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Analysis and Evaluation of Geometrics on the Ciawi-Sukabumi Toll Road Section 1 Package 1 (STA -0+750 to STA 4+850)

Dimas Fauzi Prasetyo[1], Jody Martin Ginting[2]
[1]Civil Engineering Department, Faculty of Engineering, Mercu Buana University, Indonesia
[2]Faculty of Civil Engineering & Planning, Universitas International Batam, Indonesia

E-Correspondence: d.fauziprasetyo@gmail.com

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ABSTRACT

Ciawi – Sukabumi toll road become one of the alternative routes to reduce traffic congestion which was originally focused on the national roads before. Considering the hilly contour of the Ciawi – Sukabumi toll road, road conditions must be in accordance with the standards to support vehicle and driver performance. The research methodology used in this journal is to collect field data for the Ciawi – Sukabumi Toll Road Project Section 1 Package 1 (STA -0+750 to STA 4+850), both vertical alignment data, horizontal alignment, road width, and speed plan. The geometric analysis of toll roads Ciawi – Sukabumi Toll Road Project Section 1 Package 1 (STA -0+750 to STA 4+850) also considers factors such as sight distance, design speed, and safety considerations. Adequate sight distance is crucial for drivers to anticipate and respond to potential hazards, while the design speed ensures that the road is designed to support safe travel at desired speeds. Safety considerations encompass aspects like radius of curvature, signage, markings, and other measures to enhance road safety.

1. Introduction

In this pandemic covid 19 era, mass vaccination has been done with the result that makes people fearless to do activities and interactions outside their house. This is reflected by the increasing number of mobility and interactions among people. Not only people, but it also has an impact on goods mobilization and services too. Thus, there are increasingly a significant number of vehicles on the road and toll roads, especially for those countries with car-oriented concepts. Despite numerous studies suggesting a path-dependent relationship between transport–land use policies and urban structures, especially on the emergence of car-oriented development, this connection has rarely been explained with spatial evidence [1].

As one of the countries that adopt the car-oriented concept, Indonesia's infrastructure has been dominated by cars and motorcycles. Along with that, toll road becomes the most needed infrastructure in order to support land mobilizations. It also helps to reduce traffic jams caused by a high number of cars and people. Toll road works as a freeway to shorten travel distance and time [2].

Sukabumi, as a city and district centre of food, pharmaceutical, garment, drinking water, and tourism industries, requires good connectivity and accessibility. The inter-city connecting route from Sukabumi currently still relies on the National Road. Where along the road from Sukabumi to Jakarta, the centre of the National Capital, cross lots of trade areas and factories, which are

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points of traffic jams. This mobilization is needed as demands from other economic, trade and tourism activities [3] [4].

Therefore, the Ciawi – Sukabumi toll road has become one of the alternative routes to reduce traffic congestion initially focused on the national roads. Ciawi – Sukabumi toll road focuses on Ciawi – Cigombong segment was built to shorten the travel time from Jakarta to Sukabumi. And as expected, travel time from Ciawi to Cigimbong is now only 15 minutes away, but without Ciawi – Cigombong toll road, it takes up to one hour travel time.

Considering the hilly contour of the Ciawi – Sukabumi toll road, road conditions must be in accordance with the standards to support vehicle and driver performance. Maximum and minimum speed requirements for vehicles while crossing the toll road depend on the speed plan, which is used as a reference during the planning stage of the toll road. Thus, good and correct road geometric planning is needed in accordance with the Road Geometric Design Guidelines issued by the Director General of Highways in Circular Letter Number: 20/SE/Db/2021.

2. Literature Review

Road Geometry

Planning and design of roads pay attention to road geometry which is important to achieve safety, comfort, and efficiency. In the planning, important elements such as the track, road width, curvature, and alignment must be right calculated. Apart from that, the geometric types of roads, such as straight roads, winding roads, and freeways, are also things that need to notice. Elements of the geometric design of the road include the dimensions of horizontal and vertical alignment, cross sections, intersections, and pedestrian and cyclist facilities [5] [6] [7]. Overall, all of these elements and aspects must be carefully considered in order to create a safe, comfortable, and efficient road for all users.

