THE GEOMETRIC DESIGN OF HORIZONTAL CURVES USING THE AUTOCAD CIVIL 3D® METHOD: A CASE STUDY OF TRANS FLORES ROADS

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ABSTRACT
In general, the geometric planning of roads is done manually using drawing tools and mathematical techniques. When done manually, geometric design is complicated, time-consuming, and prone to errors. Therefore, this study will use AutoCAD Civil 3D®. This study aims to redesign the Trans Flores road because of the frequent accidents found on curves and climbs and the current road drops on the Trans Flores road. This study will use research methods using secondary data and qualitative research methods. When designing geometric roads using AutoCAD Civil 3D®, data from Google Maps, Google Earth, and Global Mapping is also required. This research will focus on the 3.5 km of road traffic starting from Sta 0+000 to Sta 3+500. The result of this study is that corners P1-P4 are planned with the type of Bend S-C-S. By using AutoCAD Civil 3D®, this research can be completed quickly and accurately.

INTRODUCTION
Highway construction can be related to carefully considering environmental, economic, and social aspects with a long-term perspective. Road construction will be regarded as 'sustainable' when it supports economic development and consistently meets people's transport needs with environmental protection. In developing countries, road construction aims to connect isolated areas and boost economic growth through better mobility of people. To improve traffic safety, traditional highway planning and design often require more conservative solutions, including expanding road widths and increasing lane lengths, to overcome significant elevation differences. The highway project is vital because it will be people's access to health, education, housing, trade, and so on. Therefore, governments around the world prioritize significant financial investments to develop new highway projects and maintain existing highways (Suprayoga, Witte, & Spit, 2020); (Li, Ding, & Zhong, 2019); (Castañeda, Sánchez, Herrera, & Mejía, 2022).

Roads designated for public traffic are referred to as public roads. If the road used for traffic is in good condition, it can support the improvement of the community's economy and the welfare of the community. Therefore, in the construction of highways, special attention is required. The
The Geometric Design of Horizontal Curves Using The Autocad Civil 3D® Method: A Case Study of Trans Flores Roads

road has three essential parts. They are namely horizontal and vertical alignment, as well as a cross-section, which, when combined, will produce three formats of road dimensions. Horizontal alignment is a projection line of the steep road's axis. It is also commonly referred to as a bend or turn. While the vertical alignment is a cut line formed by a vertical plane through the axis of the road with a paving surface midwife, commonly called a ramp and a descent road (Syafial & Rusfana, 2022); (Gaikawad & Ghodmare, 2020).

The Trans Flores highway is a road that connects Maumere City with Larantuka City, East Nusa Tenggara (NTT). The Trans Flores highway is famous for its winding and uphill terrain. Traffic rates often need to match the planned use of the road. The accident rate on the horizontal curve results from the inconsistency between the design and the desired speed. It is 1.5 to 4.0 times greater than that of the tangent. Several findings of traffic accidents occur in road users who pass through horizontal paragraphs (bends) on Trans Flores Road. It can be caused by a bend radius not following Bina Marga guidelines (Ouma, Yabann, Kirichu, & Tateishi, 2014).

In general, the geometric planning of roads is done manually using drawing tools and mathematical techniques. When done manually, geometric designs are very time-consuming and very error-prone. Manual planning usually uses a two-dimensional design. This analysis does not guarantee satisfaction by design. Current trends are geared towards using highly advanced computer programs for highway geometry designs that offer exceptional precision and save time and effort (Raji, Zava, Jirgba, & Osunkunle, 2017). AutoCAD Civil 3D® is a software application used by civil engineers and professionals to plan and design projects for building construction, road engineering projects, and water, including the construction of dams, ports, canals, embankments, and so on (Mandal, Pawade, Sandel, & Infrastructure, 2019). AutoCAD Civil 3D® provides a real-time and comprehensive overview of the road surface, horizontal, vertical paragraphs, etc. Using AutoCAD Civil 3D® can make it easier for the author to plan geometric roads. It is because, in AutoCAD Civil 3D®, the author can design geometric road planning and produce output in the form of plan drawings from geometric road planning without calculating it manually.

