

Road Geometric Design used AutoCAD® Civil 3D: A Case Study Jalan Campaka-Wanaraja Garut, Indonesia

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Abstract

The growth of road infrastructure has an essential role in economic growth in Indonesia. However, in its development, there needs to be more growth of vehicles and roads within the city. Road development is relatively slower than vehicle growth. One of the areas that experience congestion due to the imbalance of vehicle and road growth is the Campaka - Wanaraja road section. In this paper, a geometric design of the Campaka – Wanaraja road using the AutoCAD® Civil 3D method. The geometric design of this road is in the form of horizontal and vertical alignment. The geometric design of the Campaka – Wanaraja road aims to be safe and streamline the travel time of road users. The Result of the geometric design of the Campaka – Wanaraja road with a plan speed (V_D) of 40 Km / h and the assumption of flat terrain is a horizontal alignment that has a curved radius plan (R_c) of 120 m and uses superelevation (e_{max}) 8%. This horizontal alignment consists of two horizontal plan arches, one full circle arch, and one Spiral-Circle-Spiral arch. In addition to horizontal alignment, a vertical alignment with an arch radius (L) of 200 m is also planned. Vertical alignment consists of a convex arch of seven pieces and a concave arch of six. In addition, the results of the calculation of the cut volume of 30,300,563.31 m³ and the fill volume of 255,154.40 m³ were obtained.

Keywords: Geometric design, horizontal alignment, vertical alignment

1. Introduction

The road is an infrastructure used to transport people or goods from one region to another. The road is expected to guarantee the comfort and safety of its users, simplify time, and be economical in its construction and maintenance (Raji, Zava, Jirgba, & Osunkunle, 2017). The number of roads that have been legally registered has increased since 2003 by 12 million km. Increasing the number of roads proves the critical role of road infrastructure in the development of each country. Effective road infrastructure development can positively impact economic growth and social integration, as well as access to larger cities for local producers (Alamgir, et al., 2017).

Similarly, in Indonesia, infrastructure development is believed to drive the real sector to absorb labor, increase public and government consumption, and encourage various other productive activities. To realize comprehensive growth, the government must guarantee reliable and adequate transport infrastructure and support its substantial and decisive role in the country's productivity (Rifai, Latief, & Rianti, 2018). Furthermore, the growth of road infrastructure also has an essential role in economic growth in Indonesia (Nugraha, Prayitno, Situmorang, & Nasution, 2020). According to their function, roads are separated into arterial, collector, local, and neighborhood roads (Pemerintah RI, 2004). In its development, there is an imbalance between the growth of vehicles and roads within the city. As a result, road development is relatively slower than vehicle growth. The imbalance between the growth of vehicles and roads causes a

build-up of vehicles, resulting in congestion (Amril & Junaidi, 2019). Therefore, good road geometric planning is needed so that congestion does not occur, especially in urban areas in Indonesia. The geometric design of roads aims to unite the territories safely and comfortably for their users and technically economically for the territories they pass (Lopes, et al., 2019). The road's geometric design must accommodate pedestrians, cyclists, stops, and motor vehicles (Chakole & Wadhai, 2022).

One of the areas that experienced congestion due to the unbalanced growth of vehicles and roads was the Campaka - Wanaraja road section. Therefore, that section of the road will be used as a case study. The congestion on the Campaka - Wanaraja road section is caused by the increasing economic growth in Garut Regency. So it is necessary to design the geometric road to simplify the journey from Campaka - Wanaraja Road. The geometric road of Campaka - Wanaraja Road has been discussed in the paper entitled "Perencanaan Geometrik Jalan dan Anggaran Biaya Ruas Jalan Campaka - Wanaraja Kecamatan Garut Kota" (Badrujaman, 2016).

By and large, geometric design is done manually. The manual geometric design includes complexity (Pandey, Atul, & Bajpai, 2019). However, at this present, more sophisticated technology is used for geometric road design, which can be a more practical option, namely with 3D modeling, AutoCAD® Civil 3D. As a result, volume calculations can be completed objectively, automatically, and accurately, making it easier for Civil Engineers, especially from developing countries, to design roads (Gaikawad & Ghodmare, 2020). In this paper, the Campaka – Wanaraja road will be designed using the AutoCAD® Civil 3D method. The geometric design of this road is in the form of horizontal alignment and vertical alignment. The geometric design of the Campaka – Wanaraja road aims to be safe and simplify the travel time of road users. In addition, geometric road design is also expected to balance the economic growth of the people in the region.