Road geometry affects the sight distance available to the driver. In the context of road design, sight distance is defined as "the length of roadway ahead visible to the driver." [8]. Visibility analysis involves determining the distance in front of the driver that allows them to see objects or vehicles ahead clearly. This is important to avoid collisions and allow sufficient time for drivers to respond to road conditions.

Road geometrics on toll road sections refers to the planning and design of physical features and dimensions of toll roads. This geometric design involves elements such as horizontal alignment, vertical alignment, cross-sectional elements, visibility, and other elements that ensure smooth and safe traffic on toll roads [9].

Vertical Alignment

Vertical alignment is an integral part of geometric road planning. At the time when planning the vertical alignment, important things that need to be considered are the safety and comfort of road users, an efficient drainage system, and compatibility with local topographical conditions. By taking this into account, vertical alignment can be optimally planned to create a safe, comfortable, and efficient road for road users. The purpose of designing a vertical alignment is to determine the elevation of important points of the road to ensure proper road drainage and an acceptable level of safety [10] [11] [12].

Effect of vertical alignment on driver perception of horizontal curves and found that the perception of the driver is an important factor and should be addressed in road design. demonstrated that conventional linear regression models are not appropriate for modelling

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vehicle accident events on roadways, and statistics from these models often need to be revised. It was concluded that Poisson and Negative Binomial Regression models are more appropriate tools in accident modelling for highways [13].

Vertical alignment involves the design of the vertical profile of the toll road, including the grade and vertical curves. It aims to provide smooth vertical transitions, minimize steep slope levels, and ensure adequate visibility for the driver [14].

Alinyemen Horizontal

Horizontal alignment is the projection of the road axis on the horizontal plane. Horizontal alignment is also known as "road situation" or "road alignment" [15]. The initial step in horizontal alignment is to define a path that connects the starting and ending points. In this alignment, there are several main factors that must be considered, such as determining the appropriate radius for the curvature of the road to match the planned speed, as well as superelevation, which considers the centrifugal force when passing corners. Apart from that, road width is also an important factor which includes lane width, shoulders, and median, which need to be adjusted according to traffic volume and desired design speed.

Horizontal curves are provided to change the direction of the centre line of the road. When a vehicle negotiates a horizontal curve, centrifugal force acts outwards through the centre of gravity of the vehicle, which depends upon the radius of the curve and the speed of the vehicle. Curves are sections of the road where the alignment deviates from a straight line. They are used to change the direction of the road and allow it to follow the natural topography or accommodate specific design requirements. Curves are typically defined by their radius, which determines the sharpness of the curve [16].

Horizontal alignment on toll roads includes determining the right bend design, bend radius, transition curve, and lateral shift. The goal is to accommodate a safe and comfortable speed for the rider when going through corners and changes of direction [17].

Toll Road

Toll roads are a type of road that has special characteristics and functions to serve high-speed vehicular and smooth mobility. Toll roads are often faster due to less traffic congestion and higher speeds compared to regular roads. In addition, toll roads also provide better safety and comfort because there is a separation of traffic from other roads. Toll road users not only can avoid traffic on city streets but also travel times can be better predicted. The implementation of toll roads themselves is intended to achieve equitable distribution of development and its results, as well as balance in regional development with due regard for justice, which can be achieved by fostering a road network that is funded comes from road users [18].

Although there has been little research on freeway design in the 1990s, several recent studies have focused on design of certain aspects of urban freeways : acceleration lanes, high-occupancy-vehicle (HOV) lanes, entrance and exit ramps, and incident detection sites [19].

A toll road, also known as a tollway or turnpike, is a type of road or highway where drivers are required to pay a fee, known as a toll, to use the road. Toll roads are a means of financing and maintaining the infrastructure of the road, often providing an alternative to traditional government funding. Toll roads often have controlled access points, such as designated entrance and exit ramps, to regulate traffic flow and ensure toll collection. This helps in managing congestion and improving overall efficiency [20].

