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Geometric Road Evaluation on Sukanagara Road – Bukanagara Road, Lembang District, West Bandung Regency

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Abstract— *The Sukanagara – Bukanagara Road in Pagerwangi, Lembang District, West Bandung Regency, is an alternative route to the Lembang tourist area. This route is frequently used to avoid traffic congestion; however, accidents, such as vehicles failing to climb steep slopes, are frequent. This study aims to analyze, evaluate, and redesign the geometric aspects of the road, focusing on horizontal and vertical alignments, traffic signs, and road markings. The evaluation is based on the Road Geometric Design Guidelines (PDGJ) 2021 by Bina Marga and the Ministry of Transportation regulations 2014. Data is collected through field surveys and Digital Elevation Model (DEMNAS) and processed using Civil 3D software. The research results include the existing road conditions, evaluations based on standards, and redesign recommendations to enhance road safety and users' comfort.*

Keywords— *Evaluation, Road Geometrics, PDGJ 2021*

I. INTRODUCTION

Roads are essential to land transportation infrastructures and crucial in supporting economic growth as the demand for transportation facilities increases (Anjali Putri Lisu Langi, Joice E. Waani, 2019) Ensuring driver safety and comfort is vital to reducing traffic accidents (Diva Rizqandro & Fauziah, 2023). According to data from the Statistics Indonesia, in 2022, Indonesia recorded 139,258 traffic accident cases, with the primary causes being human factors (61%), vehicle-related issues (9%), and infrastructure and environmental conditions (30%).

The Sukanagara – Bukanagara Road in Lembang District, West Bandung Regency, is an alternative route frequently used by vehicles, particularly those heading to tourist areas. However, this road has a high accident rate, with 63 cases reported over the past three years, including four fatalities. The primary causes of accidents include vehicles failing to climb steep inclines and brake failures due to the road's steep ascents and descents (Wilton Wahab, 2023).

Given these issues, an evaluation of the geometric design of this road section is necessary to assess the suitability of horizontal and vertical alignments and the adequacy of road markings and traffic signs to avoid accidents efficiently(Salsabila et al., 2023). This research evaluates these aspects using Civil 3D software, referencing the 2021 Road Geometric Design Guidelines (PDGJ) by Bina Marga and traffic sign and road marking regulations outlined in Ministry of Transportation Regulation No. 13 of 2014 and Regulation No. 34 of 2014.

II. RESEARCH METHODOLOGY

A. Research Location

This study is conducted on the Sukanagara – Bukanagara Road in Pagerwangi, Lembang District, West Bandung Regency, covering a 1.4 km segment (STA 0+000 – 1+400). The road consists of two lanes and two-way traffic (2/2 UD). Based on data from the Pagerwangi Village Office and West Bandung Regency Regional Regulation No. 2 of 2012 regarding the Spatial Planning 2009-2029, this road segment functions as a secondary local road planned for upgrading to a collector road.

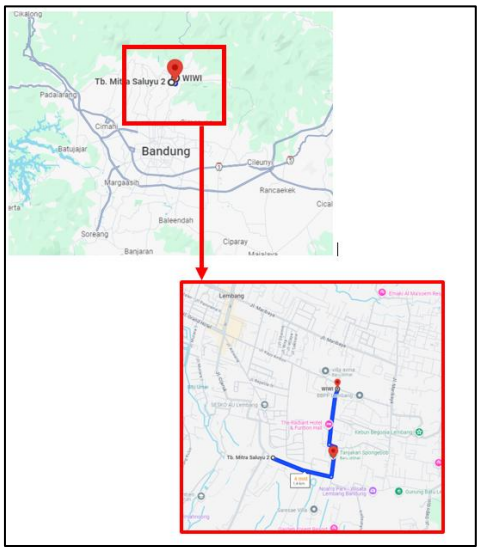

Figure. 1. Research Location Map

B. Research Stages

1. Start – This stage follows the background preparation, problem formulation, research objectives and benefits, and the collection of all references related to the study.
2. Problem Identification – At this stage, various transportation-related issues are identified, leading to the selection of the problem concerning road geometry, which creates fear and discomfort for drivers.

