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Road Geometric Horizontal Alignment Planning Using Manual Design Method

(Case Study: Alternative Road Between Cibalong District – Santolo Beach STA 0+000 to STA 2+500 Garut Regency, West Java)

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ABSTRACT
An alternative road between Cibalong District - Santolo Beach was made can provide solutions to traffic problems and provide security, comfort, and smooth traffic, and is expected to support economic development with easy access to Santolo Beach. This journal aims to design the geometric design of Alternative Roads in Cibalong District – Santolo Beach STA 0+000 to STA 2+500 Garut Regency, West Java based on "2021 Road Geometric Design Guidelines". This road planning uses data that is divided into primary data and secondary data. From the calculation,s it can be concluded that on a 2,500 km road, 4 different types of turns can be applied. Type Full Circle 1 (FC) uses a radius of 800 m, an arc length is 287,665 m, Type Full Circle 2 (FC) uses a radius of 800 m, arc length is 337,866 m, Type Spiral-Circle-Spiral 1 (SCS) uses a radius of 250 m, length arc 67,803 m, and the Spiral-Circle-Spiral 2 (SCS) type uses a radius of 250 m, arc length of 67,803 m. Road geometric planning that takes into account cost efficiency and safety is very important in the infrastructure development of an area, especially access to tourist areas that can support the local economy.

1. Introduction

Roads are created and maintained to provide services, such as the capacity to move people and products over predetermined timeframes. The main objective of the road is to achieve safe road performance and improve the smooth flow of traffic. This goal can be achieved because of the geometric planning of the road as the first step in road construction. Road safety is defined as the fulfillment of the physical roal elements in accordance with the technical requirements of roadside conditions so that the road does not contribute to traffic accidents [1]

Alternative roads are roads that function to separate vehicles passing on the main route so that they are not concentrated in one place. Making alternative roads is one of the efforts to support smooth traffic and travel efficiency from one area to another. Engineering planning must be carried out in order to produce a road design that meets the standards. In order to get a good and comfortable road, in accordance with the road class that has been determined by the government, namely the Directorate General of Highways, it is necessary to review the geometric aspects as a basis for planning to determine the speed of the plan that is feasible for the road [2]

Road planning is very important for achieving national goals, especially in the Garut Regency area which functions to improve infrastructure for better logistics and transportation. Road infrastructure is the first facility that can be seen directly by the community and migrants in an area, therefore roads are one of the important components in development [3]

As the population increases, the government is obliged to build adequate infrastructure. Viewed from various aspects because of the growth that has occurred, the government is obliged to build transportation infrastructure that meets the requirements and fulfills its role in increasing people's productivity [4]

The planning of an alternative road for the Cibalong-Pantai Santolo sub-district aims to provide security, comfort, and smooth traffic and is expected to support economic development with easy access for traffic actors on the alternative road for Cibalong-Santolo District. Road geometric planning is route planning for road sections, including several elements that are adjusted to the completeness and basic data that are available from the results of field surveys and have been analyzed and referred to applicable regulations [5]

In this paper, based on the description above, the author will carry out road geometric planning, especially horizontal alignment for case studies of alternative roads in Cibalong District - Pantai Santolo STA 0+000 to STA 2+500 Garut Regency, West Java. Road infrastructure design must pay attention to all aspects that affect the safety of its users [6]

2. Study of Literature

2.1. Road Geometric Planning

The transport network is a fundamental component of an infrastructure as well as a key element of sustainable development, which is essential for the effective operation of the transport system [7]. Road geometric planning is the beginning of a transportation network in which the description of the physical form of the road to be built is incorporated into several road elements. Roads are one of the infrastructures that help an area to develop its potential while facilitating the movement of people and the delivery of commodities [8]

Road geometric planning aims to connect two or more locations appropriately, namely by considering the safety conditions of road users and the technical conditions of the area that will be traversed by road users. [9]. Road infrastructure development requires geometric planning that functions to provide optimal service to traffic flow and prevent the ratio of the level of use of implementation costs so as to provide a sense of security and comfort for road users [10]

Road geometry is designed with the problem of mind safety and mobility which has conflicting interests; therefore, these two considerations must be balanced. Mobility is considered not only about mobility motor vehicles but mobility-motorized and pedestrian. In addition, road geometric planning includes several elements that are adjusted to the completeness and existing basic data from field survey results and has been analyzed and referred to applicable regulations [11].