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3. METHOD

The research methodology used in this journal is to collect field data for the Ciawi – Sukabumi Toll Road Project Section 1 Package 1 (STA -0+750 to STA 4+850), both vertical alignment data, horizontal alignment, road width, and speed plan. Data is one of the main strengths in compiling research and scientific modelling [21]. A systematic scientific research process must begin with identifying the right problem [22]. With quantitative research, an analysis and evaluation were carried out by comparing the results obtained with the 2021 Road Geometric Design Guidelines. It should be noted that the toll roads studied have been in operation since 2018. As for the project locations under study, they can be seen in Figure 1.

Figure 1. Ciawi – Sukabumi Toll Road Project Section 1 Package 1 (STA -0+750 to STA 4+850) location.

The location for the analysis and evaluation of geometry is at the Ciawi ramp interchange, as depicted in Figure 2.

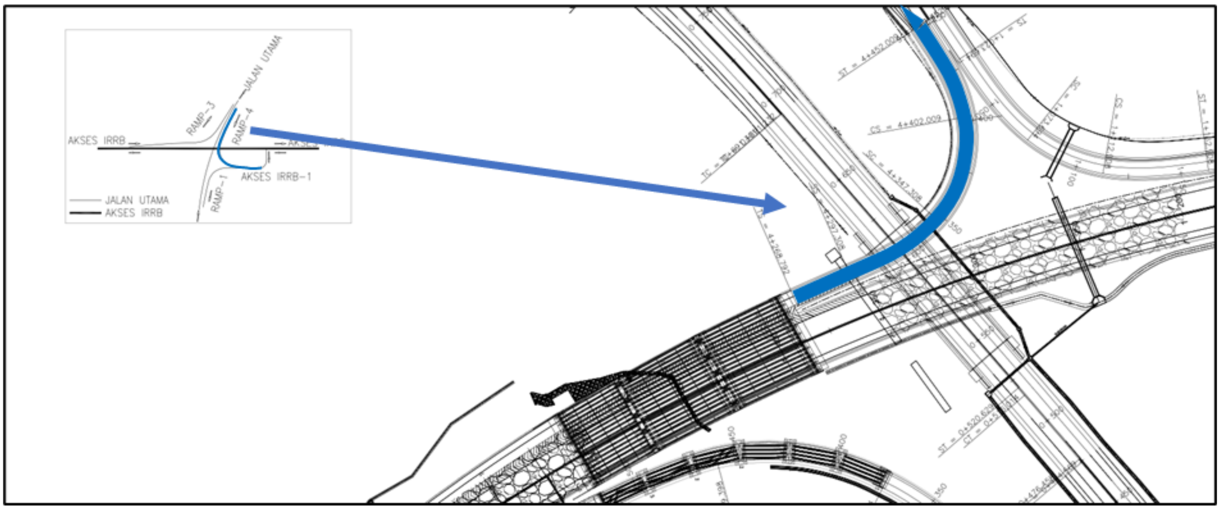

Figure 2. Layout Ramp 4 – Interchange Ciawi

The typical cross-section design of the ramp can be seen in Figure 3 below, and for the ramp design at ramp 4 location, please refer to Figure 4.

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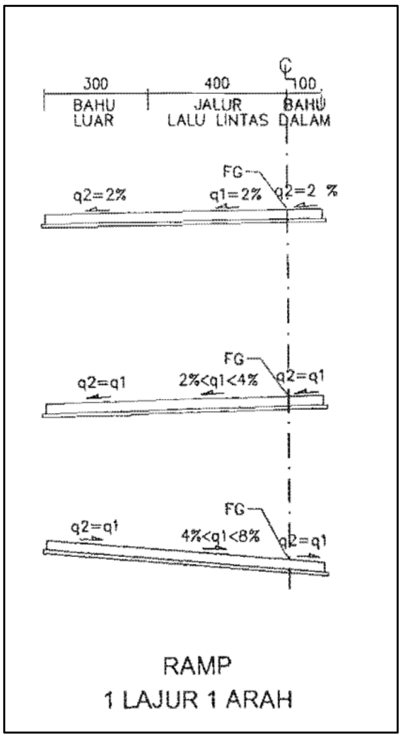

