THE HORIZONTAL CURVED GEOMETRIC PLANNING USING THE AUTOCAD CIVIL 3D® METHOD ON TANAH MERAH ROAD, BANJARBARU CITY, SOUTH KALIMANTAN

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ABSTRACT

In modern times, technological developments are very rapid, one of which is in the field of transportation, which is now a hot research topic. Transportation is closely related to safety factors, so this study discusses how to plan roads by looking at safe and comfortable design aspects. This research opens new access roads on Tanah Merah roads by concentrating on geometric horizontal arches using the AutoCAD Civil 3D® application. The writing method and research method in the preparation of this research used secondary data and qualitative research methods. The data is collected from various sources: the internet, Google Maps, Google Earth, and Global Mapping. The length of the trace along ±1.519 Km. The arch discussed in this study is the Pl4 arch with the type of Spiral Circle Spiral (S-C-S) arch. Superelevation with a radius of 300 m is 4.5%. After doing this planning, it can be concluded that using AutoCAD Civil 3D® is considered more manageable, faster, and more effective than using manual methods.

INTRODUCTION

In modern times, technological developments are very rapid, one of which is in the field of transportation, which is now a hot research topic. Road projects promote the socio-economic development of countries and regions because an efficient road infrastructure network allows access to health, education, housing, trade, and so on. It is estimated that the total length of paved roads will increase by 25 million km by 2050, which is done to meet population growth and from the transition of global population collision. The cause of regional development is to cause the addition and expansion of social and transportation facilities and infrastructure to serve the needs of its population (Castañeda, Sánchez, Herrera, & Mejía, 2022); (Strano, et al., 2017); (Rifai, Surgiarti, Isradi, & Mufhidin, 2021).

Currently, the population in the country is more than 230 million people, which will drive an increase in transportation and vehicle ownership demand. Indonesia has 34 provinces, with traffic conditions and many drivers having considerable spatial differences. Indonesia also accommodates heterogeneous traffic with hybrid vehicles. In addition to a large human population, Indonesia also has great tourism potential, one of which is a tourism destination, namely the island of Kalimantan. Infrastructure related to accessibility is one of the factors that influence the
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development of tourism potential in Kalimantan, as many access roads to tourist attractions must be built (Soehodho, 2017); (Siregar & Tjahjono, 2021); (Agustaniah & Wicaksono, 2020).

With infrastructure, the basis of people's livelihood, complete life in the countryside is possible. The need for more infrastructure makes the existence of rural areas as places of residence and community work unpromising (Bryzho, 2019). Highway Design Standard of Indonesia 2021, which can be used as a geometry road plan design guide, replaces the previous guide. The regulation results in a road geometry design that is safe, environmentally friendly, effective, cost-effective, and efficient (Directorate General of Highways, 2021).

An essential factor in the field of transportation is traffic safety. Therefore, strengthening road safety facility planning is one of the most critical issues because if the design is safe and comfortable, it will create safety for the driver and provide driving comfort. An indicator in measuring the safety design of road traffic engineering is that it is necessary to regulate traffic safety facilities appropriately and reasonably (Lihong, Tongshuai, & Wei, 2018); (Li, 2021); (Cui, 2020). Building Information Modelling (BIM) has been widely adopted within transportation, and its well-established methods and technologies show enormous potential in providing benefits to industrial transportation. So this study discusses how to plan a road by looking at safe and comfortable design aspects using AutoCAD Civil 3D® (Costin, Adibfar, Hu, & Chen, 2018®).

The road is expected to guarantee the comfort and safety of users, allow efficient traffic operations, and at the same time, attract the minimum possible costs in construction and maintenance. This research opens new access to Tanah Merah roads by planning roads concentrating on geometric horizontal curves using the AutoCAD Civil 3D® application, which is as maximum and efficient as possible, rather than planning using manual methods. The planning of the Tanah Merah road includes the Local Primary highway because the road is close to Syamsuddin Noor International Airport. There are several fundamental reasons for the selection of Tanah Merah road. First, it is the only road that is still based on the ground level. However, there has not been a road suitable for use and is used as an alternative to divert passenger vehicles from the primary arterial road (Ahmad Yani road to Trikora road) and can facilitate the movement of people and goods to airports or vice versa (Mandal, Pawade, Sandel, & Infrastructure, 2019).