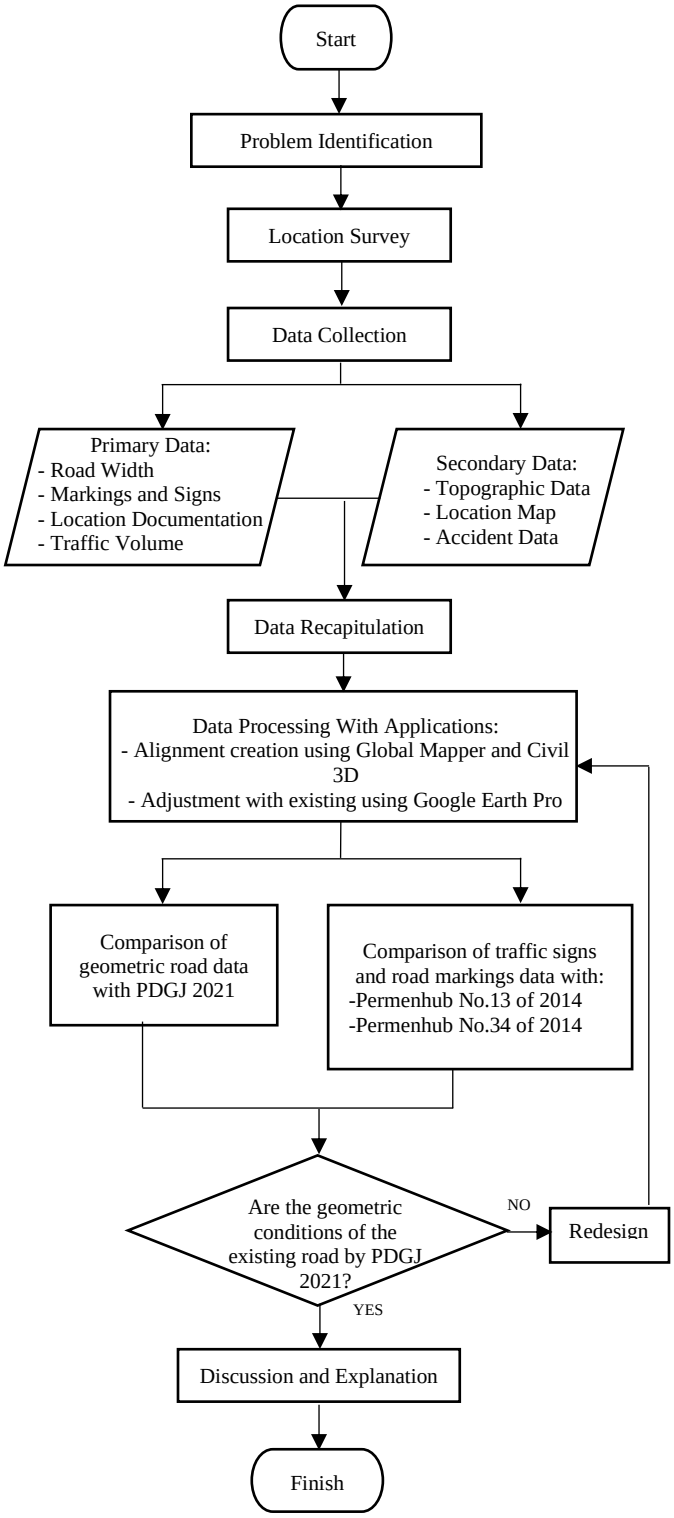

Figure 2. Research Flowchart
Source: personal

1. Location Survey – This stage involves surveying the research site to better understand the location being studied.
2. Data Collection – At this stage, the researcher gathers the planned data for evaluation and redesign. The collected data is divided into two categories: primary and secondary data. Primary data includes road width, traffic signs and road markings, and site documentation. Secondary data consists of topographic data obtained from the Geospatial Information Agency.
3. Data Recapitulation – At this stage, all collected data from the previous step is compiled and summarized.
4. Data Processing – The recapitulated data is processed further. The obtained topographic data is analyzed using the Global Mapper application to generate contour data and elevation details. The processed contour data from Global Mapper is then exported to Civil 3D for further analysis to obtain surface data, road alignment, and geometric conditions in the field.
5. Evaluation Based on Standards – The data obtained from Civil 3D is then compared with the Bina Marga Road Geometric Design Guidelines (PDGJ) 2021 to evaluate vertical and horizontal alignments. Additionally, Ministry of Transportation Regulation No. 13 of 2014 and Regulation No. 34 of 2014 are used to evaluate road markings and traffic signs.
6. Results Presentation – The findings will be presented in a table showing the conformity between the existing conditions and the applied standards.
7. Geometric Road Redesign – If any horizontal or vertical alignments do not meet the Bina Marga PDGJ 2021 requirements, a redesign will be conducted to ensure compliance with the standard.
