

Planning and design evaluation of pedestrian overpass (JPO) facilities in Pidie Regency arterial roads

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Abstract: Transportation infrastructure on primary arterial roads supports mobility but often creates spatial conflicts with pedestrians at public activity hubs. This study examines the feasibility of planning non-level crossings along a main educational corridor on the Banda Aceh–Medan national highway in Pidie Regency. Current conditions indicate that inadequate crossing facilities in areas with high student activity have increased accident risk and reduced traffic flow efficiency. The research methodology involved surveying vehicle volume and pedestrian density over a full week, with technical analysis based on the PV2 parameter in accordance with the latest guidelines from the Directorate General of Highways. The study found a peak traffic volume of 3,127 vehicles per hour and a pedestrian intensity of 50 people per hour. The PV2 calculation yielded 488,906,450, which significantly exceeded the technical threshold of 2×10^8 . Based on these results, constructing a pedestrian overpass or JPO was deemed highly feasible as a planning solution to separate conflicting traffic flows, ensure student safety, and improve arterial road efficiency in Pidie Regency. This recommendation is expected to minimize traffic conflicts and support public safety and accessibility in Pidie.

Keywords: *pedestrian accessibility; traffic flow; overpass JPO planning; level of service*

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INTRODUCTION

Modern transportation systems serve as spatial integrators that align vehicle mobility with the safety of active pedestrian movement in strategic urban areas. In developing regions such as Pidie Regency, primary arterial roads, such as the Banda Aceh–Medan route, serve as strategic corridors within the national road network hierarchy, connecting interprovincial growth centers for logistics distribution and population mobility. However, as motor vehicle volume increases, spatial conflict between traffic flow and pedestrians has become a serious challenge in regional transportation management, especially in sensitive zones such as educational areas. The absence of official crossing facilities on primary arterial roads in Pidie Regency has created dangerous spatial conflicts between high-speed traffic flows and pedestrians. In educational zones with heavy crossing activity, students often resort to uncontrolled mid-block crossings, directly increasing the risk of fatal traffic accidents. This condition is further exacerbated by the national road's high average daily traffic volume, creating an unsafe environment for vulnerable pedestrian groups. Beyond safety, the lack of grade-separated crossing infrastructure, such as pedestrian overpasses, reduces road efficiency due to high side friction. Educational areas serve as major trip-attraction hubs, where student and staff activities concentrate at specific peak times (Ristiyanto & Supranoto, 2024).

In Pidie Regency, an educational corridor along a 2/2 UD road segment currently lacks adequate official crossing facilities. This forces pedestrians to make uncontrolled, at-grade, mid-block crossings. The conflict between high-speed vehicles on the arterial road and pedestrian movements not only triggers congestion caused by side friction but also increases the risk of fatal traffic accidents. Pedestrian safety is a paramount priority in planning inclusive transportation infrastructure (Panggalo, 2025). Based on technical standards, determining the type of pedestrian crossing facility cannot be done subjectively; rather, it must be grounded in a comprehensive analysis of traffic characteristics (Gerike et al., 2021). One parameter used to evaluate the need for grade-separated crossing facilities is the PV2 value, which integrates vehicle volume (P) and pedestrian volume (V) (Azka et al., 2024).

The technical provisions for pedestrian overpass construction adhere to Pd 02/SE/M/2018 concerning Technical Design of Pedestrian Facilities (KPUPR, 2018) as follows: Pedestrian overpasses are bridge structures designated for pedestrians to cross from one side of the road to the other; pedestrian overpasses must be built with structural strength and ease of maintenance; pedestrian overpasses must have a minimum width of two meters and a maximum staircase gradient of 20°; if the overpass is also intended for bicycles, the minimum width shall be 2.75 meters; pedestrian overpasses must be equipped with adequate protective railings/handrails; central section of the overpass staircases must be equipped with a ramp to serve as an accessible facility for wheelchair users with disabilities; the location and structure of the pedestrian overpass must align with pedestrian needs and aesthetic values; and the placement of the overpass must not reduce the effective width of the sidewalk (Panggalo, 2025). These guidelines are illustrated in Figure 1.

