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The Horizontal Curved Geometric Redesign on Jalan Lingkar LIPI Cibinong Using The AutoCAD® Civil 3D Method

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ABSTRACT

Road geometric planning is one of the requirements for road construction that aims to provide comfort, safety, and speed for road users. In this geometric road planning, the author plans the horizontal curved road geometrics on the Cibinong Lipi Ring Road at STA 0+000 - STA 0+553.46, located in Bogor Regency, West Java Province, by using AutoCAD® Civil 3D auxiliary program. This research uses quantitative methods by taking data from Google Earth and Global Mapper. The steps in this research include terrain classification, road trajectory planning, horizontal alignment planning, design planning criteria, and bend design. The design results show that the Lingkar Lipi Cibinong Road is a Primary local road class III, with a 2/2 TT road type. On this road, the geometric horizontal alignment is designed with two bend designs using the Full Circle (F-C) bend type with a radius of 151 m and SCS (Spiral - Circle - Spiral) with a radius of 165 m, plan speed (Vr) 60 km/h, maximum superelevation of 8%.

1. Introduction

Infrastructure refers to the underlying physical framework, the public works that facilitate the smooth functioning of the country. Developing an advanced infrastructure is essential to the country's growth and development. This infrastructure consists of roads, bridges, airports, railways, ports, communication systems, and other crucial structures without which the country cannot function properly [1]. Road infrastructure development is essential in conservation planning and development throughout the global South. Throughout the history of road construction, road users have always viewed speed, safety, and comfort as simple enough responsibilities to justify road construction [2].

Roads are essential infrastructure for every human being. Roads can open access to a place or facilitate the distribution of goods/services [3]. In addition, the principal objective of the road is to achieve a safe, balanced, and sustainable way. It is represented in the geometric design of the road, which includes the symmetrical arrangement of the physical parts of the road, cost analysis (efficiency), reduction of adverse environmental impacts, traffic volume, road accessibility, etc. [4]. Roadways can contribute to and facilitate the achievement of economic, infrastructure, and social growth objectives in a sustainable environment. Road development is considered "sustainable" if it supports economic development and consistently meets people's transport needs while protecting the environment [5].

Indonesia has abundant natural resources that open up opportunities for development in developed countries. Indonesia's rapid economic development can also lead to even more congestion. Indonesia is populated and home to more than 230 million people, and the country's economic growth has increased the demand for transport and vehicle ownership. Indonesia is also a country with great tourism potential, so there is a need for accessible infrastructure, such as road connections to tourist attractions [2]; [6].

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The Indonesian Institute of Sciences (LIPI), located in Cibinong, Bogor, is in the process of developing the Cibinong Botanical Garden. The Indonesian Institute of Sciences (LIPI) and the Bogor Regency government have started preparing infrastructure facilities and infrastructure before opening the Cibinong Botanical Garden to the public. The upcoming infrastructure is a road that will be called the LIPI ring road. The entrances to the LIPI Cibinong Science Centre (CSC) can be accessed through the main gate of the CSC, located on the edge of Jalan Raya Bogor-Jakarta. The road access will be upgraded by building new roads and widening existing roads [7]

The manual method is still used in drawing geometric drawings. Manually takes more time, cost calculation errors can occur, and inaccurate drawing results. In today's fast-paced digital world, there is one road planning software: AutoCAD Civil 3D® is a software dedicated to designing civil engineering models. Designing roads with AutoCAD Civil 3D® results in a more efficient, accurate, and time-saving road design process than the manual method [8]. A road alignment is defined as a specific set of parameter values that indicate the typical geometric properties of a road, such as curvature, slope, superelevation, etc. [9]. A 3D highway model is a high-resolution digital representation of the high-resolution digital representation of roadway and surrounding terrain [10]. The significance of planning and uniformity in highway design is to produce a road surface that is safe and comfortable to drive on [11].

