

MODELLING GEOMETRIC DESIGN OF A RING ROAD AS A TRAFFIC CONGESTION MITIGATION STRATEGY FOR RAILWAY LEVEL CROSSING

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ABSTRACT: Railway level crossings on primary arterial roads frequently cause significant congestion due to regular train movements, resulting in long queues and disruption at nearby intersections. This study proposes a geometrically designed ring road as an alternative traffic network to reduce congestion along the Kadungora–Garut corridor in West Java, Indonesia. A quantitative engineering approach was applied by integrating multi-criteria route screening, constraint-based geometric design, and traffic performance analysis. Route selection considered topographic, geological, environmental, land acquisition, and traffic factors, followed by detailed horizontal and vertical alignment design in accordance with Indonesian highway standards. The proposed ring road is 2.95 km in length and designed as a 4/2D facility with a design speed of 80 km/h, serving a projected average daily traffic (LHRT 2024) of 13,145 smp/day. The alignment includes five Spiral–Circle–Spiral horizontal curves and six vertical intersection points that meet geometric requirements for curvature, gradients, and stopping sight distance. Traffic evaluation shows that diverting through traffic to the ring road can reduce queue lengths at the railway crossing by approximately 45–55% during peak hours and improve the level of service from E to C. The alternative route also provides travel time savings of 6–9 minutes per vehicle during train closures while limiting congestion spillback. The selected alignment primarily crosses agricultural land, reducing land acquisition impacts and associated costs, demonstrating the effectiveness of constraint-based ring road planning for improving intercity traffic performance.

Keywords: Overpass Design, Traffic Congestion, Level Crossing Mitigation, Geometric Alignment.

1. INTRODUCTION

Road network infrastructure is one means of transportation that connects one region to another and has an important role in the survival of society as a means of movement of people and goods [1–3]. The highway is also one of the factors supporting economic growth, socio-cultural, and tourism in an area or region [4–6]. The economy of the community in an area will increase rapidly with the construction of road infrastructure. Therefore the highway must fulfill its function as quality as well as quantity.

The smoothness of traffic on the highway is greatly influenced by the level of service capabilities that can be provided by each section of the highway, namely by the width of the road and the number of lanes [7,8]. The more the amount of traffic that burdens a road, the traffic becomes increasingly crowded [9]. This situation can be interpreted that the traffic density is becoming higher, therefore there is a need to improve road services. Improvement of road services can be done in quantity with regard to the addition of the number of lanes and road widening [10].

Kadungora Highway is a road with type 2/2 TT with national road status and with primary collector

road classification. The road has a railway crossing. At the intersection, there is a queue density caused by delays when trains pass. The queue caused blocking at several nearby intersections.

Based on the description, it is necessary to plan a new highway network as an alternative to main roads to reduce queue density due to delays at intersections of railway crossings. Therefore, this study was conducted to analyze the geometric planning of the ring road which includes the calculation of horizontal alignment and vertical alignment.

Previous studies have explored various aspects of highway geometric design, traffic flow optimization, and alternative alignment planning. For example, Wang shows investigated the safety implications of horizontal and vertical alignments in 3D highway layouts, demonstrating how geometric parameters directly impact crash frequency and severity [11]. In another research, Development of Motorway Horizontal Alignment Databases and Their Use in Safety Models, De Santos-Berbel et al., proposed a methodology to extract accurate horizontal alignment data over 150 km of motorway, highlighting large discrepancies between inventory and actual geometry that affect performance modelling [12]. Moreover, Khan et al., developed a BIM based framework

integrating traffic dynamics and alignment design in a bypass project in Pakistan, showing how alignment planning can directly support traffic congestion mitigation [13]. More recent studies have extended this body of knowledge toward railway related operational and safety issues. Anagnostopoulos applied microsimulation techniques to evaluate safety and queue dynamics at railway level crossings, demonstrating that infrastructure design and traffic control strategies strongly influence spillback and operational reliability [14]. Using a multi-criteria decision making approach, Kriswardhana et al. show through a bibliometric and systematic review that AHP and hybrid MCDM methods are widely used in transportation planning to support multi-criteria infrastructure and corridor selection, thereby providing a strong methodological basis for applying AHP-based route screening in ring road alignment planning [15]. Furthermore, Supriyatno et al. emphasized the need for context-specific design solutions and regulatory alignment in managing highway rail crossings, particularly in developing country settings [16]. While these studies collectively underline the importance of geometric design, safety assessment, and decision-support frameworks, they generally address these aspects in isolation. A methodological gap remains in integrating multi-criteria route evaluation, locally calibrated traffic growth, and detailed geometric design into a unified framework that is consistent with current speed design standards and corridor-specific conditions, forming the basis for the present study on the Kadungora Garut ring road.

2. RESEARCH SIGNIFICANCE

This study is significant in advancing geometric design and transportation infrastructure planning by developing an optimized ring road design to reduce traffic congestion caused by railway crossings along the Kadungora Garut corridor. The proposed geometric planning enhances road network efficiency, safety, and mobility performance, aligning with sustainable urban transportation goals. The findings provide a practical framework for highway geometric analysis and can serve as a reference for policymakers and engineers in developing alternative road systems for regions facing similar traffic management and topographical challenges.

3. RESEARCH METHODS

The location of this study is at the intersection of railway crossings on the highway Kadungora-Garut, the road is located in the District of Kadungora, Garut Regency, West Java, Indonesia. The method used is a quantitative descriptive method, with an approach that is intended to describe or explain a situation objectively using data in the form of numbers, starting

from the data collection process to the interpretation and presentation of the results.

This study was conducted by analyzing secondary data obtained from various sources. The secondary data is geographic data in the form of topographic maps and land use at the research site. The research data in Table 1 were used in this study. Computational programming for accurate road planning, aimed at planning results images.

Table 1. Research Data

Data	Sources
Topographic Maps and Land Use Maps	National DEM Data (ArcGis software output) Indonesia Terrain Map (ArcGIS software output) Map Open Street Map (ArcGIS software output)
Traffic Counting Data	Tranportation Department Garut District Public Work Department Garut Districtt

The methodology is based on a land use speed design approach to terrain/road topography, geography, and geological environmental factors. All of these influence the basic parameters of volume for road capacity and geometry, as well as large vehicle factors. The variables described above are parameters whose influence has been identified as indicators of their relationship to the development of a geometric design model.

After obtaining the required data then proceed with processing and calculation as follows:

1. Geometric planning of ring road which includes calculation of horizontal alignment, vertical alignment, side freedom distance, widening at bends and cross sections.
 - Horizontal alignment inculdes:
 - Horizontal arch (Full Circle, Spiral-Circle-Spiral dan Spiral-Spiral), determination of the length of the transitional arch.
 - Widening of the carriageway around the corner.
 - Side freedom around the corner.
 - Vertical alignment includes:
 - The calculation of the convex vertical arch on two circumstances, that is, if the viewing distance is less than the length of the vertical arch ($S < L$) and if the viewing distance is greater than the vertical arch ($S > L$).
 - The calculation of the concave vertical arch based on the stopping viewing distance.

The flowchart for this study is shown in Fig. 1.