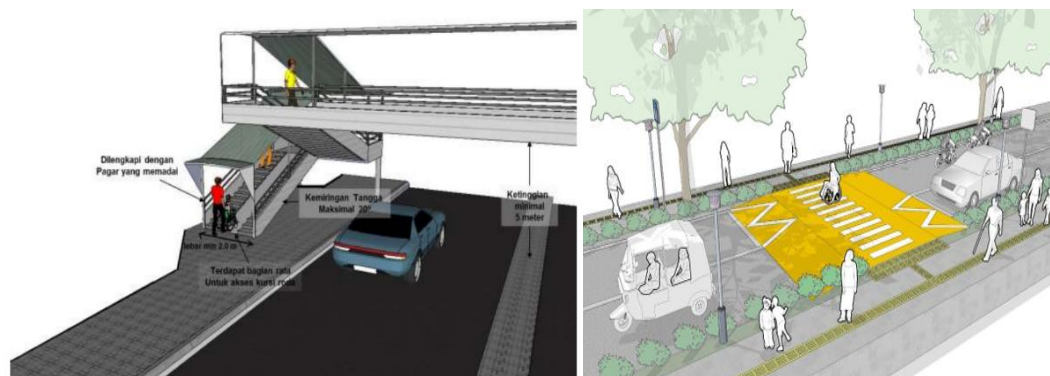


Figure 1. Perspective view of a pedestrian overpass and an example on a road segment

Install pedestrian facilities where they provide maximum benefits in safety, comfort, and smooth mobility for users (Mashuri & Ikbali, 2011). Two types of at-grade crossing facilities can support pedestrian accessibility at intersections or along road segments (Chandrappa et al., 2021). At-grade crossing facilities/Zebra Cross: a road marking consisting of a series of white lines parallel to the road axis that provides a priority area for pedestrians crossing vehicular traffic (Hadijah & Setiawan, 2025). At-grade crossing markings are limited to low-density traffic to ensure sufficient gap acceptance for pedestrians without requiring complex traffic signal interventions. Requirements for at-grade crossing facilities include: installation at intersection approaches without traffic light signals or along road segments; If the intersection is uncontrolled by traffic lights, the vehicle speed limit criterion is 40 km/h; If the intersection is controlled by traffic lights, the pedestrian crossing signal timing must be integrated into the overall intersection traffic signal cycle; and implementation of zebra crossings must refer to guidelines for road marking execution. Pelican Crossing: Short for pedestrian light-controlled crossing. A pelican crossing is essentially a zebra crossing equipped with a traffic light control mechanism at the pedestrian crossing location (Ramadhan et al., 2022). Figure 2 illustrates this. Criteria

for a Pelican Crossing are as follows Installed along a road segment, at a minimum distance of 300 m from an intersection; and Applied on roads with an average operational vehicle traffic speed of >40km/h (Landis et al., 2001).

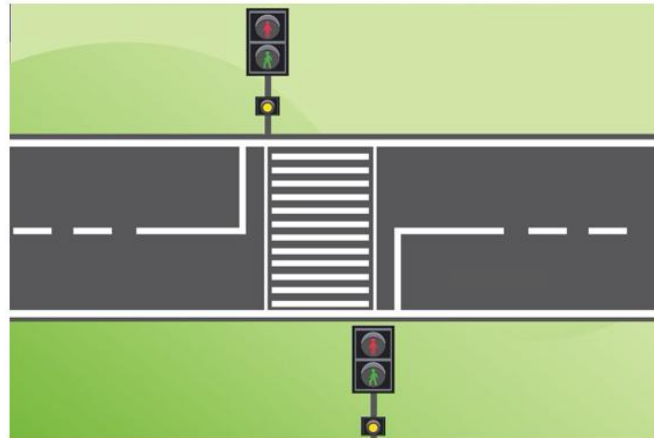


Figure 2. Criteria for a Pelican Crossing

The criteria for selecting at-grade crossing facilities are:

- 1) Based on the empirical formula (PV^2), where P is the pedestrian flow crossing a 100-meter road segment per hour and the two-way vehicular flow per hour;
- 2) P and V represent the average peak-hour flows of pedestrians and vehicles, with initial recommendations as shown in Table 1 below (KPUPR, 2018):

Table 1. Selection of at-grade crossing facilities

P (Peds/hour)	V (Veh/hr/hour)	PV^2	Recommendation
50 – 1100	300 – 500	$>10^8$	Zebra cross or pedestrian platform **
50 – 1100	400 - 750	$>2 \times 10^8$	Zebra cross with pedestrian refuge island
50 – 1100 > 1100	> 500 > 300	$>10^8$	Pelican crossing
50 – 1100	> 750	$>2 \times 10^8$	Pelican crossing with pedestrian refuge island

Note: *Pedestrian platforms are only applicable on collector or local roads.*

Using Equation: PV^2 (1)

Where:

P : Pedestrian flow crossing a 100 m road segment per hour (pedestrians/hour).

