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THE ALIGNMENT HORIZONTAL DESIGN OF ALTERNATIVE ROAD: A CASE OF JALAN SUBANG – CIKAMURANG, WEST JAVA

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ABSTRACT

Horizontal alignment belongs to the aspect of the geometric design of the road. Jalan Subang - Cikamurang, located in Indramayu, West Java, is planned to have three horizontal alignments. This design aims to connect Subang and Cikamurang to shorten the travel time for the surrounding community's needs. This research uses the Bina Marga method, referring to the 2021 Road Geometric Design Guidelines. First, road traffic data is obtained from the google earth application and then processed with a manual method to determine the coordinates of the road traffic and the location of horizontal alignment. Then the data obtained is processed by referring to the Bina Marga method to design horizontal alignment. Jalan Subang - Cikamurang is a Primary Local Road (Arterial Road), Primary Collector, and class III C road type. Three horizontal alignments with Spiral-Circle-Spiral (SCS) type, the first horizontal alignment is at STA 0+544.018 – 0+819.445, the second horizontal alignment is at STA 1+224.778 – 1+474.695, and the third horizontal alignment is at STA 1+763 – 2+164.390.

INTRODUCTION

Roads are built and maintained to provide services, such as the capacity to move people and products within a predetermined period, with a reasonably low probability of goods being damaged and people being harmed or losing their lives. The road's primary goal is to achieve safe, balanced, sustainable road performance. It is reflected in the geometric planning of roads which includes the symmetrical placement of physical elements of the road, cost analysis (efficiency), reduction of adverse environmental impacts, traffic volume, road accessibility, etc. In addition to ensuring a higher level of road safety, the secondary objectives of roads also include maximizing economic effectiveness in road infrastructure development and reasonable goal accessibility time to maintain sustainable social, environmental, and economic growth (Adey, Burkhalter, & Martani, 2019); (Mitrović Simić, et al., 2020); (Sedivy, et al., 2021).

As a result of the ability of roads to promote economic growth and improve human well-being, the road network is increasing at an unprecedented pace in the world. It is related to the ability of a region to develop and compete globally because it facilitates the transportation of people and goods, communicates information, and provides access to essential services, all of which are prerequisites for the contemporary economy. The World Economic Forum analyzed the

improvement of living standards in 140 countries each year, and the results showed that geographic regions with more vital connectivity experienced greater prosperity. In terms of public welfare, road infrastructure is critical (Carter, Killion, Easter, Brandt, & Ford, 2020); (Ruiz & Guevara, 2020); (Mejía, Sánchez, Castañeda, & Pellicer, 2020).

Indonesia's national goal is to improve infrastructure initiatives for better logistics and transportation. In addition, the government prioritizes improving institutional connectivity, with a particular focus on specific regions. By improving institutional connectedness, social, economic, cultural, and educational efforts will be strengthened by improving institutional connectedness and access and mobility for individuals across the archipelago (Leung, 2017).

Especially Subang is one of the areas in West Java province, the distance to Kertajati International Airport is approximately 70.2 km via the Cikopo - Palimanan Toll Road or 67.2 km via the Jalan Subang - Cikamurang. Jalan Raya Subang - Cikamurang is one of the roads to Kertajati International Airport that is often passed. For this reason, adequate facilities and infrastructure are needed so that access to Kertajati International Airport can be given faster, so a new road construction project that connects Jalan Beber with Jalan Bantar Huni Cikamurang was designed. The construction of this alternative road can shorten the journey to Kertajati International Airport by up to 4.2 km so that the distance from Subang to Kertajati International Airport will be 63 km.

In general, this area has unique soil contours and moderately little rainfall. Inside is a plantation, which is divided by a river. For this reason, it is projected that building new roads in this area can increase the economic income of the area, and its residents can also feel easy access to the place they want to go.

The systematic scientific research process must begin with identifying the exact problem. Therefore, based on the background information and description that has been given above, the author is interested in creating a horizontal geometric road within the city manually with a primary local road classification with road class III C and a planned speed of 100 km / h (Rifai, A. I.; Hadiwardoyo, S. P.; Correia, A. G.; Pereira, P. A., 2016).

LITERATURE STUDIES

Road Geometric Planning

The transport network is a fundamental component of the civil infrastructure and a key element of sustainable development. It is essential for the effective and reliable operation of the transport system. Roads are part of the infrastructure that helps an area develop its potential while facilitating people's movement and goods delivery. When the local economy undergoes a relatively large expansion, the availability of roads is seen as urgent (Mahanpoor, Monajjem, & Balali, 2021); (Howe, 2019); (Nolte, Kister, & Maurer, 2018).