Based on the explanation above, the author will do geometric planning of the road on the Trans Flores Road on a horizontal arch. This planning will use methods assisted by AutoCAD Civil 3D®. This geometric planning has been carried out previously with manual calculations with title "Analisis Desain Geometrik Jalan Pada Lengkung Horisontal Tikungan Dengan Metode Bina Marga dan AASHTO Studi Kasus Ruas Jalan Km 180–Waerunu Sta 207+ 500 s/d Sta 207+ 700" (Pau & Aron, 2018).

LITERATURE REVIEW
AutoCAD® Civil 3D

AutoCAD Civil 3D® is an application software used by civil engineers and professionals to plan and design projects. Civil 3D is software for engineering that is used to design, plan and manage civil engineering works, including roads, highways, water, land development and railways. Civil engineers and other experts commonly use this software. Civil 3D is generally used
to minimize design time and evaluate various situations (Chakole & Wadhai, 2022). AutoCAD Civil 3D® software reduces human effort in designing the necessary project structure and gives more precise design results. AutoCAD Civil 3D® is a superior software in model design related to Civil Engineering (Pandey, Atul, & Bajpai, 2019).

Three-dimensional (3D) reconstruction is the process of generating a 3D Representation of a 3D view of the output of data collection equipment. 3D reconstruction of image-based civil infrastructure is a new topic attracting significant interest in the construction industry's scientific and commercial sectors. Reliable computer vision-based algorithms have been available for the past decade and can now be applied to solve real-life problems in uncontrolled environments. Civil 3D provides for creating 3D models of projects and helps adapt for small and large-scale projects. In addition, it helps to imagine things in 3D visualization, reducing time and budget (Ma & Liu, 2018; Sukalkar & Pawar, 2022).

3D modeling is one of the leading technologies necessary to create a unified system to ensure road safety in a large city. The current trend relies on highly advanced computer technology for highway geometry designs that offer exceptional precision and save time and effort (KS, 2017). AutoCAD Civil 3D® helps to complete the design process casually and comfortably in terms of time and saves a lot of time and effort. AutoCAD Civil 3D® is very effective for geometric road planning because it can carry out the process and plan the depiction simultaneously, making the road geometric planning process easier and faster.

Horizontal Arch

Horizontal alignment is a projection of the axis of the road on the horizontal plane, also known as the "road situation". Such curved lines may consist of a circle arc plus an intermediate arc, a transitional arc or a circle arc only. Horizontal alignments consist of a straight section and a curved part (also known as a bend). On geometric planning, the curved portion is intended to compensate for the centrifugal force received by the running vehicle. The horizontal alignment of the highway determines its location and orientation in the view of the plan (Sitompul, 2020).

Horizontal alignment consists of three geometric elements: tangents (straight sections), circular curves, and spiral transitions between tangents and curves (Raji, Zava, Jirgba, & Osunkunle, 2017). Horizontal alignment tends to be associated with a disproportionate number of severe accidents. Many treatments have been proposed to reduce traffic accidents and deaths in horizontal bends. However, geometric problems of roads at bend points or horizontal paragraphs, and planning of bends that do not comply with established regulations, can create new problems. Many bends often cause accidents. It can be caused by the bend radius not following Bina Marga guidelines (Geedipally, Pratt, & Lord, 2019).

Characteristics of horizontal alignment can have a significant impact on traffic flow. For example, on sharp turns, the vehicle can reduce its speed or increase the longitudinal gap; As a result, the current decreases. Horizontal alignment consists of straight elements (allusions) or curved elements. Each of these elements has its geometric characteristics that affect the maximum traffic flow that can be achieved. Poor coordination between geometric elements of horizontal
alignment can lead to unsafe speeds. The horizontal alignment of the highway provides a smooth transition between the two intersecting sections of the highway. Therefore, they allow vehicles to adjust their direction of travel gradually. However, changes in the geometry of highway sections with an H curve often pose safety concerns (Sil, Nama., Maji, & Maurya, 2020); (Ma, Yang, Wang, Xie, & Yang, 2020).