2. Literature Review

Road geometric design is part of road design that focuses on engineering the physical shape of the road so that it can fulfill the essential functions of the road (Veer, Gupte, & Juremalani, 2018). Elements of geometric design of the road include the dimensions of horizontal and vertical alignment, cross sections, intersections, and pedestrian and cyclist facilities. The main goal of geometric design is to create a safe, efficient, and economical path in maintaining its aesthetics and environmental quality. The geometric design of the road is influenced by the number of vehicles and the driver's traffic characteristics (Kumar, 2017). So good geometric design is needed by considering these factors in the future.

The horizontal alignment of a road is a projection of the centerline of the road space (axle of the road) in the horizontal plane (HE & PEI, 2017). The design elements of the horizontal alignment of the road are straight and curved lines in the shape of a circular arc, as well as those connected by transitional arches or without intermediate arches. The often-used bend designs are Full Circle and Spiral-Circle-Spiral (Pemerintah RI, 2021). Radius and deflection angle of horizontal curves, the horizontal distance between the horizontal cut point and vertical cut point, vertical curve length, class, and superelevation rate can affect vehicle speed plan (Llopis-Castelló, González-Hernández, Pérez-Zuriaga, & García, 2018).

Vertical alignment is defined as the projection of the axis of the road on a vertical plan, taking the form of a cross-section extending the road. Vertical alignment is also called longitudinal cross-sections or road profiles. Vertical alignment consists of longitudinal slumps with concave and convex arches. The maximum and minimum vertical curvature values are selected based on visibility, appearance, and driving comfort. This vertical alignment profile depends on topography, horizontal alignment design, design criteria, geology, earthworks, and other economic aspects (Pemerintah RI, 2021). Vertical cement is the most critical factor affecting the cost of earthworks. Minimizing earthworks can be done by balancing cut-fill and existing soil elevation for vertical alignment (Ghanizadeh & Heidarabadizadeh, 2018).

The classification of roads according to their function is as arterial roads, collector roads, local roads, and neighborhood roads. Arterial roads are public roads that serve major transportation with the characteristics of long-distance travel, high average speeds, and narrow driveways. Meanwhile, The collector's road is a public road that serves collection or divider transportation with the characteristics of

medium-distance travel, moderate average speed, and a limited number of driveways. Local roads are public roads that serve local transportation with the characteristics of short-distance travel, low average speed, and the number of driveways that is not limited. Last, the neighborhood road is a public road that serves environmental transportation with short-distance travel and low average speed (Pemerintah RI, 2004).

AutoCAD® Civil 3D is a Building Information Modelling (BIM) software application used by civil engineers and professionals to plan roads quickly and accurately (Nisarga & Amate, 2018). The use of AutoCAD Civil 3D® software has replaced the manual method that is still traditional. Geometric design using manual methods is inefficient in time and money, but the design results are inaccurate and only produce a 2D view (Mandal, Pawade, Sandel, & Infrastructure, 2019).

3. Methodology

Data is one of the main strengths in compiling scientific research and modeling (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015). Systematic scientific research must identify the problem (Rifai, Hadiwardoyo, Correia, & Pereira, 2016). The research method used in this study is qualitative. Meanwhile, the data used in this study is in the form of primary and secondary data. The primary data in this study is the calculation of horizontal and vertical alignment. Meanwhile, the secondary data includes plan speed data, road classification, and topographic maps between the Campaka region and the Wanaraja region.

The geometric design of this road uses the AutoCAD® Civil 3D application by involving several other supporting applications such as Google Earth, Global Mapper, and SAS Planet. The map of the Campaka region and the region Wanaraja is shown in the figure below.

