

THE INFLUENCE OF BUILT-UP AREA ACTIVITY INTENSITY ON BUS RAPID TRANSIT (BRT) CORRIDOR EFFECTIVENESS: A CASE STUDY OF THE RAJABASA-PANJANG CORRIDOR

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Abstract

Bandar Lampung's rapid growth has put significant pressure on its transportation system, as reflected in the increasing number of private vehicles, worsening traffic congestion, and intensive land use development. The Rajabasa-Panjang corridor of the Trans Bandar Lampung Bus Rapid Transit (BRT), inaugurated in 2012 as a solution, was ineffective and ceased operations in 2019. One of the key factors contributing to this failure is the land use characteristics along the corridor that trigger side obstacles. This study aims to identify and analyze the dominant land use types and characteristics of these obstacles at congestion points along the Rajabasa-Panjang BRT corridor. The analysis was conducted using satellite imagery and field observations processed through Geographic Information System (GIS). The results indicate that side obstacles, such as illegal parking, street vendor activities, and cargo loading/unloading, significantly reduce road capacity and slow down traffic. These obstacles are caused by intensive land use, such as markets, schools, and retail stores. Understanding the patterns and distribution of these obstacles could provide policy recommendations for more effective land use planning and traffic management, supporting the revitalization and sustainability of the public transportation system in Bandar Lampung.

Keywords: *Urbanization, Bus Rapid Transit, land use, side obstacles, congestion, Bandar Lampung*

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INTRODUCTION

Rapid urbanization in Indonesia has put significant pressure on urban transportation systems, including those in Bandar Lampung. It is estimated that 70% of Indonesia's population will reside in urban areas by 2045, which will lead to substantial growth in private vehicle ownership [1]. On the one hand, urbanization contributes to economic growth and the creation

of new employment opportunities. On the other hand, rapid population growth in major urban areas has exacerbated traffic congestion problems [2]. In Bandar Lampung, the number of motor vehicles is expected to exceed 1 million by 2025, the majority of which are motorcycles [3]. Despite the government's efforts to implement solutions such as the Bus Rapid Transit (BRT) system, this situation exacerbates traffic congestion.

The Rajabasa-Panjang BRT corridor began operations in 2012 but has not effectively addressed traffic congestion and ceased operations in 2019 [4]. One of the main causes is the influence of land use and obstacles alongside the road. Land use development generates movement flows, thereby increasing the demand for transportation networks and facilities [5]. Higher levels of land use intensity produce greater levels of travel demand [6]. Intensive activities such as markets, schools, and shops along the corridor increase vehicle and pedestrian movement, creating obstacles such as illegal parking, street vendors, and loading and unloading activities. These obstacles directly reduce road capacity, slow vehicle speeds, and decrease BRT service efficiency [7]. Consequently, the public is reluctant to use the BRT, and congestion continues to occur at critical points, such as Jalan Z.A. Pagar Alam, Jalan Teuku Umar, Jalan Raden Intan, Jalan Diponegoro, and Jalan Yos Sudarso.

Given the important role of the BRT corridor and the existing challenges, researching land use characteristics and side obstacles along the Rajabasa-Panjang BRT corridor is crucial. This study aims to identify dominant land use types and the characteristics of side obstacles, as well as analyze their patterns and distribution at congestion points. The results of this study will serve as the basis for formulating better land use and traffic management policies, which will help achieve a sustainable public transportation system in Bandar Lampung.

METHODOLOGY

Secondary Data Collection

The land use survey is conducted by classifying the types of activities along the corridor, focusing on three designated locations. The survey examines the activities along the corridor and calculates the side obstacles as the relationship between traffic performance and land use. The land use data required are:

- Existing land use conditions (vacant land, residential areas, markets, etc.)
- Types of activities
- Land use intensity
- Land use plans in accordance with the RTRW

The observation locations, as shown in Figure 1, consist of three congestion points, namely:

1. ZA Pagar Alam Road from the Darma Bangsa School to Bandar Lampung University, spanning 200 meters.
2. Raden Intan Road from the Cathedral Church to the Pasar Tengah pedestrian bridge, spanning 200 meters.
3. Yos Sudarso Road from Bank BCA to the Ikan Baung Road intersection, spanning 200 meters.