Sharp turns have been known to cause driver instability (positioning themselves on a passing line), leading to a collision. Another reason for reducing safety in acute sections of the road is that visibility can be significantly reduced, affecting the driver's ability to evaluate road conditions correctly. Horizontal alignments are prone to accidents if they are not designed precisely and must be checked continuously and accurately protected. Geometric planning on horizontal sections (bends) is intended to compensate for the centrifugal force received by vehicles running at speed (VR) (Koloushani, Ozguven, E., & Tabibi, 2020).

Highway Geometrics

The road is one land transportation access that connects one region to another. Roads are also the infrastructure that is essential in advancing goods and services and connecting other areas to increase the community's needs. In geometric road planning, it is necessary to pay attention to the topographic conditions and the surrounding environment to provide economic planning and provide services optimally and efficiently. Elements of highway geometry are expected to be selected, measured, and positioned in a way that satisfies design criteria such as visibility, vehicle stability, driver comfort, drainage, economy, and aesthetics. The design process involves some drafting and some analyses and calculations. Tasks typically performed by design engineers include: creating road alignment and plotting road profiles using coordinates (or bearings), stations, and elevations; calculation of distance vision, the radius of the horizontal curve, and length of the vertical curve; the calculation of the Number of earthworks, and many other analyses and calculations aimed at finding optimal alignment while satisfying design standards and constraints (Sinaga, Sendow, & Waani, 2019); (Raji, Zava, Jirgba, & Osunkunle, 2017).

Design control governs vital aspects of highway design and is critical to safety and efficiency. The geometric features considered in this section include the essential components that guide the horizontal and vertical alignment, including curvature and slope, and the elements that make up the cross-section of the highway, including lanes, shoulders, and medians. In addition, interchanges and interchanges are an essential part of road design due to their significant impact on safety performance and operational efficiency. The Ministry of Federal Works Nigeria (FMW) said, "geometric design focuses on specific measures that provide efficiency and appropriate road operation, as well as providing for all the specific details that make the road safe and compatible with the social and environmental circumstances surrounding the road" (Findley, 2022).

The primary purpose of geometric design consistency is to minimize the appearance of unforeseen events when road users drive along road segments. A consistent highway design ensures that successive geometric elements act coordinated. The consistency of highway geometric design is categorized into three main areas: (a) speed considerations, (b) safety considerations, and
The Geometric Design of Horizontal Curves Using The Autocad Civil 3D® Method: A Case Study of Trans Flores Roads

(c) performance considerations. Speed considerations overcome the different effects of geometric parameters on operating speed prediction. To improve traffic safety, traditional highway planning and design often require more conservative solutions, including expanding road widths and increasing lane lengths, to overcome significant elevation differences. However, most of these repairs are expensive. The cost of a highway life cycle depends on its length, geometric parameters, and type of infrastructure (that is, bridges, tunnels, etc.), which is another factor deep in traffic safety (Chaudhari, Goyani, Arkatkar, Joshi, & Easa, 2022); (Li, Ding, & Zhong, 2019).

METHOD

In the redesign process, it is necessary to carry out a careful analysis. The more complicated the problems faced, the more complex the analysis will be carried out. Research methods are an essential part of compiling a design journal. The research method will contain: procedures and steps to be done, the time of the study, the source of data, and the data used, and then it will be analyzed. This research method aims to achieve the goals and produce answers to the problems being analyzed. In making research methods, complete and accurate data is needed, accompanied by relevant fundamental concepts.