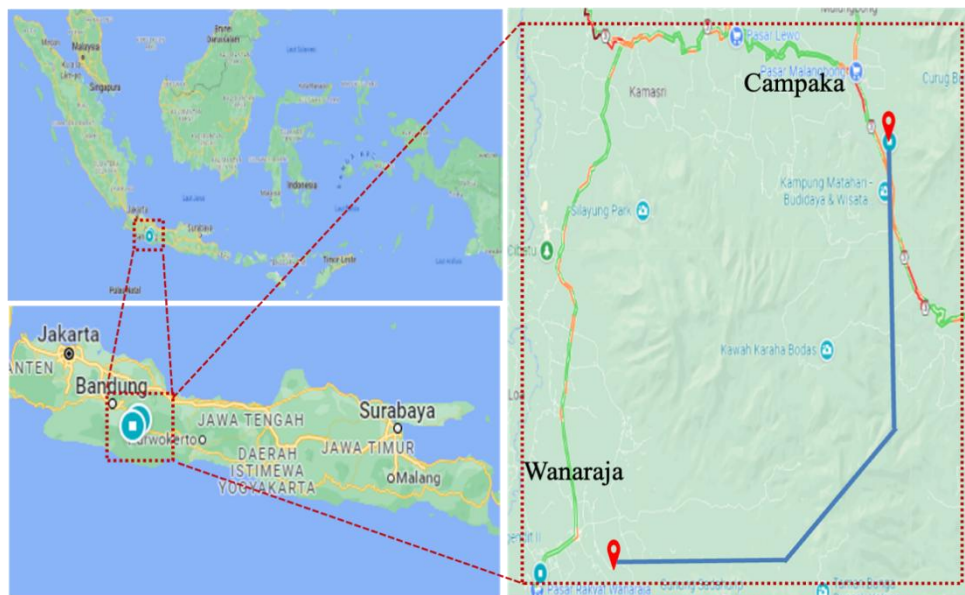


Figure 1. Map of Campaka and Wanaraja Region

The first step in carrying out geometric road design is to determine the map of the area, namely between the Campaka and Wanaraja areas. Then from the map of the area will be made a surface or polygon on Google Earth software which includes coordinate points for planning the trace of the road. Furthermore, the surface area will be obtained its elevation through the National Digital Elevation Model (Demnas). Then, using the Global Mapper and SAS Planet data Demnas will produce soil contours. The contours of the land are used as a reference to make road traces from the coordinates Wanaraja (830681.00, 9207096.00) and Campaka (180309.00, 9213122.00). Suppose the road trace plan has been determined. In that case, a Horizontal Alignment is made by adjusting the flat contours of the ground, and a Vertical

Alignment is made by adjusting the contours of the hill and mountain areas. The next step is to create corridors. Finally, create cross sections and calculate the volume of cuts & fills.

4. Result and Discussion

The geometric design of the Caampaka – Wanaraja road is carried out using AutoCAD Civil 3D® based on contour data obtained using Global Mapper and SAS Planet. The display of the work area of the AutoCAD Civil 3D® used is as follows.

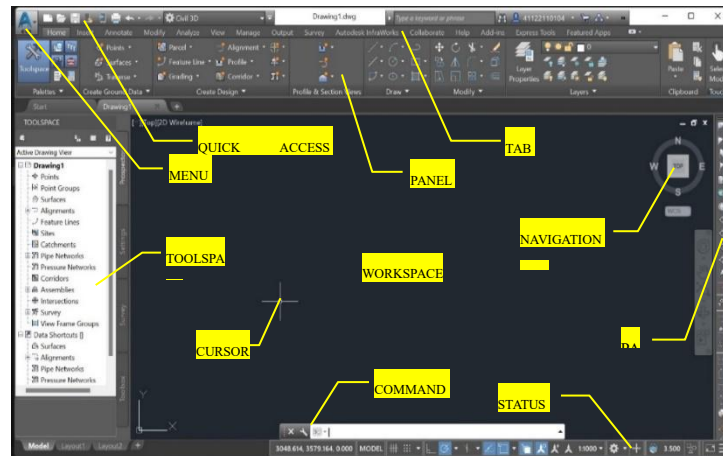


Figure 2. Display of the AutoCAD Civil 3D® 2018 work area

4.1. Road trace

The design of the Campaka-Wanaraja road trace has a planned length of $\pm 15,500$ km with the assumption of flat land contours. Road trace planning adjusting to the contours of the soil can be seen in Figure 3.