2.2. Horizontal Alignment

In the geometric planning of the road there are two alignments, consisting of a vertical alignment and a horizontal alignment [9]. Horizontal alignment is an image made flush with the horizontal plane of the road. Horizontal alignment consists of straight lines connected by curved lines. The curved line can consist of a circle curve plus a transitional curve. Horizontal alignment has a critical point at the bend, where centrifugal force pushes the vehicle out of the bend area. Therefore, the safety of road users' needs to be considered in this section. Matters such as transition turns, visibility, free side area, and widening of the traffic lane in the bend area must be considered for the safety of road users.

There are three elements to the horizontal alignment that have a relationship between the vehicle's steering wheel and the longitudinal axis, namely 0° (straight line), constant (circular arc), and also changeable (temporary arc) [12]. For zero curvature (0°) the running track line has an infinite radius, so the line is straight. Circle curves and relief curves are usually joined by straight lines, for example connecting circle curves to other circle curves, or circle curves to intermediate curves.

The techniques in designing road geometrics include design criteria, visibility, determining corridors, cross-sections of roads, and element coordination. The design criteria are the basis for determining visibility, horizontal alignment design, and typical road cross-sections. Each traffic lane must comply with the Stopping Sight Distance (JPH) throughout the horizontal alignment design. The horizontal alignment design should avoid the shape of the road that is the same or monotonous, as much as possible the horizontal alignment design is made straight with a large bend radius.

2.3. Manual Road Design

Manual road design in outline/general to determine the road alignment, after a decision has been made that the location of the plan is feasible to build a road. In this initial planning, general research will be carried out on the selected planned route to determine or find possible local obstacles, which can be in the form of topographical conditions, such as hills, mountains, ravines, the groundwater table is close to the ground surface and land uses such as factories, the source of life for the local population. The geometric design is related to what is seen from the road where safety is a major factor in the design of a road [13]

Planning is carried out and calculated according to applicable regulations, where in Indonesia MKJI 1997 is used as a guideline for analysis, planning, design, and all operations of traffic facilities. This guide is primarily designed to allow users to predict the traffic behavior of a facility under certain traffic conditions, geometries, and environmental conditions [14] [15] [16] [17] [18] [19].

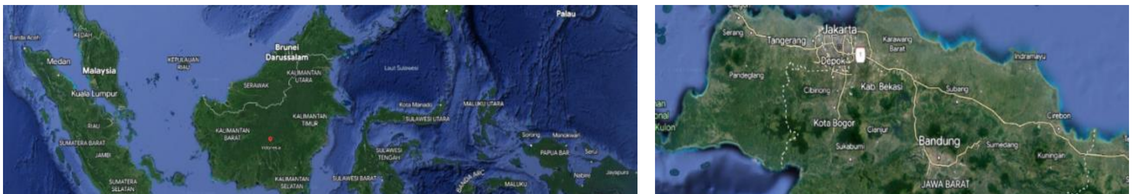
Apart from MKJI 1997, SE PDGJ 2021 is also a more specific guideline for road geometric planning. In road geometric planning, taking horizontal and vertical alignments must follow the requirements that have been determined. Comparison of the use of AutoCAD® Civil 3D in the geometric design of roads using the manual method has far-reaching effectiveness corrections with planning using the manual method [20]

3. Research Method

Writing begins with the method of collecting data and identifying problems with the construction of the Cibalong District Alternative Road - Santolo Beach. The process of systematic scientific research must begin with the identification of the right problem [21].

In planning, research methods and data collection methods are needed. The first stage of a research is to find and collect the data needed. Data was obtained according to a research plan for precise and appropriate data [22]. This study uses the literature method in collecting and processing data which is a method for identifying and processing written materials to be used [23].