The first stage is the preparatory stage, where data collection and processing will be carried out in the preparation stage. At this stage, a plan will be prepared that will be carried out to obtain efficiency and effectiveness of time and work. At this stage, preliminary observations are also carried out to get an overview of identifying and formulating problems in the field. Furthermore, the survey stage will be carried out in the form of primary data or secondary data. Primary data is data obtained from direct observations in the field. Meanwhile, secondary data is obtained from local governments, books, journals, and related agencies.

This journal will use the research method of collecting secondary data. Secondary data is a source of research data obtained by researchers indirectly through intermediary media (obtained and recorded by other parties) such as several books, collections of journals, and others. In this study, secondary data were obtained from existing data from the results of Geometric Design Analysis of Roads on Horizontal Arches (Bends) With the Bina Marga and AASHTO Methods owned by Dedi Imanuel Pau and Siprianus Aron. This horizontal curved geometric design will use the AutoCAD Civil 3D® method, which connects Maumere City with Larantuka City. Using AutoCAD Civil 3D® can simplify the process and save time.

The selection of the Trans Maumere – Larantuka Road is due to frequent accidents on the road. On the Trans Maumere - Larantuka road, it is often traversed by vehicles with large loads, such as trucks. This excess truckload capacity can also be one of the causes of damage and accidents on the road (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015). It can also be caused by a bend radius not following Bina Marga guidelines. In horizontal arches, accidents are often found. It can be caused by visibility, bend radius, and road slumps that do not follow the clan service guidelines. Most notably, the process of systematic scientific research must begin with the identification of appropriate problems. Therefore, the author conducted a geometric review of the
The Geometric Design of Horizontal Curves Using The AutoCad Civil 3D® Method: A Case Study of Trans Flores Roads

The following is geometric road planning using the AutoCAD Civil 3D® application, especially in calculating horizontal paragraphs equipped with the steps taken and standards. It referred to the Circular Letter of Road Geometric Design Guidelines (Highway Design Standard-Indonesia) of the Directorate General of Highway in 2021.

Planning Criteria

At the initial planning stage, a determination will be made for planning criteria, including the planned location, road function classification, terrain class classification, plan vehicle, Road parameters, and plan speed. The planning location is on the planned 3.5 km Trans Flores Road starting from Sta 0+000 – Sta 3+500, along with the location of the Trans Flores seen in Figure 4.

RESULT AND DISCUSSION

Figure 1. Location of the Trans Flores Road

Figure 2. Location of Trace Sta 0+000 – Sta 3+500
The Geometric Design of Horizontal Curves Using The Autocad Civil 3D® Method: A Case Study of Trans Flores Roads

In determining these planning criteria, it will refer to the Highway Design Standard-Indonesia 2021. There are four types of road classifications based on road use described in Table 5-1 of the Highway Design Standard of Indonesia 2021. The Trans Flores highway connects Maumere City with Larantuka City, East Nusa Tenggara (NTT). It is a public road organized by the central government, so the road status for the Trans Flores Road is national. Based on its function, the Trans Flores Road is included in the function of a class I primary arterial road. Based on the calculation of the slope of the road trace measured every 100 m, the average slope of the road trace is 2.5% with a flat terrain classification. Based on the Highway Design Standard of Indonesia regarding rumaja, rumija, and ruwasja, wide roads can be categorized, Rumaja is 24 m, Rumija is 25 m, and Ruwasja is 15 m. Trans Flores road is designed with a planned speed of 75 vcu / hour. Road traffic lanes are categorized as two-lane roads, four lanes 2 T directions with a width per lane of 3.5 m, and for the width of the road shoulder, the minimum width is taken based on the Highway Design Standard-Indonesia, which is 2 m. Based on Table 5-2, the maximum superelevation used is 8%, with a transverse slope of the road body used at 2%, and the slope of the road shoulder used is 3%. Based on the classification of road functions, namely arteries and flat road terrain, the deliberate speed is 75 km/hour.