LITERATURE REVIEW
AutoCAD Civil 3D®

Building Information Modeling (BIM) is a design method becoming a new trend in the construction industry, developed in recent years in many countries. Building Information Modeling (BIM) is a new technology transforming the infrastructure design and construction sector. The impact of digital tools such as (Vignali, et al., 2021). Building Information Modeling (BIM) can generate excellent value, increase productivity, and drive innovative solutions. Advantageous in the use of BIM for the project life cycle, such as information management at construction sites, which typically face problems in managing the exchange of information (e.g., daily safety reports) and addressing matters from various overlapping sources of information (Nikologianni, Mayouf, & Gullino, 2022).
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AutoCAD Civil 3D® was developed by the company Autodesk. Autodesk Civil 3D® plans, designs and delivers land, water, and transportation development projects. 3D modeling is one of the leading technologies required to create a unified system to ensure road safety in a large city. AutoCAD (Autodesk Inc., 2022); (Eliseev, Tomchinskaya, Lipenkov, & Blinov, 2017) Civil 3D also helps para-engineers in improving data storage, more consistent processing processes and being able to respond more quickly to changes that occur in the project®.

In making geometric planning for manual roads, what is done will be very complicated, take a long time to work, and there can be undetected errors, increasing the work cost. One of the well-known software for Building Information Modeling for geometric designing roads is AutoCAD Civil 3D®. As a result, the road design process becomes more efficient, accurate, and time-saving compared to designing the same road manually. It can be concluded that in geometric road planning using AutoCAD Civil 3D® (Pandey, Atul, & Bajpai, 2019)® is considered faster, more accessible, and practical, and can provide solutions whether the design is feasible or not.

Horizontal Arch

In the current trend, geometric design is one part of road planning that fulfills functions and roads by generating physical shape planning. The design process involves some drafting and several analyses and calculations. There are three main elements in geometric road planning: horizontal paragraphing, vertical alignment, and road cross-section. In the geometric design of roads, things need to be done using coordinates (or bearings), stations, and elevations; calculation of visibility, the radius of the horizontal arch and length of the vertical arch; the calculation of the number of earthworks, and many other analyzes and calculations are aimed at finding the optimal alignment while meeting design standards and constraints (Gaikawad & Ghodmare, 2020); (Raji, Zava, Jirgba, & Osunkunle, 2017).

The design of a horizontal alignment is influenced by many factors, including the terrain's functional classification, the design's speed, the traffic volume, the right of way, environmental conditions, and the level of service required. Horizontal alignment must comply with particular design criteria, such as minimum radius, superelevation level, and visibility. A circular curve is a curve with a constant radius connecting two tangents. A compound curve consists of two or more circular curves side by side with different radii. Spiral curves are used in horizontal alignment to provide a gradual transition between tangent and circular sections of the curve (Abdulhafedh, 2019).

A horizontal path paragraph must be a series of straight lines (allusions) and circular curves spliced through a transition curve. Allusions, circular curves, and transition curves are the three elements of the horizontal paragraph of the modern road. The main task of the horizontal paragraph design is to determine the tangent cut point, circular curve, and transition curve. Once the parameters of these elements are determined, the center line of the road is determined entirely (Casal, Santamarina, & Vázquez-Méndez, 2017); (You, Yu, Huang, & Hu, 2022).
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Road

Infrastructure is the embodiment of the service delivery system to the community. Transport infrastructure is an integral part of the transport system of any city or state. Transportation as an economic factor is a measure of economic activity, and at the same time, transport reflects economic activity. Therefore, the question of measuring the performance of transport infrastructure and the relationship between transport infrastructure and economic growth became the subject of discussion in both academic and non-academic circles (Skorobogatova & Kuzmina-Merlino, 2017).