The road design location is in Cibalong District and Pamempeuk Region, Garut Regency. This road aims to connect disconnected roads and find the shortest and most effective distances compared to other routes as well as increase the potential of the area and surrounding areas in the tourism and small and medium-sized economy sector as shown in **Figure 1** below. The road planning that will be discussed and discussed is the Cibalong District Alternative Road – Santolo Beach STA 0+000 to STA 2+500. The following image is taken from Google Earth.



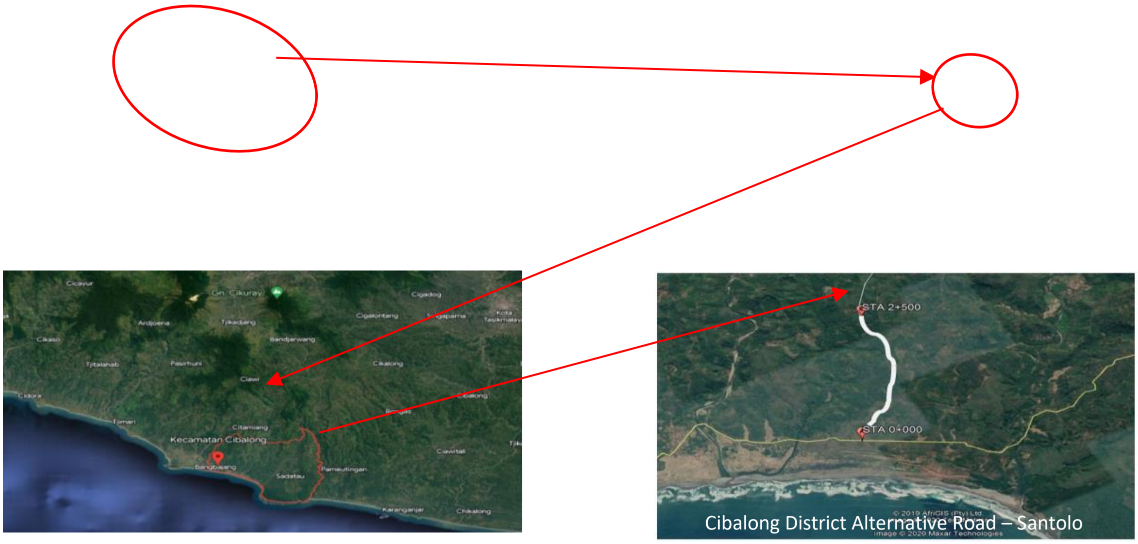


Figure 1. Road Planning Locations

This plan takes the decision to determine the direction of the road by considering the following matters namely connecting the disconnected road between Cibalong District and Pamempeuk Region in Garut Regency, is the shortest and most effective distance compared to using other routes based on land contours, and roads can be used to increase the potential of the area and the surrounding area in the tourism and small and medium economy sectors. Identification of the right problem can be achieved if the scientific research process is carried out systematically [21].

4. RESULTS AND DISCUSSION

According to the 2021 Road Geometric Planning Guidelines, the alternative road for Cibalong District – Pantai Santolo is included in the local secondary road. The design planning clarification for the road is on flat terrain with a 2/2 UD road type, 3.5/lane width, and the design speed is taken to be 60 km/hour. The maximum superelevation value is 2.67%.

4.1. Calculation of Horizontal Alignment

Before calculating the horizontal alignment, it is necessary to obtain the ground surface contour to calculate the coordinates of the connecting road to be built. As can be seen in Table 1, coordinate points on the horizontal alignment are obtained with the help of Global Mapper and implemented in AutoCAD® 2D.

Table 1. Calculation of Horizontal Curvature

Point	Coordinate	
	X	Y
A	811487,3448	9149047,804
1	812170,4954	9149529,185
2	812557,9047	9150586,636
3	812643,9658	9150586,636

4	812544,3079	9150907,709
B	812573,327	9151068,13

The coordinates were obtained from the results of data visualization from Google Earth to AutoCAD® 2D with the help of the Global Mapper application and 2 horizontal alignment curves were obtained which were made with the provisions of the first and second curves (Full Circle), and the third and fourth curves (Spiral-Circle-Spiral).