8. Discussion and Analysis – In this stage, the researcher summarizes the study results and provides potential solutions for the research topic.
9. Completion – The stage where the research is concluded.

III. Results And Discussion

A. *Existing Condition*

Horizontal Alignment

The Sukanagara – Bukanagara road is a secondary local road with two lanes and two-way traffic without a median (2/2 UD). Field measurements indicate that the road width is 4.8 meters. The existing road alignment can be seen in the following figure.

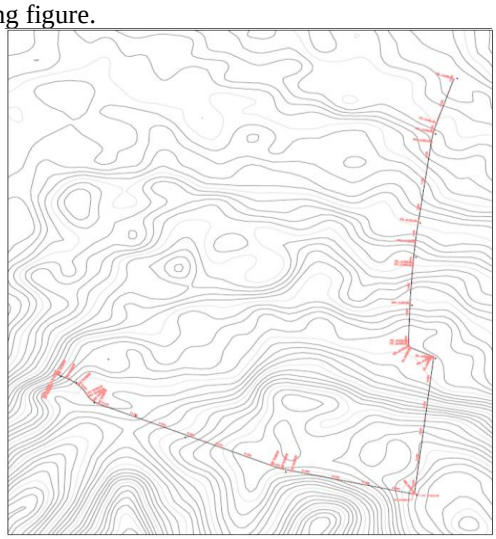

Figure 3. Existing Road Alignment
Source: Processed Data

The curve radius values were obtained using an approach with the Civil 3D application, as shown in Table 1.

TABLE 1. Existing Curve Radius

No.	PI Number	STA (m)	Curve (R) Existing (m)
1	PI 1	0+631	19.95
2	PI 2	0+891	20.27
3	PI 3	0+936	21.84

Source: Processed Data

Vertical Alignment

The existing vertical alignment was obtained using the Civil 3D application. The longitudinal section along the observed road is presented as follows.

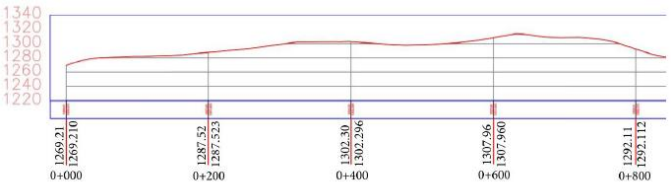

Figure 4. Longitudinal Section of the Existing Road (STA 0+000 – STA 0+800

Source: Processed Data

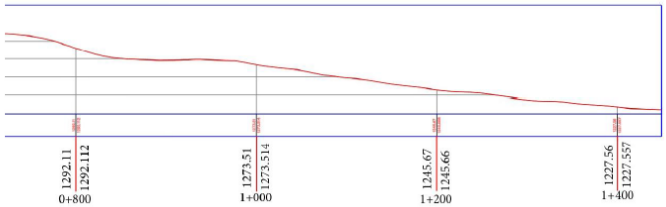

Figure 5. Longitudinal Section of the Existing Road (STA 0+800 – STA 1+400

Source: Processed Data

Three sections with steep slopes were identified, and the slope values are shown in Table 2.

TABLE 2. Existing Longitudinal Slopes

No.	STA (m)	H1 (m)	H2 (m)	Slope (%)
I	0+150 – 0+300	1,283.31	1,298.7	10.26
II	0+750 – 0+850	1,305.75	1,280.28	25.48
III	1+000 – 1+400	1,227.56	1,227.56	22.45

Source: Processed Data

Traffic Signs

A field survey of existing warning signs along the Sukanagara – Bukanagara road provided the following data.

