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# Road Geometric Redesign of Horizontal Alignment on Kunciran–Serpong Toll Road Using AutoCAD® Civil 3D

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*ABSTRACT*

*Transportation network systems are designed to provide efficient connectivity between various locations. The toll road is a transportation network system connecting one area to another. As a freeway, toll roads must have a higher safety level than regular roads. Therefore, geometric road planning must be done carefully so that the toll road can provide safety and comfort. Currently, applications are used to get accurate calculations and speed up processing time. In this paper, geometric redesign especially on horizontal alignment on Kunciran–Serpong toll road using AutoCAD® Civil 3D. The Kunciran - Serpong toll road is part of the Jakarta Outer Ring Road (JORR) network that connects Banten to Jakarta. The secondary data for coordinates and contour data were obtained from Google Earth® and processed using the Global Mapper®. The design result shows that the Kunciran–Serpong toll road is a primer arterial road class I, with a 4/2-T road type. The horizontal alignment is designed as a Full Circle (F-C) type arch on both bends (PI1 and PI2), with a total length value is 3819.286 m, a planned radius value is 600 m and a velocity design of 100 km/h. Using AutoCAD® Civil 3D to design and calculate the road geometric helps to receive accurate results and is more efficient than the manual method.*

## 1. Introduction

Roads are one of the transportation infrastructures most often used by people in carrying out daily activities. Transportation has increased vehicle mobilization in relatively high numbers; the density of vehicles is quite dense with large dimensions, so road infrastructure and capacity are needed to be able to accommodate the mobility of people, goods, and services [1]. Roads are built and maintained to provide services, such as the capacity to move people and goods within a predetermined time frame with a low probability of goods being damaged and people being injured or losing their lives [2]. Therefore, roads must provide safety and comfort for their users.

Indonesia is currently encouraging development in all fields on a national scale to improve the welfare of its people. Infrastructure development is one of the work priorities under President Joko Widodo's leadership. From 2014 to 2019, in the transportation infrastructure sector, especially toll roads, 1.235 km of new toll roads were built throughout the country. This figure is a significant development achievement since Indonesia's independence in 1945 until 2014 [3]. The contribution of transportation infrastructure to economic development and the causal relationship between the two has received significant attention from empirical studies in economics [4]. Investment in expanding transportation infrastructure, especially roads, impacts economic development. Policymakers and planners often advocate road investments to stimulate local economies and regional growth. Therefore, constructing new significant roads and expanding existing road capacity can drive travel demand and new road investments [5].

The transportation network is a system used to connect one area to another. It is essential to have an effective and reliable transportation system operation, as transportation networks are a fundamental component of civil infrastructure and an essential element of sustainable development [6]. As one transport system, Toll roads function as freeways providing more benefits and convenience than public roads. Toll roads overcome traffic congestion and shorten the time and distance to a destination. The Kunciran - Serpong toll road is part of the Jakarta Outer Ring Road 2 network with a length of 11.19 km which was built in 2017 and inaugurated in 2019. Divided into two sections, namely Kunciran - Parigi along 6.72 km and Parigi - Serpong along 4.42 km. This toll road is expected to be a connectivity that can accelerate and facilitate the flow of transportation from Banten to Jakarta.

Nowadays, the utilization of technology is advancing. The implementation of modeling in computer-based software can optimize the design process. In addition, the optimization model could reduce more redundant debugging work for the designer and reduce the influence of the designer's subjectivity [7]. There are many software developments in the field of civil engineering, one of which is AutoCAD Civil 3D. AutoCAD® Civil 3D is a software that can maximize the demonstration of precise road geometric planning and save time and energy. It offers 3D project modeling and support with project adaptation for both small and large-scale projects. Without 3D modeling, the design of highways would have caused significant challenges [4].

This paper will discuss the redesign of horizontal curve road geometrics on the Kunciran - Serpong Toll Road with the help of AutoCAD® Civil 3D software. The research is expected to provide an understanding of the geometric design of horizontal curved roads using AutoCAD® Civil 3D. In addition, it is also to open readers' insights that using such software can increase work efficiency.

## 2. Literature Review

### 2.1 Road Geometric Design

Road geometric design is part of road planning that focuses on planning the physical form. Elements of geometric road planning include horizontal and vertical alignment dimensions, cross sections, intersections, and facilities for pedestrians and cyclists [8]. These elements will affect traffic operations; thus, planning is essential. Geometric planning aims to provide optimal service by producing a safe infrastructure design that can maximize traffic flow efficiency and implementation costs [9].