1) Coordinate Difference (Δx and Δy)

Δx Coordinate x

$$\Delta xA - 1 = 811487{,}3448 - 812170{,}4954 = 683{,}1506$$

$$\Delta x1 - 2 = 812170{,}4954 - 812557{,}9047 = 387{,}4093$$

$$\Delta x2 - 3 = 812557{,}9047 - 812643{,}9658 = 86{,}0611$$

$$\Delta x3 - 4 = 812643{,}9658 - 812544{,}3079 = 99{,}6579$$

$$\Delta x4 - B = 812544{,}3079 - 812573{,}327 = 29{,}0191$$

Δy Coordinate y

$$\Delta yA - 1 = 9149047{,}804 - 9149529{,}185 = 481{,}3808$$

$$\Delta y1 - 2 = 9149529{,}185 - 9150098{,}884 = 569{,}6998$$

$$\Delta y2 - 3 = 9150098{,}884 - 9150586{,}636 = 487{,}7525$$

$$\Delta y3 - 4 = 9150586{,}636 - 9150907{,}709 = 321{,}0721$$

$$\Delta y4 - B = 9150907{,}709 - 9151068{,}13 = 160{,}4215$$

2) Length Before The Curve (D)

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

$$D(A-1) = \sqrt{683{,}1506^2 + 481{,}3808^2} = 835{,}717\ m$$

$$D(1-2) = \sqrt{387{,}4093^2 + 569{,}6998^2} = 688{,}943\ m$$

$$D(2-3) = \sqrt{86{,}0611^2 + 487{,}7525^2} = 495{,}287\ m$$

$$D(3-4) = \sqrt{99{,}6579^2 + 321{,}0721^2} = 336{,}183\ m$$

$$D(4-B) = \sqrt{29{,}0191^2 + 160{,}4215^2} = 163{,}025\ m$$

3) Azimuth Angle Calculation (Z)

$$Z = Arc\ tg \frac{\Delta x}{\Delta y}$$

$$Z(A-1) = Arc\ tg\ \frac{683{,}1506}{481{,}3808} = 54{,}8296°$$

$$Z(1-2) = Arc\ tg\ \frac{387{,}4093}{569{,}6998} = 34{,}2167°$$

$$Z(2-3) = Arc\ tg\ \frac{86,0611}{487,7525} = 10,0065°$$

$$Z(3-4) = Arc\ tg\ \frac{99,6579}{321,0721} = 342,7561°$$

$$Z(4-B) = Arc\ tg \frac{29,0191}{160,4215} = 10,025°$$

4) Delta Angle Calculation (Δ)

$$\Delta A - 1 = 54,8296° - 34,2167° = 20,6130°$$

$$\Delta 1 - 2 = 34,2167° - 10,0065° = 24,2102°$$

$$\Delta 2 - 3 = 10,0065° - 342,7561° + 360° = 27,2504°$$

$$\Delta 3 - 4 = 342,7561° + 360° - 10,025° = 27,4974°$$

The resume results from calculating the coordinates to get azimuth angle, delta angle, and arc type determination.

Table 2. Calculating Horizontal Arch Planning

Point	**Coordinates**		**Different Coordinates**		**Distance**	**Azimuth**	**Δ**	**type**
	X	**Y**	**ΔX**	**ΔY**				
Start	811487.344	9149047						
			683.1506	481,380	835,717	54,829		
1	812170.495	9149529					20,613	**FC**
			387.4093	569,698	688,943	34,216		
2	812557.904	9150098					24,210	**FC**
			86061	487,752	495,287	10006		
3	812643.965	9150586					27,250	**SCS**
			99,657	321,072	336,183	342,756		
4	812544.307	9150907					27,497	**SCS**
			29019	160,421	163,025	10.253		
Finish	812573.327	9151068						

After obtaining coordinate data and curved length, proceed with data collection by calculating the horizontal curved curve according to PDGJ 2021.

