UNIVERSITY OF ZIELONA GÓRA

CEER CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

E-ISSN 2450-8594

CEER 2025; 35 (2): 0035-0046
DOI: 10.59440/ceer/202031
Original Research Article

ROAD SAFETY EVALUATION ON COLLECTOR ROAD SECTION OF SILUK-PANGGANG, YOGYAKARTA, INDONESIA

Noor MAHMUDAH[1*], Wahyu Arif PRATAMA[1], Muhamad Nur FADHILAH[2]
[1] Master Program of Civil Engineering, Universitas Muhammadiyah Yogyakarta, Indonesia
[2] Department of Civil Engineering, Universitas Muhammadiyah Yogyakarta, Indonesia

Abstract

The Siluk – Panggang road section is a provincial road that functions as a primary collector road. The sharp horizontal alignment and steep vertical alignment conditions make this road section potentially cause traffic accidents. Therefore, the objective of this study is to evaluate the road geometric conditions of the roads to enhance road safety. Specifically, this study includes identifying the types and number of accidents, carrying out Road Safety Inspections (RSI) according to the 2005 Bina Marga Technical Guidelines, and analysing road geometry (horizontal and vertical alignments) with AutoCAD Civil 3D software which is further compared to the 2021 Bina Marga Regulation concerning Road Geometric Design Guidelines. Based on the RSI results, it is known that this road has the number of lanes and lines, as well as the width of the shoulder according to the requirements, but the width of the traffic lane does not meet the requirements. Based on the geometric modelling of the road, 12 bends can be identified, where 46% of the bend radius does not meet the requirements. In addition, vertical alignment consists of 14 curves with 7 convex curves and 7 concave curves. However, 40% of slopes exceed the maximum and 57% of K values do not meet the requirements. Therefore, geometrically this road has a high potential for accidents.

Keywords: road geometrics, horizontal alignment, vertical alignment, AutoCAD Civil 3D, traffic accidents

1. INTRODUCTION

Yogyakarta is one of Indonesia's most renowned tourist destinations, known for its rich cultural heritage and diverse natural attractions. The region consistently attracts millions of visitors annually, with domestic tourism playing a significant role in its popularity. According to the Indonesian Central Bureau of Statistics (2024), Yogyakarta recorded 25.44 million domestic tourist visits in 2024, highlighting its status as a key hub for tourism. Among the various attractions, natural tourism sites, such as beaches, caves, and hills, are particularly popular. These destinations are often located in rural areas and are

[1] Corresponding author: Master Program of Civil Engineering, Universitas Muhammadiyah Yogyakarta, Brawijaya Street, Bantul, Yogyakarta, Indonesia - 55183, email: noor.mahmudah@umy.ac.id, Phone: +628112557711

primarily accessed via intercity and rural road networks. Due to this tourism activity, the mobility from urban to rural areas and vice versa have increased drastically [1, 2].

One of the main routes facilitating access to these natural attractions is the Siluk-Panggang road section located in Bantul Regency, Special Region of Yogyakarta (shown in Fig. 1.), which connects the city of Yogyakarta to Gunung Kidul Regency, a region known for its scenic landscapes and outdoor activities. This road serves as a vital link for both locals and tourists traveling to Gunung Kidul's natural sites. However, despite its importance, the Siluk-Panggang road section has become a site of concern due to its safety record. In recent years, the route has experienced a number of traffic accidents, resulting in slight injuries, serious injuries, and even fatalities.