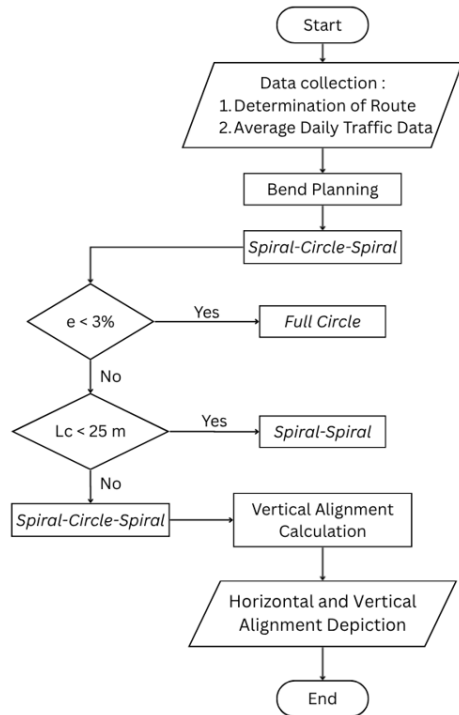


Fig. 1 Flowchart of the research

Technical indicators related to geological structure conditions are determined based on the proximity of the fault location to the alternative route plan used, as presented in Table 2. Suprayitno et al. explain that the closer the fault is to the route, the higher the risk of road infrastructure damage due to fault activity that could potentially cause deformation of the road surface [17]. The assessment table is intended to review the design conditions with the design shown, and it is hoped that the correlation will not be too high. This design therefore meets the requirements for the intended development plan

Table 2 Geological structure scores and indicators

Score	Fault Location	Quantitative Indicators *)
1	Very Far	Pixel distance to fault > 20.0 km
2	Far	Pixel distance to fault 10.0 – 20.0 km
3	Near	Pixel distance to fault 5.0 – 10.0 km
4	Very Near	Pixel distance to fault < 5.0 km

Technical indicators of lithology refer to the characteristics of rocks or subsurface geological structures at the original site, as listed in Table 3. If the geological formations along the alternative routes are dominated by volcanic rocks, the level of road damage due to geological dynamics tends to be lower. Geometric road technical indicators refer to the

longitudinal slope or gradient characteristics of a roadway alignment in Table 5, serve as a fundamental parameter in evaluating the geometric feasibility and operational performance of a route.

Table 3 Scores and lithological indicators

Score	Ease of Damage Pavement Damage	Quantitative Indicators *)
1	Very difficult to damage	Volcanic (Tertiary volcanic eruption products)
2	Difficult to damage	Sediment (Peat and swamp deposits)
3	Easy to damage	Alluvium (Semi-hard and massive rocks)
4	Very easy to damage	Colluvium (Soil from landslides/debris)

Technical indicators for soil type assessment are determined based on soil characteristics and classification according to geological and geotechnical aspects, as shown in Table 4. Amayke et al. states that the higher the clay content in the soil, the more difficult it is to handle road pavement and the higher the construction costs [18]. Clayey soils are given the highest score, so that alternative routes are designed to avoid subgrade conditions with predominantly clayey characteristics [19].

Table 4. Soil score and indicators

Score	Soil Support Capacity Level	Soil Type	Quantitative Indicators *)
1	Very strong	Litosol, Umbrisol, Alluvial, Renzina, Entisol, Vertisol, Grumusol, Regosol, Arenosol	Silt
2	Strong	Andosol, Latosol, Molisol	Silt Sandy
3	Weak	Kambisol, Ultisol, Gleisol, Inseptisol, Nitosol, Podsolik, Alfisols, Planosol, Mediterranean	Silt loam, Loam silt
4	Very weak	Podsol, Oksisol, Lateritic, Orgonosol	Loam

Salihu et al. explain that higher gradient values indicate increasingly steep geometric conditions, which can significantly influence vehicle operating speeds, fuel consumption, safety levels, and design constraints, particularly in hilly or mountainous terrain where compliance with design standards becomes more critical. [20].

Table 5 Road scores and geometric indicators

Score	Slope Ectension	Quantitative Indicators *)
1	Flat road geometry	Gradient 0.0 – 3.0%
2	Gentle road geometry	Gradient 3.0 – 10.0%
3	Steep road geometry	Gradient 10.0 – 24.0%
4	Very steep road geometry	Gradient > 24.0%

Technical indicators of traffic volume are determined based on the average number of vehicles passing through, as shown in Table 6. Nauatiyal and Sharma state that the higher the traffic intensity on an alternative route, the greater the priority needed in handling and managing its infrastructure [21].

Table 6 Traffic score and volume indicators

Score	Volume Level Vehicles	Quantitative Indicators *)
1	Road capacity improvement urgent	Average number of vehicles > 1,000.0
2	Road capacity improvement is necessary	Average number of vehicles 501.0 - 1,000.0
3	Road capacity improvement is rarely necessary	Average number of vehicles 101.0 – 500.0
4	Road capacity improvement is not yet necessary	Average number of vehicles 0.0 –100.0

Technical indicators of geological bearing capacity refer to the Geological Strength Index (GSI) values, as listed in Table 7. Islam et al. explain that the higher the GSI value, the greater the ability of the rock to support road pavement loads, so that planned routes should pass through areas with high GSI values [22].

Table 7. Rock support score and indicators

Score	Durability Level Road	Quantitative Indicators *)
1	Very high	> 50.0 Geological Strength Index (GSI)
2	High	40.0 – 50.0 Geological Strength Index (GSI)
3	Low	30.0 – 40.0 Geological Strength Index (GSI)
4	Very low	< 30.0 Geological Strength Index (GSI)

Technical indicators related to water boundaries are determined based on the proximity of the route to river flows, as listed in Table 8. Kastridis explains that the greater the distance between the route and the river, the safer the road construction is from potential environmental disturbances to the waterways, so routes that are too close to rivers should be avoided [23].

Table 8. Water boundary scores and indicators

Score	Distance to the River Center Line	Quantitative Indicators *)
1	Very far	River distance > 200.0 m
2	Far	River distance 150.0 – 200.0 m
3	Close	River distance 100.0 – 150.0 m
4	Very close	River distance ≤ 100.0 m

The river order technical indicator refers to the bridge span required to cross a river, as shown in Table 9. The river order represents the level of complexity of bridge construction based on the span size. Öztürk et al. adds that the higher the river order, the greater the difficulty and cost of road infrastructure construction, so the selection of the route must consider the most appropriate and economical river order [24].

Table 9. River order score and indicators

Score	Level of Ease Crossing Rivers Span Bridge	Span Bridge	Quantitative Indicators *)
1	Very easy	Not a bridge	Not a bridge
2	Easy	Bridge span 20.0–40.0 m	Orde 1 (10.0 m) Orde 2 (20.0 m)
3	Difficult to cross	Bridge span 20.0–40.0 m	River order 3 (50.0 m)
4	Very difficult to cross	Bridge span 20.0–40.0 m	River order 4 (110.0 m) River order 5 (>110.0 m)

Technical indicators for land acquisition are determined based on land ownership status and land use, as listed in Table 10. He et al. explain that the closer the land is to restricted areas or conservation areas, the higher the level of difficulty and cost involved in the land acquisition process for road infrastructure development [25]. Technical indicators for forest areas are based on the existence

of forest areas around alternative route options, as shown in Table 11. The assessment of forest areas differs from land cover indicators, because the process of land acquisition in forest areas has a more significant environmental impact on the surrounding ecosystem [19].

