this study therefore provide a quantitative foundation for the subsequent calculation of roadway capacity and degree of saturation based on the PKJI 2023 framework.

The observed traffic volume was subsequently evaluated against the practical roadway capacity to determine the operational performance of the Sapta Marga Road section using the PKJI 2023

analytical framework. The field observations indicated that traffic demand increased noticeably during the morning and afternoon peak periods, resulting in a corresponding rise in the degree of saturation while maintaining traffic flow within stable operating conditions. Vehicle speeds were observed to decline during these periods because drivers experienced more frequent interruptions caused by merging, turning, and roadside activities, although uninterrupted traffic movement was still generally maintained. According to PKJI 2023, the relationship between traffic volume and roadway capacity provides a reliable basis for assessing operational quality because the degree of saturation reflects the proportion of available capacity being utilized under prevailing traffic conditions (Direktorat Jenderal Bina Marga, 2023). The calculated traffic performance indicators show that the roadway has not yet reached a critical congestion level, but the available operational margin becomes considerably smaller during peak traffic periods. This pattern demonstrates that increasing traffic demand has begun to reduce operational efficiency despite the roadway continuing to accommodate existing traffic movements.

The analysis of the degree of saturation indicates that the Sapta Marga Road section operates within the Level of Service (LOS) C–D, signifying that traffic flow remains stable but is increasingly influenced by higher traffic demand and roadside disturbances. Under LOS C conditions, drivers retain reasonable freedom to select travel speed despite experiencing moderate interactions with surrounding traffic, whereas LOS D reflects a condition in which operational flexibility becomes progressively constrained as roadway demand approaches practical capacity. These findings indicate that the roadway still performs adequately under existing conditions, although recurring peak-hour traffic may gradually reduce service quality if traffic demand continues to increase without corresponding operational improvements. Similar operational characteristics were identified in the evaluation of Jalan Khatulistiwa, where increasing traffic demand resulted in a transition toward LOS D while traffic flow remained stable under prevailing roadway capacity (Arief et al., 2025). A comparable conclusion was reported by Putri et al. (2025), who demonstrated that the application of PKJI 2023 provides consistent performance indicators for assessing roadway operational conditions and identifying the proximity of traffic demand to roadway capacity. The consistency between the present findings and previous investigations strengthens the reliability of the calculated traffic performance indicators and confirms the applicability of PKJI 2023 for evaluating collector roads under mixed traffic conditions.

The relationship between traffic volume, roadway capacity, and level of service demonstrates that operational performance on the Sapta Marga Road section is influenced by the interaction of traffic demand and roadway operating characteristics rather than by traffic volume alone. Although the calculated degree of saturation remains below the threshold associated with severe congestion, periodic reductions in travel speed indicate that the roadway is becoming increasingly sensitive to fluctuations in peak-hour traffic demand. Such conditions suggest that future increases in traffic generation resulting from urban growth, commercial expansion, or intensified land-use activities could accelerate the deterioration of roadway performance if no traffic engineering measures are introduced. Similar trends have been observed on collector roads experiencing progressive development, where moderate increases in travel demand produced disproportionately larger reductions in operational performance because available roadway capacity remained unchanged (Permana & Mukhlis, 2026). These findings provide quantitative evidence that the existing roadway still accommodates current traffic demand while simultaneously indicating the necessity of proactive traffic management to maintain acceptable operational performance in the coming years. The following section further examines how side-friction activities contribute to the observed operational characteristics and influence the effectiveness of the available roadway capacity.

Influence of Side Friction on Road Operational Performance

Side friction was identified as one of the dominant factors influencing the operational performance of the Sapta Marga Road section during the field observation period. The observed roadside activities consisted primarily of on-street parking, pedestrian movements, vehicles entering and exiting residential areas, and commercial activities associated with small shops and roadside businesses. These activities created repeated interruptions to the traffic stream by reducing the effective width available for moving vehicles and increasing the frequency of braking and lane adjustment maneuvers. Traffic engineering principles recognize side friction as an operational factor capable of significantly reducing practical roadway capacity, particularly on urban collector roads characterized by intensive roadside access and mixed traffic composition (Direktorat Jenderal Perhubungan Darat).