1. Turn 1 (Full Circle)

Δ = 20,6130°

Vplan = 60 km/hour

Rplan = 800m

a. Determine the minimum radius (Rmin)

SPEED PLAN (KM/H)	MINIMUM RADIUS(M)
120	2000
100	1500
80	1100
60	700
40	300
30	180

b. Determining Degrees of Curvature (D) and Super Elevation (e)

1) D $= \frac{1432,4}{Rrencana} = \frac{1432,4}{800} = 1,7905°$

2) Dmax $= \frac{1432,4}{Rmin} = \frac{1432,4}{115} = 12,45565°$

3) e $= \frac{e\ maks\ x\ D}{Dmaks}\left(2 - \frac{D}{Dmaks}\right)$

$= \frac{0,1\ x\ 1,7905}{12,45565}\left(2 - \frac{1,7905}{12,45565}\right)$

$= 0,0267 = 2,67\%$

c. Determine Ls

1) $B = \frac{1}{2}\ x\ Pavement\ Width = \frac{1}{2} x\ 7 = 3,5\ m$

2) $m = \frac{1}{landai\ relatif} = \frac{1}{1:160} = 160$

Obtained based on the following table:

Speed Plan (km/h)	Relative Ramps
60	1:160
80	1:200
100	1:240
120	1:280

Ls fictitious $= B\ x\ m(e + en) = 3,5\ x\ 160(0,0267 + 0,02) = 26,152\ m \approx 30\ m$

Ls outside the curve $= \frac{2}{3}\ x\ 30\ m = 20\ m$

Ls in curve $= \frac{1}{3}\ x\ 30\ m = 10\ m$

d. Determine TC (start of arc), Ec (distance of PI to arc), and Lc (length of arc)

1) TC $= Rrenc\ x\ \left(tan\frac{\Delta}{2}\right)$

TC $= 800\ x\ \left(tan\frac{20{,}6130°}{2}\right) = 145{,}4784\ m$

2) $Ec = \frac{R}{cos\frac{\Delta}{2}} - R = \frac{800}{COS\frac{20{,}6130°}{2}} - 800 = 13{,}1198\ m$

3) Lc $= \frac{\Delta}{360}\ x\ 2\pi R = \frac{20{,}6130°}{360}\ x\ 2\pi 800 = 287{,}6653\ m$

2. Turn 2 (Full Circle)

Δ = 24,2102°

Vplan = 60 km/hour

Rplan = 800m

a. Determine the minimum radius (Rmin)

district Plan (km/h)	Minimum Radius (M)
120	2000
100	1500
80	1100
60	700
40	300
30	180

b. Determining Degrees of Curvature (D) and Super Elevation (e)

1) D $= \frac{1432{,}4}{Rrencana} = \frac{1432{,}4}{800} = 1{,}7905$

2) Dmax $= \frac{1432{,}4}{Rmin} = \frac{1432{,}4}{115} = 12{,}45565$

3) e $= \frac{e\ maks\ x\ D}{Dmaks}\left(2 - \frac{D}{Dmaks}\right)$

$= \frac{0{,}1\ x\ 1{,}7905}{12{,}45565}\left(2 - \frac{1{,}7905}{12{,}45565}\right) = 0{,}0267 = 2{,}67\%$

c. Determine Ls

$$1)\ B = \frac{1}{2}\ x\ pavement\ width = \frac{1}{2} x\ 7 = 3{,}5$$

$$2)\ m = \frac{1}{landai\ relatif} = \frac{1}{1:160} = 160$$

Obtained based on the following table:

Speed Plan (km/h)	Relative Ramps
60	1:160
80	1:200
100	1:240
120	1:280

Ls fictitious $= B\ x\ m(e + en)$

$= 3{,}5\ x\ 160(0{,}0267 + 0{,}02) = 26{,}152\ m \approx 30\ m$

Ls outside the curve $= \frac{2}{3}\ x\ 30\ m = 20\ m$

Ls in curve $= \frac{1}{3}\ x\ 30\ m = 10\ m$

d. Determine TC (start of arc), Ec (distance of PI to arc), and Lc (arch length)