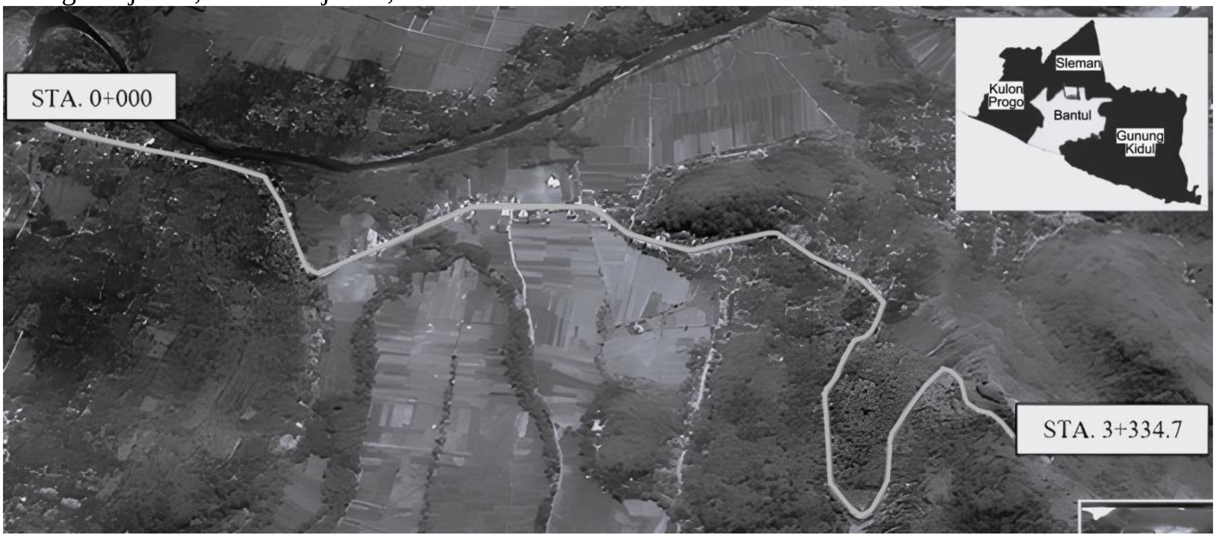

Fig. 1. Location of Study

Road geometric design is a fundamental aspect of road planning, involving the alignment and visualization of road trajectories to ensure they meet safety, security, comfort, and efficiency standards. Various factors influence the selection of road alignment, affecting horizontal alignment, vertical alignment, and cross-section design, all of which must comply with efficiency requirements and regulatory limits. The Siluk - Panggang road section in Yogyakarta features sharp bends and steep slopes on hilly terrain, making its geometry a potential contributing factor. These parameters highlight the need for a comprehensive analysis of the road's geometric design and safety features to address potential hazards and improve overall traffic safety.

Traffic accidents, particularly in bent road sections, present significant challenges and are often underestimated. The frequency of accidents on bent roads is 1.5 to 4 times higher than on straight road sections. Sharp bends, in particular, are among the most hazardous locations. However, geometric standards permit them under specific conditions, primarily for roads with certain functional classifications and lower speed limits [3]. Geometric planning is a complex task, requiring careful consideration and detailed analysis to comply with applicable regulatory standards [4]. Based on the preceding discussion, this research aims to evaluate the geometric conditions to enhance road safety. Specifically, this study includes identifying the types and number of accidents, carrying out Road Safety Inspections (RSI) according to the 2005 Bina Marga Technical Guidelines, and analysing road geometry (horizontal and vertical alignments) with AutoCAD Civil 3D software which is further compared to the 2021 Bina Marga Regulation concerning Road Geometric Design Guidelines [5–7].

Based on accident data obtained from the Indonesian National Police Traffic Unit Bantul Resort, the number of accidents, accident locations, number of victims, fatalities, and types of accidents were collected. The data cover a 5-year period from 2018 to 2022, detailing accidents by the number of victims, vehicle types involved, and accident types. There are five main types of accidents: head-on (Ho), angle (SF), sideswipe (SS), hit-and-run (HnR), single-vehicle (S), and rear-end (RE). Over the past five years, the data consistently show that motorcycles are the most frequently involved in accidents, accounting for more than 70% of the cases [8, 9]. Therefore, it is crucial to investigate the factors that may have contributed to such accidents.

2. LITERATURE REVIEW

The literature identifies that the primary factors contributing to traffic accidents are human behaviour, vehicle conditions, road characteristics, and environmental factors, along with the interaction between these elements. Accident risk is strongly correlated with road geometric features, such as straight road length, sight distance, bend angle, bend radius, superelevation, number of intersections, main road access, slope, roadside environment, lane width, climbing lanes, and transition bends [10–12]. Furthermore, the relationship between road geometric factors and traffic characteristics, such as bend radius, lane width, shoulder conditions, average annual daily traffic (AADT), and the percentage of heavy vehicles, also influences accident occurrences [13].