Given many cases and the constant search for general road safety improvement, many studies to promote road safety have been developed. Traffic accidents are one of the most important causes of death worldwide: nearly 1.2 million people die, and 50 million are injured worldwide every year [12]. The objective of geometric road design is to design roads with safety in mind. Most investigations into safe road design components have focused on understanding the relationship between geometric and other design components and safety, indexing crash records, and driver perception under various geometric and environmental conditions through simulation. Therefore, this plan is based on the Road Geometric Design Guidelines 2023 (PDGJ) [6] [13]. The purpose of this paper is to Redesign On Jalan Lingkar Lipi Cibinong Using The Autocad Civil 3D® Method. The road is designed to connect the CSC area with the east entrance of Pakansari Stadium, among others. The location was chosen to update the existing design using Autocad Civil 3D®.

2. Literatur Studies

2.1 Public Roads

Based on Law No. 2 of 2022, public roads are roads intended for general public traffic, which include arterial roads, collector roads, local roads, and neighborhood roads. In this research, the roads used are class III local roads. Primary roads serve local public transport with the characteristics of short-distance travel, low average speed, and the number of driveways that are not limited. On the new road, Lingkar Lipi Cibinong is an infrastructure facility built to be travel access to the tourist attractions of the Botanical Garden. Moreover, this road is an alternative for the surrounding community that connects the Jakarta Bogor road to Jl H. Moh Ashari and Jl Raya Mayor Oking Atmajaya.

2.2 Road geometric planning

Road geometric planning is a part of road planning that concentrates on planning the physical form so that it can fulfill the primary function of the road, namely providing optimal service to traffic flow and maximizing the ratio of the level of use of implementation costs. Road infrastructure plays an instrumental role in ensuring the proper functioning of national transport. Road geometry planning should be selected, measured, and positioned to fulfill design criteria such as vehicle stability, driving comfort, drainage system, economy, and aesthetics. [14], [15]

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The geometric design is a means to meet the requirements of Roadways, is expected to ensure user comfort and safety, enable efficient transportation operations, and keep construction and maintenance costs as low as possible. Highways are also expected to cause as minor environmental damage as possible and be aesthetically pleasing in their final form [16] [17] [18]. Road safety planning aims to provide a safe and secure driving environment for road users [19].

A geometric route is a form of road design that allows people to travel from one area to another while maintaining safety. Geometric design plays a vital role in every road and affects the direction of the road. Aspects such as: efficient, effective, cost-effective, safe, and environmentally friendly [8]. Road geometric design has one main goal. Therefore, the main objective of road geometry design is to create safe and comfortable road physics, i.e., a design that takes into account: visibility, adequate maneuverability, and adequate surface friction coefficient; economical, efficient, and easy to implement; Provides integrated physical infrastructure for different types of road terrain [20]

2.3 Alinyemen Horizontal

Horizontal alignment is the tracing of a road which is the projection line of the road axis perpendicular to the map plane. Road tracing is usually called a road situation drawing or road plan that shows the direction of the road concerned. Trase is an arrangement of straight lines (tangents) connected to each other with curves (curves) to form a bend [21]. Horizontal curves are one of the most valuable features for road performance and safety. Good planning results in higher speeds in terms of safety and comfort. A fundamental consideration with horizontal curves is that they are designed to have the most significant radius value and not less than the minimum value suitable for the design speed [22], [23].

The main task of horizontal planning is determining the intersection of tangents, loops, and displacement curves. The horizontal orientation of the highway determines the position and direction of the highway in the plan view. The horizontal alignment consists of three geometric elements: Tangents (straight sections), circular curves, and spiral transitions between tangents and curves. When designing the horizontal alignment, the curve's minimum radius and length should be determined,d and the horizontal offset from the tangent to the curve calculated to facilitate curve placement in the field. Safety is an essential factor in road planning [8] [24]. Planning for horizontal alignment should first determine the function and class of the road based on the nature of the road, the amount of traffic on the road, and the terrain conditions. When selecting the road layout, planners usually choose straight roads because the total length of straight roads is short [25].