Table 10. Land cover score and indicators

Score	Ease Score Land Acquisition	Quantitative Indicators *)
1	No costs or administration required	- Roads
2	Low costs, easy administration	- Open land - Dry land farming - Scrubland - Rice fields - Plantations
3	High costs, difficult administration	- Forests
4	High costs, difficult administration	- Settlements - Historical sites - Waterways (lakes/ponds, swamps, rivers, fish ponds, pools) - Mining - Marine training sites

Table 11. Forest area scores and indicators

Score	Level of Ease of Land Acquisition	Quantitative Indicators *)
1	No costs or administration required	Non-Forest Areas
2	Low costs, relatively easy administration	Production Forests (secondary dryland forests, plantation forests)
3	Relatively high costs, difficult administration	Protected Forests
4	Very difficult administration/cannot be released	Conservation Forests (nature reserves, nature conservation areas)

The technical indicators for slopes are determined based on the measured slope gradients within the terrain surrounding each alternative route, as presented in Table 12, reflecting the topographic conditions that directly influence geometric design feasibility, construction complexity, vehicle performance, and overall operational safety along the proposed alignment. Technical indicators of rainfall are determined based on the intensity or level of rainfall, as listed in Table 13. The closer the

alternative route is to an area with high rainfall, the greater the potential for seepage and puddles to form on the road surface, which can ultimately accelerate damage to the pavement layer [26,27].

Table 12. Slope score and indicators

Score	Safety Level	Slope Type	Quantitative Indicators *)
1	No slope	Flat	Slope 0–2%
2	Stable and safe	Gentle	Slope 2–14%
3	Dangerous	Steep	Slope 15–25%
4	Very dangerous	Very steep	Slope > 25%

Table 13. Rainfall score and indicators

Score	Damage Level	Rainfall	Quantitative Indicators *)
1	Rare	Low	0.0 – 100.0 mm
2	Slow	Medium	101.0 – 300.0 mm
3	Fast	High	301.0 – 500.0 mm
4	Very fast	Very high	> 500.0 mm

To improve methodological rigor in route selection, this study formulates a constraint-based linear regression model to quantify route feasibility. The dependent variable Y represents a Route Feasibility Index, while the independent variables X_1 – X_{12} describe geological, geotechnical, geometric, environmental, land-use, and traffic-related conditions derived from standardized scoring criteria. The model is expressed as:

$$y = \beta + \beta X_1 + \beta X_2 + \beta X_3 + \dots + \beta X_{12} \quad (1)$$

where:

- X_1 : Geological structure score
- X_2 : Lithology score
- X_3 : Soil type score
- X_4 : Road slope (gradient) score
- X_5 : Traffic volume score
- X_6 : Rock bearing capacity (GSI) score
- X_7 : Distance to river score
- X_8 : River order score
- X_9 : Land acquisition score
- X_{10} : Forest area constraint score
- X_{11} : Rainfall intensity score
- X_{12} : Design geometry compliance score (curvature, sight distance, and speed consistency)

In the absence of observed dependent variable data, the regression formulation is applied as a deterministic analytical model, where coefficients β_i are predefined based on engineering relevance rather than statistical estimation. The route selection objective is to minimize Y , subject to explicit geometric and environmental constraints, including maximum allowable gradient, minimum curve radius,

stopping sight distance requirements, and restricted land-use zones. Route alternatives that violate these constraints are excluded during the screening stage. Sensitivity analysis is inherently represented by the regression coefficients, where each β_i reflects the relative influence of the corresponding parameter on route feasibility. This formulation enables transparent route comparison, constraint enforcement, and robustness assessment within the geometric design process.

4. RESULT AND DISCUSSION

4.1 Trase Plan

The proposed ring road alignment extends for approximately 2.95 km, designed as an alternative route to bypass the existing congested railway intersection. The alignment begins before the railway crossing on the main highway, passes through paddy field areas, and reconnects beyond the railway line. The alignment design incorporates five points of intersection (PI) utilizing the *Spiral–Circle–Spiral* (SCS) curve type, ensuring smooth directional transitions and optimal driving comfort, particularly at high design speeds is presented on the Fig. 2 and

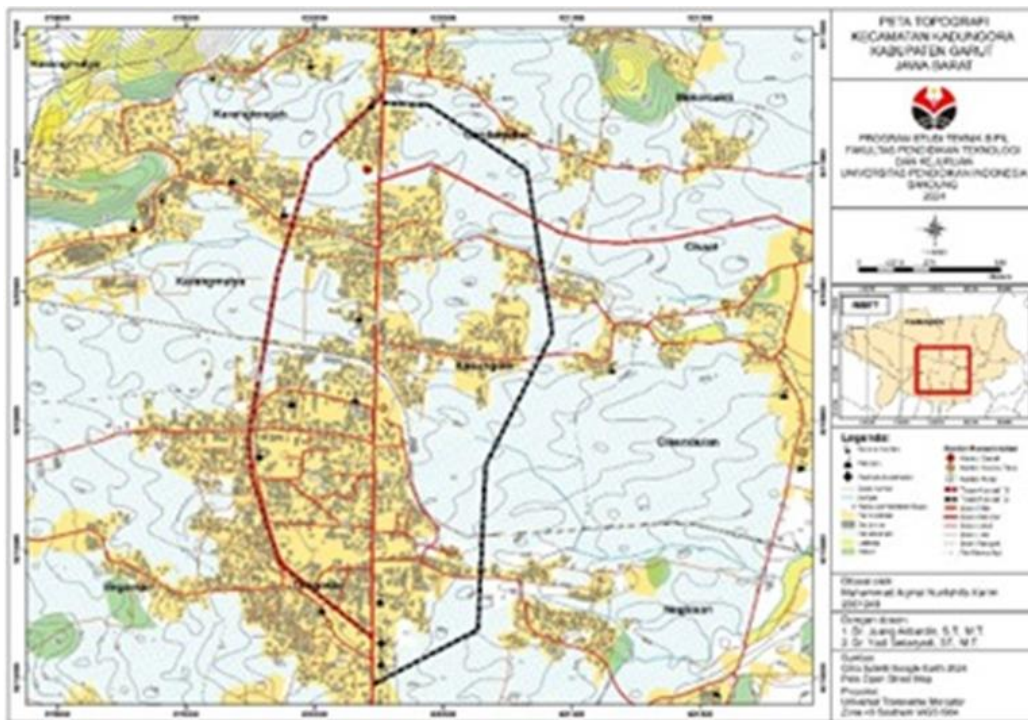


Fig. 2 Alternative trase plan (Source: Analysis Results, 2024)

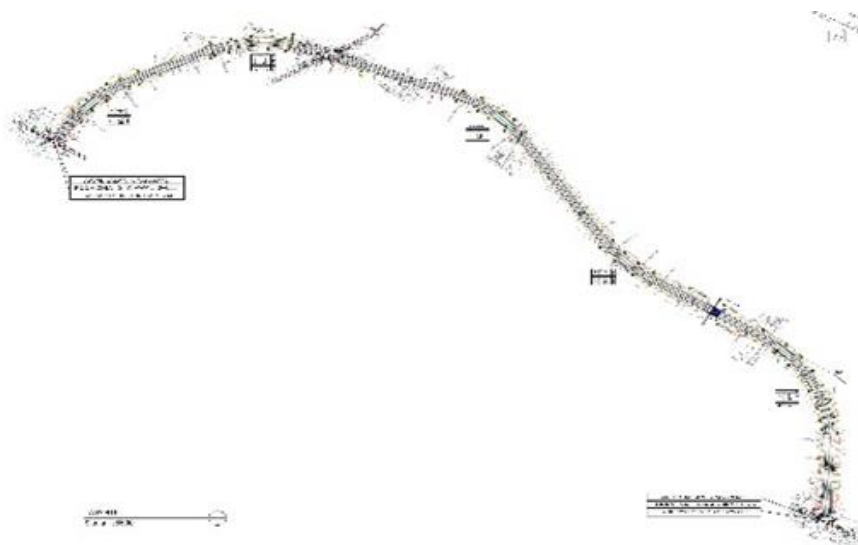


Fig.3 Selected plan of the trase ringroad

Fig. 3.