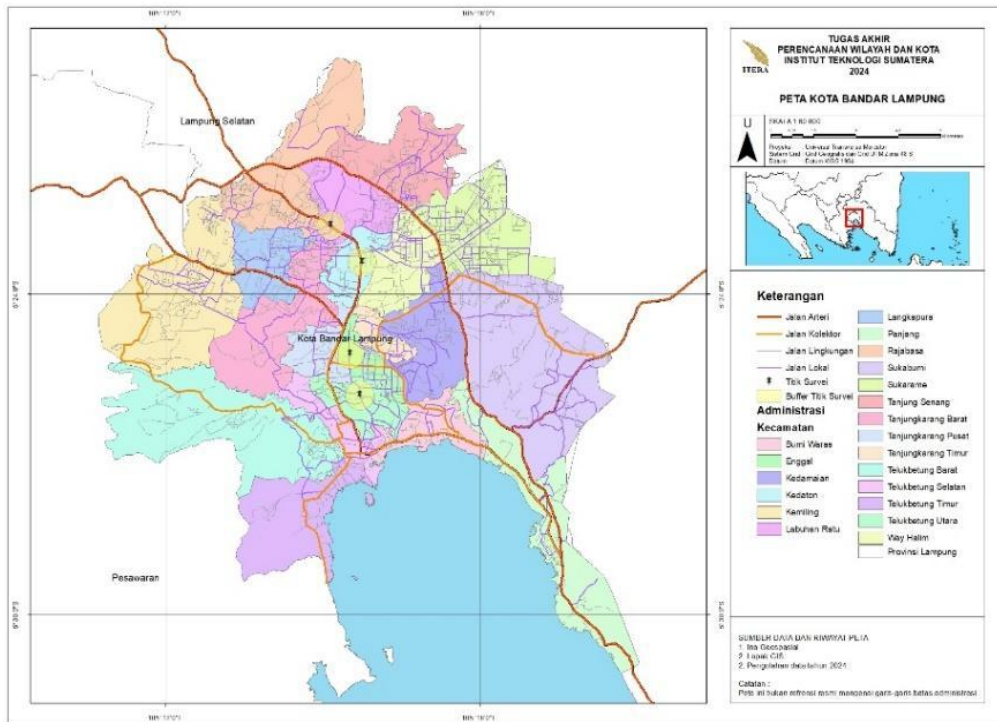


Figure 1. Survey Location map

Side Obstacle Survey

The side obstacle survey was conducted at congestion points along a 200-meter stretch of road. The data collection method involved preparing the location with clear markings, using measuring instruments, survey forms, stopwatches, and visual documentation by a survey team of at least two people. The survey was conducted during morning rush hour (6:30–7:30 a.m.), normal hours (10:00–11:00 a.m.), and afternoon rush hour (4:30–5:30 p.m.). Recorded types of obstacles include pedestrians, parked vehicles, stopped vehicles, vehicles entering and exiting, and street vendors. Data is systematically recorded using forms, supported by photos or videos, then compiled, analyzed to identify dominant obstacles, and interpreted to provide improvement recommendations.

Analyses Methods

Land use analysis in this study was conducted by collecting spatial data on land use along the Rajabasa-Panjang BRT corridor, using high-resolution satellite imagery and field data. This spatial data was then processed using a Geographic Information System (GIS) to identify land use types, such as residential, commercial, industrial, and green open space. Field observations were also conducted to understand the characteristics of each land use, activity patterns, and their impact on road performance.

Referring to Government Regulation No. 34 of 2005 on Roads, it states that road right-of-way (rumija) must have a minimum width as follows:

- Freeway 30 meters;
- Highway 25 meters;
- Medium roads: 15 meters; and
- Small roads: 11 meters.

The road supervision area (Ruwasja), which is the area whose use is under the supervision of the road authority, is determined from the road edge with a minimum width as follows:

- Primary arterial roads: 15 meters;
- Primary collector roads: 10 meters;
- Secondary arterial roads: 15 meters;
- Secondary collector roads: 5 meters.

Based on these regulations, the study site, which is a primary arterial road and primary collector road, has a minimum rumija of 25 meters and a ruwasja of 10-15 meters, totaling 35-40 meters. However, for more detailed data, the researcher used a 100-meter radius from the road, allowing buildings located further inward to be considered in the analysis.

In addition to examining land use spatially, researchers also looked at side obstacles caused by existing land use. Side obstacles can be calculated using the side obstacle coefficient (SOC) value. The SOC value is the result of calculations based on the frequency of various types of side obstacles encountered along the observed road segment [8].

The frequency of occurrence is calculated through direct observation for one hour. Each type of obstacle is assigned a specific weight according to its severity, which has been determined beforehand. The weights for each type of obstacle can be seen in the table 1. The KHS value is subsequently calculated as the product of the frequency of occurrence and the weight of each type of obstacle. The side friction class criteria are presented in Table 2.