To develop the good road infrastructure, geometric road planning is essential. It is part of road planning that focuses on physical shape planning so that it can fulfill the basic functions of the road, which are providing optimal service to traffic flow and maximizing the ratio of the level of use of implementation costs to give a sense of security and comfort for road users. In addition,

geometric road planning includes elements adapted to the completeness and existing primary data from field survey results and has analyzed and referred to applicable provisions (Jima & Sipos, 2022); (Malaghan, Pawar, & He, 2021).

Geometric planning of roads is a preliminary step in constructing connecting roads or access roads. The access road is a road that connects one road with another that already exists to achieve goals both in terms of economic, social, educational, and others that facilitate people's lives. Access roads provide access to infrastructure such as markets, schools, and hospitals, while the high transportation costs associated with poor transport infrastructure hinder development. Research on planning the access road to the Bailey Mountain Bridge Span states that the results of geometric planning using type III C, lane width 3.5 m, plan speed 100 km / h, total road length 2,335 m consisting of 3 intersection points (Wenz, Weddige, Jakob,, & Steckel, 2020); (Hasan, Firdaus, Sundara, & Astor, 2020).

Alignment Horizontal

Horizontal alignment consists of straight lines connected by curved lines comprised of a circular arc plus a transition arc or a circular arc. It includes a straight section of the road and a circular curve connecting the change in direction. The alignment design mainly depends on the design speed chosen for the road. The most critical part of the horizontal alignment is in the bend, where a centrifugal force pushes the vehicle out of the corner area. Therefore, for the safety of road users, the planning of curve sections needs to consider things such as maximum transverse slope, transition curve, visibility, side-free area, and widening of traffic lanes in the bend area (García, Camacho-Torregrosa, & Baez, 2020); (Garber & Hoel, 2018); (You, Yu, Huang, & Hu, Safety-Based Optimization Model for Highway Horizontal Alignment Design, 2022).

The horizontal alignment is divided into three elements that have a relationship between the steering wheel of the vehicle and the longitudinal axis of the body, such as 0° (straight line), constant (circular curve), or changeable (transition curve). For zero curvature (0°), the line of the running track has an unlimited radius. Therefore the line is straight. Circle curves and relief curves are usually combined with straight lines, for example connecting a circular curve to another circle curve or a circular curve to a transition curve. Circular curves are mainly used to turn and change the direction of vehicles. For constant curvature, the line has a circular curvature because the radius of the running track line is also stable. For changeable curvature, the radius of the running track line also varies, shifting from infinity to a constant value, causing the line to change from a straight line to a circular curve. As long as the use is appropriate and each element, when properly designed, can meet the driving requirements, there is no consistent limit to limit the number and frequency of use of such features when building public roads (Pei, He, Ran, Kang, & Song, Horizontal alignment security design theory and application of superhighways, 2020).

The road was a three-dimensional tape. Its projection line on the horizontal plane is referred to as the road's horizontal alignment, and its midline space's shape is referred to as the route. The development of horizontal alignment theory to support effective and safe road planning is growing, one of which is using trajectory speed. This method is most suitable for designing horizontal

alignment of slow-moving highways through bumpy terrain, especially two-lane mountain routes. This method can be incorporated into the current design process, adding additional design steps, given the traditional way street designers work in different countries. Existing route optimization software can be equipped simultaneously with decision models. Based on research, horizontal alignment can influence the prediction of the trajectory of a typical directional control pattern in the pavement width motorists can use (He & Pei, 2017) (Xu, Lin, & Shao, 2017).

Manual Road Planning

Manual road planning is a design carried out and considered regarding applicable regulations. In Indonesia, MKJI 1997 (Indonesian Road Capacity Manual) is used as a manual for the analysis, planning, design, and operation of traffic facilities such as signaled intersections, interchanges, and interlaced and roundabout sections, as well as roads (urban roads, outside the city) city roads, and expressways). This guide is mainly designed so that users can estimate the traffic behavior of a facility in specific traffic conditions, geometry, and environmental conditions (Israd i & Primary, 2020).

In addition to MKJI, PDGJ (Highway Design Standard of Indonesia) 2021 is a more specific guideline in geometric road planning. This guideline is intended as a technical reference for geometric road designers to obtain the minimum and maximum limits of their design parameters by considering the ideal design requirements, field survey results, and terrain conditions.