Transportation has been responsible for the development of civilization from ancient times by meeting the needs of human travel and transportation of goods needs. Today, roads and transportation have become integral to every human being. The road contributes to sustainability and economic growth, offering great social benefits. Therefore, developing an adequate road transport system is the primary need of any developing country. The improvement of the existing road network system is significant for developed countries because the road capacity on urban and non-urban highways will reach a level of saturation over time (Chakole & Wadhai, 2022)(KS, 2017).

A highway consists of buildings and other outbuildings that maintain traffic above and below ground and at the water's surface. It is generally built to move people, goods, and services from one place to another. A road is an access that connects one place to another on one landmass. In other words, the definition of a road is a main road that can connect one area with another to distribute services (Setyawan, et al., 2021); (Directorate General of Highways, 2021).

METHOD

The horizontal curved geometric planning that will be discussed is Jalan Tanah Merah, located in Landasan Ulin Timur Village, Landasan Ulin District, Banjarbaru City, South Kalimantan, in which Banjarbaru City is the capital of South Kalimantan province. The length of the geometric planning of the Tanah Merah road is ± 1,519 Km. The road is a road that is only covered by the ground surface and is currently not a suitable road for the community. Therefore, Jalan Tanah Merah is devoted to an alternative road that connects Jalan Ahmad Yani with Jalan Trikora. The location of Jalan Tanah Merah can be seen in Figure 1. Location of Jalan Tanah Merah.
The basis for planning is necessary to determine the data collection method and research methods. The data obtained can be used to analyze road planning data, identify relationships between variables, and obtain information about data predictions. Technological advances have led to the collection, compilation, and archiving of large amounts of data that can now be easily researched. As a result, using existing data in research becomes more familiar with its secondary data analysis. Therefore, secondary data or information collected by researchers from different current sources or indirectly obtained information is used in the methodology of this study to meet the information needs of the survey (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015); (Johnston, 2017); (Rifai, Rafianda, Isradi, & Mufhidin, 2021).

The secondary data obtained in this study are topographic data on the planned road area. The information is collected from various sources: the internet, Google Maps, Google Earth, and Global Mapping. Then the data will be processed into a calculation plan for the geometric design of horizontal arches on Jalan Tanah Merah. It is known that the process of systematic scientific research must begin with the identification of appropriate problems. Research methods that have these characteristics are qualititative research methods. Therefore, the research method used in this study is qualitative research. Descriptive and analytical techniques are used in this qualitative research (Rifai, Hadiwardoyo, Correia, & Pereira, 2016).

RESULTS AND DISCUSSION

The results and discussion contain road design criteria, horizontal paragraphs, and superelevations equipped with stages of work on AutoCAD Civil 3D®. This planning work refers to the Highway Design Standard of Indonesia 2021.

Design Criteria

The design criteria concerning the Highway Design Standard of Indonesia 2021 for Tanah Merah roads can be seen in the following table:
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Table 1. Design Criteria

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>Public Roads (Primary Local)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Network System</td>
<td>Primary</td>
</tr>
<tr>
<td>Road Status</td>
<td>Provincial Roads (Provincial Government)</td>
</tr>
<tr>
<td>Design Speed ($V_D$)</td>
<td>50 km/h</td>
</tr>
<tr>
<td>Road Class According to the User</td>
<td>Class II</td>
</tr>
<tr>
<td>Road Class Based on Road Infrastructure Provision Specifications</td>
<td>JSD</td>
</tr>
<tr>
<td>Road Terrain</td>
<td>Flat (Terrain slope &lt; 10%)</td>
</tr>
<tr>
<td>Lane Width</td>
<td>3.5 m</td>
</tr>
<tr>
<td>Outer Shoulder Width</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Road Land Width</td>
<td>10 m</td>
</tr>
<tr>
<td>Overall Width Between Building Lines</td>
<td>15 m</td>
</tr>
<tr>
<td>Overall Width Between Control Lines</td>
<td>16 m</td>
</tr>
<tr>
<td>Friction Coefficient Value</td>
<td>0.35 for passenger cars</td>
</tr>
<tr>
<td>(Longitudinal Roughness)</td>
<td></td>
</tr>
<tr>
<td>Road Type</td>
<td>2/2-TT or 2 lanes 2 way</td>
</tr>
<tr>
<td>Shoulder Superelevation</td>
<td>5%</td>
</tr>
<tr>
<td>Maximum Slope</td>
<td>6%</td>
</tr>
</tbody>
</table>

Stages of Geometric Planning Work

The stages of road geometric planning work using AutoCAD Civil 3D® are as follows:

1. Contour Data Search Process
   The contour data retrieval process is carried out on Google Earth software, the DEMNAS website, and Global Mapper software. One of the outputs issued is the dwg format. The data will be entered into AutoCAD Civil 3D®, which will then be planned.