V : Two-way vehicular volume per hour on undivided roads (vehicles/hour).

A grade-separated crossing is a pedestrian crossing facility that vertically separates pedestrians from vehicular traffic (Nugroho & Tanan, 2020). Its purpose is to completely eliminate traffic conflict points, either by placing pedestrians above the road surface via a pedestrian overpass or below the road surface via a pedestrian underpass (Meviana et al., 2022; Gerike et al., 2021). Such facilities are typically implemented

on arterial roads characterized by high traffic volumes and high vehicle speeds that exceed specific technical parameter thresholds, as illustrated in Figure 3.



Figure 3. Example of a Pedestrian Overpass

The selection criteria for grade-separated crossings are shown in Table 2 below:

Table 2. Selection of grade-separated facilities

P (Peds/hour)	V (Veh/hour)	PV ²	Recommendation
>1100	>750	>2x10 ⁸	grade-separated crossing

The performance, or Level of Service (LOS), of a pedestrian path is both technical and general, adapting to the surrounding environment (Landis et al., 2021). The Guidelines for the Planning, Provision, and Utilization of Pedestrian Network Infrastructure in Urban Areas (Cirianni et al., 2022) determine pedestrian path performance. The analysis of pedestrian path performance involves five steps: calculating pedestrian flow, pedestrian speed, pedestrian density, pedestrian space, and the volume-to-capacity (V/C) ratio, as shown in Table 3.

Table 3. Pedestrian Level of Service (LOS)

Level of Service	Space (m ² /pedestrian)	Pedestrian Flow	Average Speed (m/min)	Ratio (V/C)
A	≥12	≤16	≥78	≤0,08
B	≥36	≤23	≥75	≤0,28
C	≥2.2	≤33	≥72	≤0,40
D	≥1,4	≤50	≥68	≤0,60
E	≥0,5	≤83	≥45	≤1.00
F	≥0,5	Variable	≥45	1,00

METHOD

The research framework outlines the sequence of analytical activities from the study's initial to

final stages, ultimately yielding recommendations and conclusions. Observations or field surveys were carried out over seven consecutive days, each lasting 11 hours, from 07.00 to 16.00 WIB. This observation window covered morning-to-afternoon activity periods, providing a comprehensive overview of traffic conditions and pedestrian crossing behaviour around the school. The collected data are expected to reflect actual traffic flow characteristics and the need for crossing facilities suited to field conditions.

This method was used to collect field data through direct observations to accurately capture baseline traffic performance in the study area.

1. Road Inventory Survey: Conducted to determine the current geometric and physical conditions of the road segment under study, including length, width, cross-sectional dimensions, and supplementary road infrastructure such as traffic signs, road markings, traffic light signals (APILL), sidewalks, crossing facilities, medians, street lighting, and other auxiliary appurtenances.
2. Traffic Count Survey: Aimed at determining traffic density and volume levels within the study area during morning, midday, and afternoon peak hours, comprising:
 - a. Traffic volume per 15-minute time interval for each vehicle class per direction;
 - b. Peak-hour volume for each specific time window
3. Speed Survey: Conducted to evaluate vehicle operating speeds, delays along the road segment, and the underlying causes of congestion. The survey used the Moving Car Observation (MCO) method, where speed samples were gathered by observing overtaking and overtaken vehicles and recording travel times across designated checkpoints along the study corridor.
4. Pedestrian Survey: Conducted to analyze pedestrian movement characteristics, categorized into two observation types:
 - Longitudinal Movement: Performed to measure the pedestrian volume walking along the left and right sidewalks. The survey was conducted during peak periods, from which the maximum volume was extracted and converted into pedestrians per minute. Data were collected by counting pedestrians approaching and moving away from the surveyor within specified time intervals, serving as a baseline for determining required pedestrian facilities.
 - Crossing Movement: Executed to determine the pedestrian crossing volume across the road segment within given time frames. This technique quantifies pedestrian crossing demand to assess the Level of Service (LOS) and to design appropriate pedestrian crossing facilities.
5. Parking Survey: Carried out to assess parking infrastructure conditions within the study site, including road width, sidewalk width, presence of medians, parking bay length and width, and existing parking signage and markings.
6. Visual Inspection: Conducted to evaluate the operational compliance of on-field parking practices against local parking regulations and applicable statutory laws.