In addition, various countries have their manuals for designing roads, such as the USA using AASHTO (American Association of State Highway and Transportation Officials), Japan using JRA (Japan Road Association), Indians using IRC (Indian Road Congress), and others. Therefore, each guide differs depending on the conditions in each country that are made to produce products that are accurate in design, meet needs and technical rules, and can be applied in physical execution in the field.

METHOD

Data is one of the leading forces in structuring scientific research and modeling. In obtaining and managing data, this study uses a literature method for identifying and processing written materials used in library data collection activities. After the preparation period before the study is carried out, data collection is then carried out. Finally, the data are obtained according to the research plan to get precise and appropriate data (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015); (Rifai, Wibowo, Isradi, & Mufhidin, 2020); (Rifai, Surgiarti, Isradi, & Mufhidin, 2021).

The location of the road planning is in Subang City, West Java, one of the roads leading to Kertajati International Airport shown in Figure 1 below. The road will consist of 2 sections, while in this section, the planning will be discussed in section 1 from STA 0 + 000 to STA. STA 2+236,126. The data is taken from Google Earth, the primary data used for road design in this region.

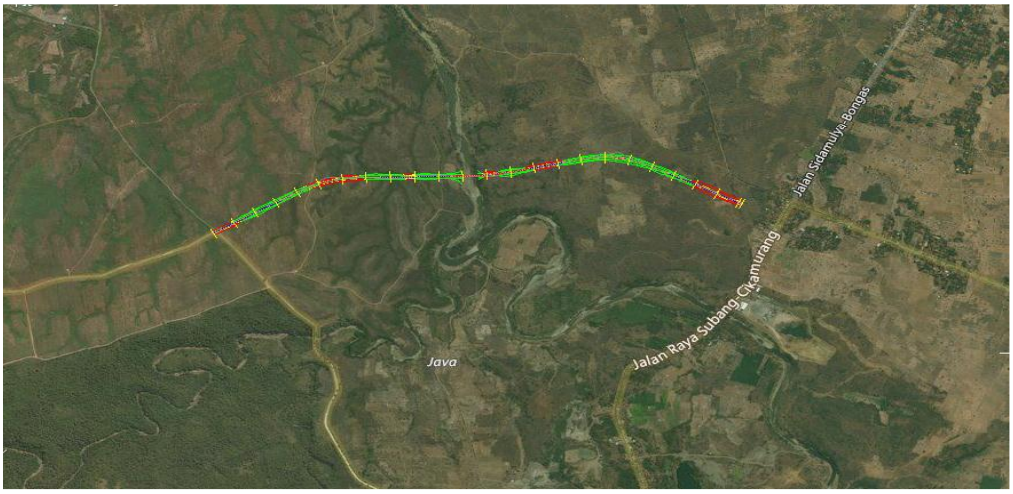

Figure 1. The Location of the Jalan Subang Cikamurang

The study used road class rules based on the function and classification of roads referenced on pages 30 of Table 4-1, 42 of Table 5-1, and 9 of Table 5-3 (Ministry of PUPR, Directorate General of Wildlife Development, 2021). Road planning was done manually with guidelines and standards from Bina Marga 1997 Procedures for Geometric Planning of Inter-city Roads, SE PDGJ 2021 and RSNI T-14-2004.

RESULT AND DISCUSSION

Horizontal Alignment Design

The designation of the road as a public road with the status of a city road (city road) with a function as a primary local road. The road is classified as Class III C and has a lane width of 3.5 m. The plan speed (Vd) is 100 km/h, where the road terrain is flat, with a slope of < 10% for a geometric length of 2,335 km. Here are the coordinates of the road route.

Table 1. Road Route

Point	X	Y
Start	563,963	-717,163
1	1034,069	-443,360
2	1714,773	-434,597
3	2240,886	-318,623
End	2753,922	-572,924

Based on the coordinates of the above road route data, it is calculated to determine the angle of theta, which can be described as follows:θ

a. Different Coordinates

Δx start-1 = x coordinates of point 1 - x coordinates of the starting point
= 563,963 - 1034,069
= 470,093 m

Δy start-1 = y coordinate of point 1 - y coordinate of the starting point
= -443,360 - (-717,163)
= 273,803 m

Δx 1-2 = x coordinates of point 2 - x coordinates of point 1
= 1714,773 – 1034,069
= 680,704 m

Δy 1-2 = y coordinates of point 2 - y coordinates of point 1
= -434,597 – (-443,360)
= 8,763 m

b. Long Internodes Before Curved

The results of the calculation of the coordinate differences are processed into calculations of the distance between points so that the path length is known as follows:

$D = \sqrt{\Delta x^2 + \Delta y^2}$ ..... (1)

