Department of Digital Business
Journal of Artificial Intelligence and Digital Business (RIGGS)
Homepage: https://journal.ilmudata.co.id/index.php/RIGGS
Vol. 4 No. 4 (2026) pp: 8992-9002
P-ISSN: 2963-9298, e-ISSN: 2963-914X

Geometric Analysis of the Subang Road Section Sta 0+000 – Sta 3+000, West Java Province

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Abstract

Integrated road infrastructure planning is an important factor in ensuring traffic safety, comfort, and smoothness. This study aims to evaluate and redesign the technical aspects of the ±3 km Subang Road section in Subang Regency, West Java Province, with a focus on road geometric planning, flexible pavement structures, and drainage systems. The research method used is a quantitative-descriptive approach based on primary data from field surveys and secondary data covering traffic data, subgrade conditions, and regional rainfall. The planning analysis refers to applicable national standards to ensure that technical and road user safety criteria are met. The evaluation results showed that the existing road conditions did not fully comply with the planning requirements, thus requiring adjustments to the horizontal and vertical alignment elements to be consistent with the planned speed. The redesign resulted in a geometric layout that improved stopping sight distance, vehicle stability, and driving comfort. The flexible pavement structure is designed based on the bearing capacity of the subgrade and projected traffic growth during the design life, so that it is expected to be able to withstand vehicle loads optimally and extend the service life of the road. In addition, the drainage system is designed to effectively drain rainwater runoff to prevent puddles and pavement damage. Overall, the results of the study show that the application of integrated road planning based on technical standards can improve road operational performance, reduce the potential for accidents, and support smooth mobility and economic growth in Subang Regency.

Keywords: Road Planning, Geometric Design, Flexible Pavement, Road Drainage, PDGJ 2021, Subang.

1. Introduction

1.1 Background

Roads play a very important role in people's lives, including as a means of facilitating the distribution of goods and services, connecting regions, and contributing to improving the economy and welfare of the community. Economic progress cannot be achieved without adequate road infrastructure support. This support is realized through various efforts, such as establishing good road conditions and constructing roads in accordance with planning standards[1].

Both the construction of new roads and the improvement of existing road capacity require effective design methods in order to obtain optimal and efficient results that meet the safety and comfort requirements of road users [2], [3], [4], [5]. Safe, comfortable, and smooth road services can be achieved if the road width is sufficient and the curves are designed in accordance with technical specifications for highways, including vertical alignment, horizontal alignment, and appropriate pavement thickness [6], [7], [8], [9]. Thus, vehicles can pass safely and comfortably in accordance with the planned load and speed [10], [11], [12].

However, road infrastructure development is not a simple matter as it requires large costs and careful planning. One of the local government's efforts to improve the quality of transportation infrastructure is through the Subang Road Pavement Planning Project [13], [14], [15]. The construction of this road is expected to facilitate the flow of human traffic and the distribution of goods and services, thereby boosting economic growth and improving the welfare of the community in the region [13], [16], [17].

2. Research Method

2.1 Approach, Location, and Research Period

This study uses a quantitative-descriptive approach, in which analysis is conducted based on numerical data from field surveys and secondary data obtained from relevant agencies. This approach aims to describe existing conditions, analyze geometric characteristics and pavement, and systematically estimate road construction costs in accordance with applicable technical standards [18], [19], [20], [21].

The research location is on Jalan Subang, Subang Regency, West Java Province, with a planned road length of approximately 3 km. This location was chosen based on the need to improve the quality of transportation infrastructure in order to smooth traffic flow and support local economic growth.

The research was conducted from January to March 2025, covering field surveys, secondary data collection, technical analysis, and the preparation of road infrastructure planning reports.

Figure 1. Research Location

2.2 Types and Sources of Data

- Primary Data, obtained through direct field surveys on the Subang Road section, including:
  a. Road geometric measurements (width, slope, curves, elevation).
  b. Existing conditions of pavement and surrounding environment.
  c. Observation of drainage and topography conditions.