The analysis and determination of the appropriate crossing facility type were carried out by referencing Table 1 and Table 2 for at-grade and grade-separated facility criteria:

- If $PV^2 > 2 \times 10^8$ and $P > 1100 \rightarrow$ Pedestrian Overpass / JPO (Grade-separated crossing);
- If $PV^2 > 2 \times 10^8$ and $P = 50 - 1100 \rightarrow$ Pelican crossing or Zebra cross with a pedestrian refuge island.

To determine the critical gap parameter, we used the Raff method based on critical gap acceptance, calculating the number of pedestrians who cross safely versus those who wait, using headway distributions. Pedestrian decisions were recorded (code = 1) for accepted gaps and (code = 0) for rejected gaps. We then grouped the data into cumulative frequency distributions for accepted and rejected gaps. The cumulative curves of accepted and rejected gaps were plotted on a single graph, with the horizontal axis representing time gaps (in seconds) and the vertical axis showing cumulative

percentages.

The resulting PV^2 values and gap acceptance parameters determine whether at-grade or grade-separated crossing facilities are required. Detailed structural and geometric designs for the recommended facilities are developed in accordance with Indonesian National Standards (SNI) and site-specific operational requirements.

FINDINGS AND DISCUSSION

This chapter presents the results of field data collection with analysis of the existing road infrastructure conditions along the arterial road segment in Pidie Regency. To provide a systematic overview, the discussion begins with the analysis of geometric characteristics and existing traffic volume, followed by an evaluation of traffic conflicts around the school area, and concludes with the visualization of design recommendations for the planned public safety and accessibility facilities.

Road Geometry

The geometric condition of the arterial road segment surveyed in Pidie Regency features a 2/2 UD (Two-Lane Undivided) configuration, consisting of two lanes for two-way traffic without a physical median. The traffic layout along this segment is designed to accommodate both through-traffic flow and local accessibility needs. This is briefly illustrated in the figure 4.

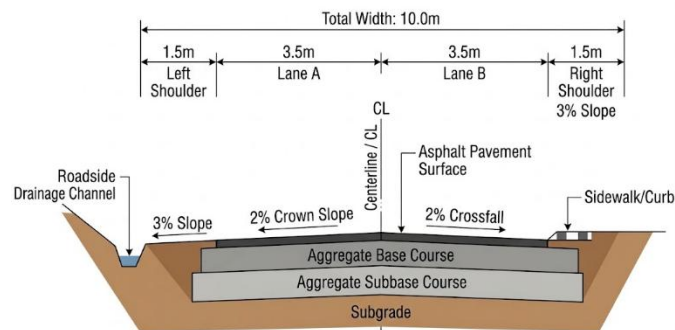


Figure 4. Typical Cross-Section of the Road Segment

Traffic Volume

Traffic volume analysis was conducted to determine density levels, vehicle characteristics, and flow fluctuations at site. Traffic volume data were obtained through at observation points. The summarized results are presented in Table 4.

Table 4. Recapitulation of Vehicle Volumes

Days	Time	Traffic Flow		Total Vehicles
		A - B	B - A	
Sunday	16.00 – 17.00	1081	1033	2114
Monday	07.00 – 08.00	1480	1647	3127
Tuesday	07.00 – 08.00	1384	1490	2874
Wednesday	12.00 – 13.00	1304	1434	2738
Thursday	12.00 – 13.00	1217	1315	2532
Friday	07.00 – 08.00	1188	1327	2515
Saturday	07.00 – 08.00	1240	1279	2519