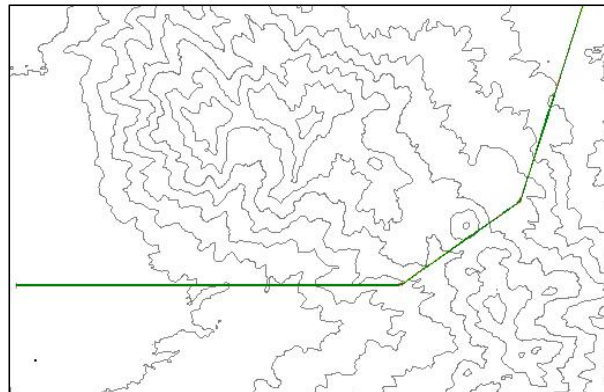


Figure 3. Road trace design

4.2. Design Requirement

In geometric road design, several design parameters are needed, including the speed of the plan and the classification of roads. Campaka–Wanaraja Road is a national road connecting the district road. So, according to its function, including the type of primary collector road. Primary collector roads have the highest plan speed (V_0) provision of 40 Km/h with flat terrain assumption. In addition, the primary collector road has a width of at least 7.5 m. The planned road class is Class II, with two lanes and two lanes (Pemerintah RI, 2021). The average daily traffic amount is ≤ 22.000 vehicles per day.

4.3. Alignment Horizontal

In geometric road design, a horizontal alignment calculation is carried out first. This calculation will be used as a reference for making curves and switching arches with AutoCAD® Civil 3D. In calculating the minimum curved radius (R_{min}), a superelevation (e_{max}) of 8% is used, which is taken from Table 5-2. Main design criteria. In addition, a transverse tightness (f_{max}) of 0.23 was used, taken from the diagram of Figure 5-17—transverse Roughness Factor (Pemerintah RI, 2021). The calculation of minimum curved radius (R_{min}) uses the formula (1) as follows.

$$R_{min} = \frac{V_D^2}{127(f_{max}+e_{max})} \dots\dots\dots (1)$$

$$R_{min} = \frac{40^2}{127(0,23+0,08)} = 40,64 \text{ m}$$

$$R_C = 120 \text{ m}$$

After obtaining the plan's curved value, the transition curve is calculated according to formula (2). Next, the maximum relative severity (Δ) of 0.70% used is obtained from tables 5-21. Maximum relative slump. Then, the number of rotational lanes (n) is 1, and the adjustment factor is 1, according to tables 5-22. Rotation Lane Number Adjustment Factor (Pemerintah RI, 2021). The results of the calculation of the *superelevation runoff* using formula (2) can be seen in figure 4.

$$L_S = \frac{wn_1e_d}{\Delta} (b_w) \dots\dots\dots (2)$$

$$L_S = \frac{3,5 \times 1 \times 8\%}{0,70\%} (1) = 40 \text{ m}$$

$$L_S = 50 \text{ m}$$

The results of curved calculations on AutoCAD® Civil 3D are shown in the screenshot of figure 4.

No.	Type	Length	Radius	Design Speed	A	Start Station	End Station	Delta angle	Chord length	Degree of Curvature by Arc
1	Line	8192.180m		40 km/h		0+000.00m	8+192.18m			
2	Curve	72.991m	120.000m	40 km/h		8+192.18m	8+265.17m	34.8507 (d)	71.871m	9.5493 (d)
3	Line	3029.116m		40 km/h		8+265.17m	11+294.29m			
4.1	Spiral-Curve-Spiral	50.000m		40 km/h	77.460m	11+294.29m	11+344.29m	11.9366 (d)		
4.2	Spiral-Curve-Spiral	28.032m	120.000m	40 km/h		11+344.29m	11+372.32m	13.3844 (d)	27.969m	9.5493 (d)
4.3	Spiral-Curve-Spiral	50.000m		40 km/h	77.460m	11+372.32m	11+422.32m	11.9366 (d)		
5	Line	4393.116m		40 km/h		11+422.32m	15+815.44m			

Figure 4. Screen Shot of Horizontal Alignment Calculation Results

In addition, the results of horizontal arch design in full circle and spiral-circle-spiral can be seen in figure 4 below.