TABLE 3. Existing Traffic Sign Conditions

No.	STA (m)	H1 (m)	H2 (m)	Slope (%)
I	0+150 – 0+300	1,283.31	1,298.7	10.26
II	0+750 – 0+850	1,305.75	1,280.28	25.48
III	1+000 – 1+400	1,227.56	1,227.56	22.45

Source: Processed Data

Road Markings

The existing road markings along the Sukanagara – Bukanagara road consist of only one transverse marking: a zebra crossing with a width of 28.74 cm. Field observations indicate that road markings are minimal along the entire stretch of the road.

B. Evaluation of Existing Conditions

Horizontal Alignment

The Sukanagara Road is a secondary local road with an existing width of 4.8 meters. This is not in compliance with the Bina Marga Road Geometric Design Guidelines 2021 (PDGJ 2021), which require a minimum width of 7.5 meters for secondary local roads. Therefore, a minimum road widening of 2.7 meters is necessary.

The compliance of the existing road radius at PI 1, PI 2, and PI 3—obtained using the Civil 3D application—compared to the minimum required radius (Rmin) according to PDGJ 2021 is as follows:

TABLE 4. Suitability of Existing R with Rmin Based on PDGJ 2021

PI No.	STA (m)	Existing R (m)	Rmin Based on PDGJ 2021 (VD = 30 km/jam)	R Meets Requirement if R > Rmin
1	0+631	19.95	29	no
2	0+891	20.27	29	no
3	0+936	21.84	29	no

Source: PDGJ 2021

From the suitability table above, it can be concluded that the radius of the existing curves is not in compliance with the provisions of PDGJ 2021, requiring a redesign.

Vertical Alignment

From the calculation results, the average slope per 50 meters is 6.949%. Since this value is <10%, according to PDGJ 2021, the Sukanagara – Bukanagara road section is classified as flat terrain. The maximum slope for small roads (JKC) in flat terrain is 6%.

The results of the conformity assessment of the existing slope with the maximum slope according to PDGJ 2021 are presented in the following table:

TABLE 5. Suitability of Existing Slope with PDGJ 2021

No.	STA (m)	Existing Slope (%)	Maximum Slope According to PDGJ 2021 (%)	Remarks
I	0+150 – 0+300	10.26	6	unsuitable
II	0+750 – 0+850	25.48	6	unsuitable
III	1+000 – 1+400	22.45	6	unsuitable

Source: PDGJ 2021

From the above calculations, it is evident that the slopes in condition I (10.26%), condition II (25.48%), and condition III (11.49%) exceed the maximum allowable slope of 6%. Therefore, it can be concluded that the existing longitudinal slope is not in compliance with PDGJ 2021 regulations.

Traffic Signs

The evaluation of traffic signs on the Sukanagara – Bukanagara road section is presented in the following table.

From the table below, it is evident that there are no warning signs on sharp turns and steep ascents/descents. Thus, the traffic signage conditions on the Sukanagara – Bukanagara road section are not in compliance with the provisions of PM No. 13/2014.

TABLE 6. Suitability of Existing Traffic Signs with PDGJ 2021

STA (m)	Existing Terrain Condition	Presence of Existing Signs	According to PM No. 13/2014	Remarks
0+000	Steep ascent/descent	None	Required	Unsuitable
0+629	Sharp turn	None	Required	Unsuitable
0+750	Steep ascent/descent	None	Required	Unsuitable
0+891	Sharp turn	None	Required	Unsuitable
1+100	Steep ascent/descent	None	Required	Unsuitable

Source: PDGJ 2021

Road Markings

The evaluation results of road markings along the Sukanagara – Bukanagara road section show that the width of the zebra crossing line is 28.75 cm. However, according to PM No. 34/2014, the required width for transverse markings (zebra crossing) is 30 cm. Therefore, the existing road markings are not in compliance with regulations.

C. Redesign

After being evaluated according to geometric planning standards, re-planning (redesign) must be carried out on the horizontal alignment and vertical alignment.(Angraini Daulay et al., 2024). From the evaluation results we obtained data that can be used as a reference to determine the area's situation (Anugraha et al., 2024).