2.4 AutoCAD Civil 3D®

AutoCAD Civil 3D® is 3D software developed by Autodesk used by civil engineers and professionals to design civil and civil engineering projects, including dams, harbours, canals, and weirs. AutoCAD Civil 3D® is widely used to create and sketch designs. AutoCAD Civil 3D® can reduce the time needed to change designs and evaluate different situations. AutoCAD Civil 3D® provides 3D project modeling and helps both small and large projects. It is beneficial for designing 3D renderings, saving time and budget. In addition, there are many advantages to using AutoCAD Civil 3D® [8]. AutoCAD Civil 3D® is commonly used to minimize planning time and evaluate various situations. In addition, the software can also be used to create 3D models of transport projects, water, or land and reference data sources such as contour lines, corridors, and assessments [16] [26].

The advantages of using AutocadCivil 3D® include, Quantitative data calculation. The process can determine design requirements, design factors, and economic factors. It can also reduce design requirements and demolition costs, improve energy efficiency, maximize and minimize return on investment, can identify potential hazards and safety risks [27]. Using AutocadCivil 3D® for highway

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geometry planning must comply with the IRC, adhere to all safety measures, and make the design process fast, easy, and highly accurate [22].

3. Method

This research methodology contains the necessary data sources, which discuss the geometric planning of the Lipi Cibinong Lingkar Alternative Road, Bogor Regency. This research uses data obtained and processed Mathematically based on existing formulas. The data used are primary data, such as situation maps, road traffic, and contours obtained from Google Earth® and Global Mapper®. For geometric road planning, the author uses the AutoCAD Civil 3D® application. The location used for planning is the new road Lipi Cibinong Circle. The road is an infrastructure facility built to be used as an access trip to the Botanical Gardens tourist attractions. In addition, this road is used as an alternative road for the surrounding community that connects the Jakarta-Bogor road to Jl H. Moh Ashari and Jl Raya Mayor Oking Atmajaya with straight road conditions, and several sharp bend points, which can be seen in the following location map Figure 1.

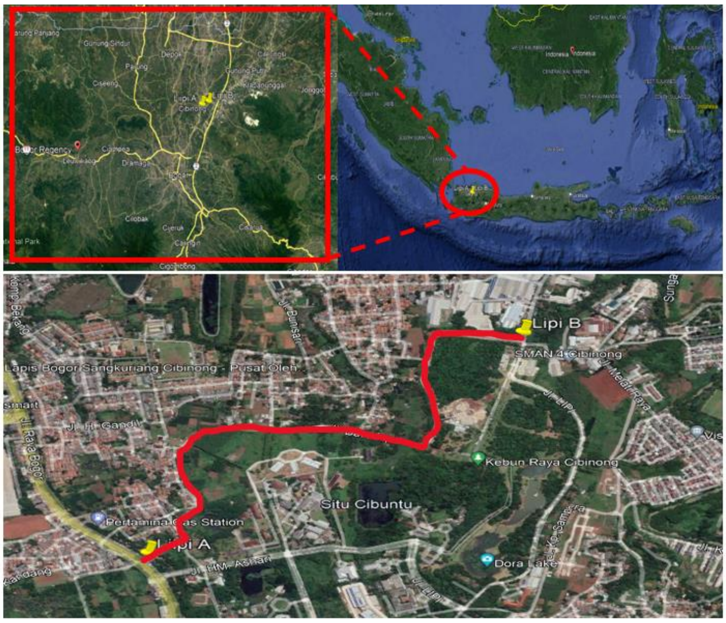

Figure 1 Location of Research
Sumber: Google Mapper

A systematic scientific research process must begin with identifying the right problem. Based on the data obtained, the new Lipi Cibinong road is a class III primary local road with the heaviest axis load of 8 tonnes, making it possible for medium vehicles to pass. In addition, this road is located in a flat area with two lanes. Contour data for this road planning is sourced from Google Earth® and Global Mapper®.