Based on the traffic survey data presented in Table 4, the overall highest traffic volume on Monday morning during the 07.00–08.00 WIB period, reaching a peak volume of 3127 vehicles (comprising 1480

vehicles in A–B and 1647 vehicles in B–A). The morning peak period (07.00–08.00 WIB) consistently dominates traffic demand across most days, including Monday, Tuesday, Friday, and Saturday. Conversely, midweek traffic peaks transition toward the midday period (12.00–13.00 WIB) on Wednesday and Thursday, recording maximum hourly flows of 2738 vehicles and 2532 vehicles, respectively. On Sunday, traffic activity peaks in the late afternoon (16.00–17.00 WIB) with a total volume of 2114 vehicles, representing the lowest peak-hour total recorded throughout the survey week. A cross all survey periods, directional distribution remains relatively balanced, with B–A registering slightly higher vehicular volumes during peak periods.

Pedestrian Crossing Activity

Analyzing pedestrian characteristics in planning safety facilities, given that pedestrians particularly school aged children represent road users who are highly susceptible to traffic accident risks. Based on field observations and pedestrian volume surveys in Table 5 below.

Table 5. Recapitulation of Pedestrian Crossing Volumes

Times	Pedestrian Crossing Activity (P)						
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
07.00 – 08.00	32	38	41	39	40	37	36
08.00 – 09.00	22	36	32	34	41	33	30
09.00 – 10.00	21	32	38	30	29	34	28
10.00 – 11.00	24	30	32	29	20	33	24
11.00 – 12.00	11	35	35	30	22	42	20
12.00 – 13.00	19	50	32	37	36	45	37
13.00 – 14.00	24	44	31	31	24	43	34
14.00 – 15.00	18	32	22	22	29	31	19
15.00 – 16.00	11	28	26	24	28	38	18
16.00 – 17.00	21	31	34	23	25	35	32
17.00 – 18.00	25	34	25	19	18	21	21
Totals	228	390	348	318	312	392	299
Maximum	32	50	41	39	41	45	37

Based on Table 5, pedestrian crossing activity varied distinctly by daily functional activities, particularly school schedules and commercial operations. Overall, pedestrian crossing volumes peak during two main intervals: the morning arrival period (07.00–08.00 WIB) and the midday dismissal period (12.00–14.00 WIB). The highest hourly crossing volume occurs on Monday from 12.00–13.00 WIB (50 pedestrians/hour), followed closely by Friday from 12.00–13.00 WIB (45 pedestrians/hour). On weekdays (Monday through Friday), morning crossing demand is consistently high between 37 and 41 pedestrians/hour during 07.00–08.00 WIB, coinciding with school entry hours and morning commute trips. In contrast, Sunday shows significantly lower pedestrian crossing activity across all time intervals, peaking at only 32 pedestrians/hour during 07.00– 08.00 WIB, with a minimum of 11 pedestrians/hour. The concentration of high crossing volumes during school operational hours highlights the urgent need for dedicated crossing infrastructure to protect road users during peak demand.

Vehicle Speed

To determine a representative sample size for vehicle speed observations, a normal distribution statistical approach was applied using the following formula: In this study, a confidence level of 95% ($Z = 1.96$) was established, with a speed standard deviation based on field free-flow traffic conditions of 7.35

km/h, and an allowable margin of error ($E = 2.0$ km/h). Based on these criteria, the minimum sample size calculation is as follows:

$$N = \left(\frac{Z \cdot \sigma}{E}\right)^2$$

$$N = \left(\frac{1.96 \times 7.35}{2.0}\right)^2 = 51.88 \approx 52 \text{ Vehicles/Day}$$

As a regional logistics and mobilization corridor, the arterial road segment in Pidie Regency is designed to accommodate continuous flow movement at relatively high speeds. The average vehicle speed calculation during the 07.00–08.00 WIB period is presented as follows:

$$U_t = \sum \frac{U_i}{n} = \frac{45.671 + 41.640 + 38.500 + 45.272 + 45.358 + 40.181}{6} = 42.770 \text{ km/h}$$

Table 6. Recapitulation of Vehicle Speeds

Time	Speed (km/h)					
	A - B			B - A		
	MC	LV	HV	MC	LV	HV
07.00-08.00	45.671	41.640	38.500	45.272	45.358	40.181
10.00-11.00	56.803	62.205	51.230	57.941	61.367	48.542
12.00-13.00	43.550	48.229	37.139	43.424	46.214	35.662
15.00-16.00	49.051	60.214	50.432	57.136	59.044	43.432
17.00-18.00	44.082	53.405	46.467	43.206	52.138	39.341