The use of the AutoCAD Civil 3D application has been widely recognized as an effective tool for evaluating road geometric conditions, particularly concerning road safety factors. This application provides advanced capabilities for detailed analysis and visualisation of road geometry, enabling researchers and engineers to identify potential hazards and deficiencies that may contribute to traffic accidents. Evidence from several previous studies highlights the effectiveness of this approach, with findings consistently pointing to recurring geometric issues that compromise road safety consisting of small bend radius and inadequate road alignment. Among the most common problems identified are bend radius that are too small, which can make it challenging for vehicles to navigate curves safely, and insufficient superelevation, which reduces the ability of roads to counteract centrifugal forces on curves. Furthermore, inadequate horizontal radius and poor visibility have been shown to significantly increase the risk of accidents, particularly on rural roads with complex and challenging terrain. Several key factors influence road safety at bends, including the bend radius, bend length, the number and spacing of bends, access roads, average curve length, and the average central angle. In addition, road widening at bends is a critical measure for improving safety, as it provides additional space for vehicles to manoeuvre, especially on sharp curves. Another essential consideration is determining a design speed (Vd) that aligns with the average speed of road users, ensuring that the road geometry accommodates typical driving behaviour. These factors collectively emphasize the importance of geometric analysis in designing safer roads and reducing accident risks [12, 14–19].

Preventing and addressing traffic accidents in road infrastructure begins with proper planning, design, construction, and upgrades, following the procedures outlined in Road Safety Inspections [10]. A Road Safety Inspection (RSI) involves assessing a road section to identify hazards, faults, and deficiencies that may contribute to accidents [20]. To analyse road geometrics, AutoCAD Civil 3D software is commonly used. This software, based on Building Information Modelling (BIM), is widely utilised for road design and evaluation.

3. RESEARCH METHODOLOGY

The stages of this research are illustrated in Fig. 2., starting with the collection of secondary data, including accident data of 2018-2022, and provincial collector road data for the Special Region of Yogyakarta. Primary data on road geometrics and environmental conditions were obtained through Road Safety Inspection (RSI) in accordance with the 2005 Bina Marga Guidelines. The collected data were then modelled using AutoCAD Civil 3D to analyse both horizontal and vertical alignments. The key geometric attributes were compared with the standards set out in the 2021 Bina Marga Regulation.

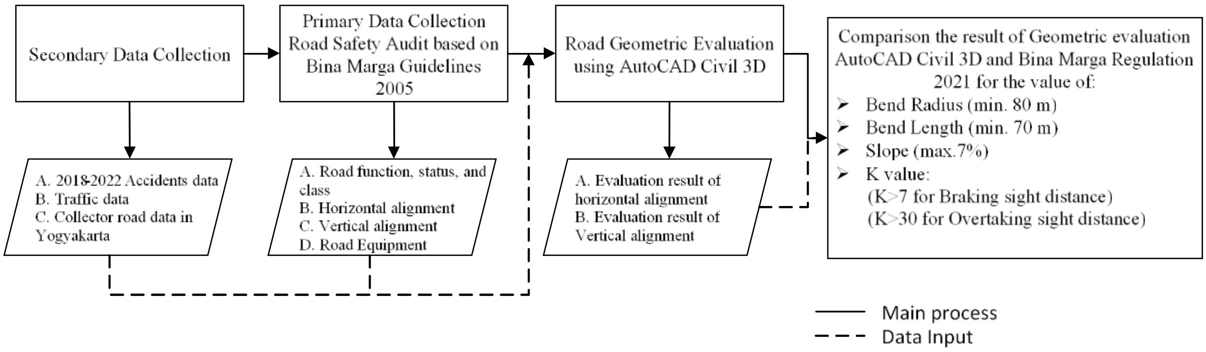

Fig. 2. Research Stages

The important horizontal alignment attributes analysed and compared include bend radius, horizontal curve length, and bend angle. Meanwhile, the important attributes of the vertical alignment obtained from the analysis results are slope, and design control value (K) which considers stopping sight distance (SSD) and overtaking sight distance (OSD). The K value is determined based on the 2021 Bina Marga Regulation, which refers to AASHTO 2011. Bend radius (Rmin) is the length of the radius required for a vehicle to turn, expressed in metre (m). According to the Bina Marga Regulation number 13/P/BM/2021, the minimum value of the bend radius for a design speed (Vd) of 50 km/h is 80 m which is obtained using Table 1. This design speed is determined according to the 2021 Bina Marga Regulation for Primary Collector Roads of 20 - 60 km/h. The length of the horizontal curve (Lh) is the curved part of the road in the horizontal direction consisting of a circular arc with or without a transition curve, expressed in metres (m). Based on Bina Marga Regulation number 13/P/BM/2021, the minimum horizontal bend length according to the design speed is 70 m obtained using Table 2.