Information:

$\Delta x^2 = \text{x coordinate difference}$

$\Delta y^2 = \text{y coordinate difference}$

$\text{Dawal} - 1 = \sqrt{470{,}093^2 + 273{,}803^2} = 544{,}018 \text{ m}$

$D1 - 2 = \sqrt{680{,}704^2 + 8{,}763^2} = 680{,}760 \text{ m}$

c. Azimuth Angle (Z)

The results of the calculation of coordinate differences are also processed into azimuth angle calculations as follows:

$Z = \arctan\frac{\Delta x}{\Delta y}$ ..... (2)

Information:

$\Delta x^2 = \text{x coordinate difference}$

$\Delta y^2 = \text{y coordinate difference}$

$\text{Zawal} - 1 = \arctan\frac{470{,}093}{273{,}803} = 59{,}782°$

$Z1 - 2 = \arctan\frac{680{,}704}{8{,}763} = 89{,}262°$

d. Teta Corner (θ)

$$\theta awal - 1 - 2 = 59{,}782° - 89{,}262° = 29{,}481°$$

The complete calculation results for all points are shown in **Table 2.**

Table 2. Calculation of All Points

Point	X	Y	Δ X	Δ Y	Length	Azimuth	θ	STA
Start	563,963	-717,163						
			470,093	273,803	544. 018	59,782		544. 018
1	1034,069	-443,360					**29,481**	
			680,704	8,763	680. 760	89,262		1224. 778
2	1714,773	-434,597					**11,694**	
			526,113	115,974	538. 744	77,569		1763. 522
3	2240,886	-318,623					**38,798**	
			513,036	254,351	572. 604	116,367		2336. 126
End	2753,922	-572,974						

Horizontal Alignment Calculation

Based on table 5-18, page 96, Rmin with Vd = 100 km/h and e = 8% is 30 m, so R = 480 m, and based on table 5-21, page 101, m max = 133 (Ministry of PUPR, Directorate General of Wildlife Development, 2021).

a. Ls (Sro) ≥ e × B × m max..... (3)
   Information:
   e = pavement superelevation, %
   B = lane width, m
   m = relative slope equivalent
   Ls (Sro) ≥ 37.24 m ≈ 38 m

b. Run out (Tro) = exbxm max ..... (4)
   Information:
   e = pavement superelevation, %
   B = lane width, m
   m = relative slope equivalent

   Exhausted (Tro) = 0.08 x 3.5 x 133 = 37.24 m ≈ 38 m

c. Le = Exhausted + ls = 38 + 38 = 76 m

d. $p = \frac{Ls^2}{24R}$.....(5)
   Information:
   Ls = transition length, m
   R = radius, m

$$p = \frac{38^2}{24 \times 480} = 0.271 \text{ m} \geq 0.25 \text{ m } (\mathbf{spiral - circle - spiral})$$

e. Lc for Vd = 100 km/h for 6 seconds = 167 m

$$Lc = \frac{\theta c}{360^\circ} \times 2\pi \times R \quad \text{.....(6)}$$

Information:
Lc = circle length, m
Θc= angle of the circle, ◦
R = radius, m

$$Lc = \frac{29{,}481^\circ}{360^\circ} \times 2\pi \times 480 = 123{,}427 \text{ m} < 50 \text{ m } (R = 480 \text{ m})$$

With R = 480 m, the planning calculation of the Spiral-Circle-Spiral (SCS) curve is further described as follows:

f. $\theta s = \frac{90 \times Ls}{\pi \times R}$ ..... (7)

Information:
Θs = transition angle, ◦
Ls = transition length, m
R = radius, m

$$\theta s = \frac{90 \times 38}{\pi \times 480} = 2{,}269^\circ$$

g. $\beta = 2\theta s + \theta c$ ..... (8)

Information:
β = total angle, ◦
Θc = angle of the circle, ◦
Θs = transition angle, ◦

$$\theta c = \beta - 2\theta s = 29{,}481 - (2 \times 2{,}269^\circ) = 24{,}943^\circ$$

h. $p = \frac{Ls^2}{6R} - R(1 - \cos\theta c)$ .....(9)

Information:
Ls = transition length, m
R = radius, m
Θc = angle of the circle, ◦

$$p = \frac{38^2}{6 \times 480} - 480(1 - \cos 24{,}943^\circ) = 44{,}269 \text{ m}$$

i. $Es = \frac{R+p}{Cos^{1}/_{2}\beta} - R$.....(10)

Information:

β = total angle, ◦

R = radius, m

$$Es = \frac{480 + 44{,}269}{Cos(14{,}740)} - 480 = 62{,}481 \text{ m}$$

j. $k = Ls - \frac{Ls^3}{40R^2} - (R \times sin\theta s)$..... (11)

Information:

Ls = transition length, m

R = radius, m

Θs = transition angle, ◦

$$k = 38 - \frac{38^3}{40 \times 480^2} - (480 \times \sin 2{,}269°) = 18.997 \text{ m}$$

k. $TS = (R + p)\tan\frac{\beta}{2} + k$..... (12)

Information:

TS = Intersects with Spiral, m

R = radius, m

$$TS = (480 + 44{,}269)\tan\frac{29{,}481}{2} + 18.997 = 156{,}932 \text{ m}$$

l. $Xs = Ls\left(1 - \frac{Ls^2}{40 \times R^2}\right)$.....(13)

Information:

Ls = transition length, m

R = radius, m

$$Xs = 38\left(1 - \frac{38^2}{40 \times 480^2}\right) = 37.994 \text{ m}$$

m. $Ys = \frac{Ls^2}{6R}$.....(14)

n. Description:

Ls = transition length, m

R = radius, m

$$Ys = \frac{38^2}{6 \times 480} = 0{,}501 \text{ m}$$

The TS point is at STA 0+544.018, then the ST point is at STA = TS + Lc + 2Le = 544.018 + 123.427 + 2(76) = 819.445 or STA 0+819.445.

All the above calculations are implemented for the other 2 points shown in Table 3

Table 3. Calculation of All Points

Point	θ	STA TS	R	Lc	θc	p	Ice	TS	STA ST
Start									
		544. 018							
1	**29,481**		480	123,427	24,943	44,269	62,109	156,932	819.445
		1224. 778							
2	**11,694**		480	97,917	7,156	3,237	19,681	68,482	1474,695
		1763. 522							
3	**38,798**		480	324,868	34,260	82,782	101,933	217,172	2164.390
		2336. 126							
End									

Superelevation

Superelevation is the transverse slope of the road at a bend that compensates for the centrifugal force acting when the vehicle is running cornering, expressed in units of %. Based on the above calculations, the superelevation diagram is shown in Figure 2 below.

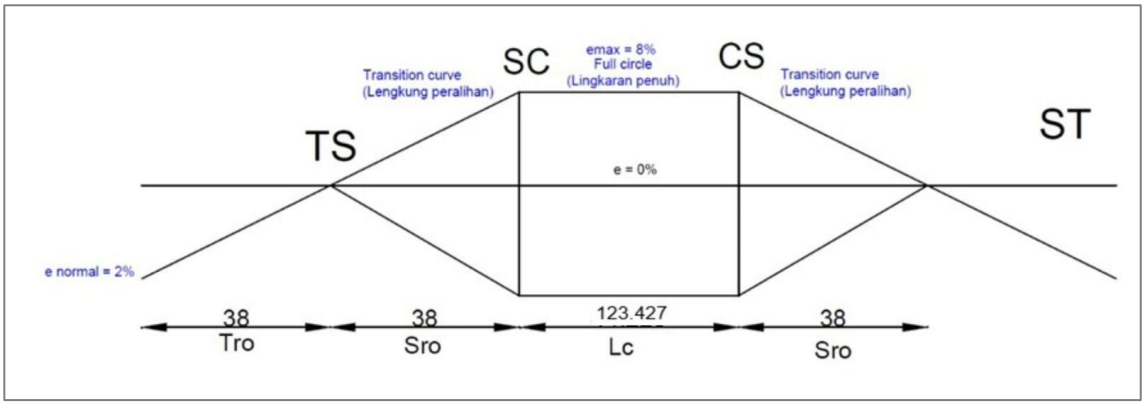

Figure 2. Superelevation Chart

Analysis of road equipment is focused on identifying transportation facilities as road supports that are considered to have the potential to cause traffic accidents through a comprehensive, systematic, and independent road inspection concept. Analysis of the findings at

the research location will be focused on findings that indicate a "No" answer as well as identification of other supports that are deemed not to meet the standards or technical requirements. Then make conclusions and suggestions from the inspection results in the study area.

CONCLUSION

Based on the calculation of horizontal alignment planning for the status of city roads with the function as primary local roads above has a plan speed (Vd) of 100 km / h, using a spiral-circle-spiral (SCS) curve, and the value of e 8%. The value of the transition curve (Ls) is 38 m, and the value of the curve (Lc) is 123.427 m, with a radius (R) of 480 m for all three points of horizontal curvature and has met the existing conditions.

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