The Sukanagara – Bukanagara road section requires redesigning. Although this road is an alternative route to the Lembang tourist area, it should still provide users with a safe and comfortable driving experience. The general design criteria for this road section are presented in the following table.

TABLE 7. General Design Criteria

No.	General Design Criteria	Description
1	Road Network System	Secondary
2	Road Function	Local
3	Road Status	District Road
4	Road Class	III
5	Road Infrastructure Provision	JKC
6	Terrain Type	Flat (<10%)
7	Design Speed	10 – 30

Source: Data processing results

TABLE 8 Technical Design Criteria

No.	Technical Design Criteria	Criteria Values
1	Design Speed (VD) (km/hour)	30
2	Maximum Grade (%)	5
3	Maximum Cross Friction (fmax)	0.1725
4	Maximum Superelevation (emax) (%)	8
5	Minimum Horizontal Curve Radius (m)	29
6	Vertical Curve K Value	K Convex > 6 K Concave > 11
7	Maximum Straight Section Length (m)	1250
8	Road Type	2/2 - TT
9	Lane Width (m)	3.5
10	Shoulder Width (m)	0.25
11	Cross Slope (%)	2
12	Shoulder Cross Slope (%)	2

Source: Data processing results

Horizontal Alignment

Below is the planned road alignment from STA 0+000 to STA 1+400.

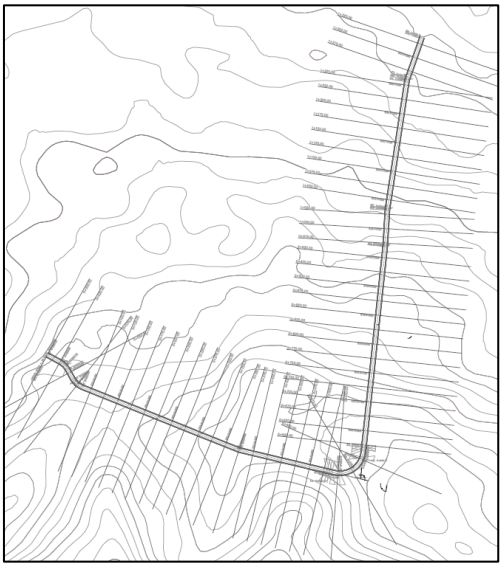

Figure 6. Re-planning result trace
Source: Data processing results

The following are the horizontal alignment calculations for PI 1

1. Deflection Angle PI 1 (Δ) = 97.23°
2. Calculation of Curve Radius

$$Rmin = \frac{VD^2}{127(e\max + fmax)}$$
$$= \frac{30^2}{127(8\% + 0.1725)} = 28{,}07\ m$$
$$\approx 29\ m$$

Chosen Rc = 40 m

3. Determining the value (Ls)
Based on Shortt's formula:
Ls min = $\frac{0{,}0214\,VD^3}{Rc \times C} = \frac{0{,}0214\,(30)^3}{135 \times 1{,}2} = 12{,}03\ m$
So, the Ls value is selected as 18 m.
Check Ls
Ls ≤ 0,5 (6detik x VD)
18 ≤ 25 → OK
4. Bend shift calculation. If P ≥ 0.25 then the bend is type S-C-S
p = $\frac{18^2}{24 \times 40} = 0{,}34$ m ≥ 0,25 m → OK S-C-S
5. Calculation of the transition curve angle
θs = $\frac{90\,Ls}{\pi\,Rc} = \frac{90 \times 18}{\pi \times 40} = 12{,}89^o$
6. Calculation of the perpendicular distance from point TS to point SC
Xs = $Ls - \frac{Ls^3}{40.Rc^2} = 17{,}90\ m$
7. Calculation of the perpendicular distance to point SC on the curve.
$Ys = \frac{Ls^2}{6.Rc} = \frac{18^2}{6 \times 40} = 1{,}35\ m$
8. Calculation of the distance of point TS.
$k = Xs - RcSin\theta s$

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$= 17{,}90 - 40 \times Sin(12{,}89) = 8{,}99$ m

9. Calculation of the length of the tangent from point PI to TS.

$$Ts = (Rc + p)tan\frac{1}{2}\Delta + k$$
$$= (40 + 0{,}34)tan\frac{1}{2}(97{,}23) + 8{,}99 = 54{,}76\ m$$