2. Initial setup and contour data input to AutoCAD Civil 3D®
   When opening AutoCAD Civil 3D®, the initial settings are made by setting an adjusted coordinate system at the location of the road used. After the initial setting, it is to input the contour data that has been obtained from the output of the Global Mapper by opening the dwg file in AutoCAD Civil 3D®.

3. Contour Surface Manufacturing
The contour surfaces are created when the contours have been input into AutoCAD Civil 3D. Creating a contoured surface on AutoCAD Civil 3D® is to right-click on the existing contour, then click *Create Surface*.

**Horizontal Alignment Creation**

In the horizontal paragraph planner, it is necessary to calculate $R_c$ and $L_s$. Horizontal linemen can be created by clicking the *Toolbar Alignment* menu and starting to line the planned trace line from the starting point (A) to the end point (B). In this process, can input the design criteria as needed. Next, make an arch on the arch as required for this planning using an arch-type *Spiral Circle Spiral* (S-C-S).

![Figure 2. Curve PI4](image)

**Superelevation**

After making horizontal paragraphs and arches of the Spiral *Circle Spiral* (S-C-S), it creates a superelevation by right-clicking on the arch created and then clicking the calculated superelevation. After that, input lane type, road type, road shoulder type, and other planning criteria.

**Horizontal Alinements**

a. Trace Planning

The traffic planning on the red dirt road has a length of 1,519 Km, starting from STA 00 + 000 to STA 01 + 519. Trace's image can be seen in Figure 3. Road Trace Plan. Topographic calculations here are used to determine the slope of the terrain. The calculation of the terrain slope on this red dirt road has 0.94%, which shows that the road terrain is contained in the Highway Design Standard of Indonesia 2021.
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![Figure 3. Road Trace Plan](image)

b. Horizontal Arch Calculation

Horizontal paragraph planning uses the Spiral *Circle Spiral* (S-C-S) arch type at the PI4 arch point. In calculating the horizontal linemen of the Spiral *Circle Spiral* (S-C-S), there are several formulas used with the SE-PDG 2021 reference, namely as follows:

\[ R_{min} = \frac{V_D^2}{127(f_{max} + e_{max})} \]  \hspace{1cm} (1)

\[ L_s = \frac{wn_1e_d}{\Delta} (b_w) \]  \hspace{1cm} (2)

\[ L_{s,min1} = \sqrt{24(P_{min})R_c} \]  \hspace{1cm} (3)

\[ L_{s,min2} = \frac{0.0214V^3}{RC} \]  \hspace{1cm} (4)

The following are the conditions used for whether the PI4 bend can use the Spiral *Circle Spiral* (S-C-S) arch type, namely as follows:

\[ p = \frac{L_s^2}{24R_c} \geq 0.25 \text{ m} \]  \hspace{1cm} (5)

If it meets, then the bend belongs to the SCS type

\[ p = \frac{(83)^2}{24(300)} \]  \hspace{1cm} \[ p = 0.957 \geq 0.25 \text{ m} \]