- Secondary data, obtained from agencies and technical references, including:
  a. Average Daily Traffic (ADT) data (LHR).
  b. CBR values of the subgrade soil.
  c. Annual rainfall data from the Subang Meteorological, Climatological, and Geophysical Agency (BMKG).
  d. Design standards from the 2021 Road Geometric Design Guide (PDGJ) and the 2024 Pavement Design Manual (MDP).

Table 1. Road Planning Criteria

Road Classification	Left Direction	Right Direction
Design Speed (Vr) (km/h)	80	
Design Pavement Life (th)	12	
CBR (%)	6	
Traffic Growth Before Road Opening	5,5	8

DOI: https://doi.org/10.31004/riggs.v4i4. 5099

Rainfall (mm/year)	1900-2500
Slope (%)	2,5
Binder Material	HRS-BC
CTB (mm)	250
LFA	Class A
LPB	Class B
Road Width = 2,75 m	2,75
e maks = 4%	4

2.3 Data Collection Techniques

Data collection techniques were carried out using the following methods [22], [23], [24]:

- Field Observation (Primary Survey)
  Surveys were conducted to obtain the actual conditions of the road sections, including measurements of road width, curve radius, cross slope, gradient, and documentation of the surrounding environmental conditions.
- Documentation Study
  Secondary data collection was carried out through literature studies and technical documents from relevant agencies, such as the Subang Regency Public Works and Spatial Planning Agency (PUPR), BMKG, and other academic literature sources.
- Technical Interviews (If Necessary)
  Conducted on a limited basis with agencies or experts to validate the technical data used in planning.

2.4 Data Analysis Techniques

- Road Geometry Analysis
  Determining geometric elements includes horizontal and vertical alignment. Curves are analyzed using the Full Circle and Spiral–Spiral (S–S) methods, with the following basic parameters:

  Design speed (Vr) = 80 km/h

  Normal superelevation = 2,5%, maximum = 4%

  Friction coefficient (f) ≈ 0.142
  Calculation results are checked for overlap between curves and stopping sight distance (Jh ≈ 129.59 m).

- Vertical Geometry Analysis
  Calculating the length of vertical curves (convex/concave) based on gradient values (g1, g2) to ensure comfort and minimum sight distance in accordance with PDGJ 2021.

- Road Drainage Analysis
  Using the rational method:

$$Q = \frac{C \times I \times A}{3,6} \quad (1)$$

  and Manning's equation to evaluate channel capacity:

$$Qsal = \frac{1}{n} \times R^{2/3} \times S^{1/2} \times F \quad (2)$$

  The channel dimensions are determined so that Qsal > Q and flow velocity V < Vijin (1.5 m/s) to prevent erosion.

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- Pavement Structure Analysis
  Based on CBR = 6%, planned life of 12 years, and annual traffic growth of 5.5%–8%. The thickness of the layers is determined in accordance with MDP 2024 with the following layer combination:

  Surface Layer: HRS – BC

  Upper Base Layer: Class A Aggregate

  Lower Base Layer: Class B Aggregate

- Traffic Performance Analysis [25]:
  Using MKJI (1997) to determine the base capacity (C0), adjustment factors (FCw, FCsp, FCsf), and degree of saturation (DS). The evaluation is carried out until the end of the design life to ensure DS ≤ 0.80.

3. Results and Discussion

3.1 Horizontal Geometry

The planned road section is located on Jalan Subang, Subang Regency, West Java Province, with a length of approximately ±3 km and a cross-section type of 2/2 TT (two undivided lanes in both directions). The design speed (Vr) is set at 80 km/h, in accordance with the slightly hilly terrain characteristics (average gradient of 2.5%).