Safety is the main focus in planning road geometrics. Road geometrics has an important role as one of the factors that cause accidents. Based on the Highway Safety Manual published by the American Association of State Highway and Transportation (AASHTO) (2008) in the journal [10], road factors contribute 3% to road accidents, while combination of road-related and other factors causes 34%. Although not the leading cause, road safety must still be considered and needs to be improved to reduce the occurrence of road accidents. One way to improve it is by improving road geometric design. A safe road is designed to meet established standards.

### 2.2 Horizontal Alignment

Horizontal alignment is an essential element of highways. The suboptimal design could reduce road performance in terms of safety and comfort. Horizontal alignment is one of the most challenging aspects of highway planning, although the geometric design is an essential component of the process [11] [12]. The horizontal alignment tends to be associated with a disproportionate number of severe accidents. Many measures have been proposed to reduce traffic accidents and deaths in horizontal alignments [13]

[14]. Creating a safe and comfortable road is the primary goal of geometric design. Therefore, it is crucial to research how to optimize the horizontal alignment of the road because this can effectively improve the safety and economy of the designed horizontal alignment [7] [15].

Horizontal alignments are points that form lines (straight and curved) as projections of axes or axles of roads on a horizontal plane. Horizontal alignments on planning maps are also known as road alignments. Horizontal alignment consists of straight lines connected by curved lines comprising a circular arc, transition arc, or circular arc. It includes a straight section of the road and a circular curve connecting the change in direction [16]. Horizontal alignment has two types of road arch: spiral-circle-spiral (S-C-S) and full circle (F-C). In designing horizontal alignments, there are several influential factors, such as road classification, terrain, speed design, traffic volume, environmental conditions, and required level of service. In addition, horizontal alignment design must meet specific design criteria such as minimum radius, superelevation level, and sight distance [17] [18].

### 2.3 Toll Road

The toll road is public in the national road network system. Therefore, toll roads are different from ordinary public roads. Toll roads have higher standards regarding safety and comfort services and can accommodate long-distance traffic flows with high mobility [19]. The users obtain more benefits, although they are required to pay toll operational costs. Toll roads save vehicle operating costs (BOK) and time compared to non-toll roads [20] [21].

Toll roads have a vital role in national development. National transportation roads are essential in supporting economic, social, cultural, and environmental movements developed through regional development approaches to achieve balance and equitable distribution of national development [22]. The development of toll roads aims to facilitate traffic in developed areas, improve the distribution of goods and services to support economic growth, increase the distribution of development results and justice, and alleviate the burden on government funds through the participation of road users, with the construction of toll roads providing benefits and influencing regional development and economic improvement [4].

### 2.4 AutoCAD® Civil 3D

AutoCAD® Civil 3Dprogram is software to fulfill the challenges of 3D-based infrastructure complexity developed by Autodesk. AutoCAD® Civil 3D is used by civil engineers, designers, surveyors, and other professionals to design construction projects. The software provides planning in 3D models on both small and large scales. In civil engineering, AutoCAD® Civil up drafting, evaluating, and design modification enhances cooperation and coordination. By analyzing the design stages and exploration functions of AutoCAD® Civil 3D, the software possible for a significant reduction in project time and reduced manpower costs. However, simultaneously, the quality of work remains high [23]. AutoCAD® Civil 3D. helps to complete the design process in a relaxed and comfortable way within time, and it also preserves a lot of time and effort [24].

## 3. Method

Geometric redesign of Kunciran-Serpong Toll Road Section 1 (Kunciran-Parigi) is located in Tangerang City and South Tangerang along 6.72 km. This toll road was inaugurated on December 6, 2019, and the implementing contractor is PT Waskita Karya (Persero), Tbk. The location of this paper observation can be seen on the location map in Figure 1.


Figure 1 Research Location Map

*Source: Google Earth®*

Secondary data for contour data were obtained from Google Earth® and processed using the Global Mapper®. Then, manual road geometric planning determines design criteria based on the Road Geometry Design Guidelines (PDGJ) of the Ministry of PUPR 2021. To get better results, in this paper, planning is carried out using the AutoCAD® Civil 3D application. The stages in geometric road planning using the AutoCAD® Civil 3D application include importing point files, creating surfaces, drawing alignments, creating existing and proposed profiles, creating cross-sections, creating assemblies, creating corridors, viewing in object viewer, and reviewing [25].