Based on the speed survey in Table 6, the surveyed arterial segment varies by time of day and vehicle classification. Across all observation periods, light vehicles (LV) consistently record the highest operating speeds, peaking during the 10.00–11.00 WIB interval at 62.205 km/h in A–B and 61.367 km/h in B–A. MC showed a similar speed trend, reaching its maximum average speeds during the same off-peak morning window (10.00–11.00 WIB) with 56.803 km/h and 57.941 km/h for A–B and B–A, respectively. Conversely, HV had lower overall operating speeds across all periods due to their physical and performance characteristics, at 51.230 km/h during 10.00–11.00 WIB (A–B). Vehicle speeds decrease during peak traffic hours, 07.00–08.00 WIB and 12.00–13.00 WIB, when traffic density is higher, with average speeds ranging from 35.662 km/h to 48.229 km/h.

Based on standard transportation engineering criteria in Table 3, the performance of road services on arterial roads in Pidie Regency is categorized as LOS D. During the off-peak (10.00 – 11.00 WIB), light vehicle speeds peak values of 62.205 km/h in A–B and 61.367 km/h in B–A ≥ 68 (Standards), the overall reduction in operational speeds reflects increased traffic density and manoeuvrability constraints that push the roadway performance toward LOS D during high-volume periods. This speed reduction under peak traffic conditions triggers increased congestion, raises vehicle density, and significantly limits drivers' manoeuvring space, confirming that the road corridor operates near its stable capacity.

Determination of Pedestrian Crossing Facility Types

To develop targeted design recommendations for arterial roads in Pidie Regency, the selection of pedestrian crossing facilities is based on objective, mathematical criteria rather than subjective judgment. The methodology follows the standards set by the Directorate General of Highways, using a PV^2 criterion analysis to determine whether a given location requires a conventional pedestrian crossing (zebra crossing) or an upgrade to a Pelican Crossing (a crossing equipped with pedestrian traffic signals). The results of this analysis are presented in Table 7.

Table 7. Recapitulation of *Pedestrian Crossing Facility Types*

Day	P	V	P.V ²	Recommendation
Sunday	32	2114	143.007.872	Zebra cross or pedestrian platform
Monday	50	3127	488.906.450	Grade-separated crossing
Tuesday	41	2874	338.654.916	Grade-separated crossing
Wednesday	39	2738	292.369.116	Grade-separated crossing
Thursday	41	2532	262.851.984	Grade-separated crossing
Friday	45	2515	284.635.125	Grade-separated crossing
Saturday	37	2519	234.778.357	Grade-separated crossing

The results show conditions on weekdays (Monday through Saturday). All weekdays consistently exceeded the technical threshold of $PV2 > 2 \times 10^8$ (or $> 200,000,000$), with the peak on Monday, when PV2 reached 488,906,450 ($P = 50$ people/hour and $V = 3,127$ vehicles/hour). According to the Bina Marga guidelines on pedestrian crossing facilities, if the PV2 criterion value reaches this figure and the hourly vehicle volume is well above 950 vehicles/hour, then implementing a pedestrian crossing facility is not feasible.

The type that best meets the requirements and is recommended for this study site is a pedestrian overpass (JPO). This choice is based on a technical review indicating that vehicle volume during peak hours is very high ($V = 3,127$ vehicles/hour) on the primary arterial road (type 2/2 UD), which necessitates vertical clearance. A pedestrian overpass is more financially and structurally rational than an underpass; underground construction in this corridor carries a high risk of disrupting existing utility networks and would require a complex drainage system with pumps to prevent flooding during the rainy season. Therefore, building a pedestrian overpass is the optimal solution to eliminate conflict points and reduce accident risk while maintaining stable traffic flow, as illustrated in Figure 5.