Figure 3. The typical design for a one-lane, one-way ramp

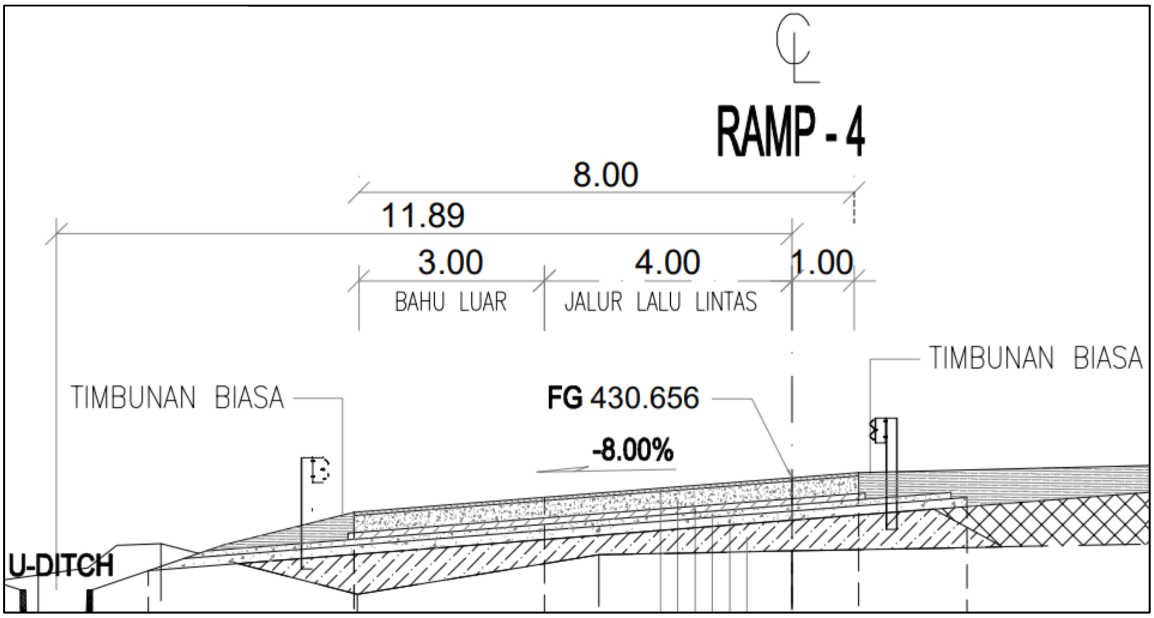

Figure 4. Cross Section Ramp 4 – Interchange Ciawi

In 2021, Ministry of Public Works and Public Housing's Road Geometric Design Guidelines explain ways to design road geometry which includes design criteria, general provisions, road geometric technical provisions, and road geometric design procedures in designing horizontal road alignment, vertical road alignment, road cross sections, and coordination of horizontal and vertical alignment of roads, for Highways, Medium Roads, Small Roads, and Freeways, both serving Inter-city traffic and intra-city traffic. General provisions and road geometric technical provisions are generally explained for Intercity roads, Urban Roads, and Freeways. The geometric elements that underlie the design are generally presented in the same tables but are given information on whether they are applicable or only apply to Intercity roads, Urban roads , or

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Freeways. Design implementation procedures are described separately, respectively, for Intercity roads, Urban Roads, and Freeways [23] [24] [25].

Geometric analysis and evaluation of toll roads involve assessing the geometric elements present to ensure the suitability and adequacy of the design to support traffic safety, comfort, and efficiency. Evaluations are made of elements such as curve radius, curve length, bend angle, and road steepness. It aims to ensure that the toll road has a suitable curvature and can be safely accessed by vehicles at the desired speed. The evaluation was also carried out on the design and geometry of ramps and interchanges on toll roads. Aspects of concern include ramp length, curve radius, bend angle, transition length, and adequate space for lane changes [26] [27] [28] [29].

4. Result and Discussion

Based on the data obtained in this project, when tabulated, it can be seen in the table 1 below.