Tabel 1. Criteria for Weighting Side Obstacles

No.	Type of side obstacle	Weight
1	Pedestrians on the road and crossing	0,5
2	Public vehicles and other vehicles stopping	1,0
3	Vehicles entering/exiting the side or adjacent land of the road	0,7
4	Slow vehicle flow (non-motorized vehicles)	0,4

Tabel 2. Side Barrier Class Criteria

KHS	Weight	Special characteristics
Very Low (SR)	<100	Residential area, frontage road available.
Low (R)	100-299	Residential area, some public transportation (city transportation) available.
Moderate (M)	300-499	Industrial area, some shops along the roadside.
High (H)	500-899	Commercial area, high roadside activity.
Very High (VH)	>=900	Commercial area, roadside market activity.

RESULT AND DISCUSSION

Existing Land Use Conditions

The Rajabasa-Panjang BRT corridor shows significant land use diversity. From the Rajabasa Terminal, there is a dominance of commercial and service areas, in line with the terminal's function as a transportation hub. Jalan Z.A. Pagar Alam and Jalan Teuku Umar have fairly similar characteristics, with many shops, higher and secondary education facilities,

shopping centers, and other public facilities. Along Raden Intan Street to Diponegoro Street, there are numerous commercial and service centers and office buildings. Moving toward Panjang, the corridor passes through densely populated residential areas, marked by red-colored buildings. At several points, industrial and warehouse areas are visible, particularly near the Panjang area. The presence of green open spaces (RTH), such as city parks and green areas around residential areas, is also noticeable, though not uniformly distributed. The following will provide a more detailed explanation of land use at the three study locations on Jl. Z.A. Pagar Alam, Jl. Raden Intan, and Jl. Yos Sudarso. The land use map of Bandar Lampung City can be seen in the Figure 2.

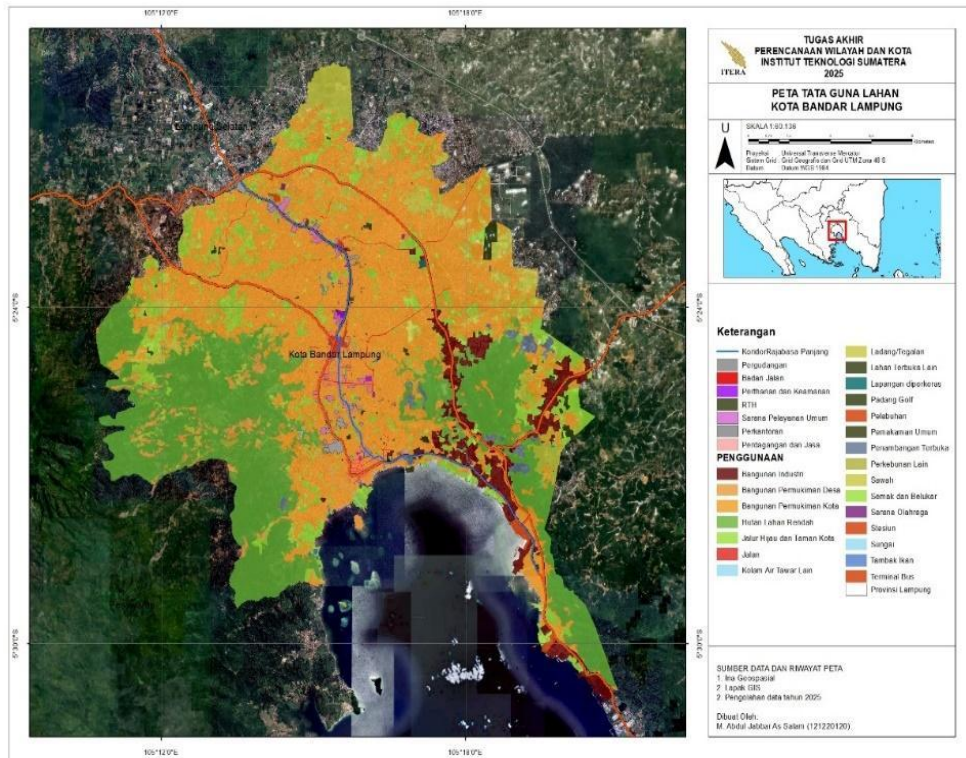


Figure 2. Land Use Map of Bandar Lampung City.