Table 14. Data LHR road Kadungora-Garut

CLAS	NUMBER OF VEHICLE			Num. Of Vehicle	EPC			Num. Of PCU
Time	LV	HV	MC		LV	HV	MC	
Vehicle Type Group					1	1.3	0.25	
BDG-GARUT	18,777	4,625	23,412	46,814	18,777	6,013	5,853	30,643
GARUT-BDG	29,678	5,496	17,385	52,559	29,678	7,145	4,346	41,169
Total (3 days)	48,455	10,121	40,797	99,373	48,455	13,157	10,199	71,812

4.2 Average Daily Traffic Data

LHR Data used in this study using secondary data sourced from Bina Marga West Java Province. These data were collected through traffic enumeration surveys conducted along the Kadungora–Garut highway segment from September 21 to September 23, 2022. The enumeration process involved both manual and automatic traffic counts, covering two-way traffic flows for various vehicle classes, including light vehicles (LV), motorcycles (MC), and heavy vehicles (HV). Data collection was carried out during peak and off-peak hours to ensure representative daily averages and capture variations in traffic behavior throughout the day.

Traffic data uses traffic predictions based on the geometric rate of growth method using existing annual data, utilizing primary traffic counting data and secondary data. The recorded traffic volumes were subsequently processed and converted into Passenger Car Units (smp) is used for standard equivalence before determining vehicle traffic volume. The standard used is the 2023 Indonesian inter-city road geometric planning guidelines., enabling consistent comparison across different vehicle categories. The processed data were analyzed to identify traffic patterns, distribution characteristics, and dominant vehicle compositions within the study corridor. The resulting dataset provides a comprehensive overview of the existing traffic conditions and serves as the foundation for forecasting traffic growth, determining the design service volume, and establishing geometric design parameters for the proposed Kadungora Ring Road. The detailed results of the traffic enumeration are presented in Table 14.

The LHR is averaged into 2 directions and averaged over 3 days of observation, then the LHR value in 2022 will be 11,969.59 smp/Day/ 2 directions. After obtaining LHR data in 2022, traffic growth is calculated to 2024, where the road is planned to be operated in 2024. This calculation used a traffic growth rate factor of 4.8%, for arterial and urban roads in Java.

Traffic growth to the plan year using Equation 2

$$LHRT_n = LHRT_o(1 + i)^n$$

$$LHRT_{2024} = 11.969,59(1 + 4.8\%)^2$$

$$LHRT_{2024} = 13.145,15 \text{ smp/ day/ 2 way} \quad (2)$$

Table 15. Horizontal curve calculation

Curve Parameters	Point				
	PI-1	PI-2	PI-3	PI-4	PI-5
Δ (°)	31	47	36	24	60
V_D (km/h)	80	80	80	80	80
R_c (m)	400	360	400	400	400
L_s (m)	66.67	66.67	66.67	66.67	66.67
Y_C (m)	1.85	2.06	1.85	1.85	1.85
X_C (m)	66.62	66.61	66.62	66.62	66.62
θ_s (°)	4.77	5.31	4.77	4.77	4.77
ΔC (°)	21.45	36.39	26.45	14.45	50.45
k (m)	33.33	33.32	33.33	33.33	33.33
p (m)	0.46	0.52	0.46	0.46	0.46
T_s (m)	144.38	190.08	163.44	118.45	264.53
E_s (m)	15.58	33.12	21.07	9.41	62.42
L_c (m)	149.75	228.64	184.66	100.88	352.21
L total (m)	283.09	361.98	317.99	234.22	485.55

4.3 Basic Geometry Road Planning

In the geometric planning of the new road as an alternative intersection plot on the highway Kadungora-Garut using data that has been determined as follows:

- Road Classification : Secondary Highway II A
- $LHRT_{2024}$: 13.145,15 smp/ day/ 2 way
- VD (km/h) : 80
- Pavement Width : 2 x (2 x 3,5 m)
- Median Width : 1.5 m
- Outer Shoulder Width : 1.5 m
- Inner Shoulder Width : 0.5 m
- Max Cross Slope : 8%
- Max Number Of Longitudinal Slope : 5%

The design speed (VD) of 80 km/h and the selected road classification were determined in accordance with the Indonesian geometric design guidelines issued by the Directorate General of Highways (PDGJ/2021) and national technical requirements for road planning. These standards ensure consistency between projected traffic demand, safety performance, and the geometric elements of intercity ring roads [28].

4.4 Horizontal Alignment Design

The horizontal alignment planning involved five curvature segments located at the five PI points, as summarized in Table 15, with curve radii ranging between 360 m and 400 m and a uniform transition curve length of 66.67 m. The SCS curve type was selected to ensure a gradual change in curvature, minimizing centrifugal forces and enhancing driving comfort. The alignment layout and geometric parameters, as shown in Figs. 4–7, were validated against national standards, confirming that all horizontal curve parameters satisfy the minimum radius and transition length requirements for the selected design speed.

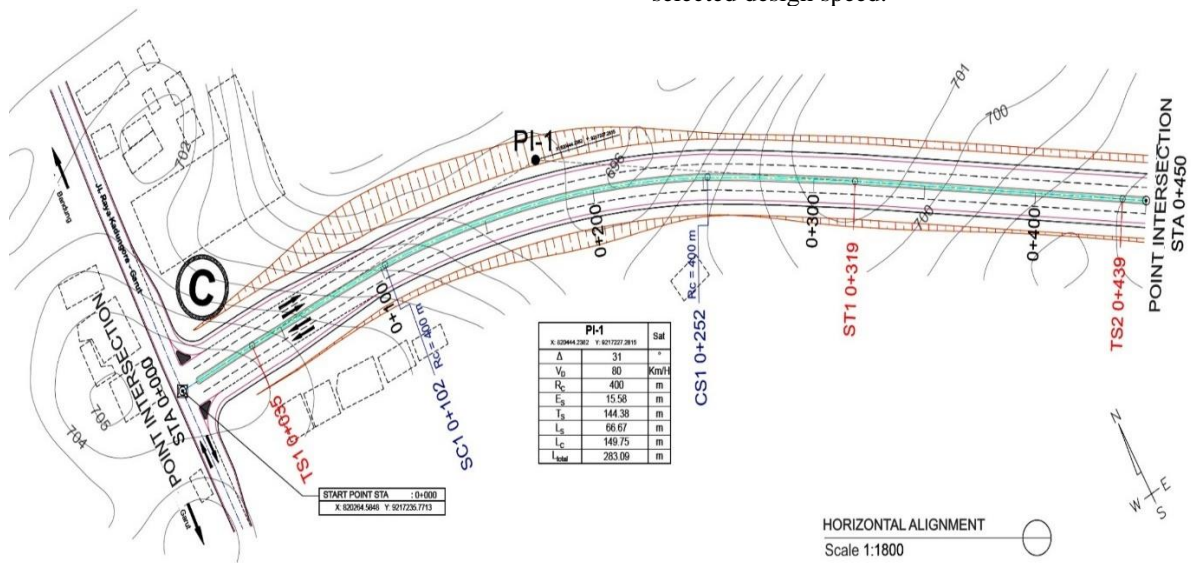


Fig. 4 plan of Long section sta. 0+000 – sta. 0+450 (Source: Analysis Results, 2024)