10. Calculation of the angle of the curved circle bend.
θc = $(\Delta - 2\theta s) = 97{,}23 - 2(12{,}89) = 71{,}46^{o}$
11. Calculation of the length of the circular arc.
$Lc = \frac{2\pi}{360} \times \theta c \times Rc = \frac{2\pi}{360} \times 71{,}46 \times 40 = 49{,}91$m
Check Lc
Lc ≤ $6\ detik \times VD$
49,91 m ≤ $6\ \left(\frac{30\times1000}{3600}\right)$
49,91 m ≤ $50\ m \rightarrow$ OK
12. Calculation of the total length of the curve based on formula 2.14
L total = Lc + 2Ls = 85,91 m
13. Distance between bends
Because PI 2 and PI 3 have a very small straight section length, only one bend is made in the redesign of this road route so that the calculation of the distance between bends is not carried out.

From the calculation results of the Horizontal alignment re-planning, the S-C-S bend type was obtained, with a bend radius of 40 meters, and the values of the straight section length, transition curve length, and circle curve length, which can be seen in the following TABLE

TABLE 9. Horizontal alignment design results

No	Mark	Component	Design result length (m)	Max length according to PDGJ 2021 (m)	Description
1	A – PI 1	L_L	415	1,250	OK
2	PI 1	Lc	49.9	50	OK
		Ls	18	25	OK
3	PI 1 - B	L_L	640	1,250	OK

Source: Data processing results

From the planning results in the TABLE above, it is known that all planning result values meet the provisions of PDGJ 2021. The planned superelevation diagram for PI 1 is as follows.

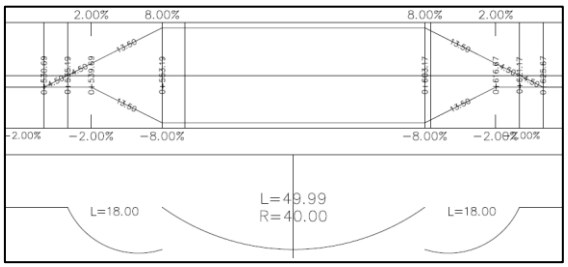

Figure 7. Planned superelevation diagram
Source: Data processing results

Vertical Alignment

The following are the Point Vertical Intersection (PVI) points in the vertical alignment re-planning on the Sukanagara – Bukanagara road section.

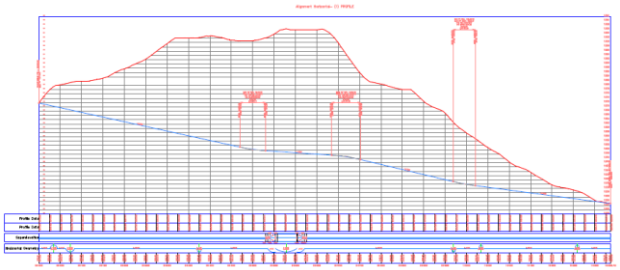

Figure 8. Vertical alignment plan
Source: Data processing results

TABLE 10. STA and elevation of planned PVI

Point	STA (m)	Elevation (m)
Initial STA	0+000	1,271
PVI 1	0+500	1,250
PVI 2	0+718	1,247
PVI 3	0+995	1,234
Final STA	1+400	1,225

Source: Data processing results

The following is an example of vertical alignment calculation on PVI 1:

1. Calculation of longitudinal slope
The calculation of the longitudinal slope is as follows

$$g2 = \frac{\text{Elevation}_{\text{final}} - \text{Elevation}_{\text{initial}}}{\text{STA}_{\text{final}} - \text{STA}_{\text{initial}}} \times 100\%$$
$$g2 = \frac{1247 - 1250}{718 - 500} \times 100\% = -1.38\ \%$$