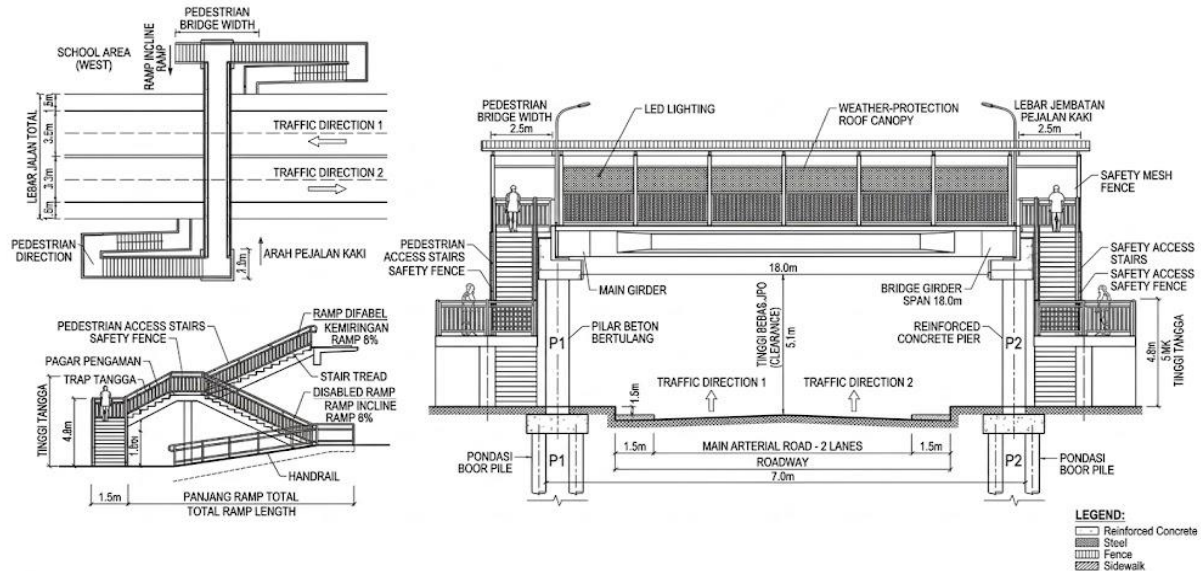


Figure 5. Pedestrian Bridge Plan for Pidie Regency

Overall, the synthesis of road geometry, peak traffic demand, vehicle speed profiles, and pedestrian activity confirms that arterial road corridors in Pidie Regency require integrated safety interventions and traffic management (Roess et al., 2011). The combination of high-speed vehicular traffic and vulnerable road users, particularly school-aged pedestrians during morning arrival and afternoon dismissal hours, renders standard at-grade crossings both unsafe and operationally inadequate (World Health Organization, 2013). Implementing the recommended pedestrian overpasses, supplemented by safety facilities that meet national technical criteria (Directorate General of Highways, 2014), can effectively eliminate conflict points without disrupting the smooth flow of traffic on major arterial roads. Ultimately, these infrastructure improvements will not only reduce the risk of pedestrian accidents and protect students, but will also prevent further degradation of road performance, maintain a stable Level of Service (LOS), and support long-term mobility throughout the regency (Transportation Research Board, 2016).

CONCLUSION

This study evaluates traffic characteristics and pedestrian crossing requirements along the arterial road segment in Pidie Regency, which currently operates as a two-lane undivided (2/2 UD) roadway. Field data analysis reveals severe operational conflict, particularly during morning peak hours (07.00–08.00 WIB) and midday school dismissal (12.00–13.00 WIB), when traffic volumes reach up to 3,127 vehicles per hour and pedestrian crossing flows reach 50 pedestrians per hour. High operating speeds exceeding 60 km/h during off-peak hours, combined with high traffic density during peak periods, degrade road service performance to LOS D and expose pedestrians, especially school-aged children, to severe safety risks. Quantitative evaluation using the Bina Marga standard criteria yields PV2 values consistently exceeding 2×10^8 (or $> 200,000,000$) on all weekdays, peaking at 488,906,450 on Monday. Because high vehicle volumes make conventional at-grade crossings infeasible and underpass construction poses significant flooding and utility-disruption risks, a grade-separated Pedestrian Overpass (JPO) is the most viable solution. The proposed 18-meter-span JPO, with a 5.1-meter vertical clearance, LED lighting, safety mesh fencing, and an 8% gradient ramp for accessibility, eliminates traffic conflict points while safeguarding pedestrian mobility and maintaining stable vehicular flow along this critical regional corridor.

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