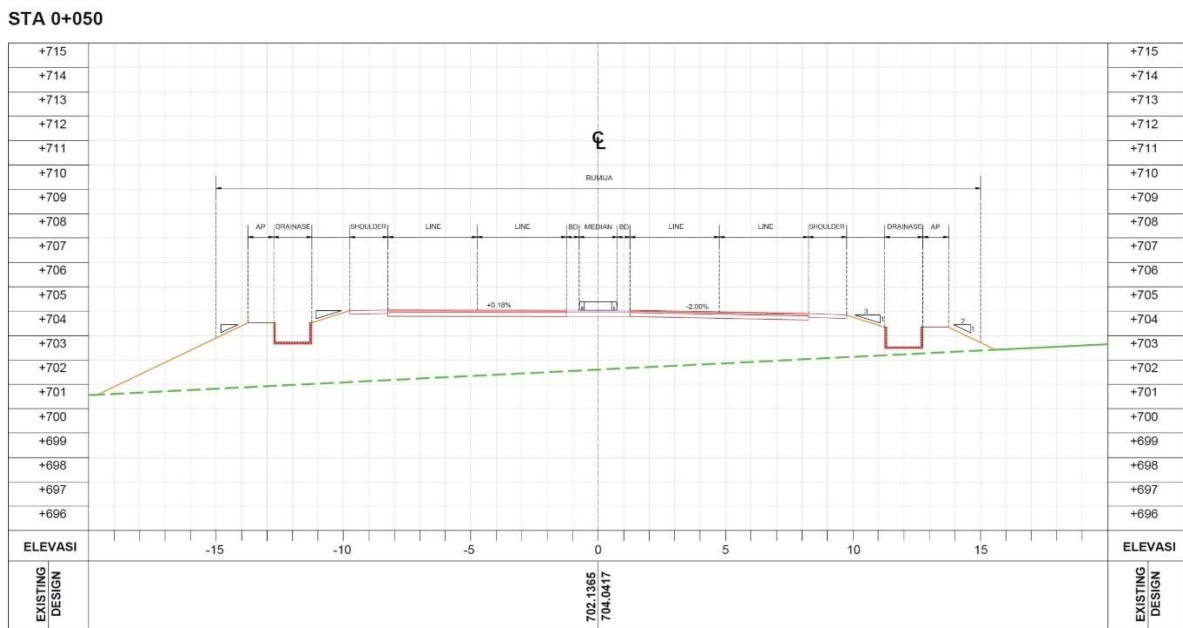


Fig. 5 Cross section sta. 0+50 (Source: Analysis Results, 2024)

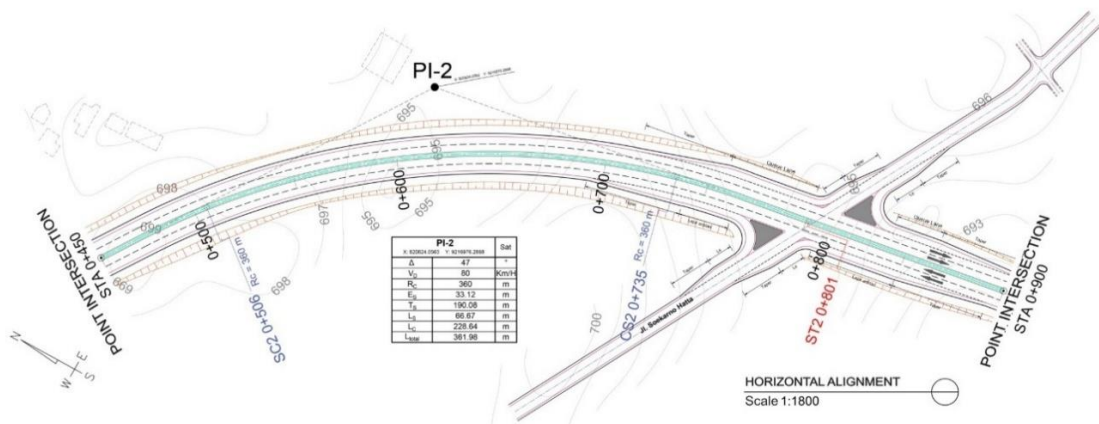


Fig. 6 Plan of long section sta 0+450 – sta 0+900 (Source: Analysis Results, 2024)

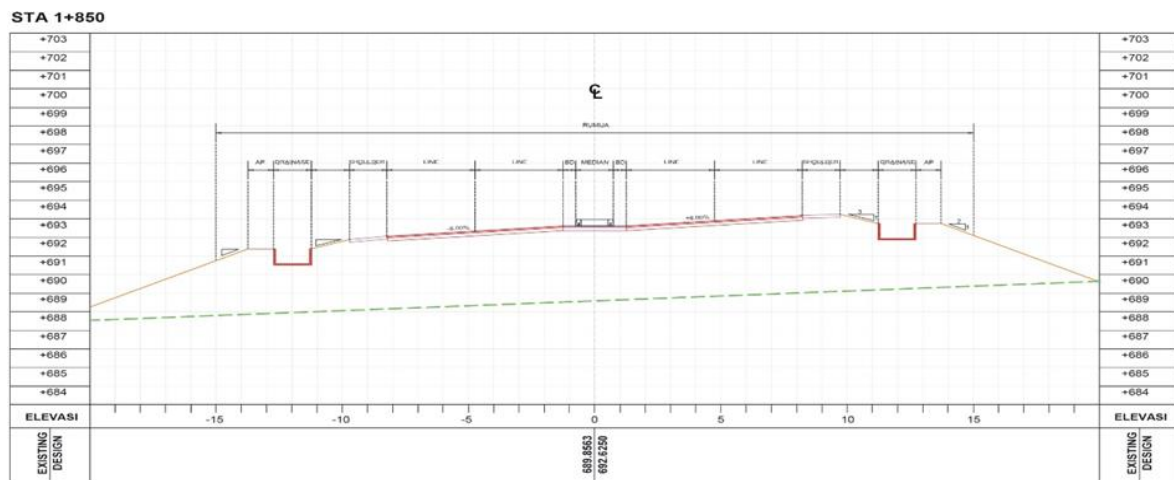


Fig. 7 Cross Section STA 1 + 850 (Source: Analysis Results, 2024)

4.5 Vertical Alignment Design

Five profile vertical intersections (PVI) were identified from the comparison between the existing ground longitudinal grades and the planned alignment grades. The elevations for these five PVI, which mark the locations of grade changes along the alignment, are listed in the elevation table for the longitudinal profile in Fig. 8. These PVI elevation

values were used to define the vertical geometry and to calculate grade lengths, slopes between PVI, and any required vertical curve parameters for the final design, as shown in Figs. 9–12. The elevation table is provided in Table 17 for reference and further analysis. The design of vertical curves does not exceed the maximum limit of the specified standard of 8%.