The first location, ZA Pagar Alam street, particularly around the Darma Bangsa School and Bandar Lampung University, up to the Sultan Agung Road intersection are shown in the figure 3. In general, this main arterial road is dominated by mixed land use, including residential areas, commerce and services, and educational facilities. Residential areas are scattered along the road, marked by red buildings on the map, indicating commercial and service areas such as shops and retail stores. In the study area, there are commercial and service facilities such as retail stores, Kedaton Gas Station, and Fitrihofane Supermarket. Burger King, Mie Gacoan, Dunkin Donuts, McDonald's Kedaton, KFC Kedaton, Pizza Hut, Mr. DIY, Waroeng Steak, Jaya Bakery, Bebek Goreng H. Slamet, and many more. Public facilities and schools, indicated in purple, are concentrated in several areas. At the study site, educational activities include Darmajaya Institute of Information Technology and Business, Darmajaya School, Muhammadiyah 1 Elementary School, Muhammadiyah 2 High School, Muhammadiyah Lampung University, Bandar Lampung University, Lampung Provincial Library, UIN Raden Intan Graduate School, and Teknokrat University near the Sultan Agung Road intersection. Additionally, there are scattered green open spaces (RTH), though not in large numbers. Other land uses, such as offices and public service facilities, also contribute to

the area's character, though on a smaller scale. This diverse land use reflects the dynamic and developing nature of ZA Pagar Alam Road as an area where economic, educational, and residential activities interact. The land use conditions along Jalan ZA Pagar Alam, particularly around the Darma Bangsa School and Bandar Lampung University, up to the Sultan Agung Road intersection are shown in the Figure 3.

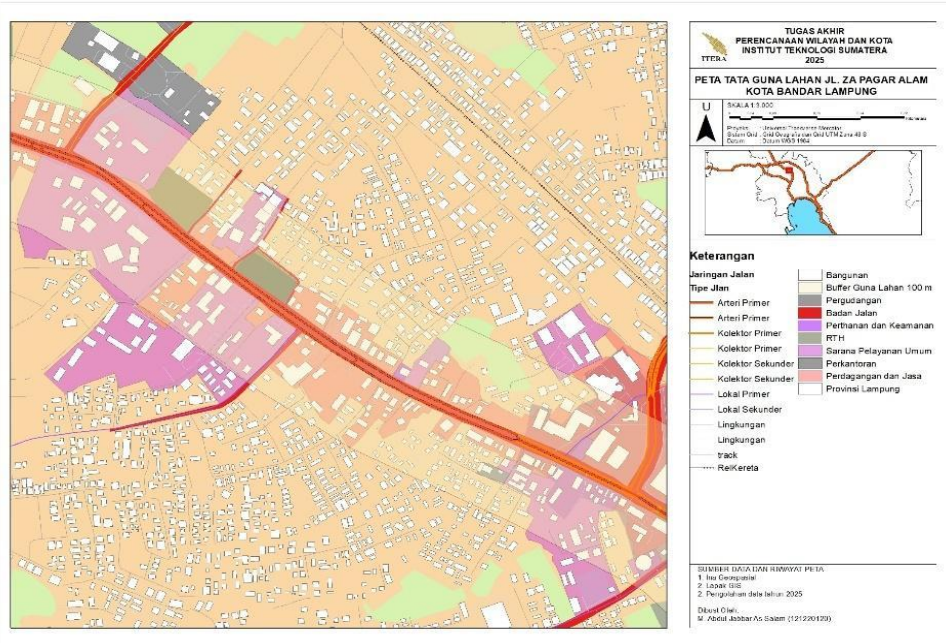


Figure 3. Land Use Map of Z.A. Pagar Alam Street

The second location, Jl. Raden Intan, is in Tanjung Karang Pusat, Tanjung Karang Pusat District, which serves as the City Service Center (PPK), making Jl. Raden Intan extremely vital. The existing land use conditions on Jl. Raden Intan can be seen on the Figure 4.