4. Result and Discussion

To process data on the planning of the Jalan Baru Lingkar Lipi Cibinong, the author uses AutoCAD Civil 3D®Here are the steps in doing geometric planning of Jalan Baru Lingkar Lipi Cibinong. Table 1 is the horizontal alignment planning criteria for the Jalan Baru Lingkar Lipi Cibinong on the Highway Design Standard of Indonesia 2023.

Table 1. Design Criteria

No	Description	Value	Unit
1	Road Function	Local Primary	
2	Class Road	Class III	
3	Provider Specifications	Medium Road	

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4	Road Type	2/2-T	
5	Lane Width	7	m
6	Plan Capacity	24000	smp/hari
7	Vd	40-60	kpl
8	Outside Shoulder Width	1	m
9	Road Shoulder Width	8	m
10	Rumaja		
	Width	10	m
	Height	5	m
	Deep	1.5	m
11	Rumija (new road)	11	m
12	Ruwasja (Local)	3	m
13	Width of Edge Channel	1	m
14	Normal Slope	2-3	%
15	Road Shoulder Slope	4-6	%
16	Superelevation	8	%
17	Flat Alignment Slope	6	%

Sumber: Highway Design Standard of Indonesia 2023.

4.1 Terrain Classification

Google Earth data shows that the average slope of the Lingkar Lipi Cibinong Road traffic is 1.8% - 2.3%. Terrain slopes < 10% can be classified as flat terrain following the geometric planning regulations for class III primary roads according to the 2021 Indonesian Highway Design Standards.

4.2 Road Trace Planning

The road sections were drawn following the existing field topography. The road Lingkar Lipi Cibinong will be planned to have two bends with trace lengths starting from STA 0+000 - STA 0+553.46. Figure 2 is the planning trajectory of the Lingkar Lipi Cibinong Bogor road.

4.3 Horizontal Alignment Planning

Horizontal alignment geometry planning compensates for the centrifugal force a vehicle receives at plan speed (Vr). Horizontal alignment consists of three types: Full Circle and Spiral Circle Spiral. Here is the horizontal alignment planning for both corners. Horizontal alignment planning uses the Full Circle (F-C) arch type and Spiral Circle Spiral (S-C-S). Several formulas are used concerning in calculating the horizontal alignment of the Full Circle. The highway Design Standard of Indonesia 2023, namely as follows:

Table 3. Planning Criteria

Planning Criteria	Value
V (Vehicle Design Speed)	60 km/h
e_n	3%
e_{max}	8%
LHRT Planning Year	24000 smp/day
R_{min}	250 m
f_{max}	0,1525
Lane width	3,5 m
Total number of lanes	2/2

Here are the formulas–formulas that are considered to find the value of Full Circle:

Length of full circle curve

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$$L = \frac{\Delta}{360} \,.\, 2\pi R = 0.01745\, \Delta \,.\, R \qquad (1)$$

Superelevation

$$e = \frac{(e_{maks} \,.\, D)}{D_{maks}} \,.\left(2 - \frac{D}{D_{maks}} \right) \qquad (2)$$

Length of full circle curve

$$L = \frac{\Delta}{360} \,.\, 2\pi R = 0.01745\, \Delta \,.\, R \qquad (3)$$

Degree of curvature

$$D = \frac{1432.4}{R_{plan}} \qquad (4)$$

$$D_{maks} = \frac{1432.4}{R_{min}} \qquad (5)$$

Transitional arch

$$Ls\ fictitious = B\,.\,m\,.\,(e + en)\frac{2}{3}\ Ls\ outside\ the\ arch\ \frac{1}{3}\ Ls\ inside\ the\ archB = \frac{1}{2}\ Pavement\ width\ m = \frac{1}{relative\ slope} \qquad (6)$$