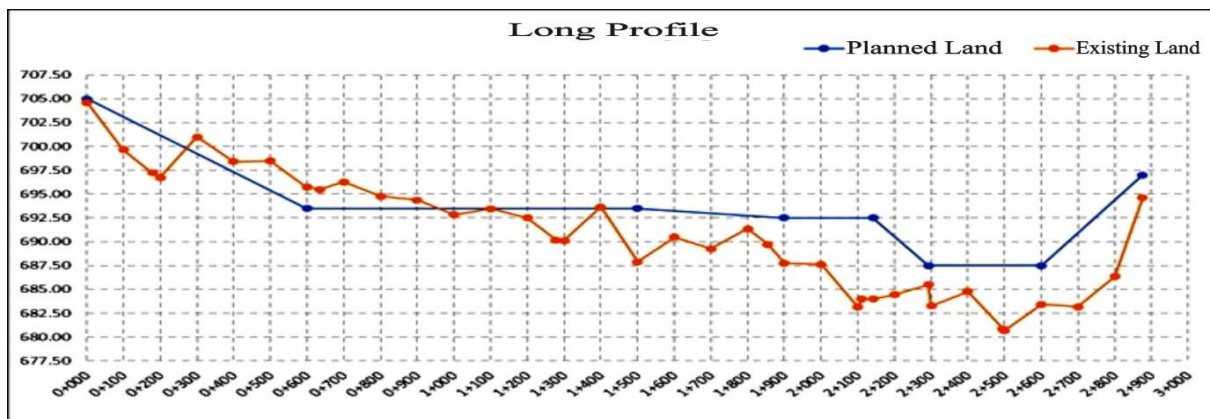


Fig. 8 Long Profile (Source: Analysis Results, 2024)

4.5.1 Stopping Sight Distance

The calculation of stopping sight distance is needed to determine the length of the vertical curve and aims to make road users feel safe and comfortable while driving. The stopping sight distance used is based on the planned vehicle JPH, namely a truck. The JPH value is obtained:

$$J_{PH} \text{ truck} = 142m \quad (\text{PDGJ/ 2021/ ex: 78})$$

4.5.2 Stopping Sight Distance

In this vertical alignment planning, two types of vertical curves are used, namely concave and convex. Calculation of vertical curves for example at point PVI-1 as follows:

$$\begin{aligned} V_D &= 80 \text{ km/h} \\ J_{PH} &= 142 \text{ m} \\ K J_{PH} &= 30 \quad (\text{PDGJ/ 2021/ ex: 160}) \end{aligned}$$

Determining the gradient and difference in algebraic slopes.

$$\begin{aligned} G1 &= -1.92\% \\ G2 &= 0.00\% \\ A &= (G1 - G2) \\ &= -1.92 - 0.00 \\ &= -1.92\% \quad (\text{Concave curve}) \end{aligned}$$

Determining the length of the concave L_V

- L_V length based on comfort factor

$$\begin{aligned} L &= \frac{V_D^3}{3600} \times 1000 \times 3 \\ L &= \frac{80^3}{3600} \times 1000 \times 3 = 66.67 \text{ m} \end{aligned}$$

Based on several results of the calculation of the vertical curve length above, the L_V value of PVI-1 = 66.67 m is obtained. For all vertical curves, calculations are presented in Table 16. The length of this vertical curve is designed based on an empirical formula comparing the design speed with variables determined based on the PDGJ/2021 standard.

Table 16. Vertical curve calculation

L_V (m)	Point					
	PVI-1	PVI-2	PVI-3	PVI-4	PVI-5	PVI-6
G1 (%)	-1.92%	0.00%	-0.25%	0.00%	-3.31%	0.00%
G2 (%)	0.00%	-0.25%	0.00%	-3.31%	0.00%	3.45%
A (%)	-1.92%	0.25%	-0.25%	3.31%	-3.31%	-3.45%
Arch Type	(CONCAVE)	(CONVEX)	(CONCAVE)	(CONVEX)	(CONCAVE)	(CONCAVE)
L _V length for $J_{PH} < L_V$						
L_V (m)	62.64	12.63	8.17	167.38	108.24	112.67
L _V length for $J_{PH} > L_V$						
L_V (m)	-37.91	-1312	-2184	163.53	87.72	105.04
Minimum L_V length						
L_V (m)	48	48	48	48	48	48
L _V length based on comfort factor						
L_V (m)	66.67	66.67	66.67	66.67	66.67	66.67
L _V length based on vertical curvature						
$L_V J_{PH}$ (m)	57.5	6.5	7.5	86.12	99.36	103.43
$L_V J_{PM}$ (m)	-	17.5	-	-	-	-
Design L_V length						
L_V (m)	66.67	66.67	66.67	86.12	99.36	105.04

Table 17. Stationing and elevation calculation of curved parameter points

Parameter Point	Point					
	PVI-1	PVI-2	PVI-3	PVI-4	PVI-5	PVI-6
EV (m)	-0.16	0.02	-0.02	0.69	-0.41	-0.45
STA PVI	0+600	1+500	1+900	2+141	2+292	2+600
STA PLV	0+567	1+467	1+867	2+057	2+242	2+547
STA PTV	0+633	1+533	1+933	2+225	2+342	2+653
EVI (m)	693.50	693.50	692.50	692.50	687.50	687.50
ELV (m)	694.14	693.50	692.58	692.50	689.15	687.50
ETV (m)	693.50	693.42	692.50	689.73	687.50	689.31

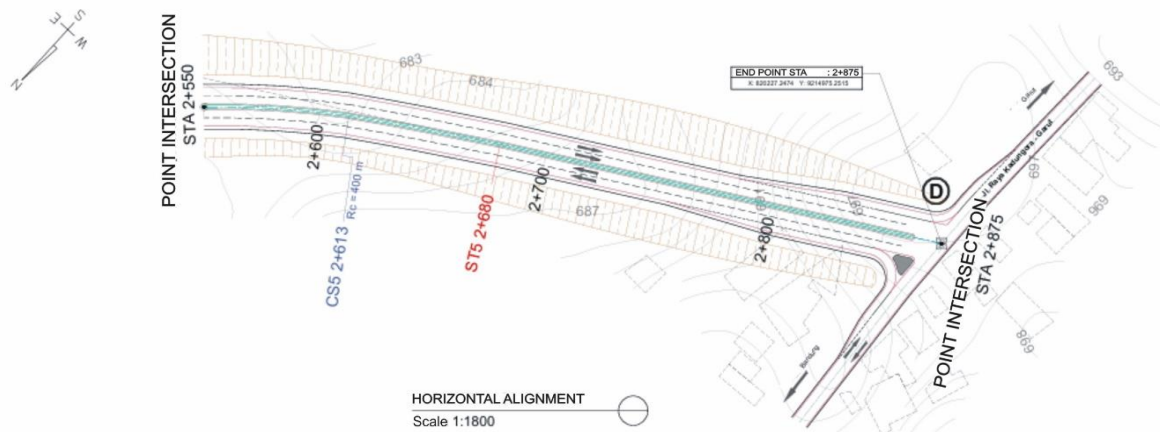


Fig. 9 Plan Long section sta 2+550 – sta 2+875 (Source: Analysis Results, 2024)