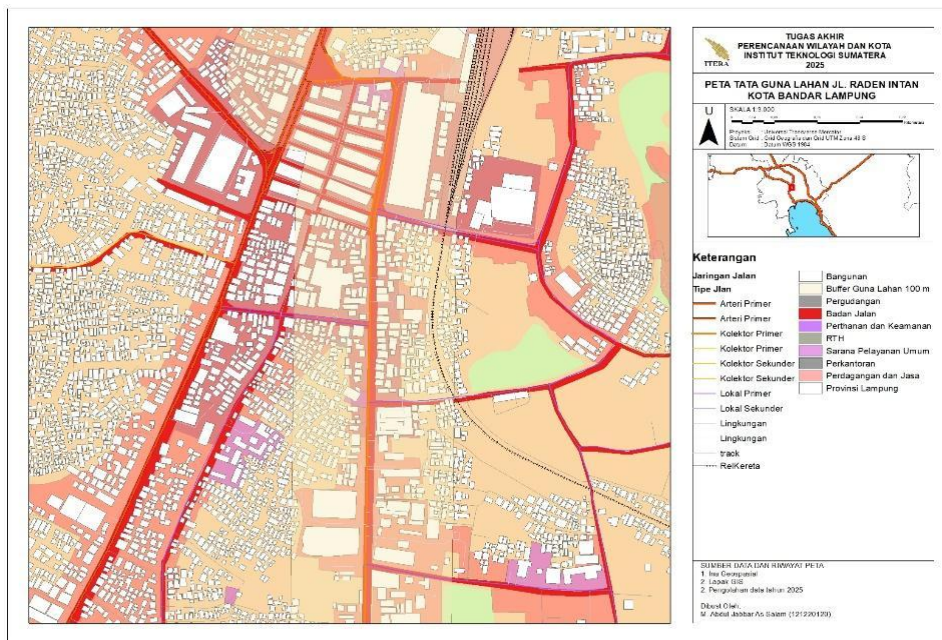


Figure 4. Land Use Map of Raden Intan Street

Raden Intan street, as one of the main arterial roads in Bandar Lampung City, is dominated by commercial and service land use. This is evident from the numerous red-colored buildings along the road, indicating commercial areas such as shops, retail units, and shopping centers. Some of the shopping centers along Raden Intan Street include Ramayana Tanjung Karang, Pasar Tengah, Simpura Center, and Karang Indah Mall. Raden Intan Street has a strategic location, making it home to numerous accommodations/hotels, such as Arinas Hotel, Amalia Hotel, Grand Mercure Lampung, Hotel Grande, Hotel Kurnia Dua, Hotel Andalas, and Hotel Grand Anugerah. Tanjung Karang Station, the main station in Lampung Province, is also located near Raden Intan street. Additionally, there are office areas indicating business and administrative activities.

At several points, public service facilities and schools are marked in purple, indicating public service functions along this road. Green open spaces (RTH) are also found, including Saburai Field, though on a smaller scale, providing a little green space amid the city's dense activities. Other land uses, such as residential areas, are scattered around the commercial area, indicating integration between residential and economic activities.

The third research location, as shown in figure 5, is located on Jalan Yos Sudarso, in the Bumi Waras subdistrict of Bandar Lampung. Jalan Yos Sudarso has different characteristics compared to other main roads in the city. Functionally, this road serves as the main route for industrial and logistical activities, particularly due to its location directly leading to the Port of Panjang. This results in the road being dominated by heavy vehicle traffic, such as trucks and containers. The land use along this road also reflects this function, with many industrial and warehousing areas. However, at some points, residential areas are mixed with industrial areas, creating a unique land use pattern. Traffic conditions on Jalan Yos Sudarso tend to be congested, especially during peak hours, due to industrial and port activities. Therefore, road infrastructure, including maintenance and supporting facilities, is very important to ensure the smooth running of economic activities and community mobility in this area.