## 4. Result and Discussion

### 4.1 Design Criteria

The design criteria in geometric road planning are divided into two, namely, main design criteria and technical criteria. The main design criteria are about the role and classification of roads. Based on Road Geometric Design Guidelines 2021, the Kunciran–Serpong Section 1 (Kunciran–Parigi) toll road is classified as a Primer Road Network System with function as an artery and road status as National Road. Categorized as Class 1, and the provider specifications are a Freeway. The main design criteria for the Kunciran–Serpong Section 1 (Kunciran–Parigi) toll road can be seen in Table 1.

Table 1. Main Design Criteria of Kunciran–Serpong Section 1 (Kunciran–Parigi) Toll Road

| No | Element | Value |
|---|---|---|
| 1 | Road Network System | Primer |
| 2 | Road Status | National Road |
| 3 | Road Function | Artery |
| 4 | Road Class | 1 |
| 5 | Provider Specification | Freeway |

*Source: Road Geometric Design Guidelines 2021*

The technical design criteria for the Kunciran–Serpong Section 1 (Kunciran–Parigi) toll road is a 2-way and 4-lane road type (4/2-T) with a road body width of 7 meters for each way. The velocity design for this toll road is in the range of 60–100 km/h. The technical design criteria for the Kunciran-Serpong Section 1 (Kunciran–Parigi) toll road can be seen in Table 2.

Table 2 Technical Design Criteria of Kunciran–Serpong Section 1 (Kunciran–Parigi) Toll Road

| No | Element | Value | Unit |
|---|---|---|---|
| 1 | Road Terrain Classification | Flat (<10%) | - |
| 2 | Velocity Design ($V_D$) | 60-100 | km/h |
| 3 | Lane Configuration | 4/2-T | - |
| 4 | Road Body Width | 2 × 7 | m |
| 5 | Outside Shoulder Width | 2 | m |
| 6 | Normal Superelevation ($e_n$) | 2 | % |
| 7 | Shoulder Superelevation | 5 | % |
| 8 | Maximum Superelevation ($e_{max}$) | 8 | % |
| 9 | Alignment Superelevation | 4 | % |
| 10 | Maximum Transverse Tightness ($f_{max}$) | 0.1275 | - |
| 11 | Right of Way Width (Rumaja) | 24.3 | m |
| 12 | Right of Way Height (Rumaja) | 5 | m |
| 13 | Right of Way Depth (Rumaja) | 1.5 | m |
| 14 | Building Line Distance (Rumija) | 30 | m |
| 15 | Controlling Line Distance (Ruwasja) | 15 | m |

*Source: Road Geometric Design Guidelines 2021*

### 4.2 Redesign of Horizontal Alignment

The existing road coordinates and contour data that have been taken and processed using Google Earth® and Global Mapper® are then modeled in the AutoCAD® Civil 3D application. The redesign begins by calculating the minimum curve radius ($R_{min}$) at points intersection (PI) and determining the type of curve. The Kunciran–Serpong Section 1 (Kunciran–Parigi) toll road has two points of intersection (PI). Based on Road Geometric Design Guidelines 2021, some formulas used to meet the required design of horizontal alignment are as follows:

$$R_{min} = \frac{V_D^2}{127(e+fm)} \quad (1)$$

$$L_L \leq 2{,}5\ minutes \times V_D \quad (2)$$

$$L_C \leq (6\ seconds \times V_D) \quad (3)$$

$$L_s \leq \frac{1}{2}(6\ seconds \times V_D) \quad (4)$$

$$p = \frac{{L_s}^2}{24R_c} \quad (5)$$

$$k = L_s - \frac{L_s^5}{40R^2L_s^2} - Rsin\theta_s \quad (6)$$

The curve radius is 379.471–1500 m, and the curve radius used value is 600 m. As seen in Formula 5, the calculation result shows that the p-value for PI1 and PI2 is 0.827, greater than 0.25 m. Therefore, PI1 and PI2 are Spiral-Cicle-Spiral (S-C-S) arch types. Otherwise, AutoCAD® Civil 3D analysis results show that arches PI1 and PI2 are Full Circle (F-C) types. There are formulas used to calculate the parameters of horizontal alignment for F-C type as follows:

$$E_s = \frac{R_c}{cos\frac{\Delta}{2}} \quad (7)$$

$$L_c = \frac{\Delta}{360} . 2\pi R_c \quad (8)$$

$$T_c = R_c \times tan\frac{\Delta}{2} \quad (9)$$

$$Ls\ fictitious = B.m.(e + en) \quad (10)$$

$$Ls\ outside\ the\ arch = \frac{2}{3} \times Ls\ fictitious \quad (11)$$

$$Ls\ inside\ the\ arch = \frac{1}{3} \times Ls\ fictitious \quad (12)$$

Information:

$R_{min}$ = Minimum curve radius

$R_c$ = Curve radius planned

$V_D$ = Velocity design

$e$ = Superelevation

$fm$ = Maximum transverse tightness

$L_s$ = Minimum length runoff superelevation curved switching

$\Delta$ = Bend corner

$L_c$ = Circle arch length

$k$ = The abscissa of p is the tangent line of the spiral

$T_c$ = Tangen length from point PI to point TC or CT

$E_s$ = The distance from PI to arc circle

Both curves PI1 and PI2 of Kunciran–Serpong Section 1 (Kunciran–Parigi) are Full Circle (F-C) arch types with *an* $R_c$ value is 600 m. Full Circle (F-C) arch is only used for large bend radii to avoid fractures. Because the radius is small, a large superelevation is needed. The visualization using AutoCAD® Civil 3D obtained a new horizontal alignment, as seen in Figure 2.

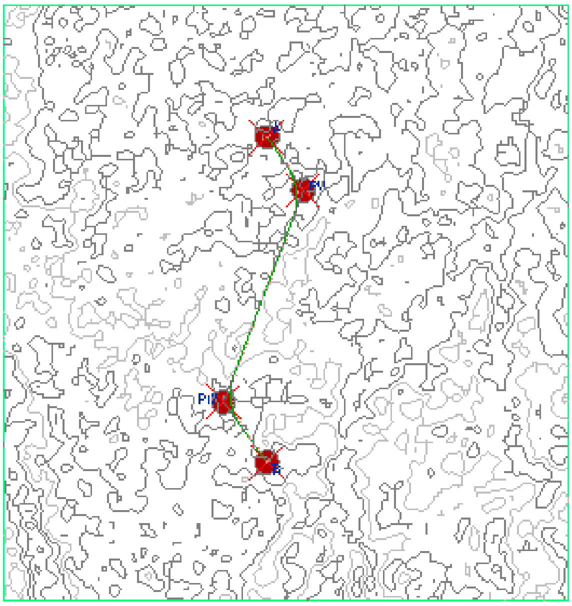

Figure 2 Visualization of New Horizontal Alignment the Kunciran–Serpong Section 1 Toll Road

The result of calculating a new horizontal alignment with the total length of the Kunciran–Serpong Section 1 (Kunciran–Parigi) toll road is 3819.286 m. By using AutoCAD® Civil 3D, the curve elements are calculated automatically. The use of applications would be beneficial to speed up the work. The value of curve elements can be seen in Table 3.

Table 3 The Calculation of Redesign Horizontal Alignment

| Curve | Curve Element | Value | Unit |
|---|---|---|---|
| PI1 | Delta Angle | 54.967 | ° |
| | Chord Length | 553.79 | m |
| | Degree of Curvature by Arc | 2.9106 | ° |
| | Curve Length | 575.611 | m |
| | TC | 379.223 | m |
| | CT | 1800.848 | m |
| | Planned Radius | 600 | m |
| | Minimum Radius | 394 | m |
| PI2 | Delta Angle | 56.339 | ° |
| | Chord Length | 567.058 | m |
| | Degree of Curvature by Arc | 2.9106 | ° |
| | Curve Length | 590.616 | m |
| | TC | 1800.848 | m |
| | CT | 472.998 | m |
| | Planned Radius | 600 | m |
| | Minimum Radius | 394 | m |

The final coordinates of Kunciran–Serpong Section 1 (Kunciran–Parigi) Toll Road can be seen in Table 4.

Table 4 Final Coordinates of Kunciran–Serpong Section 1 (Kunciran–Parigi) Toll Road

| Point | Coordinates | |
|---|---|---|
| | X (m) | Y (m) |
| A | -648773.5465 | 9300897.8381 |
| PI1 | -648559.8059 | 9300584.5887 |
| PI2 | -648494.0083 | 9298349.6822 |
| B | -649054.9709 | 9297787.5273 |

## 5. Conclusion

The redesign of horizontal alignment on Kunciran–Serpong Section 1 (Kunciran–Parigi) toll road has several conclusions. The road is classified as Primer Artery with 4/2-T, 7 meters of road body width, velocity design 100 km/h, and total length of 3819.286 m. The horizontal alignment is designed as a Full Circle (F-C) type arch on both bends (PI1 and PI2), with a planned radius value is 600 m and a velocity design of 100 km/h. Using AutoCAD® Civil 3Dto design and calculate the road geometric helps to receive accurate results. It is more efficient than the manual method.

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