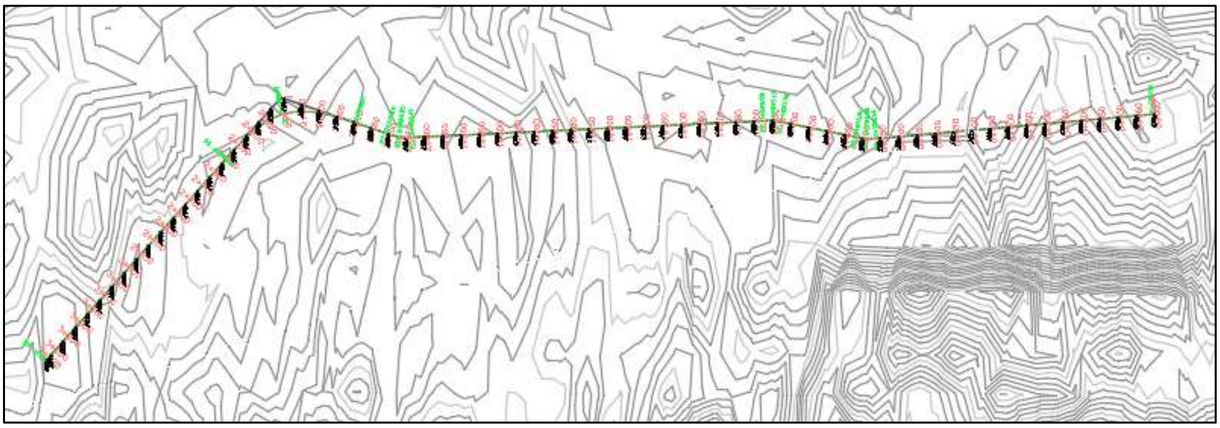

Figure 2. Research Location Layout

Table 1. Horizontal Alignment

`PI	R (m)	Rmin (m)	Description	Superelevation (%)		Description	Bearing Angle	Curve Type
		Vr = 80km/h		e (%)	e max			
1	500	276	Fulfilled	3,5	4	Fulfilled	15,974	Full Circle
2	400	276	Fulfilled	3,7	4	Fulfilled	13,935	Full Circle
3	400	276	Fulfilled	3,7	4	Fulfilled	14,812	Full Circle
4	300	276	Fulfilled	4	4	Fulfilled	60,327	SS

The analysis results show that there are four main curves, consisting of three Full Circle types and one Spiral–Spiral (S–S) type. The basic parameters used are:

- Normal superelevation (en) = 2,5%
- Maximum superelevation (emaks) = 4%
- Friction coefficient (f) ≈ 0,142

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The minimum radius (Rmin) obtained is:

$$\text{Rmin} = \frac{V\text{^}2}{127\ (e+f)} = \frac{80\text{^}2}{127\ (0{,}04+0{,}142)} = 276{,}89\text{m} \quad (3)$$

Each curve is tested for overlapping control, sight distance, and pavement widening requirements. The results show that all curves meet the PDGJ 2021 geometric design criteria, with the distance between tangents still within safe limits (example: PI1–PI2 = 179.04 m < limit of 200 m → OK).

The last type of curve (S–S) with an angle of 60.33° uses R = 300 m and a spiral length (Ls) resulting from a 3-second travel time control of ≈133.3 m, which is declared safe against centrifugal force transition.

The stopping sight distance (Jh) for a design speed of 80 km/h is obtained as:

$$Rmin = \frac{V\text{^}2}{2gf} = 129{,}59m \quad (4)$$

This value meets the minimum stopping sight distance required for an urban road with a design speed of 80 km/h (≥120 m), ensuring safety for emergency stopping maneuvers.

Table 2. Horizontal Alignment Design

PI	R (m)	Vr (km/h)	Overlapping		
			Ts/Tc n + Ts n+1	<dn	Control
A-PI.1	500	80	70,155	100,155	OK
PI.1-PI.2	400	80	70,155	179,040	OK
PI.2-PI.3	400	80	48,885	162,380	OK
PI.3-PI.4	400	80	51,994	183,256	OK
PI.4-B	300	80	309,234	372,750	OK

Table 3. Planning for road length numbering

NO.	D (m)	Ts/Tc	Ls	Lc
1	799	70,155	19	139,373
2	250	48,885	21	97,269
3	1000	51,994	21	103,390
4	400	309,234	44	133,333
5	916			