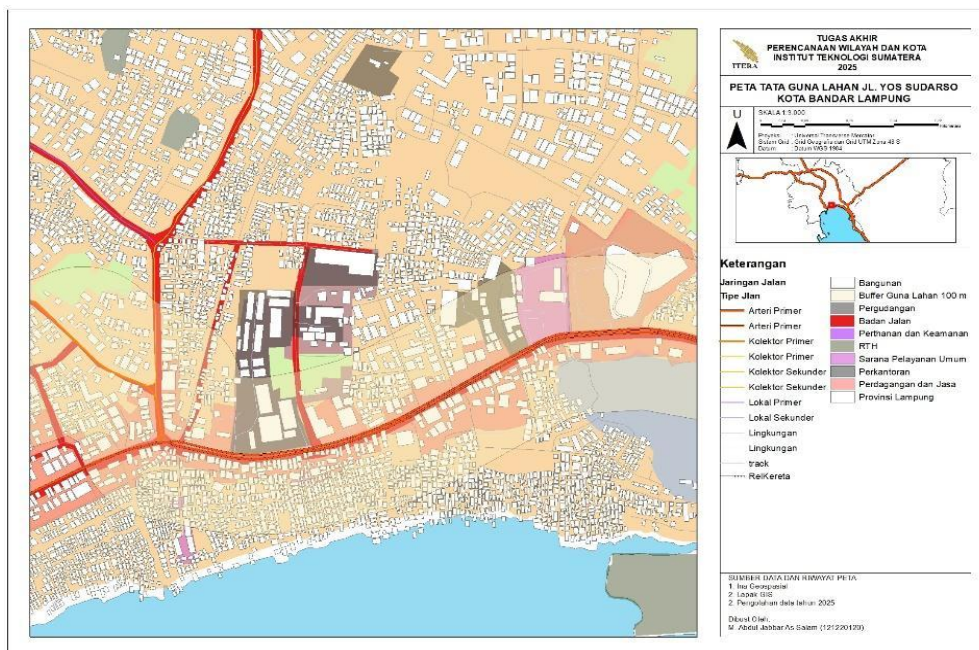


Figure 5. Land Use Map of Yos Sudarso Street

Yos Sudarso street, shows land use characteristics dominated by warehousing (brown) and trade and services (pink). This is in line with the road's role as the main access to and from Pelabuhan Panjang, which is a center of industrial and logistics activities. Some of the trade

and service activities along Yos Sudarso Street include Bank BCA, retail stores, and the Lampung City Superblok area, which consists of a mall and hotel. Additionally, there are public service facilities (purple) such as healthcare, education, and religious institutions scattered across several locations. One of the larger healthcare facilities on Yos Sudarso Street is Budi Medika Hospital, indicating the presence of public facilities serving this area. Although dominated by economic activities and public services, the map also shows residential areas (as seen from the dense building patterns). Green open spaces (RTH) are limited, but there are some areas allocated for this purpose.

Side Obstacles at Research Locations

Side obstacles are obstacles located on the side of the road that can cause traffic congestion. Side obstacles can arise due to activities on land around the road, so they are related to land use on a particular road section. This study discusses side obstacles at three research locations, namely Z.A. Pagar Alam street, Raden Intan street, and Diponegoro street, with each location having side obstacles determined to be 200 meters long.

Point 1: ZA Pagar Alam Street (Darma Bangsa-UBL School)

Table 3 presents data on side obstacles on ZA Pagar Alam Road collected during three different time periods: morning (06:30–07:30), afternoon (10:00–11:00), and evening (16:30–17:30). These side obstacles are categorized into pedestrians, stopped vehicles, entering vehicles, exiting vehicles, slow-moving vehicles, and non-motorized vehicles (becaks/bicycles). Each category has a different weight factor for calculating the Side Obstacle Coefficient (SOC), namely 0.5 for pedestrians, 1.0 for stopped vehicles, 0.7 for entering and exiting vehicles, 1.5 for slow vehicles, and 0.4 for non-motorized vehicles.

Table 3 Lateral Resistance at Point 1 (Z.A. Pagar Alam Street)

Time	Side		Pedestrian (0.5)	Vehicle Stop (1.0)	Vehicle Enter (0.7)	Vehicle Exit (0.7)	Street vendor (1.5)	Slow Vehicle (0.4)	Total KHS	Classification
06.30	A	Total	240	36	544	408	2	6	827.8	
		KHS	120	36	380.8	285.6	3	2.4		
07.30	B	Total	8	100	632	484	1	6	889.1	Very High 1716.9
		KHS	4	100	442.4	338.8	1.5	2.4		
10.00	A	Total	0	0	268	300	2	2	401.4	
		KHS	0	0	187.6	210	3	0.8		
11.00	B	Total	0	7	131	147	3	3	207.3	High 608.7
		KHS	0	7	91.7	102.9	4.5	1.2		
16.30	A	Total	116	78	498	566	9	19	901.9	Very High 1390.7
		KHS	58	78	348.6	396.2	13.5	7.6		
17.30	B	Total	136	98	154	284	10	3	488.8	
		KHS	68	98	107.8	198.8	15	1.2		

During the morning period (06:30-07:30), both sides A and B of the road showed very high KHS values (ST). Side A recorded a total KHS of 827.8, with significant contributions from incoming vehicles (380.8) and outgoing vehicles (285.6). Side B also showed a high KHS of 889.1, with incoming vehicles (442.4) and outgoing vehicles (338.8) as the main contributors. During the daytime period (10:00–11:00), the KHS value decreased. Side A

recorded a KHS of 401.4, classified as high (T), with the largest contributions from outgoing vehicles (210) and incoming vehicles (187.6). Side B showed a lower KHS of 207.3.