Table 1. Minimum radius (Rmin) value based on Bina Marga Regulation number 13/P/BM/2021 (Bina Marga, 2021)

Vd (Km/h)	**Friction (f)**	**Rmin (m) for e=4%**	**Rmin (m) for e=6%**	**Rmin (m) for e=8%**
30	0.17	35	30	30
40	0.17	60	55	50
50	**0.16**	100	90	**80**
60	0.15	150	135	125

Table 2. The length of the horizontal curve (Lh) value based on Bina Marga Regulation number 13/P/BM/2021 (Bina Marga, 2021)

Vd (Km/h)	Lh (m)
40	45
50	**70**
60	100
70	140

Slope is a quantity that indicates a vertical increase or decrease in units of horizontal distance. Slope can be expressed in percentages with different maximum values depending on the road infrastructure provision system as regulated in the Bina Marga Regulation number 13/P/BM/2021 as in Table 3. Based on the data, it is known that the Siluk-Panggang road section is a medium road with a maximum slope of 7%, thus it still meets the Bina Marga Regulation number 13/P/BM/2021.

Table 3. Slope value based on Bina Marga Regulation number 13/P/BM/2021 (Bina Marga, 2021)

Road Classification	Maximum Slope (%)		
	Flat	Hill	Mountain
Freeway	4	5	6
Motorway	5	6	10
Medium road	6	**7**	10
Small road	6	8	12

The vertical curve design control (K value) is the vertical curve length per cent change in slope. The minimum K value is determined according to the SSD and OSD values for each design speed. Stopping sight distance (SSD) is the sight distance required for a driver to safely stop their vehicle and is measured in metres. Based on Bina Marga Regulation number 13/P/BM/2021, the minimum K value can be determined using Table 4. The overtaking sight distance (OSD) is the visibility distance required for the driver to safely precede the vehicle in front of him against traffic coming from the opposite direction and is measured in metres. According to Bina Marga Regulation number 13/P/BM/2021, the K value can be determined using Table 5.

Table 4. Minimum design control (K) for vertical curve according to SSD (Bina Marga, 2021)

V_D (Km/h)	SSD (m)	K
20	20	1
30	35	2
40	50	4
50	**65**	**7**
60	85	11
70	105	17
80	130	26
90	160	39
100	185	52
110	220	74
120	250	95

Table 5. Design control (K) for vertical curve according to OSD (Bina Marga, 2021)

V_D (Km/h)	OSD (m)	K
30	120	17
40	140	23
50	**160**	**30**
60	180	38
70	210	52
80	245	70
90	280	91
100	320	119
110	355	146
120	395	181

For the horizontal alignment, the minimum bend radius (Rmin) for medium roads with a design speed of 50 km/h was 80 m, while the minimum horizontal bend length was determined to be 70 m. In terms of vertical alignment, the maximum slope was 7%, which complied with the 2021 Bina Marga Regulations. Additionally, the minimum K value, which represents vertical curve design control based on Stopping Sight Distance (SSD) and Overtaking Sight Distance (OSD), was determined to be 7 and 30, respectively.