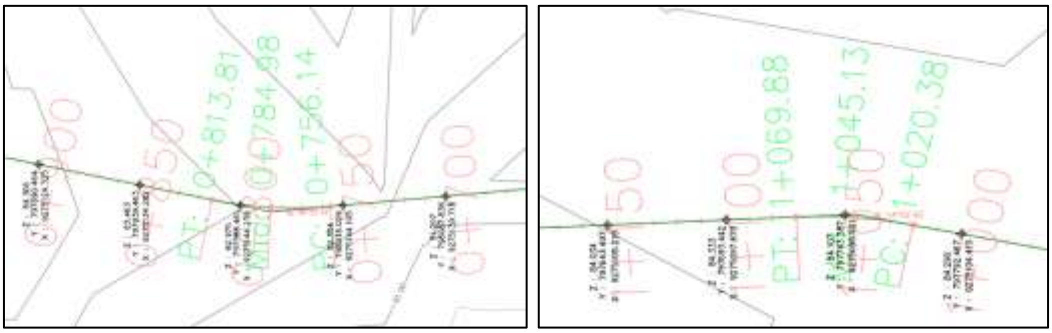

Figure 3. Turn 1 (Full circle) and Turn 2 (Full Circle)

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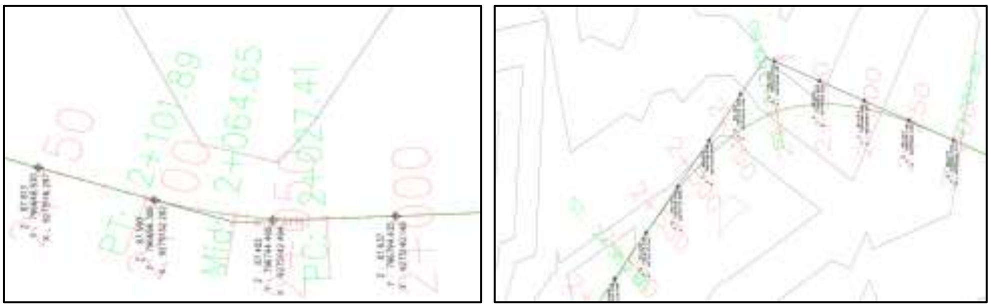

Figure 4. Turn 3 (Full Circle) and Turn 4 (SS)

3.2 Vertical Geometry

Vertical analysis was conducted to determine the maximum slope, vertical curve length (Lv), and curve point elevation.

From the survey results, an average gradient of 2.5% was obtained, with varying gradient values at several STAs.

For example, on vertical curve 1 (convex) at STA 0+873.75 with g_1 = 0.363% and g_2 = 0.364%, the results are:

$$A = g1 + g2 = 0{,}727\% \quad (5)$$

$$Lv = \frac{S\hat{}2}{200\ (A)} => Lv = 58{,}12m \quad (6)$$

Elevation calculations show that the elevation transition between the PLV, PPV, and PTV points occurs smoothly without extreme gradient changes, thus maintaining comfort and vertical sight distance. Thus, the combination of horizontal and vertical alignment is consistent (no hidden crests or sag curves that intersect the line of sight).

Table 4. Vertical Alignment Planning

Planning					
Points	STA	Elevation	g	A	Requirements g<8%
A	0+000	80,432			
			0,362		OK!
PPV1	0+873,75	83,6			
				0,364	OK!
PPV2	1+075	84,333			
			0,328		OK!
PPV3	2+075	87,61			
				0,285	OK!
PPV4	2+275	88,18			
			0,460		OK!
B	3+366	93,199			