Horizontal Alignments
a. Trace Plans

The planned trace on the Trans Flores road will be 3.5 km long, starting from Sta 0+000 – Sta 3+500. This planning will use bend points on the PI1 – PI4 arc, which can be seen in Figure 3. Road Trace Plan. Based on the calculation of the slope of the road trace measured every 100 m, the average slope of the road trace is 2.5%. In the provisions of the Highway Design Standard-Indonesia slope below 10% is a category with flat terrain. Therefore, for the determination of the straight distance (d), Azimuth Angle (α), and Bend Angle /Bearing (Δ) of the trace, coordinate numbers at the beginning and end of each point of intersection are needed in the horizontal paragraph which can be seen in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Geometric data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>PI1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>PI2</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>B</td>
</tr>
</tbody>
</table>

257 | Indonesian Journal of Multidisciplinary Science, Vol. 1, Special Issue, No. 1, December 2022
b. Horizontal Alignment Calculation

At the minimum bend radius count \( R_{\text{min}} \) using a superelevation of 8\% taken from Table 5-2. For transverse roughness) which is 0.15, then for the calculation of the minimum bend is as follows:

\[
R_{\text{min}} = \frac{V^2}{127(e_{\text{max}} + f_{\text{max}})}
\]

Based on formula (1), \( R_{\text{min}} \) is 192.57 m

After obtaining the value of the plan bend, a calculation is made of horizontal paragraphing. The following are the formulas used in Horizontal Alignment modeling and superelevation diagrams:

\[
L_{s \text{ min} 2} = \frac{w \cdot n_1 \cdot e_d}{\Delta} (b_w)
\]

where:
- \( w \) = width of one lane of traffic
- \( e_d \) = Design superelevation rate (\%)
- \( n_1 \) = Number of rotated paths
- \( b_w \) = Adjustment factor for the Number of rotated paths

\[
L_{s \text{ min} 3} = \frac{0.0214 \cdot V^3}{R \cdot C}
\]

where:
- \( C \) = maximum rate of lateral acceleration change (1,20 m/s^3)

Figure 3. Road Trace Plan

258 | Indonesian Journal of Multidisciplinary Science, Vol. 1, Special Issue, No. 1, December 2022
The Geometric Design of Horizontal Curves Using The Autocad Civil 3D® Method: A Case Study of Trans Flores Roads

\[ L_s \min 4 = \sqrt{24 \cdot P_{\min} \cdot R} \]  
\[ P_{\min} = \text{Minimum lateral offset distance between straight section and circular arc (0.20m)} \]

Check whether the arch is the full circle or spiral circle spiral (SCS), by the way if,

\[ p = \frac{L_s^2}{6 \cdot R_c} \geq 0.25 \text{ m, it's SCS} \]  
\[ \theta_s = \frac{90 \cdot L_s}{\pi \cdot R_c} \]  
\[ \theta_c = \beta - 2 \cdot \theta_s \]  
\[ L_c = \frac{\theta_c}{360} \cdot 2 \cdot \pi \cdot R \]  
\[ p = \frac{L_s^2}{6 \cdot R_c} - R_c (1 - \cos \theta_s) \]  
\[ E_s = \frac{(R_c + p)}{\cos \frac{1}{2} \beta} - R_c \]  
\[ k = L_s - \frac{L_s^2}{40 \cdot R_c^2} - R_c \cdot \sin \theta_s \]  
\[ T_s = (R_c + p) \tan \left( \frac{1}{2} \beta \right) \]  
\[ X_s = L_s \left( 1 - \frac{L_s^2}{40 \cdot R_c^2} \right) \]  
\[ Y_s = \frac{L_s^2}{6 \cdot R_c} \]

The planned bend has four bends/PI on the Trans Flores Road based on the bend angle's size, the distance between the two bends, and the land/topographic conditions. It was then obtained for all four planned corners using the SCS corner. The results of the calculation of SCS bends utilizing the help of AutoCAD Civil 3D® from PI1 –PI4 can be seen in Table 2.
Table 2. Bend Calculation Results 1