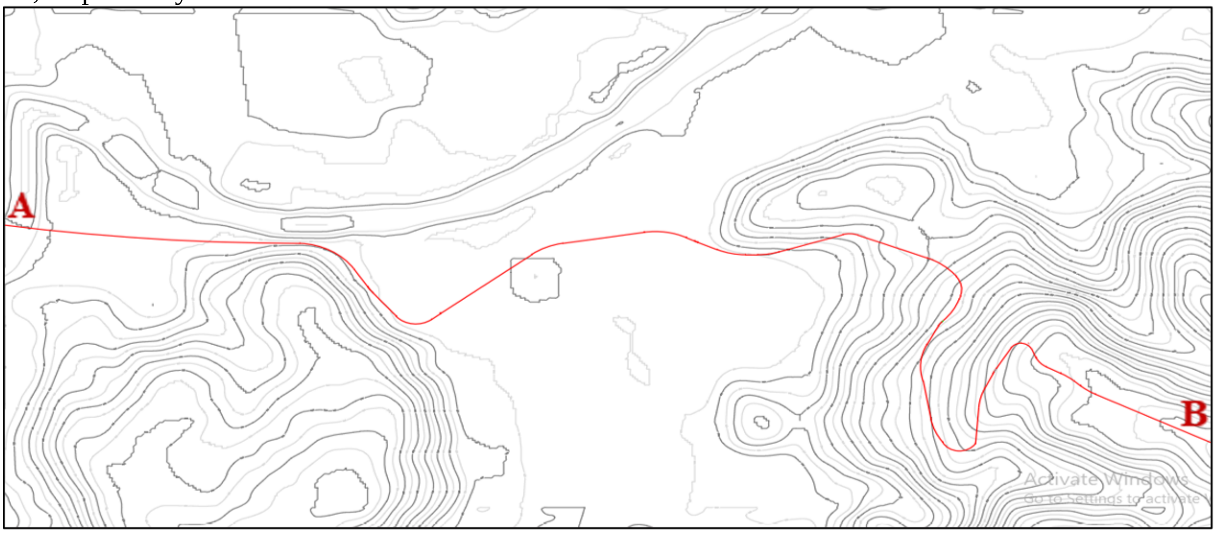

Fig. 3. Existing road trajectories of Siluk-Panggang Road Section from STA 0+000 (Point A) to STA 3+334.7 (Point B)

The existing road trajectory of the Siluk-Panggang road section which is the object of this research (see Fig. 3.) has a trajectory length of 3,334.7 m and starts from STA 0+000 (Point A) to STA 3+334.7 (Point B) and stationing points are made every 20 metres both on straight trajectories and bend trajectories. Analysis of the road's geometric attributes helps evaluate the potential for accidents on the Siluk-Panggang road section by comparing these values with established safety standards.

4. RESULT AND DISCUSSION

The Siluk-Panggang road section is classified as a primary collector road with the status of a provincial road, situated in hilly terrain. Despite its classification as a medium road, the geometric attributes indicate some areas of non-compliance with current regulations (see Table 6). Specifically, the lane width of 2.5 metres is below the minimum required standard of 3.5 metres, rendering it unqualified according to the applicable guidelines. However, other attributes such as the number of lanes and shoulder width, meet the required standards. The inventory of sharp bends in Siluk-Panggang road section is shown in Fig. 4. The circles indicating qualified bends and the triangles indicating unqualified bends (provided with field condition photo) based on the 2021 Bina Marga Regulation.

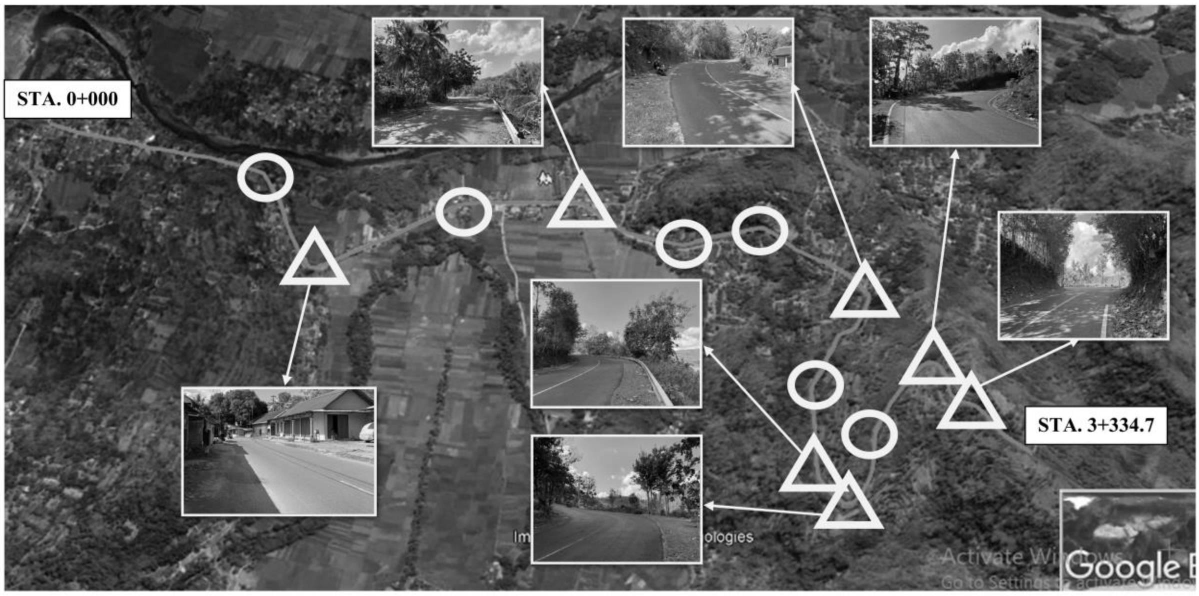

Fig. 4. Road Bend Inventories of Siluk-Panggang Road Section from STA 0+000 to STA 3+334.7