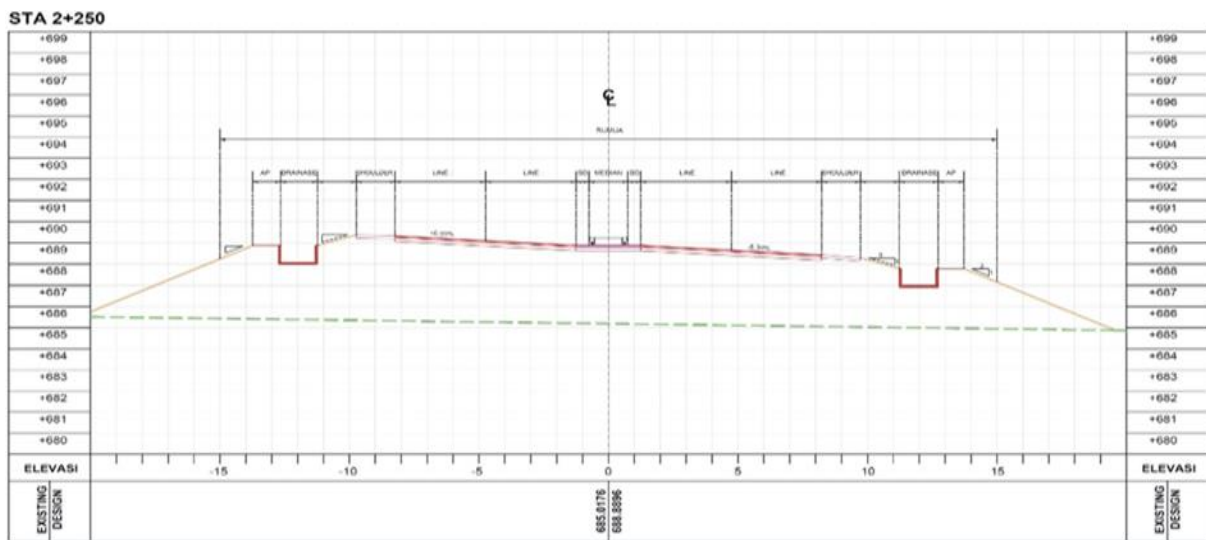


Fig. 10 Cross section 2+250 (Source: Analysis Results, 2024)

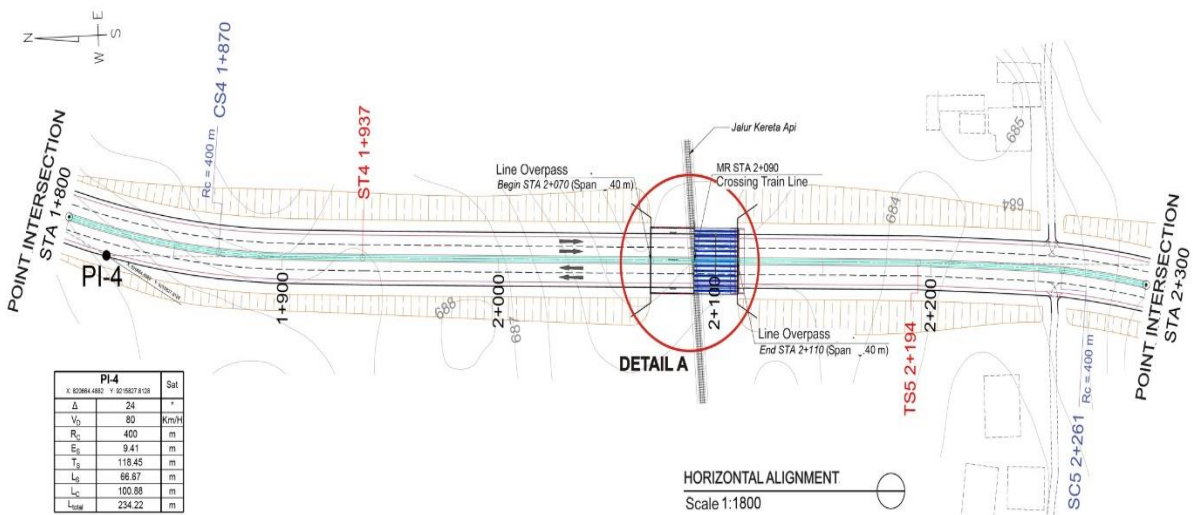


Fig. 11 Plan long section sta 1+800 – sta 2+300 (Source: Analysis Results, 2024)

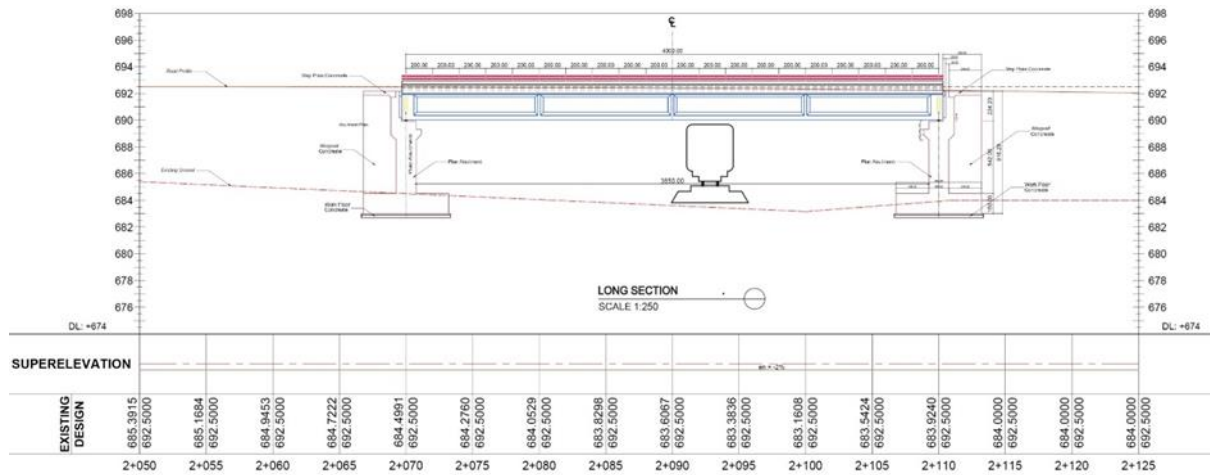


Fig. 12 Detail Cross section 2+100 Longitudinal Profile of the Proposed Road Overpass (Source: Analysis Results, 2024)

5. CONCLUSION

In the geometric planning of the road is planned to use the type of road 4/2 d. 4/2D roads are divided because they are primary arterial roads outside the city according to Indonesian road capacity guidelines, which aim to divide traffic for safer driving., the speed of the plan (VD) of 80 km/h will remain valid for the next 20 years if there are no significant changes in land use. LHRT2024 of 13.145,15 smp/Day/2 directions, pavement width 2 x (2 x 3.5 m), median width 1.5 m, shoulder width in 0.5 m, shoulder width outside 1.5 m, transverse ramps max 8%, and longitudinal ramps max 5%. Planning horizontal alignment there are 5 points of Intersection (PI) with the type of SCS bend and the length of the transition curve 66.67 m. Vertical alignment planning there are 6 Vertical points of Intersection (PI) with 4 concave curves and 2 convex curves.