1) TC $= Rrenc\ x\ \left(tan\frac{\Delta}{2}\right)$

TC $= 800\ x\ \left(tan\frac{24{,}2102°}{2}\right) = 171{,}5793\ m$

2) $Ec = \frac{R}{cos\frac{\Delta}{2}} - R = \frac{800}{COS\frac{24{,}2102°}{2}} - 800 = 13{,}1198\ m$

3) Lc $= \frac{\Delta}{360}\ x\ 2\pi R = \frac{24{,}2102°}{360}\ x\ 2\pi 800 = 337{,}8662\ m$

3. Turn 3 (Spiral Circle Spiral)

Δ = 27,2504°

Vplan = 60 km/hour

Rplan = 250m

a. Determine Minimum Radius (Rmin)

Rplan = 250 m

b. Determining Degrees of Curvature (D) and Super Elevation (e)

1) D $= \frac{1432{,}4}{Rrencana} = \frac{1432{,}4}{250} = 5{,}7296°$

2) Dmax $= \frac{1432{,}4}{Rmin} = \frac{1432{,}4}{115} = 12{,}45565°$

3) e $= \frac{e\ maks\ x\ D}{Dmaks}\left(2 - \frac{D}{Dmaks}\right)$

$= \frac{0{,}1\ x\ 5{,}7296}{12{,}45565}\left(2 - \frac{1{,}7905}{12{,}45565}\right) = 0{,}0708 = 7{,}08\%$

c. Determine Ls

1. Based on Relative Slope

$$B = \frac{1}{2}\ x\ pavement\ width = \frac{1}{2} x\ 7 = 3{,}5\ m$$

$$m = \frac{1}{landai\ relatif} = \frac{1}{1:160} = 160$$

Obtained based on the following table:

Speed Plan (km/h)	Relative Ramps
60	1:160
80	1:200
100	1:240
120	1:280

lsmin $= B\ x\ m(e + en) = 3{,}5\ x\ 160(0{,}0708 + 0{,}02) = 50{,}848\ m$

2. Based on Centrifugal Force

$$Ls\ min = 0{,}022\ x\ \frac{Vrenc^3}{Rrenc\ x\ c} - 2{,}727\ x\ \frac{Vrenc\ x\ e}{c}$$

$$= 0{,}022\ x\ \frac{60^3}{250\ x\ 0{,}4} - 2{,}727\ x\ \frac{60\ x\ 0{,}0708}{0{,}4} = 18{,}5429\ m$$

3. Based on travel time

$$Ls = \frac{Vrenc}{3{,}6}x\ T = \frac{60}{3{,}6}x\ 3 = 50\ m$$

The largest Ls is taken, namely 50.848 m ≈ 51 m (based on relative slope)

d. Determine θs and Δc

$$\theta s = \frac{28{,}648\ x\ Ls}{Rrenc} = \frac{28{,}648\ x\ 51}{250} = 5{,}8515°$$

$$\Delta c = \Delta - 2\theta s = 24{,}2102° - (2x5{,}8515°) = 15{,}5473°$$

e. Determine Lc

$$Lc = \frac{\Delta c}{360}\ x\ 2\pi\ x\ Rrenc = \frac{15{,}5473°}{360}\ x\ 2\pi\ x\ 250 = 67{,}8036\ m$$

f. Determining Arch Length (L)

$$L = Lc + 2Ls = 67{,}8036 + 2(51) = 169{,}8036\ m$$

1. Define Xc

$$Xc = Ls - \frac{Ls^5}{40\ x\ Rrenc^2\ x\ Ls^2}$$

$$= 51 - \frac{51^5}{40\ x\ 250\ x\ 51^2} = 50{,}9469\ m$$

2. Determine Yc

$$Yc = \frac{Ls^3}{6\ x\ Rrenc\ x\ Ls} = \frac{51^3}{6\ x\ 250\ x\ 51} = 1{,}734\ m$$