The field observations indicate that these disturbances occurred more frequently during the morning and afternoon peak periods when both traffic demand and roadside activities reached their highest intensity. As a result, the operational characteristics of Sapta Marga Road were influenced not only by the number of vehicles using the roadway but also by the frequency and intensity of roadside interactions.

Among the observed side-friction components, on-street parking represented the most significant source of operational disturbance because parked vehicles reduced the effective carriageway width and forced approaching drivers to adjust their trajectories. Vehicles stopping temporarily to pick up or drop off passengers near schools and commercial establishments also interrupted traffic continuity by creating localized bottlenecks that propagated upstream during periods of high demand. Residential access movements further contributed to operational instability because vehicles entering and leaving private driveways generated additional conflict points with through traffic. Previous studies have demonstrated that side-friction intensity has a direct influence on roadway capacity, where frequent roadside disturbances increase traffic turbulence and reduce average operating speed even when traffic demand remains relatively unchanged (Misbah & Hendrizal, 2023). Similar operational conditions have also been reported for road segments located adjacent to traditional market areas, where commercial activities substantially affected traffic flow characteristics and reduced the efficiency of roadway operations (Maulana et al., 2024). These findings indicate that managing roadside activities is equally important as increasing roadway capacity because operational performance depends on both infrastructure availability and traffic environment.

The observed interaction between moving traffic and roadside activities explains why traffic speed declined during peak periods despite the roadway continuing to operate within an acceptable level of service. Drivers were frequently required to reduce speed in response to unexpected pedestrian crossings, vehicles re-entering the traffic stream, and temporary stopping maneuvers occurring along the roadway edge. Such operational interruptions increase travel time variability and reduce the stability of traffic flow without necessarily causing complete congestion. Similar characteristics have been identified on urban road segments where moderate traffic volumes produced noticeable operational degradation because the roadway was subjected to persistent side-friction disturbances rather than excessive traffic demand alone (Salsabila & Hariani, 2023). This operational behavior demonstrates that the quality of traffic flow is governed by the combined influence of traffic demand and roadside operational conditions, making side-friction management a critical component of roadway performance improvement strategies. Consequently, any effort to enhance the operational efficiency of Sapta Marga Road should prioritize reducing unnecessary roadside disturbances alongside maintaining adequate roadway capacity.

The influence of side friction on the Sapta Marga Road section also reflects the interaction between roadway function and surrounding land-use development. The presence of residential areas, educational facilities, commercial activities, and public offices generates continuous access movements that increase the number of traffic conflict points throughout the day. As these roadside activities intensify, the available roadway capacity is progressively utilized to accommodate both through traffic and local access, resulting in reduced operational efficiency during peak periods. A comparable relationship was identified in road segments affected by new activity centers, where increased trip generation contributed to higher operational pressure even without significant changes in roadway geometry (Antoro et al., 2024). These findings indicate that traffic performance should be evaluated not only from existing traffic demand but also from the dynamics of surrounding land use that continuously influence travel behavior and roadside interactions. Such characteristics explain why collector roads often experience localized operational problems despite carrying lower traffic volumes than principal arterial roads.

The operational conditions observed in this study demonstrate that effective traffic engineering should focus on managing the sources of side friction before considering more costly infrastructure expansion. Measures such as regulating on-street parking, organizing loading and unloading activities, improving pedestrian crossing facilities, and controlling access points can substantially improve traffic flow by minimizing unnecessary traffic interruptions. These strategies are consistent with the principles of traffic management, which prioritize operational optimization through engineering, regulatory, and traffic control measures before implementing physical road widening projects (Kementerian Perhubungan Republik Indonesia, 2015). Similar recommendations were proposed by Saputra and

Muhtadi (2022), who found that improving roadside traffic facilities and traffic control devices effectively enhanced roadway operational performance while simultaneously supporting traffic safety. From an engineering perspective, these interventions represent practical solutions because they address the operational causes of performance degradation rather than merely increasing roadway capacity. The findings therefore suggest that improving traffic management practices may provide immediate operational benefits for the Sapta Marga Road section without requiring substantial infrastructure investment.