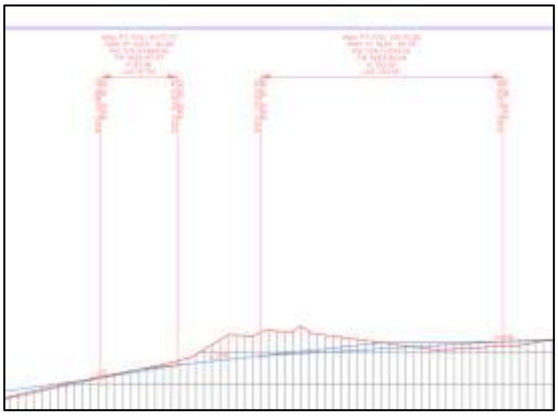

Figure 5. PPV1 and PPV2 Profiles

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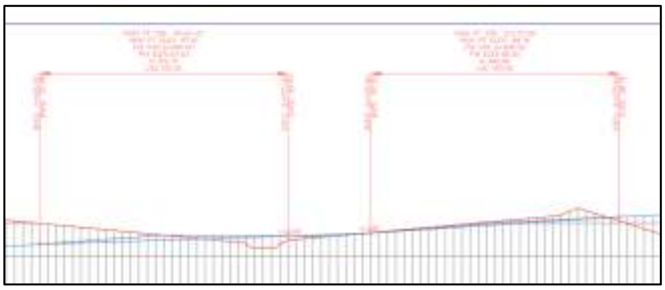

Figure 6. Profile PPV3 and PPV4

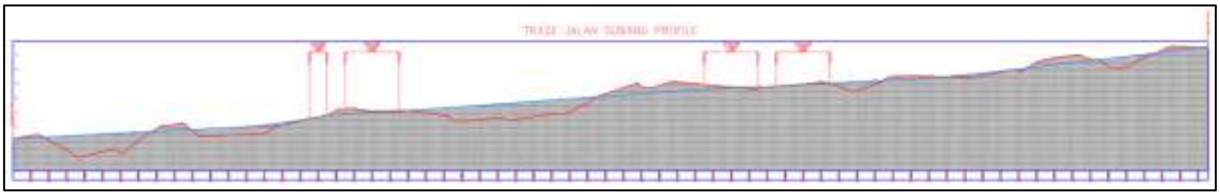

Figure 7. Vertical Long Section

3.3 Road Drainage

The drainage system is designed to safely channel rainwater from the road surface to the side channels. Design data:

- Design rainfall intensity (I) = 1,900 mm/h
- Example segment length = 100 m
- Combined runoff coefficient (C) = 0.8 (road), 0.2 (shoulder), 0.3 (outer soil)
- Total drainage area (A) = 21.5 m × 100 m = 2,150 m²

Design flow rate calculated using the rational method:

$$Q = \frac{C \times I \times A}{3,6} = \frac{0,36 \times 1900 \times 2150}{3,6 \times 10^{\wedge}6} = 1,13 m^3/s \quad (7)$$

To ensure channel capacity, the Manning equation is used with the following parameters:

- B = 1,2 m
- H = 1,31 m
- n = 0,013
- Is = 0,001

Calculation results:

$$V = \frac{1}{n} \times R^{2/3} \times S^{1/2} = 1,345 \text{ m/s} \quad (8)$$

$$Qsal = V \times F = 1,345 \times 1,57 = 2,12 \text{ m}^3/\text{s} \quad (9)$$

Since Qsal (2.12 m³/s) > Q (1.13 m³/s) and V (1.345 m/s) < Vijin (1.5 m/s), the channel design is declared to meet the capacity and flow velocity requirements.

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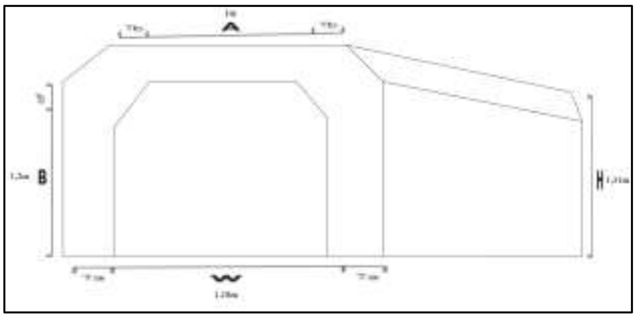

Figure 8. Road Drainage

3.4 Pavement Structure

The CBR value of the subgrade soil = 6% is categorized as moderate bearing capacity, and the design life is 12 years according to MDP 2024. Annual traffic growth is taken as 5.5% in the left direction and 8% in the right direction. The analysis results in the following layer arrangement:

Table 5. Structure of Pavement

Layer	Material Type	Thickness (mm)
Surface Layer	HRS–BC	40
Upper Foundation Layer	Class A Aggregate	200
Lower Foundation Layer	Class B Aggregate	150

This configuration meets the criteria for resistance to medium-heavy traffic loads for CBR 5–7%. This structure is expected to function optimally throughout its design life with periodic maintenance.