3. Determine P

$$P = Yc - Rrenc(1 - cos\theta s)$$

$$= 1{,}734 - 250(1 - cos5{,}8515°) = 0{,}4314\ m$$

4. Determine k

$$k = Xc - Rrenc\ sin\theta s = 50{,}9469 - 250(sin5{,}8515°) = 25{,}4592\ m$$

5. Determine Ts

$$Ts = (Rrenc + P)tan\frac{\Delta}{2} + k$$

$$= (250 + 0{,}4314\ )tan\frac{24{,}2102°}{2} + 25{,}4592 = 86{,}1615\ m$$

6. Define Es

$$Es = \frac{Rrenc + P}{cos\frac{\Delta}{2}} - Rrenc$$

$$= \frac{250 + 0,4314}{cos\frac{24,2102°}{2}} - 250 = 7,6832\ m$$

5. Conclusion

The results of planning the horizontal alignment of Alternative Roads for Cibalong District – Pantai Santolo STA 0+000 to STA 2+500 Garut Regency, West Java using the 2021 Road Geometric Design Guidelines, obtained an alternative road with a total length of 2,500 km consisting of 4 bends with first and second arcs are Full Circle (FC), third and fourth arcs are Spiral-Circle -Spiral (SCS). Based on these calculations, it is found that on a 2,500 km long road, 4 different types of turns can be applied. Type Full Circle 1 (FC) uses a radius of 800 m, arc length is 287,665 m, Type Full Circle 2 (FC) uses a radius of 800 m, arc length is 337,866 m, Type Spiral-Circle-Spiral 1 (SCS) uses a radius of 250 m, length arc 67,803 m, and the Spiral-Circle-Spiral 2 (SCS) type uses a radius of 250 m, arc length of 67,803 m.

References

[1] A. M. Fitra, "Analisis Uji Laik Fungsi Jalan Aspek Teknis Pada Ruas Jalan Nasional Tambu–Tompe Provinsi Sulawesi Tengah.," *Journal of Civil Engineering and Planning (JCEP), 1(2),* pp. 137-150, 2020.

[2] M. Lubis, N. M. Rangkuti and M. Ardan, "Evaluasi geometrik jalan pada tikungan Laowomaru.," *In Seminar Nasional Teknik (SEMNASTEK) UISU (Vol. 2, No. 1, pp. 37-43).,* pp. 37-43, 2019.

[3] V. S. Mamahit, F. Singkoh and S. Sampe, "Pengaruh Pembangunan Infrastruktur (Jalan) Terhadap Efektivitas Distribusi Pupuk Bersubsidi Kabupaten Bolaang Mongondow Timur (Studi kasus di Kecamatan Mooat).," *GOVERNANCE, 1(1).,* 2021.

[4] N. Zulfa, A. I. Rifai and M. Taufik, "Road Geometric Design used AutoCAD® Civil 3D: A Case Study Jalan Campaka-Wanaraja Garut, Indonesia.," *Citizen: Jurnal Ilmiah Multidisiplin Indonesia, 2(5),* pp. 843-850, 2022.

[5] M. L. Yudhistira, A. Tribhuwana and S. Anwar, "PERENCANAAN GEOMETRIK JALAN RUAS JALAN MUNJUL-JATIGEDE.," *Jurnal Konstruksi dan Infrastruktur, 6(4).,* 2020.

[6] A. Pembuain, S. Priyanto and L. Suparma, "The effect of road infrastructure on traffic accidents.," *In 11th Asia Pacific Transportation and the Environment Conference (APTE 2018) (pp. 176-182). Atlantis Press.,* pp. 176-182, 2019.

[7] M. Mahanpoor, S. Monajjem and V. Balali, "An optimization model for synchronous road geometric and pavement enhancements.," *Journal of Traffic and Transportation Engineering (English Edition), 8(3),* pp. 421-438, 2021.

[8] M. Aker, K. Altenmüller, M. Arenz, M. Babutzka, J. Barrett, S. Bauer and R. Robertson, "Improved upper limit on the neutrino mass from a direct kinematic method by KATRIN," *Physical review letters, 123(22), 221802,* 2019.