Table 1. Access Ramp Data

BP				PI				EP	
X	703279.773	V (Km/jam)		40.000		V (Km/jam)		X	703396.914
Y	9263555.723	TIPE		SCS		TIPE		Y	9263951.519
STA	4+000	Δ		104°25'37"		Δ		STA	4+452.009
		R (m)		70.000		R (m)			
		A		59.161	59.161	A			
		TS/TC (m)		117.092	117.092	TS/TC (m)			
		LC (m)		77.582		LC (m)			
		LS (m)		50.000	50.000	LS (m)			
		L (m)		177.582		L (m)			
		e max (%)		8%		e max (%)			
		PI	X	703540.200		X	PI		
			Y	9263863.931		Y			
		TS/SS	X	703456.166		X	TS/SS		
			Y	9263782.391		Y			
			STA	0+268.792		STA			
		SC/TC/CC	X	703487.487		X	SC/TC/CC		
			Y	9263821.001		Y			
			STA	4+347.308					
		CS/CT/CC	X	703479.339		X	CS/CT/CC		
			Y	9263894.221		Y			
			STA	4+402.009		STA			
		ST/SS	X	703440.295		X	ST/SS		
			Y	9263925.000		Y			
			STA			STA			
28°45'06"		AZIMUT		301°26'11"		AZIMUT			

From the table 1 above, an analysis and evaluation are conducted based on the provisions in the Road Geometric Design Guidelines issued by the Director General of Highways. One of the indicators to calculate the data for horizontal alignment is determined by equation 1. Horizontal alignment on toll roads refers to the design and layout of curves, tangents, and transitions to ensure safe and efficient movement of vehicles (Qu et al., 2019).

$$L_S = \frac{(wn_1)e_d}{\Delta}\ (b_w) \ \text{........} \ (1)$$

where:

L_s = minimum length of superelevation runoff, m

w = width of one traffic lane, m

n_1 = number of lanes rotated

e_d = design superelevation rate, percent

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b_w = adjustment factor for number of lanes rotated

Δ = maximum relative gradient, percent

Other parameters that need to be calculated include :

Rc = Circular arc radius ;

ΔPI = Bend angle ;

V_r = Design speed ;

R_{min} = Minimum Radius ;

θs = Spiral curve angle ;

θc = The curved angle of the circle ;

Lt = Length of bend ;

Xs = abscissa of point SC on tangent line, distance from point ST to SC ;

Ys = distance perpendicular to point SC on arc ;

K = abscissa of p on the spiral tangent line ;

P = tangent shift to spiral ;

TS = Point from tangent to spiral ;

Es = The distance from II to the

From the above parameters, a comparison summary can be created, as shown in Table 2 below.

Table 2. Calculation Spiral Circle Spiral (SCS)

Item		Unit	Bina Marga 2021	Design	Deviation
Vr		(Km/Hour)	40.00	40.00	
Rc		(m)	70.00	70.00	
e		(%)	2 - 8	8.00	
w		(m)	3.5 - 4.5	4.00	
Ls		Min (m)	46.15	50.00	3.85
θs	(90 x Ls)/(π x Rc)	(°)	18.89		
θc	ΔPI - 2θs	(°)	66.22		
Lc	(θc/360) x 2π x Rc	Min (m)	80.91	77.58	-3.32
Lt	Lc + 2Ls	Min (m)	173.21	177.58	4.37
Xc	$Ls - (Ls^3 / (40 \times Rc^2)$	(m)	45.65		
Yc	$Ls^2 / (6 \times Rc)$	(m)	5.07		
P	Ys – Rc (1 - cos θs)	(m)	1.30		
K	Xc – Rc (sin θs)	(m)	22.99		
Ts	(Rc + P) x tan (ΔPI/2) + K	Min (m)	114.25	117.09	2.84

5. Conclusion

Through the analysis of horizontal alignment, the appropriate design of curves, transitions, and superelevation can be determined to provide smooth and safe navigation for drivers. Cross-section evaluation ensures sufficient width and space for vehicles, pedestrians, and other road users, while ramps and interchanges are designed to facilitate efficient movement and safe merging.

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The comparison geometric analysis between the design toll roads Ciawi – Sukabumi Toll Road Project Section 1 Package 1 (STA -0+750 to STA 4+850) and manual calculation according to Road Geometric Design Guidelines 2021, there are differences in the parameter Ls, Lc, Lt and TS. The difference in calculation can be caused by the width of one traffic lane because before Road Geometric Design Guidelines 2021, the calculation to find the Ls parameter was not calculate the width of one traffic lane.

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