During the afternoon period (16:30–17:30), the KHS value increased again and was classified as very high (ST) for both sides of the road. Side A recorded a KHS of 901.9, with significant contributions from outgoing vehicles (396.2) and incoming vehicles (348.6). Side B also showed a high KHS of 488.8.

This data indicates that ZA Pagar Alam Road experiences significant lateral obstructions, particularly during morning and afternoon peak hours, dominated by vehicle stopping, entering, and exiting activities on both sides of the road. During daytime, lateral obstructions tend to decrease but remain high on one side of the road. The high level of lateral obstructions has the potential to affect road performance, leading to reduced speed and increased congestion risk.

Point 2: Raden Intan Street (Cathedral Church-JPO Ramayana Tanjung Karang)

Table 4 presents data on side obstacles observed on Jalan Raden Intan during three different time periods: morning (06:30-07:30), afternoon (10:00-11:00), and evening (16:30-17:30).

Table 4. Lateral Obstructions at Point 2 (Raden Intan Street)

Time	Side		Pedestrian (0.5)	Vehicle Stop (1.0)	Vehicle Enter (0.7)	Vehicle Exit (0.7)	Street vendor (1.5)	Slow Vehicle (0.4)	Total KHS	Classification
06.30	A	Total	164	72	100	132	0	28		Medium
-		KHS	82	72	70	92.4	0	11.2	327.6	(M) 327.6
07.30									6	
10.00	A	Total	564	240	104	100	6	16		High (H)
-		KHS	282	240	72.8	70	9	6.4	680.2	680.2
11.00									2	
16.30	A	Total	496	220	136	292	1	36		High (H)
-		KHS	248	220	95.2	204.4	1.5	14.4	783.5	783.5
17.30									5	

This data includes the number of incidents for various types of side obstacles, namely pedestrians, stopped vehicles, entering vehicles, exiting vehicles, street vendors, and slow-moving vehicles. Each type of obstacle has a different weighting factor for calculating the Side Obstacle Coefficient (SOC).

During the morning period (6:30–7:30 AM), the total SBC on the A side of Raden Intan Street was 327.6, classified as moderate (M). The largest contributions to this SBC value came from pedestrians (82), stopped vehicles (72), and exiting vehicles (92.4). During the daytime period (10:00–11:00), the total SRC on Side A increased to 680.2, classified as high (H). During this period, pedestrians contributed the highest SRC (282), followed by stopped vehicles (240). During the afternoon period (16:30–17:30), the total KHS increased again to 783.5, also classified as high (T). The main contributors to the KHS during this period were pedestrians (248), stopped vehicles (220), and departing vehicles (204.4).

Side obstacle data on Raden Intan Street tends to increase from morning to afternoon. At 10:00 AM, activity tends to be higher due to many shops opening and market activities not occurring in the morning. Pedestrians and stopped vehicles consistently remain significant sources of lateral obstruction throughout the day. This is due to the observation location’s high

activity levels, as it is situated in a market area, resulting in heavy foot traffic, road crossings, and stopped vehicles, which ultimately increase the KHS value and may impact traffic performance on the road. Although the classification does not reach “very high” as observed on ZA Pagar Alam Street during peak hours, these high side obstacles still have the potential to affect traffic flow on Raden Intan Street.

Point 3: Yos Sudarso Street (Bank BCA-Ikan Baung Street)

Table 5 presents data on side obstacles observed on Jalan Yos Sudarso during three time periods: morning (06:30-07:30), afternoon (10:00-11:00), and evening (16:30-17:30).

Table 5 Side Obstacles at Point 3 (Yos Sudarso Street)

Time	Side		Pedestrian (0.5)	Vehicle Stopped (1.0)	Vehicle Enter (0.7)	Vehicle Exit (0.7)	Street vendor (1.5)	Slow Vehicle (0.4)	Total KHS	Classification
06.30-07.30	A	Total	38	66	82	92	6	10	219.8	Medium (M) 459.3
		KHS	19	66	57.4	64.4	9	4		
10.00-11.00	B	Total	96	22	82	146	1	21	239.5	Medium (M) 429.4
		KHS	48	22	57.4	102.2	1.5	8.4		
16.30-17.30	A	Total	84	86	52	54	7	14	218.3	Medium (M) 429.4
		KHS	42	86	36.4	37.8	10.5	5.6		
17.30-18.30	B	Total	128	26	84	80	1	12	211.1	High (H) 531
		KHS	64	26	58.8	56	1.5	4.8		
19.30-20.30	A	Total	78	70	58	62	8	17	211.8	High (H) 531
		KHS	39	70	40.6	43.4	12	6.8		
21.30-22.30	B	Total	152	44	88	186	2	11	319.2	High (H) 531
		KHS	76	44	61.6	130.2	3	4.4		

Similar to observations on other roads, the data includes the number of incidents of various types of side obstacles and the side obstacle coefficient (SOC) values calculated based on the weighting factors for each type of obstacle.