Bend pavement width

$$Td = \sqrt{R^2 + A(2P + A} - R \qquad (7)$$

$$Z = 0.105\ x \frac{V}{R^{0.5}} \qquad (8)$$

$$b" = R - (R^2 - P^2)^{0.5} \qquad (9)$$

$$B = n(b" + b + c) + (n - 1)Td + Z \qquad (10)$$

Noted:

PI = Point of Intersection (intersection point of tangent)

R = Radius (m)

Δ = Tangent angel

TC = Tangent circle (beginning of the curve)

CT = Circle tangent (end of the arch)

TS = Distance TC – PI or PI – CT

L = Arch length

Ts = R tg Δ/2

Es = PI to arc distance

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$$Es = \frac{R}{\cos\frac{\Delta}{2}} - R = R\left(\frac{1}{\cos\frac{\Delta}{2}} - 1\right) \quad (11)$$

Here are the formulas–formulas that are considered to find the value of Spiral Curved Spiral:

$$R_{min} = \frac{V_D^2}{127(f_{\max} + e_{\max})} \quad (12)$$

Where:

R_{min} = Minimal curved Radius

V_D = speed of design or plan

$f_{\max}$ = Transverse roughness factor

$$f_{\max} = -0{,}000625\,V + 0.19 \quad (13)$$

$e_{\max}$ = Maximum superelevation

Counting LS (Spiral arch)

$$Ls_1 = \frac{Vr}{3.6}\,x\,T \quad (14)$$

Calculates Ls based on the degree of achievement of the change in a slump

$$Ls_2 = \frac{(ed - en)vr}{3.6\,re} \quad (15)$$

$$\theta_s = \frac{Ls}{2R}\frac{360}{2\pi} \quad (16)$$

$$\Delta_c = \Delta - 2\theta s \quad (17)$$

$$Lc = \frac{\Delta_c}{360}\,2\pi R \quad (18)$$

$$Yc = \frac{Ls^2}{6R} \quad (19)$$

$$Xc = Ls\left(1 - \frac{Ls^3}{40R^2}\right) \quad (20)$$

$$k = Xc - R\,Sin\theta s \quad (21)$$

$$Ts = (R + p)\tan\left(\frac{\Delta}{2}\right) + k \quad (22)$$

$$Es = \frac{(R + p)}{Cos\left(\frac{\Delta}{2}\right)} - R \quad (23)$$

Counting L total (24)

$$L\ total = L + 2\ Ls$$

Redesigning Jalan Lipi Cibinong using AutoCAD Civil 3D® before performing calculations and data processing, the existing route must be modeled in AutoCAD Civil 3D® using Google Earth® and Global Mapper® software to obtain contour data, topography, and road coordinates. After modeling the existing route, the horizontal flow redesign can be done in AutoCAD Civil 3D®. Starting from the road

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cut to the bend to get two bends. The new horizontal flow with the total length of Lingkar Lipi Cibinong Road is still 553.46 meters with two bends represented by P1 dan P2. The bends of this road use Full Circle (FC) and S-C-S Spiral Circle bend types. The design drawing of the new horizontal alignment of the Lingkar Lipi Cibinong Road can be seen in Figure 2.