3.5 Road Pavement Analysis Calculation

Road pavement analysis is a technical calculation to determine the type and thickness of pavement layers to withstand traffic loads throughout the planned service life. This calculation considers traffic volume and growth, vehicle axle load (ESA), subgrade bearing capacity (CBR), and environmental conditions. The analysis results in a pavement layer design that distributes loads evenly, ensuring the pavement has strength, durability, and provides safe and comfortable road service.

Table 6. LHR Analysis

Vehicle Type	LHR 2025 Right Direction	LHR 2025 Left Direction	EMP 2025	LHR 2037 Left Direction	LHR 2037 Right-hand drive	EMP 2037
(2) Light Vehicles	874	1096,8	1,2	1661,655343	2761,928984	1,2
(5B) Large Bus	432	441,6	1,2	821,3216338	1112,023924	1,2
(6B) 2-Axle Truck	111	243	1,8	211,0340309	611,9153384	1,8
(7A2) Heavy 3-Axle Truck	87	136,8	1,8	165,4050513	344,485672	1,8
(7A3) Heavy 3-Axle Truck	99	147,6	1,8	188,2195411	371,6819092	1,8
(7B1) Heavy 4-Axle Truck	47	120,6	1,8	89,35675183	303,6913161	1,8
(7C2A) Heavy 5- Axle Truck	16	16,2	1,8	30,41931977	40,79435589	1,8
Total	1666	2202,6		3167,411671	5546,521499	
Total right & left LHR	3868,6		Per day	8713,933171		Vehicles/day
	161,1916667		Vehicles/hour	363,0805488		Vehicles/hour

DOI: https://doi.org/10.31004/riggs.v4i4. 5099

Table 7. CESAL Analysis 2025

Vehicle Axis Configuration	LHR 2025 LEFT LEFT	LHR 2025 RIGHT RIGHT	VDF 4 ACTUAL	VDF 5 ACTUAL	CESAL 4 2025 LEFT	CESAL 4 2025 RIGHT	CESAL 5 2025 LEFT	CESAL 5 2025 RIGHT
(2) Light Vehicles	1048,8	1096,8	-	-	-	-	-	-
(5B) Large Bus	518,4	441,6	1,2	1,3	2732967,78	2331289,50	2960715,09	2525563,63
(6B) 2-Axle Truck	199,8	243	3,5	4,9	3072216,38	3741624,62	4301102,94	5238274,47
(7A2) Heavy 3-Axle Truck	156,6	136,8	5,7	9,2	3921524,08	3430416,48	6329477,46	5536812,56
(7A3) Heavy 3-Axle Truck	178,2	147,6	-	-	-	-	-	-
(7B1) Heavy 4-Axle Truck	84,6	120,6	-	-	-	-	-	-
(7C2A) Heavy 5-Axle Truck	28,8	16,2	2,6	3,5	328968,34	185299,51	442842,00	249441,64
TOTAL KI, KA CESAL ACTUAL 2024					10055676,58	9688630,11	14034137,49	13550092,31
TOTAL CESAL ACTUAL 2025					19744306,693		27584229,795	

Table 7. CESAL Analysis 2037

Vehicle Axis Configuration	LHR 2037 Left Direction (LEFT)	LHR 2037 Right Direction (RIGHT)	VDF 4 ACTUAL	VDF 5 ACTUAL	CESAL 4 2037 LEFT	CESAL 4 2037 RIGHT	CESAL 5 2037 LEFT	CESAL 5 2037 RIGHT
(2) Light Vehicles	1993,98641	3314,314781	-	-	-	-	-	-
(5B) Large Bus	985,585961	1334,428708	1,2	1,3	5195938,80	7044700,27	5628933,70	7631758,62
(6B) 2-Axle Truck	379,861	1101,447609	3,5	4,9	5840920,79	16959685,17	8177289,10	23743559,24
(7A2) Heavy 3-Axle Truck	297,729	620,0742096	5,7	9,2	7455630,93	15549070,08	12033649,93	25096744,70
(7A3) Heavy 3-Axle Truck	338,795	669,0274366	-	-	-	-	-	-
(7B1) Heavy 4-Axle Truck	160,842	546,644369	-	-	-	-	-	-
(7C2A) Heavy 5- Axle Truck	54,755	73,42984061	2,6	3,5	625437,08	839908,22	841934,53	1130645,68
TOTAL KI, KA CESAL ACTUAL 2024					19117927,59	40393363,74	26681807,25	57602708,23
TOTAL CESAL ACTUAL 2025					59511291,331		84284515,484	