During the morning period (06:30–07:30), Side A of Jalan Yos Sudarso had a total SOC of 219.8, classified as moderate (M). The largest contributions came from outgoing vehicles (64.4) and incoming vehicles (57.4). Side B also showed a moderate (S) classification with a total SSC of 239.5, where outgoing vehicles (102.2) and pedestrians (48) were the main contributors. During the daytime period (10:00–11:00), the side obstruction conditions on both sides of the road remained in the moderate (S) category. Side A recorded a total KHS of 218.3, with significant contributions from stopped vehicles (86) and pedestrians (42). Side B had a total KHS of 211.1, with pedestrians (64) and entering vehicles (58.8) having the greatest impact. During the afternoon period (16:30–17:30), there was an increase in lateral obstruction on Side B, reaching the high (T) classification with a total KHS of 319.2. The main contributors on Side B were exiting vehicles (130.2) and pedestrians (KHS 76). Meanwhile, Side A remained at the moderate (S) classification with a total KHS of 211.8, where stopped vehicles (70) and exiting vehicles (43.4) were the dominant factors.

Side obstacles on Yos Sudarso Street tend to be at a moderate level, but show an increase to high on side B in the afternoon. Unlike ZA Pagar Alam Street and Raden Intan Street, which are dominated by pedestrians and stopped vehicles, Yos Sudarso Street shows a more significant contribution from entering and exiting vehicles, possibly related to industrial and warehousing activities in this area, especially in the late afternoon.

CONCLUSION

It is known that land use along road corridors can generate community activities, which in turn create side effects, where side effects are classified into several types, each with different weights. Pedestrians have a weight of 0.5, vehicle entry/exit has a weight of 0.7, stopped vehicles have a weight of 1.0, street vendors have a weight of 1.5, and slow-moving vehicles have a weight of 0.4. The following table shows the land use at the study site and the resulting KHS.

Table 6 Relationship Between Land Use and Side Effects

Street Name	Time	Classification	Land Use Activity
Z.A. Pagar Alam Street	06.30-07.30	Very High (VH) 1716.9	Educational Facilities (IIB Darmajaya, Darmabangsa School, Muhammadiyah School Complex, Bandar Lampung University, Lampung Regional Library), Trade and Services (Shophouses in front of the Regional Library, Gas Station, Dunkin Donuts, Bakso Son Haji Sony, Alfamart, Repair Shop, Shops in front of the Muhammadiyah Complex)
	10.00-11.00	High (H) 608.7	
	16.30-17.30	Very High (VH) 1390.7	
Raden Intan Street	06.30-07.30	Medium (M) 327.6	Places of worship (Taqwa Tanjung Karang Mosque, Tanjung Karang Cathedral), Trade and Services (Ramayana Tanjung Karang, shopping complex, Pasar Tengah Market), Transportation (Tanjung Karang Station)
	10.00-11.00	High (H) 680.2	
	16.30-17.30	High (H) 783.5	
Yos Sudarso Street	06.30-07.30	Medium (M) 459.3	Trade and Services (BCA Bank Bandar Lampung Branch, shopping centers, street vendors, Alfamart, Indomaret, Florence Pharmacy, workshops, Prima), Warehousing (PT. Agreat Jaya Bima Kencana), Residential Area
	10.00-11.00	Medium (M) 429.4	
	16.30-17.30	High (H) 531	

Based on the table 6, it is known that:

1. Z.A. Pagar Alam Road has land use consisting of educational facilities and trade and services, where the most activities are carried out in the morning and afternoon during school hours, in addition to gas stations and shops, which also cause many vehicles to enter and exit the land around the corridor.
2. The land use around Raden Intan Road is dominated by commerce and services, resulting in a high volume of people moving around, vehicles stopping on the road, and vehicles entering and exiting the area. Activities are more frequent from 10:00 AM until the afternoon, following the retail stores, so the period from 6:30 AM to 7:30 AM has fewer activities compared to other times.
3. The condition of side obstacles on Yos Sudarso Road can be said to fluctuate slightly between morning, afternoon, and evening, but the highest number remains in the evening. Community activities are greatly influenced by the land use around the road, such as shops, and there are also many vehicles stopping on the road/shoulder and entering and exiting the surrounding areas.

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