Algebraic difference
$A = g2 - g1 = -1.38 - (-4.36) = 2.98\%$ *(CONCAVE)*
2. Critical slope length
The critical slope length is as follows:
g1 = 4.36 %
Critical slope length = 516 m
Critical slope length control:
500 m ≤ 516 m → OK
g2 = 1.38 %
Critical slope length = 729 m
Critical slope length control:
218 m ≤ 729 m → OK
3. Determining the minimum stopping sight distance (JPH)
Design speed (V_D) PVI 1 = 30 km/ h
Based on PDGJ 2021, it is known that JPH of 35 m has a Kref value of 6
4. Length of concave vertical curve
To calculate the length of the concave vertical curve is calculated based on the following four conditions
- Based on the stopping sight distance (JPH), this calculation referes to formula 3.2.

$$L = K \times A = 6 \times 2.98 = 17.9\ m$$

- Based on the stopping sight distance (JPH), this calculation refers to formula 3.3.

$$K = \frac{{V_D}^2}{1296a} = \frac{30^2}{1296\ \times (0{,}05 \times 9{,}81)} = 14.56$$

$$L = K \times A = 14.56 \times 2{,}98 = 43{,}45\ m$$

- Based on the appearance factor

$$L = Kmin \times A = 15 \times 2{,}98 = 44{,}76\ m$$

- Based on the drainage factor.

$$L = Kmax \times A = 20 \times 2{,}98 = 59{,}7\ m$$

Based on the four formulas, the largest L value is selected, namely 59,7 m

Check the value of Kdesign > Kref, 20 > 6 → OK

From the results of the vertical alignment design both with the Civil 3D application and calculations, the following quantities are obtained:

TABLE 11. The results of the vertical alignment re-planning on PVI 1

Description	PVI 1		
	PLV	PVI	PTV
Jenis Lengkung		Concave	
L_{VC} (m)		59,7	
K		20	
STA (m)	0+470	0+500	0+530
Elevation (m)	1,251.31	1,250	1,249.59

Source: Data processing results

TABLE 12. The results of the vertical alignment re-planning on PVI 2

Description	PVI 2		
	PLV	PVI	PTV
Curved Type		Convex	
L_{VC} (m)		67,3	
K		20	
STA (m)	0+684	0+718	0+751
Elevation (m)	1,247.49	1,247	1,245

Source: Data processing results

TABLE 13. The results of the vertical alignment re-planning on PVI 3

Description	PVI 3		
	PLV	PVI	PTV
Curved Type		Concave	
L_{VC} (m)		52,3	
K		25	
STA (m)	0+968	0+995	1+021
Elevation (m)	1,235.23	1,234	1,233.31

Source: Data processing results

Traffic Signs

From the results of the re-planning of this road section, it is known that the planned speed used is 30 km/hour, so based on the general provisions of PM 13 of 2014, the planning of the traffic signs used is as follows:

TABLE 14. Re-planning of traffic signs

No	Component	Plan
1	Placement of signs before dangerous sections (m)	50
2	Sign height (m)	1,75
3	Size of Numbers, letters, and symbols (mm)	90
4	Type of Numbers, letters, and symbols Clearview Highway	*Clearview Highway*
5	Size of Small Sign Leaves	Small

Source: PM 13 of 2014

Road Markings

From the results of the re-planning of this road section, it is known that the planned speed used is 30 km/hour, so based on the general provisions of PM 34 of 2014, the planning of the road markings used is as follows:

TABLE 15. Re-planning of road markings

No	Component		Plan
1	Material	Type	Paint
		Color	White
		sifat	non-slippery and can reflect light
		Thickness (mm)	2
2	Longitudinal markings	Solid line width (cm)	10
		Length of dotted line (m)	3
		Distance between dotted lines (m)	5
		Distance between 2 longitudinal markings (double lines) (cm)	10
3	Transverse markings (Zebra Cross)	Length of a solid longitudinal line (m)	2.5
		Width of the longitudinal solid line (cm)	30
		The distance between the longitudinal solid lines (cm)	30

Source: PM 34 of 2014

IV. Conclusion and Suggestions

Based on the results of the analysis and discussion, the following conclusions can be drawn:

1. From the results of direct measurements in the field and data processing using the Civil 3D application, the existing data along the Sukanagara road - Bukanagara road section are obtained as follows:
   a. For horizontal alignment, the width of the existing road body is 4.8 m, with a radius at PI 1 of 19.95 m, PI 2 of 20.27 m, and PI 3 of 21.84 m.
   b. For vertical alignment, it is known that the slope at STA 0+150 – 0+300 is 10.26%, at STA 0+750 – 0+850 is 25.48%, and at STA 1+000 – 1+400 is 11.49%.
   c. There are no warning signs on sharp bends, steep inclines, or descents along the Sukanagara – Bukanagara road section. There is only one transverse road marking in the form of a Zebra Cross along the Sukanagara – Bukanagara road section.
2. From the evaluation results of the Sukanagara – Bukanagara road section, there are 4 points, namely:
   a. The horizontal alignment on this road section is not in compliance with the provisions of PDGJ 2021. With the following details:
      - From the results of measurements in the field, the existing road body has a width of 4.8 meters, but the minimum road body width for secondary local roads should be 7.5 meters, so it is not in compliance with the provisions of PDGJ 2021
      - From the results of the analysis using the Civil 3D application, the existing radius approach figures for PI 1 were 19.946 meters, PI 2 20.265 meters, and PI 3 21.840 meters, while according to PDGJ 2021 the minimum bend radius should be 29 meters. Because there are existing bend radius figures that are less than the minimum radius according to PDGJ 2021, it is necessary to

redesign the horizontal alignment on this road section.

b. The vertical alignment on this road section is not in compliance with the provisions of PDGJ 2021. Based on the results of the analysis of the existing slope using the civil 3D application, it is known that the slope of the road at STA 0+150 - STA 0+300 is 10.26%, at STA 0+750 - 0+850 is 25.48%, and at STA 1+000 - 1+400 is 11.49%. Meanwhile, according to PDGJ 2021, the maximum slope should not be greater than 6%, so it is necessary to redesign the vertical alignment on this road section.

c. Traffic signs on this road section are not in compliance with the provisions of PM 13 of 2014. This road section has sharp bends and steep inclines/declines, but no warning signs were found. While the warning signs should be at a distance of 50 meters before the dangerous section.

d. The road markings on this road section are not in compliance with the provisions of PM 34 of 2014. Along this road section, there are no longitudinal markings and only 1 marking in the form of a transverse marking (Zebra crossing). From the measurement results, the existing markings have a line width of 28.75 cm, while according to the provisions of PM 34 of 2014, the width of the transverse line should be at least 30 cm.

3. From the results of the geometric road re-planning, there are 4 points, namely:

a. Horizontal alignment re-planning using the provisions of PDGJ 2021, a road with a road body width of 7.5 meters, the longest straight section length (LL) of 640 meters, and there is 1 S-C-S type bend with a bend radius (Rc) of 40 meters, a transition curve length (Ls) of 18 meters, and a circle arc length (Lc) of 49.9 meters.

b. Re-planning of vertical alignment using the provisions of PDGJ 2021, the road slope was below 6%. There are 3 PVIs with a vertical curve value (Lvc) in PVI 1 of 59.68 meters, in PVI 2 of 67.26 meters, and in PVI 3 of 52.29 meters.

c. Re-planning traffic signs using the provisions of PM 13 of 2014, the distance of the sign placement before the dangerous section was 50 m, the height of the sign was 1.75 m, and the size of the numbers, letters, and symbols was 90 mm. The types of numbers, letters, and symbols used Clearview Highway, and the size of the sign leaves was small.

d. Re-planning of road markings using the provisions of PM 34 of 2014, with the following details:

- Markings with white paint that can reflect light and is not slippery.
- Longitudinal markings have a thickness of 2 mm, a solid line width of 10 cm, a dotted line length of 3 m, a distance between dotted lines of 5 m, and a distance between 2 longitudinal markings (double lines) of 10 cm.
- Transverse markings (Zebra Cross) have a solid longitudinal line length of 2.5 m, a solid longitudinal line width of 30 cm, and a distance between solid longitudinal lines of 30 cm.

1.1 Suggestions

After conducting research and coming to conclusions, the author suggests several things.

1) For further research, it is recommended that the contour data used be the result of direct measurements in the field to obtain more actual and accurate results.
2) If it is felt that the excavation and embankment, as planned, are too expensive and not possible, traffic signs along the existing road should be equipped according to the provisions of PM 13 of 2014.

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