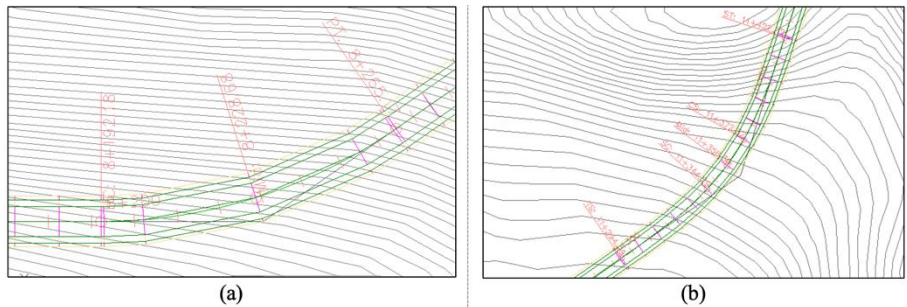


Figure 5. Horizontal Alignments include full circle (a) and spiral-circle-spiral (b).

4. 4. Alignment Vertical

After designing the horizontal arch, the vertical arch design is carried out. The planned vertical arch is convex and concave. The calculation of vertical arch (L) is the Result of a vertical arch in meters for each change of 1% (k) of a slump with the change of algebraic slump (A). The calculation of the length of the convex and concave vertical arch can be seen in the formula (3) as follow (Pemerintah RI, 2021).

$$L = KA \dots \dots \dots (3)$$

The results of the calculation of vertical curvature using AutoCAD® Civil 3D can be seen in table 2 as follows.

No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve T...	Profile Curve Length	K Value	Curve Radius
1	0+000.00m	669.894m		1.77%					
2	1+248.60m	691.973m	1.77%	0.00%	1.77%	Crest	3.537m	2.000	200.000m
3	2+102.61m	691.973m	0.00%	3.42%	3.42%	Sag	6.846m	2.000	200.000m
4	3+213.62m	730.000m	3.42%	0.00%	3.42%	Crest	6.846m	2.000	200.000m
5	4+529.22m	730.000m	0.00%	3.05%	3.05%	Sag	6.104m	2.000	200.000m
6	5+989.91m	774.577m	3.05%	0.00%	3.05%	Crest	6.104m	2.000	200.000m
7	6+780.18m	774.577m	0.00%	7.47%	7.47%	Sag	14.946m	2.000	200.000m
8	7+394.83m	820.510m	7.47%	0.14%	7.33%	Crest	14.656m	2.000	200.000m
9	8+892.44m	822.680m	0.14%	5.07%	4.93%	Sag	9.856m	2.000	200.000m
10	10+174.36m	887.713m	5.07%	0.00%	5.07%	Crest	10.146m	2.000	200.000m
11	10+910.81m	887.713m	0.00%	-4.89%	4.89%	Crest	9.784m	2.000	200.000m
12	11+841.55m	842.181m	-4.89%	0.00%	4.89%	Sag	9.784m	2.000	200.000m
13	13+170.60m	842.181m	0.00%	-2.12%	2.12%	Crest	4.231m	2.000	200.000m
14	15+815.44m	786.226m	-2.12%						

Figure 7. Screen Shoot of Result of alignment vertical's calculation using AutoCAD Civil 3D®

In addition, the visualization of the vertical arch design based on figure 7 can be seen in Figure 8.

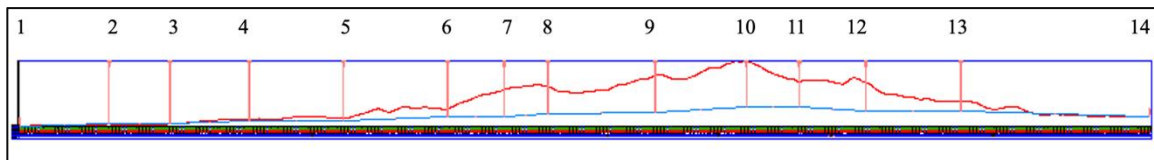


Figure 8. Vertical alignments based on Table 2

4. 5. Superelevation

Superelevation serves to balance the centrifugal force on horizontal alignment. Superelevation design is carried out after the design of the vertical alignment. The superelevation calculation is carried out using AutoCAD® Civil 3D seen in Figure 9.