Regarding road safety, the five-year accident data (2018-2022) highlights ongoing concerns, with two fatalities recorded annually and a total of 99 slight injuries over the period. The accident data for the Siluk-Panggang road section reveals that head-on (HO) collisions account for 17 cases, while rear-end (RE) collisions amount to 15 incidents (see Table 7). These accidents are primarily attributed to the narrow road width and challenging hilly terrain. Insufficient road width (less than 3.5 metres) increases the risk of vehicles encroaching into opposing lanes, leading to head-on collisions, while the steep slopes and limited space make it difficult for drivers to maintain safe distances, contributing to rear-end crashes. Side-front (SF) consist of 12 collisions, frequently occur near T-intersections located on bends and uphill sections as seen in Fig. 4., where limited sight distance hinders driver reaction time. The downhill road forces vehicles to slow down, reducing the severity of accidents and explaining the high number of slight injuries despite the frequency of incidents. These findings showed that narrow lanes, steep gradients, and poor visibility near intersections are important factors contributing to the accident patterns on this road section.

Table 6. Road classification and attributes

No	Attribute	Value	Standard BM.2021	Remark
1	Road Status	Province		2021 Bina Marga Regulation
2	Road Function	Primary Collector		
3	Road Classes	Medium Road		
4	Terrain	Hilly		
5	Number of lanes	2	2	Qualified
6	Number of lines	2	2	Qualified
7	Lane width	2.5 m	3.5 m	Unqualified
8	Shoulder width	1.5 and 1.2 m	1 m	Qualified

Table 7. Number and type of accidents

Years	HO	SF	HnR	S	RE
2018	2	3	3	4	4
2019	3	2	2	1	3
2020	4	4	2	1	1
2021	2	3	1	6	3
2022	6	0	0	5	4

Table 8. Minimum bend radius analysis result using Civil 3D

STA	Bend length (m)	Rmin Bina Marga Regulation 2021 (m)	Rmin existing road (m)	Remark
0+604.92	120.50	80	100	Qualified
0+832.06	**162,13**	**80**	**70**	**Unqualified**
1+112.86	252.00	80	-	Qualified
1+451.68	**59.45**	**80**	**65**	**Unqualified**
1+591.71	117.51	80	120	Qualified
1+805.68	109.78	80	120	Qualified
2+057.93	**137.76**	**80**	**70**	**Unqualified**
2+283.06	90.36	80	120	Qualified
2+469.56	**77.46**	**80**	**70**	**Unqualified**
2+558.31	**57.98**	**80**	**27**	**Unqualified**
2+689.63	74.42	80	112	Qualified
2+857.87	**45.11**	**80**	**21**	**Unqualified**
2+9191.53	**64.21**	**80**	**65**	**Unqualified**

In Table 8, based on the results of the analysis using the type of bend using AutoCAD Civil 3D 2015 software, the road geometric analysis for horizontal alignment shows that 46% of the existing road fail to meet the minimum required radius of 80 metres, as stipulated by the 2021 Bina Marga Regulation. According to Table 9, the analysis for vertical alignment reveals that 40% of the current road slope fail to comply with the requirements of the 2021 Bina Marga Regulation. The vertical alignment analysis on existing Siluk-Panggang road trajectories resulted 7 convex and 7 concave vertical bends as shown in Fig. 5. Furthermore, Table 10 indicates that 8 out of 14 (57%) of the road control design value (K) in existing road geometric fail to meet the K value requirements for OSD outlined in the 2021 Bina Marga Regulations.