6. REFERENCES

- [1] Gutman S. and Malashenko M. The Impact of Transport Infrastructure on Sustainable Economic Development of Russian Regions. *Sustainability*. 17(9), 2025, pp. 3776. <https://doi.org/10.3390/su17093776>
- [2] Shi J., Bai T., Zhao Z., and Tan H. Driving economic growth through transportation infrastructure: An in-depth spatial econometric analysis. *Sustainability*. 16(10), 2024, pp. 4283. <https://doi.org/10.3390/su16104283>
- [3] Wan J., Ma C., Jiang T., Phillips A., Wu X., Wang Y., Wang Z. and Cao Y. A spatial econometric investigation into road traffic accessibility and economic growth: insights from the Chengdu-Chongqing twin-city economic circle. *Humanities and Social Sciences Communications*. 11(1), 2024, pp. 1-9. <https://doi.org/10.1057/s41599-024-02695-1>
- [4] Lin Z., Liang Y., and Liu X. Study on spatial form evolution of traditional villages in Jiuguan under the influence of historic transportation network. *Heritage Science*. 12(1), 2024, pp. 29. <https://doi.org/10.1186/s40494-024-01153-0>
- [5] Jangra R., Kaushik S.P., Singh E., Kumar P., and Jangra, P. The role of transportation in developing the tourism sector at high altitude destination, Kinnaur. *Environment, Development and Sustainability*. 26, 2024, pp. 9369-9395. <https://doi.org/10.1007/s10668-023-03099-y>.
- [6] Hu X., Lin S., and Lin R. Influence from highways on regional economic growth-based on the trade potential in China. *Technological and Economic Development of Economy*. 31(1), 2025, pp. 184-210. <https://doi.org/10.3846/tede.2024.21997>
- [7] Aboyeji E., Ajani O.S., and Mallipeddi R. Effect of number of lanes on traffic characteristics of reinforcement learning based autonomous driving. *IEEE Access*. 11, 2024, pp. 80199-80206. <https://doi.org/10.1109/ACCESS.2023.3299860>
- [8] Had A., Ghazali F.E.M., Jew B., and Hassoon A. Sustainable development strategies for improving the efficiency and safety of a highway in Iraq. *Edelweiss Applied Science and Technology*. 9(5), 2025, pp. 43-52. <https://doi.org/10.55214/25768484.v9i5.6775>
- [9] Wedagama D.M.P. The influence of mixed traffic on congestion level and marginal road congestions. *International Journal of GEOMATE*. 17(64), 2019, pp. 18-25. <https://doi.org/10.21660/2019.64.15106>
- [10] Ahmed M.A., Kays H.M.I., and Sadri A.M. Centrality-based lane interventions in road networks for improved level of service: the case of downtown Boise, Idaho. *Applied Network Science*. 8(2), 2023, pp. 1-19. <https://doi.org/10.1007/s41109-023-00532-z>

- [11] Wang L. Safety evaluation for highway geometric design based on spatial path properties. *Journal of Advanced Transportation*. 2023(1), 2023, pp. 1-14. <https://doi.org/10.1155/2023/6685010>
- [12] De Santos-Berbel C., Ferreira S., Couto A., and Lobo A. Development of motorway horizontal alignment databases for accurate accident prediction models. *Sustainability*. 16(17), 2024, pp. 7296. <https://doi.org/10.3390/su16177296>
- [13] Devaru D., Prajwal K.O., N P.A., Mani M., Khan S., and P P.M. Optimization of the Distribution Network of Packaged Food Industry. *International Journal of Innovative Research in Science, Engineering and Technology*. 12(8), 2023, pp. 10821. <https://doi.org/10.15680/IJRSET.2023.1208042>
- [14] Anagnostopoulos A. Assessing Safety and Infrastructure Design at Railway Level Crossings Through Microsimulation Analysis. *Future Transportation*. 5(1), 2025, pp. 1-24. <https://doi.org/10.3390/futuretransp5010024>
- [15] Kriswardhana W., Toaza B., Esztergár-Kiss D., and Duleba S. Analytic hierarchy process in transportation decision-making: A two-staged review on the themes and trends of two decades. *Expert Systems with Applications*. 261, 2025, pp.125491. <https://doi.org/10.1016/j.eswa.2024.125491>
- [16] Supriyatno D., Syaiful S., Mudjanarko S.W., and Wardhani A.K. Highway and railway crossing management model to improve Sidoarjo-Tarik crossing safety (comparison between Indonesia and Malaysia). *Journal of Applied Engineering Science*. 23(3), 2025, pp. 456-470. <https://doi.org/10.5937/jaes0-56583>
- [17] Suprayitno A., Amiruddin A., Talaiftha A., and Maulidya R.N. Investigation of the Influence of Geological Faults with Fracture Direction on Highways: A Case Study of Jalan Besar in Balikpapan. *PETROGAS Journal of Energy and Technology*. 2(2), 2020, pp. 52-61. <https://doi.org/10.58267/petrogas.v3i2.74>
- [18] Amakye S.Y.O., Abbey S.J., Booth C.A., and Oti J. Performance of Sustainable Road Pavements Founded on Clay Subgrades Treated with Eco-Friendly Cementitious Materials. *Sustainability*. 14(19), 2022, pp. 12588. <https://doi.org/10.3390/su141912588>
- [19] Jagad S.T.S., Mulyono A.T., Utomo S.H.T., and Santosa W. Determination of the Route for the Connecting Road Between the Central Road and the Southern Road of Java Island in the Kapanjen-Balekambang Corridor, East Java, Using the Least Cost Path Approach. *Transportation Journal*. 22(1), 2022, pp. 41-60. <https://doi.org/10.26593/jtrans.v22i1.5767.41-60>
- [20] Salihu F., Demir Y.K., and Demir H.G. Effect of road slope on driving cycle parameters of urban roads. *Transportation Research Part D Transport and Environment*. 118, 2023, pp. 103676. <https://doi.org/10.1016/j.trd.2023.103676>
- [21] Nautiyal A. and Sharma S. Condition Based Maintenance Planning of low volume rural roads using GIS. *Journal of Cleaner Production*. 312, 2021, pp. 127649. <https://doi.org/10.1016/j.jclepro.2021.127649>
- [22] Islam I., Ahmed W., and Khattak S.A. Investigating the role of geological strength index and susceptible zones in landslide triggering mechanisms from Chukyatan-Kumrat road, Dir Upper, Pakistan. *International Journal of Geo-Engineering*. 16(10), 2025, pp. 1-23. <https://doi.org/10.1186/s40703-025-00240-w>
- [23] Kastridis A. Impact of forest roads on hydrological processes. *Forests*. 11(11), 2020, pp.1201. <https://doi.org/10.3390/f11111201>
- [24] Öztürk O., Bozkurtoğlu E., and Kirca V.S.O. A geology and geomorphology-based decision matrix methodology for route determination of new roads. *Arabian Journal of Geosciences*. 16(434), 2023, pp. 1-14. <https://doi.org/10.1007/s12517-023-11542-7>
- [25] He Y., Wu D., Li S., and Zhou P. Ecological and Environmental Risk Warning Framework of Land Use/Cover Change for the Belt and Road Initiative. *Land*. 13(8), 2024, pp. 1281. <https://doi.org/10.3390/land13081281>
- [26] Wang W., Wang L., Miao Y., Cheng C., and Chen S. A survey on the influence of intense rainfall induced by climate warming on operation safety and service life of urban asphalt pavement. *Journal of Infrastructure Preservation and Resilience*. 1(4), 2020, pp. 1-14. <https://doi.org/10.1186/s43065-020-00003-0>
- [27] Taufikurrahman T., Karyawan I.D.M.A., and Yasa I.W. Study of Road Surface Damage due to Rainwater Puddles using the Pavement Condition Index. *Path of Science*. 8(8), 2020, pp.3010-3018. <http://dx.doi.org/10.22178/pos.84-8>
- [28] Directorate General of Highways. Road Geometry Design Guidelines (PDGJ). Ministry of Public Works and Public Housing, Jakarta, Indonesia, 2021, pp. 1-353