The analysis confirms that side friction is one of the principal determinants of traffic performance on the Sapta Marga Road section because it directly affects traffic stability, travel speed, and the effective utilization of roadway capacity. Although the calculated degree of saturation indicates that the roadway still operates within acceptable service levels, persistent roadside disturbances reduce the operational reserve available to accommodate future traffic growth. This condition implies that continued urban development and increasing travel demand could accelerate the deterioration of roadway performance if roadside activities remain unmanaged. Traffic engineering literature consistently emphasizes that sustainable roadway performance depends on balancing infrastructure capacity with operational management capable of minimizing traffic conflicts and improving flow continuity (Oglesby & Hicks). The empirical evidence obtained from this study reinforces the importance of incorporating side-friction assessment into routine roadway performance evaluations, particularly for urban collector roads characterized by intensive roadside activities and heterogeneous traffic composition. These observations provide the analytical foundation for formulating traffic engineering recommendations aimed at improving operational efficiency and maintaining acceptable levels of service under future traffic conditions.

Traffic Engineering Recommendations for Improving Road Operational Performance

The traffic performance analysis indicates that the Sapta Marga Road section continues to operate within an acceptable level of service; however, several operational deficiencies require immediate engineering attention to prevent future deterioration in roadway performance. The identified issues, including on-street parking, faded pavement markings, insufficient traffic signs, limited pedestrian facilities, and intensive roadside access movements, reduce the efficiency of traffic flow despite the roadway having adequate geometric characteristics. Traffic engineering principles emphasize that operational improvements should prioritize optimizing the existing roadway system before implementing major infrastructure expansion because such measures are generally more efficient and economically feasible (Direktorat Jenderal Perhubungan Darat). The recommendations proposed in this study were formulated based on the observed traffic characteristics, roadway capacity, degree of saturation, level of service, and side-friction conditions identified during the field survey. This evidence-based approach enables engineering decisions to address the dominant operational constraints affecting traffic performance rather than relying on generalized improvement strategies. Implementing targeted traffic management measures is expected to preserve acceptable roadway performance while accommodating gradual increases in traffic demand. These recommendations also provide a practical reference for local transportation authorities in developing sustainable traffic management policies for urban collector roads.

The regulation of on-street parking should be considered the highest implementation priority because roadside parking represented the most frequent operational disturbance observed during the survey period. Parked vehicles reduced the effective carriageway width, forcing drivers to decrease speed and perform additional lane adjustment maneuvers when encountering opposing traffic. Restricting parking activities during peak periods or providing designated off-street parking areas would increase the effective roadway capacity without requiring physical road widening. Similar operational improvements have been reported to enhance traffic flow continuity and reduce localized congestion through better roadside traffic management practices (Saputra & Muhtadi, 2022). Complementary enforcement measures should also be introduced to discourage illegal stopping and parking that obstruct traffic movement and reduce roadway efficiency. Continuous monitoring of parking behavior is necessary because changing roadside activities may alter traffic conditions over time. Effective parking management therefore represents one of the most practical engineering interventions for improving operational performance within the existing roadway configuration.

The provision and maintenance of traffic safety facilities constitute another important component of the proposed engineering strategy. Field observations identified faded pavement markings, limited traffic signs, the absence of continuous sidewalks, inadequate pedestrian crossing facilities, and insufficient street lighting as factors that may reduce both operational efficiency and traffic safety. Improving these facilities would increase driver awareness, strengthen lane discipline, and provide safer movement for pedestrians crossing the roadway, particularly near schools and commercial activity centers. Previous studies have demonstrated that integrating traffic engineering measures with appropriate traffic control devices contributes to more stable traffic flow while simultaneously reducing potential traffic conflicts (Tapa et al., 2025). These improvements are also consistent with the objectives of national traffic regulations, which emphasize the provision of safe, orderly, and accessible transportation infrastructure for all road users (Undang-Undang Republik Indonesia Nomor 22 Tahun 2009). The implementation of pedestrian-oriented facilities is particularly important because collector roads accommodate substantial interactions between motorized traffic and vulnerable road users. Strengthening roadway facilities is therefore expected to improve not only traffic performance but also the overall safety and comfort of the transportation system.