Table 9. Slope analysis result using Civil 3D

STA	Slope of Existing Road Section (%) (Max 7%)	Remarks
0+000	0	-
0+051.96	**12.93**	**Unqualified**
0+355.20	1.16	Qualified
0+490.57	2.46	Qualified
0+664.69	1.37	Qualified
0+846,94	-1.95	Qualified
0+957.99	-3.92	Qualified
1+491.60	0.24	Qualified
1+575.17	5.20	Qualified
1+835.82	**7.99**	**Unqualified**
1+909.97	**9.04**	**Unqualified**
2+102.40	**15.34**	**Unqualified**
2+376.49	5.31	Qualified
2+667.33	**10.63**	**Unqualified**
2+920.77	**9.70**	**Unqualified**
3+334.27	-	-

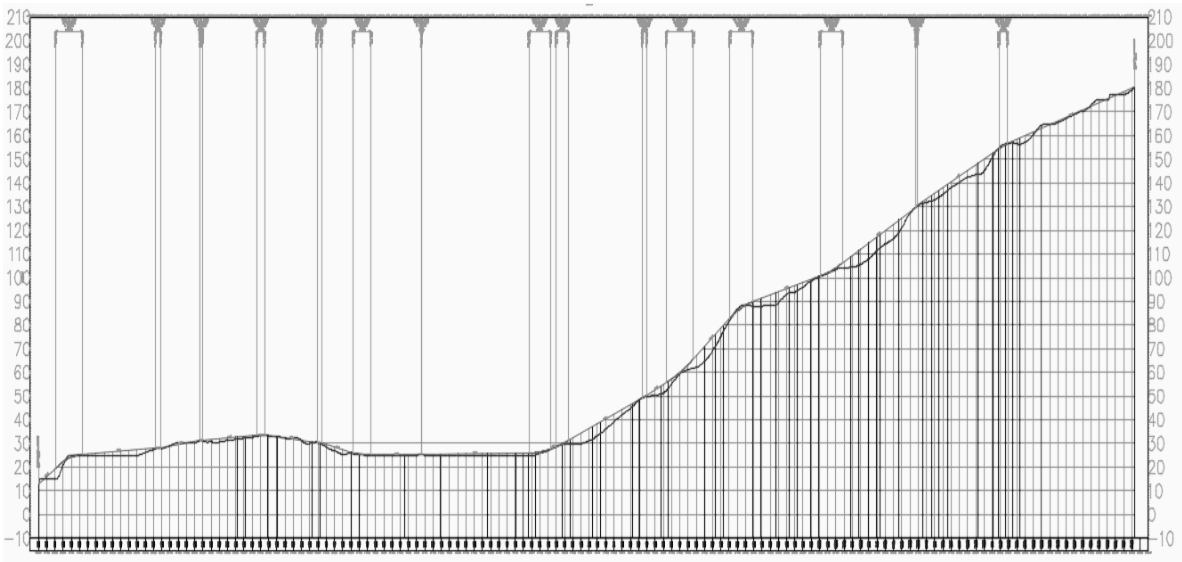

Fig. 5. Vertical alignment inventories

Table 10. K value analysis result using Civil 3D

STA	Curve Type	Curve Length	Calculated K Value on Civil 3D	Min K Value			Remark
				SSD	OSD	HSD	
0+000	-	-	-	-	-	-	-
0+093.14	**Convex**	**82.39**	**7**	**7**	**30**	**-**	**Unqualified**
0+363.30	Concave	16.81	13	-	-	13	Qualified
0+494.36	**Convex**	**7.58**	**7**	**7**	**30**	**-**	**Unqualified**
0+676.32	**Convex**	**23.26**	**7**	**7**	**30**	**-**	**Unqualified**
0+853.83	**Convex**	**13.78**	**7**	**7**	**30**	**-**	**Unqualified**
0+985.00	Concave	54.01	13	-	-	13	Qualified
1+524.47	**Concave**	**65.74**	**13**	**7**	**30**	**-**	**Unqualified**
1+593.32	Concave	36.31	13	-	-	13	Qualified
1+842.63	Concave	13.62	13	-	-	13	Qualified
1+950.89	Concave	81.83	13	-	-	13	Qualified
2+137.51	**Convex**	**70.22**	**7**	**7**	**30**	**-**	**Unqualified**
2+411.08	Concave	69.19	13	-	-	13	Qualified
2+670.00	**Convex**	**5.35**	**5.7**	**7**	**30**	**-**	**Unqualified**
2+933.72	**Convex**	**25.91**	**7.4**	**7**	**30**	**-**	**Unqualified**
3+334.27	-	-	-	-	-	-	-

5. CONCLUSION

The analysis of the Siluk-Panggang road section reveals several critical insights into its geometric attributes, classification, and accident history. Classified as a Primary Collector Road in a hilly region, the road meets some regulatory standards, such as the number of lanes and shoulder width. However, significant issues exist, particularly with the road's existing geometric attributes compared with the 2021 Bina Marga Regulation. Approximately 46% of the bend radius, 57% of the road slopes, and 40% of the road control value (K) do not comply with the 2021 Bina Marga Regulation. These conditions indicate substantial deficiencies in both horizontal and vertical alignment that potentially cause fatal accidents. Narrow lanes, steep gradients, and poor visibility near intersections are key factors contributing to the highnumber of accidents on this road section, thus can be concluded that these unqualified geometric are attributed as black spot locations.