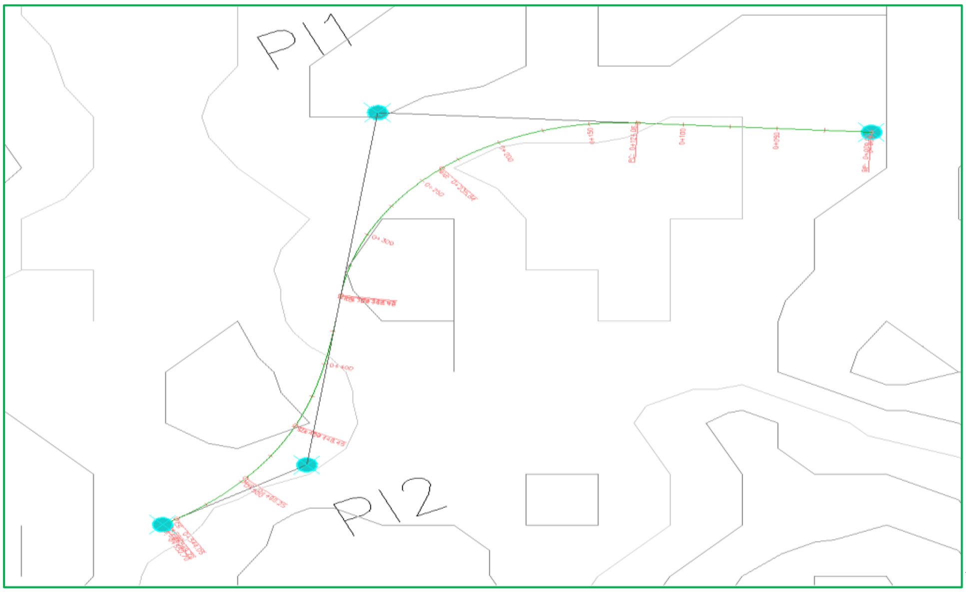

Figure 2. Trace of Redesign Horizontal Alignment Jalan Lingkar Lipi Cibinong

Sources: Result from Data Processing and Calculations in AutoCAD Civil 3D®

From the results of the redesign of Jalan Lipi Cibinong using AutoCAD Civil 3D®, calculations and checks can be obtained for the first bend (PI1), which uses a Full circle (F-C). Because the shape of the horizontal curve is a full circle, the achievement of superelevation is carried out on straight and curved sections. Calculation results of the first bend (PI1) Table 4.

Table 4. Calculation Result of PI1 Bend

Criteria	Value
Radius PI1	151 m
D PI1	11.6049 (d)
Cord length PI1	203.574m
TC	24.130 m
CT	124 m

Sources: Result from Data Processing and Calculations in AutoCAD Civil 3D®

Second bend (PI2) using SCS The following components of the calculation results for the second bend and the consequences of designing the bend through AutoCAD Civil 3D® can be seen in Table 5. Bend calculation results (PI2).

Table 5. Calculation Result of PI2 Bend

Criteria	Value
Radius	165 m
D PI2	10.5841 (d)
Cord length PI2	113.592m
Length spiral in (TS)	50 m
Length spiral out (ST)	15 m
Length spiral (SC-CS)	115.964 m

Sources: Result from Data Processing and Calculations in AutoCAD Civil 3D®

Based on re-planning using civil 3d, the ideal horizontal alignment is obtained with the final coordinates of the Cibinong Lipi Ring Road, which can be seen in Table 5.

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Table 5. Calculation Coordinate, Distance, and Bend Corner P

TITIK	KOORDINAT		JARAK			Azimuth	Sudut Tikungan
	X	Y	ΔX (m)	ΔY (m)	d (m)	α	Δ
A	-628094.27	9271523.9					
			-261.838	14.709	262.251	266.7847	
PI1	-628356.1	9271538.6					**258.693**
			-37.5182	-263.906	266.5592	8.091248	
PI2	-628393.62	9271274.7					**63.008**
			-50.9862	-17.4568	53.89186	71.09968	
B	-628444.61	9271257.2					

5. Conclusion

Conclusions obtained from the results of geometric design, calculations, and data processing carried out using AutoCAD® Civil 3D, namely the Lingkar Lipi Cibinong Bogor Road alternative is a class III (three) Primary Local road, with a 2/2 TT road type along 553.46 km at STA 0+000 - 0+553.46. On this road, a horizontal alignment is designed with two bend designs using the Full Circle (F-C) bend type with a radius of 151 m and the Spiral-Circle-Spiral (SCS) bend type with a radius of 165 m. Using AutoCAD® Civil 3D software can facilitate the planning of road geometrics so that accurate data results are obtained.

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