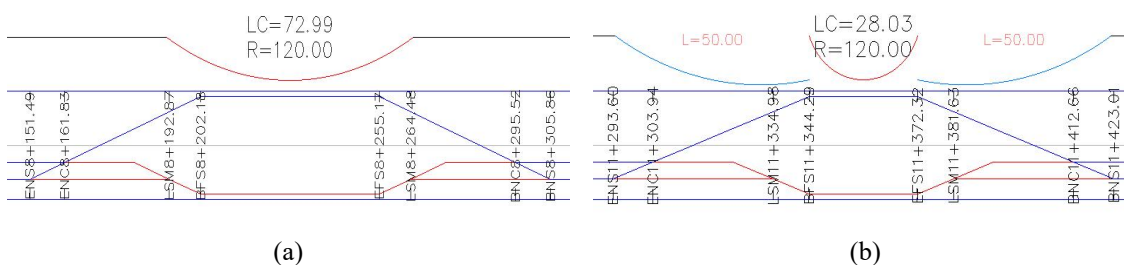


Figure 9. Superelevation diagram of horizontal alignment for full circle (a) and S-C-S (b).

4. 6. Volume cut and fill

After designing horizontal and vertical alignment using AutoCAD Civil 3D®, an estimate of the cut and fill volume of the geometric road was carried out. The calculation results from the cut volume of 30,300,563.31 m³ and the fill volume of 255,154.40 m³. The visualization of the cut and fill calculation results are shown in the screenshot of table 3 as follows.

Total Volume Table						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
11+334.98	0.00	3871.31	0.00	40165.22	82204.98	24859572.01
11+344.29	0.00	3862.01	0.00	35976.27	82204.98	24895548.28
11+372.32	0.00	3831.06	0.00	107733.63	82204.98	25003281.91
11+381.63	0.00	3810.96	0.00	35551.51	82204.98	25038833.41
11+391.98	0.00	3802.77	0.00	39367.03	82204.98	25078200.45
11+400.00	0.00	3795.58	0.00	30482.31	82204.98	25108682.76
11+402.32	0.00	3791.16	0.00	8800.01	82204.98	25117482.77
11+412.66	0.00	3770.53	0.00	39109.99	82204.98	25156592.77
11+423.01	0.00	3757.94	0.00	38940.33	82204.98	25195533.09
11+500.00	0.00	3646.46	0.00	285034.10	82204.98	25480587.20
12+000.00	0.00	3000.60	0.00	1661763.61	82204.98	27142330.81
12+500.00	0.00	1933.10	0.00	1233423.09	82204.98	28375753.90
13+000.00	0.00	1496.30	0.00	857349.38	82204.98	29233103.28
13+500.00	0.00	733.77	0.00	557517.42	82204.98	29790620.70
14+000.00	0.00	653.00	0.00	346692.44	82204.98	30137313.15
14+500.00	83.09	0.00	20771.99	163250.16	102976.97	30300563.31
15+000.00	183.04	0.00	66532.59	0.00	169609.56	30300563.31
15+500.00	159.54	0.00	85644.84	0.00	255154.40	30300563.31

Figure 10. Screen shoot of Result of cut and fill calculation

5. Conclusion

The geometric design of the road on the Campaka - Wanaraja road section, Garut Regency, using the AutoCAD® Civil 3D method and the plan speed (V_D) of 40 Km/hour and the assumption of flat terrain, including a horizontal alignment and a vertical alignment. The horizontal alignment has a curved plan radius (R_c) of 120 m and uses a superelevation (e_{max}) of 8%. This horizontal alignment consists of 2 horizontal plan arches, one full circle arch, and one Spiral-Circle-Spiral arch. In addition to horizontal alignment, a vertical alignment with an arch radius (L) of 200 m is also planned. Vertical alignment consists of a convex arch of seven pieces and a concave arch of six. In addition, the results of the calculation of the cut volume of 30,300,563.31 m³ and the fill volume of 255,154.40 m³ were obtained.

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