So, for the PI4 Bend can use the Spiral *Circle Spiral arch* type (S-C-S)

\[ \Theta_s = \frac{90L_s}{\pi R_c} \]  \hspace{1cm} (6)

\[ \Theta_c = \beta - 2\Theta_s \]  \hspace{1cm} (7)

\[ L_c = \frac{\Theta_c}{360^\circ} \times 2\pi R_c \]  \hspace{1cm} (8)

\[ L_e = \text{Runout} + \text{Runoff} \]  \hspace{1cm} (9)
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\[ p = \frac{L_s^3}{6R} - R_c(1 - \cos \Theta_s) \] .......................................................... (10)

\[ k = L_s - \frac{L_s^2}{40R_c^2} - R \sin \Theta_s \] .......................................................... (11)

\[ E_s = (R + p)sec 1/2 \beta - R_c \] .......................................................... (12)

\[ T_s = (R + p)tg 1/2 \beta + k \] .......................................................... (13)

\[ X_s = L_s \left(1 - \frac{L_s^2}{40R_c^2}\right) \] .......................................................... (14)

\[ Y_s = \frac{L_s^2}{6R_c} \] .......................................................... (15)

Information:
\[ R_{min} \] = Minimal curved radius
\[ V_D \] = speed of design or plan
\[ f_{max} \] = Transverse roughness factor
\[ e_{max} \] = Maximum superelevation
\[ L_s \] = Min length. runoff superelevation curved switching
\[ \Delta \] = Maximum relative slump, %
\[ n_1 \] = Number of rotated paths
\[ b_w \] = Adjustment Factor
\[ w \] = Width of one lane of traffic, m
\[ e_d \] = Super level of design elevation, %
\[ L_{s,min} \] = Minimum length of switching curve
\[ P_{min} \] = Minimum lateral offset distance between the straight and arc of the circle (0.20m)
\[ R_c \] = Arc radius of a circle, m
\[ V \] = Design speed, Km/H
\[ C \] = Maximum rate of lateral acceleration change (1.2m/sec^3)
\[ \Theta_s \] = Spiral curved angle, degrees
\[ \beta \] = Angle of Curve, degrees
\[ L_c \] = Curved length of the circle, m
\[ p \] = Shift of tangent to spiral, m
\[ k \] = Straight distance between the beginning of the curvature and the shift point of the circular arc, m
\[ E_s \] = Distance from PI to arc circle, m
\[ T_s \] = Point of a spiral tangent, m
\[ X_s \] = Abscissa of the point SC on the tangent line, the distance from the point TS to the SC (curved straight distance switching).
\[ Y_s \] = Coordinates of the SC point on the perpendicular line of the tangent line, the distance perpendicular to the point
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SC on the arch.

**Table 2. Planning Criteria**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Superelevation (en)</td>
<td>2%</td>
</tr>
<tr>
<td>Annual Average Daily Traffic Plan</td>
<td>600 pcu/day</td>
</tr>
<tr>
<td>Maximum superelevation (emax)</td>
<td>8%</td>
</tr>
<tr>
<td>Minimum Radius Curve (Rmin)</td>
<td>72,908 m</td>
</tr>
<tr>
<td>Transverse Roughness Factor (fmax)</td>
<td>0.19</td>
</tr>
<tr>
<td>Minimum Relative Slope</td>
<td>0.65</td>
</tr>
<tr>
<td>Number of Rotation Lines (n1)</td>
<td>1</td>
</tr>
<tr>
<td>Adjustment Factor (bw)</td>
<td>1</td>
</tr>
<tr>
<td>Increase in Length Relative to One Lane Rotation (n1, bw)</td>
<td>1</td>
</tr>
</tbody>
</table>

The following is the result of the calculation of the spiral *circle spiral* (S-C-S) arch:

**Table 3. Calculation results of the Curved Spiral Circle Spiral (S-C-S) Curve PI4**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>STA</td>
<td>01+288</td>
</tr>
<tr>
<td>Curved Corner $\beta$ or $\Delta$</td>
<td>30.083°</td>
</tr>
<tr>
<td>Curved Radius (R or Rc)</td>
<td>300 m</td>
</tr>
<tr>
<td>Level of Superelevation ($e$)</td>
<td>4.5%</td>
</tr>
<tr>
<td>Maximum Equivalent Relative Slope ($M_{\text{max}}$)</td>
<td>154</td>
</tr>
<tr>
<td>Minimum Runoff Length of The Transition Curve for Superelevation ($L_{s1}$)</td>
<td>24.23 m</td>
</tr>
<tr>
<td>Minimum Runoff Length of The Transition Curve for Superelevation ($L_{s2}$)</td>
<td>25 m</td>
</tr>
<tr>
<td>Transition Curve Minimum Length ($L_{\text{min}1}$)</td>
<td>37.95 m</td>
</tr>
<tr>
<td>Transition Curve Minimum Length ($L_{\text{min}2}$)</td>
<td>7.43 m</td>
</tr>
<tr>
<td>Maximum Length of The Transition Curve ($L_{s \text{max}}$)</td>
<td>84.85 m</td>
</tr>
<tr>
<td>Transition Curved Length Design ($L_{\text{sdesign}}$)</td>
<td>83 m</td>
</tr>
<tr>
<td>Check $L_s$</td>
<td>OK</td>
</tr>
<tr>
<td>Ltr (Runout)</td>
<td>36,889 m</td>
</tr>
<tr>
<td>Le</td>
<td>119.89 m</td>
</tr>
</tbody>
</table>
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| Curve PI4 |
|-----------------|----------------|
| Spiral-Curved Corner (s) Θ | 7.92° |
| Θc | 14.24° |
| Circle Curve Length (Lc) | 74,590 m |
| Tangent Shift to The Spiral (p) | 0.966 m |
| Calculate the Straight Distance Between the Initial Curvature and The Circular Arc's Shift Point (k) | 41,504 m |
| Distance from PI to Circular Curve (Eₙ) | 11,643 m |
| The Point of The Spiral Tangent (Tₛ) | 122,381 m |
| The Abscissa of Point SC On the Tangent Line, Distance From Point TS to SC (Xₛ) | 82,241 m |
| Coordinates of point C on the perpendicular to the tangent line, the perpendicular distance to point SC on the arc (Yₛ) | 3,827 m |

c. Superelevation

From the calculation of the curved superelevation plan of the Spiral Circle Spiral (S-C-S) at the PI4 point, the following results were obtained:

\[ R_c = 300 \, m, \]
\[ L_s = 83 \, m \]
\[ V = 50 \, Km/Jam \]
\[ e_{maks} = 4.5\% \]

The following is the result of the location of the superelevation slope.

| Table 4. Slope of the Superelevation Spiral Circle Spiral |
|-----------------|----------------|
| Section | Superelevation |
| | Left | Right |
| I-I | -2% | -2% |
| II-II | 0% | -2% |
| III-III | +4.5% | -4.5% |

Superelevation is the cross slope of the road in the bend area. For straight road sections, the road has a cross slope which is usually called the normal slope or normal trawn, which is taken at least 2% both to the left and right of the centerline of the road. The elevation value (e) which causes an increase in elevation relative to the road axis is marked (+) and which causes a decrease in elevation relative to the road is marked (-). While what is meant by a superelevation diagram is a way to describe the achievement of superelevation and normal
slopes to the cross slope. Superelevation diagrams on the height of the shape depend on the shape of the curve in question.

![Superelevation Spiral Circle Spiral Slope at Curve PI4](image)

**Figure 4.** Superelevation Spiral Circle Spiral Slope at Curve PI4

When a vehicle crosses a bend, the rear wheels of the vehicle cannot follow the tracks of the front wheels, the track is deeper than the front wheels, so that a wider track will occur, so widening is required at bends so that the vehicle's wheels remain on the pavement. The value of widening is based on the grouping of highways and the planned vehicles used, namely semi-trailers for class I roads, single unit trucks for class II, III, IV roads while class V roads do not need widening. Bend widening depends on bend radius $R$, bend angle $(\Delta)$ and design speed $(V_r)$.

**CONCLUSION**

Based on the results of the planning that has been carried out, several conclusions can be drawn from the results of calculations and data processing, namely the traffic along the Tanah Merah Road starting from STA 00 + 000 to STA 01 + 519. The arch discussed in this study is the PI4 arch with the type of Spiral Circle Spiral (S-C-S) arch. Superelevation with a radius of 300 m is 4.5%. After doing this planning, it can be concluded that using AutoCAD Civil 3D® is considered more manageable, faster, and more effective than manual methods.

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