From a broader transportation planning perspective, the proposed recommendations should be implemented through phased priorities that consider both operational urgency and available financial resources. Short-term actions may include restriping pavement markings, installing additional traffic signs, regulating roadside parking, and strengthening traffic law enforcement because these measures directly address the dominant operational problems identified during the field survey. Medium-term improvements may focus on constructing sidewalks, installing zebra crossings, and providing additional street lighting to improve pedestrian safety and roadway functionality. Long-term planning should integrate transportation management with future land-use development so that increasing travel demand can be accommodated without substantially reducing roadway performance. This adaptive planning approach is consistent with contemporary traffic engineering, which promotes periodic roadway performance evaluation and continuous operational improvement based on measurable engineering indicators (Kementerian Perhubungan Republik Indonesia, 2015). Periodic monitoring using the performance indicators specified in PKJI 2023 would enable local authorities to evaluate the effectiveness of implemented engineering measures and identify emerging operational issues before they develop into severe traffic problems. The recommendations developed in this study therefore provide an evidence-based framework for improving the operational performance of the Sapta Marga Road section while supporting safer, more efficient, and more sustainable urban transportation management.

CONCLUSION

The results of this study demonstrate that the Sapta Marga Road section serves a strategic function as an urban collector road supporting daily mobility in South Curup Subdistrict, Rejang Lebong Regency. Field observations revealed that traffic demand increased considerably during the morning and afternoon peak periods, resulting in reduced vehicle operating speeds and higher utilization of the available roadway capacity. The traffic volume analysis showed that motorcycles constituted the dominant traffic component, reflecting the travel characteristics commonly observed in regional urban areas. The operational performance assessment based on the PKJI 2023 framework indicated that the roadway operated within Level of Service (LOS) C–D, suggesting that traffic flow remained stable despite increasing interactions among vehicles and roadside activities. Moderate to high side-friction conditions generated by on-street parking, commercial activities, pedestrian movements, and vehicles entering and exiting adjacent properties were identified as the primary operational factors affecting roadway efficiency. These findings confirm that roadway performance is determined not only by traffic demand but also by the interaction between roadway geometry, surrounding land use, and roadside operational conditions. The empirical evaluation provides objective evidence that the current operational condition of the Sapta Marga Road section remains acceptable but requires proactive traffic management to maintain satisfactory service quality as travel demand continues to grow.

The study further indicates that operational improvements can be achieved more effectively through traffic engineering measures than through immediate physical roadway expansion. Priority actions include regulating on-street parking, improving pavement markings and traffic signs, providing pedestrian facilities, strengthening street lighting, and enhancing traffic law enforcement to reduce

roadside conflicts and improve traffic flow continuity. The implementation of these measures is expected to increase the effective utilization of existing roadway capacity while enhancing traffic safety for both motorized and non-motorized road users. Periodic traffic surveys should also be conducted to monitor changes in traffic demand, roadway capacity, degree of saturation, and level of service so that traffic management strategies remain responsive to evolving transportation conditions. Regular roadway performance evaluations based on the PKJI 2023 framework will enable local authorities to identify operational problems at an early stage and implement appropriate engineering interventions before congestion becomes more severe. The analytical framework adopted in this research can also be applied to other urban collector roads with similar traffic characteristics to support consistent and evidence-based roadway performance assessments. Future studies are encouraged to integrate microscopic traffic simulation, intelligent transportation technologies, and long-term traffic forecasting to develop more adaptive and sustainable traffic management strategies for rapidly developing urban environments.

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