<table>
<thead>
<tr>
<th>Bina Marga Method</th>
<th>AutoCAD Civil 3D®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rc</td>
<td>m</td>
</tr>
<tr>
<td>ΔPI1</td>
<td>°</td>
</tr>
<tr>
<td>VR</td>
<td>Km/h</td>
</tr>
<tr>
<td>Rmin</td>
<td>m</td>
</tr>
<tr>
<td>Ls</td>
<td>m</td>
</tr>
<tr>
<td>θs</td>
<td>(90 x Ls)/(π x Rc)</td>
</tr>
<tr>
<td>θc</td>
<td>ΠΔPI1 - 2θs</td>
</tr>
<tr>
<td>Lc</td>
<td>(θc/360) x 2π x Rc</td>
</tr>
<tr>
<td>Lt</td>
<td>Lc + 2Ls</td>
</tr>
<tr>
<td>Xs</td>
<td>Ls - (Ls^3/(40 x Rc^2))</td>
</tr>
<tr>
<td>Ys</td>
<td>Ls^2 / 6 x Rc</td>
</tr>
<tr>
<td>K</td>
<td>Xs- Rc(sin θs)</td>
</tr>
<tr>
<td>P</td>
<td>Ys- Rc(1 -cos θs)</td>
</tr>
<tr>
<td>Ts</td>
<td>(Rc + P) x tan (ΔPI1/2) + K</td>
</tr>
<tr>
<td>Ice</td>
<td>(Rc + P) x sec (ΔPI1/2) - Rc</td>
</tr>
</tbody>
</table>

Horizontal Alignment Profile

Figure 4.3 is the horizontal profile of the plan to find out the high and low profile along the trace or horizontal paragraphing. Point P3 is an arch Spiral Circle Spiral with R= 650 m and Spiral short = 50 m, as seen in Figure 4 SCS at point P3.

Spiral – Circle – Spiral is a bend consisting of one circular arc and two spiral arcs or intermediate arcs. This bend is intended if you can't use the FC type because the space for vehicles to turn is not too large or medium, then the second alternative is to use this type of bend, because this bend uses a transitional arch at the time of corner entry, then a circular arc at the top of the bend and ends again with transition curve when the vehicle exits the bend. In the SCS type bend, the achievement of superelevation is carried out linearly, starting from the normal shape to the beginning of the intermediate curve, then increasing gradually until it reaches full superelevation.
The Geometric Design of Horizontal Curves Using The Autocad Civil 3D® Method: A Case Study of Trans Flores Roads

Furthermore, at FC type bends, if necessary, superelevation is carried out linearly, starting from a straight section 2/3 Ls long and continuing to a full circle section along 1/3 Ls long section. Finally, in the SS type bend, the achievement of superelevation is entirely carried out on the spiral section or on the transition curve.

![Figure 5. Curve P3](image)

The subsequent superelevation calculations according to Highways standards will be presented in table 2. From the results of the horizontal alignment calculations, it shows a comparison between the existing road axles and the road axles calculated by the Highways standards at the bends under review. From figure 3 it is clear the difference between the existing road axles and the road axles calculated by the Highways standards. From the results of the superelevation calculations, it shows a comparison between the existing superelevation and superelevation results from the standard Bina Marga calculations on the bends under review. The figure also shows that at the corner there is no existing superelevation that is the same or almost close to the superelevation from the standard calculation of Highways.

CONCLUSION

From the results of planning, calculation, and data processing, several conclusions can be drawn, namely, Planning on the Trans Flores road, which is carried out along 3.5 km at Sta 0 + 000 - Sta 3 + 500. This planning only focuses on horizontal paragraphs and, after analysis, has obtained four horizontal paragraph arches consisting of 4 SCS (Spiral-Circle-Spiral) bends. To produce the SCS curve in this analysis using R of 600 m and Spiral short = 50 m. After planning, using AutoCAD Civil 3D® is considered more effective in geometric road planning because it helps the process of planning delineation simultaneously so that the planning process will be easier and faster.

REFERENCE

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