3.6 Road Operational Performance

Traffic data indicates a dominance of light vehicles (>60%), but heavy vehicles still contribute significantly to the Equivalent Standard Axle (ESA). Based on LHR growth calculations, the cumulative multiplier factors are obtained:

- Left direction: 1,90
- Right direction: 2,52

Assuming a base capacity of C_0 = 1650 vehicles/hour, the MKJI adjustment factor is applied to ensure the degree of saturation (DS) remains below 0.80 until the end of the design life. This indicates the road's service level remains adequate and efficient for two-way traffic operations.

3.7 Design Feasibility Evaluation

- Road Geometry: meets PDGJ 2021 criteria; overlapping control between curves is OK and stopping sight distance is achieved.
- Pavement: structure meets MDP 2024 for CBR 6%; layer thickness is appropriate for medium traffic.
- Drainage: channel capacity is adequate; flow velocity is < the permitted limit; there is no potential for flooding.
- Operational Performance: DS < 0.80 indicates good traffic service until the end of the design life.

DOI: https://doi.org/10.31004/riggs.v4i4. 5099

Overall, the Subang road design has met the technical criteria for geometry, structure, and hydrology in accordance with national standards, and is suitable for proceeding to the working drawing and construction cost planning stages**.**

4. Conclusion

Based on the results of the geometric analysis, pavement structure, and drainage system on the Subang Road section STA 0+000 – STA 3+000, Subang Regency, the following conclusions were obtained: 1). Road Geometric Aspects. The horizontal and vertical geometric designs produced have met the requirements of the 2021 Road Geometric Design Guidelines (PDGJ). There are four main curves consisting of three Full Circles and one Spiral-Spiral (S-S) with a design speed of 80 km/h. The overlapping control results between curves are safe, and the stopping sight distance of ±129.59 m meets the standards for suburban roads. The vertical elements also meet the requirements for driving comfort and safety with smooth gradient transitions on each convex and concave curve. 2). Road Pavement Aspects. Based on the subgrade CBR value of 6% and a design life of 12 years, the planned flexible pavement structure uses a combination of layers: a). Surface Layer: HRS–BC (40 mm), c). Upper Foundation Layer: Class A Aggregate (200 mm), c), Lower Base Course: Class B Aggregate (150 mm). This structure complies with the 2024 Pavement Design Manual (MDP) for medium bearing capacity soil and medium to heavy traffic volumes, and is capable of effectively distributing traffic loads until the end of its planned service life. 1). Road Drainage Aspects. Calculations using the Rational and Manning methods show a design flow rate Q = 1.13 m^3/s and channel capacity Qsal = 2.12 m^3/s with a flow velocity V = 1.345 m/s < Vijin 1.5 m/s. Thus, the planned drainage system is capable of accommodating rainwater runoff without causing flooding, erosion, or damage to the pavement layer. 2). Road Operational Performance. Based on traffic data, light vehicles dominate more than 60% of the total daily volume. With a traffic growth rate of 5.5% (left) and 8% (right) and a basic capacity of 1,650 vehicles/hour, the degree of saturation (DS) calculation shows a value of < 0.80, which means that road service conditions are still within safe and efficient limits until the end of the plan period. 3). General Design Feasibility. The overall results show that the Subang road design has met technical standards in terms of geometry, structure, and hydrology, and is feasible to proceed to the detailed engineering design (DED) and budget plan calculation (RAB) stages. The implementation of this design is expected to improve regional connectivity, facilitate transportation flows, and support economic growth in Subang Regency.

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