[9] R. Rizki, A. Rifai and E. Djamal, "Geometric Redesign of Jalan Cisauk–Jaha, Banten with Manual Method (Sta. 0+ 000-Sta. 0+ 350)," *Citizen: Jurnal Ilmiah Multidisiplin Indonesia, 2(5),* pp. 859-864, 2020.

[10] D. Jima and T. Sipos, "The Impact of Road Geometric Formation on Traffic Crash and Its Severity Level.," *Sustainability, 14(14), 8475.,* 2022.

[11] V. Malaghan, D. S. Pawar and H. Dia, "Modeling acceleration and deceleration rates for two-lane rural highways using global positioning system data.," *Journal of advanced transportation, 2021,* pp. 1-17, 2021.

[12] Y. Pei, Y. He, B. Ran, J. Kang and Y. T. Song, "Horizontal alignment security design theory and application of superhighways.," *Sustainability, 12(6), 2222,* 2020.

[13] M. Mandal, P. Pawade, P. Sandel and R. Infrastructure, "Geometric design of highway using Civil 3D.," *International Journal of Advance Research, Ideas and Innovations in Technology, 5(3),* pp. 214-217, 2019.

[14] M. Isradi and E. A. Pratama, "Performance analysis of Unsignal Intersection and Road section with MKJI Method 1997.," *IJTI International Journal of Transportation and Infrastructure eISSN 2597-4769 pISSN 2597-4734, 4(1),* pp. 1-11, 2020.

[15] S. Suganda, A. I. Rifai and J. Prasetijo, "The Route Choice Analysis of Parung-Sentul Traveler: A Case of Impact New Toll Road Operation," *Indonesian Journal of Multidisciplinary Science,* vol. 1, no. 1, pp. 427-436, 2022.

[16] R. Pramono, A. I. Rifai and S. Handayani, "The Student Perception of public transportation mode choice: A case study of Universitas Mercubuana," *Citizen: Jurnal Ilmiah Multidisiplin Indonesia,* vol. 1, no. 1, pp. 934-943, 2022.

[17] A. W. Rahmadhani, A. I. Rifai and S. Handayani, "The Perception of Travel Behavior on Public Transport Mode Choice: A Case of Depok-Jakarta Route," *Citizen: Jurnal Ilmiah Multidisiplin Indonesia,* vol. 2, no. 5, pp. 896-905, 2022.

[18] A. Setiawan, A. I. Rifai and J. Prasetijo, "The Phenomena of Local Public Transportation Service: A Case Oplet in Pontianak, Indonesia," *Citizen: Jurnal Ilmiah Multidisiplin Indonesia,* vol. 2, no. 5, pp. 916-923, 2022.

[19] I. Prasetyo and A. I. Rifai, "Railway Planning Double-Double Track (Case Study of Bekasi Station km 26+ 652-Jatinegara Station km 12+ 050)," *International Journal of Transportation and Infrastructure,* vol. 4, no. 1, pp. 12-21, 2020.

[20] A. Agniya, A. I. Rifai and M. Taufik, "The Geometric Design of New Jakarta-Cikampek Highway Access Using Autocad® Civil 3D: A Case of West Karawang Industrial Area.," *Indonesian Journal of Multidisciplinary Science, 1(1),* pp. 189-198, 2022.

[21] A. I. Rifai, S. P. Hadiwardoyo, A. G. Correia and P. A. U. L. O. Pereira, "Genetic Algorithm Applied for Optimization of Pavement Maintenance under Overload Traffic: Case Study Indonesia National Highway.," *Applied Mechanics and Materials, 845,* pp. 369-378, 2016.

[22] A. I. Rifai, Y. Surgiarti, M. Isradi and A. Mufhidin, "Analysis of Road Performance and the impact of Development in Pasar Minggu, Jakarta (Case Study of Jalan Lenteng Agung-Tanjung Barat).," *International Journal of Civil Engineering, 6(1),* pp. 68-74, 2021.

[23] A. I. Rifai, T. Wibowo, M. Isradi and A. Mufhidin, "On-Street Parking and Its Impact on Road Performance: Case Commercial Area in Jakarta City.," *World Journal of Civil Engineering, 1(1),* pp. 10-18, 2020.