The findings of this study are significant as they provide a detailed evaluation of the geometric deficiencies of the Siluk-Panggang road section and their direct impact on road safety. By identifying specific areas of non-compliance with safety standards, this research offers actionable insights for road planners and engineers to implement targeted interventions, such as redesigning bends, improving slopes, and adjusting K values, to enhance road safety. Furthermore, the use of AutoCAD Civil 3D software demonstrates the effectiveness of modern tools in identifying road safety hazards, providing a replicable methodology for similar studies in other regions. These contributions advance the field of road geometric analysis and offer practical implications for reducing accidents and improving traffic safety, particularly in hilly terrains with challenging road conditions.

ACKNOWLEDGEMENT

Our thanks and appreciation go to Assoc. Prof. Ghazwan Al-Haji in Linkoping University as the Coordinator of ERASMUS+ CBHE PROJECT "ASIASAFE" co-funded by the European Union with contract number 618325-EPP-1-2020-1-SE-EPPKA2-CBHE-JP and the Institute for Research and Innovation (LRI) Universitas Muhammadiyah Yogyakarta.

STATEMENTS AND DECLARATIONS

The manuscript entitled "**ROAD SAFETY EVALUATION ON COLLECTOR ROAD SECTION OF SILUK-PANGGANG, YOGYAKARTA, INDONESIA**" has not been published elsewhere before being submitted to CEER.

The accident data is collected from Indonesian Police Department as secondary data and road geometric data from field surveys as primary data and have been analysed personally.

The manuscript has been read and approved by all authors and all authors have been confirmed to approve the order of authors listed.

REFERENCES

1. Borucińska, BH 2022. The Determinants of the Existing Conditions on the Functional and Spatial Development of Rural Areas. *Civil and Environmental Engineering Reports* **32**, 225–268.
2. Mateusz, K and Wiktor, B 2022. Development of Riverside Areas in the Context of the Attractiveness for Residents. *Civil and Environmental Engineering Reports* **32**, 147–192.
3. Manggala, R et al. 2016. Case Study of Causal Factors of Traffic Accidents at Sharp Bends. *Jurnal Karya Teknik Sipil* **4**, 462–470.
4. Badrujaman, A 2016. Geometric Design and Budgeting of Cempaka-Wanaraja Road Section. *Jurnal Konstruksi* **44**, 25–34.
5. Bina Marga, 2005. Pedoman Audit Keselamatan Jalan [Road Safety Inspection Guidelines]. Jakarta, Indonesia.
6. Bina Marga, 2021. Pedoman Desain Geometrik Jalan [Road Geometric Design Regulation]. Jakarta, Indonesia.
7. Mahmudah, N, Kumalasari, SR, Setiawan, D, Nursetiawan, N 2023. *Geometric analysis of potential accidents on the Sentolo-Nanggulan road, Yogyakarta*. AIP Conference Proceedings, AIP Publishing, The 2nd International Symposium on Civil, Environmental, and Infrastructure Engineering 10 August 2022, Yogyakarta, Indonesia
8. Erlin, E 2022. Sepeda Motor Oleng, Wahono Terlindas Truk [Motorbike Swerves, Wahono is Run Over by a Truck]. Retrieved from *iNewsYogya.id*. Available online: https://yogya.inews.id/berita/sepeda-motor-oleng-wahono-tewas-terlindas-truk
9. Indonesian National Police Traffic Unit Bantul Resort 2021. Accident Dump Bantul Regency Period of 2018-2020 (Annual Accident Data), **2021**. Bantul, Yogyakarta, Indonesia.
10. Pembuain, A, Priyanto, S, Suparma, L, 2019. *The effect of road infrastructure on traffic accidents*. 11th Asia Pacific Transportation and the Environment Conference (APTE 2018), Atlantis Press, 176–182.
11. Mahmudah, N 2019. *Teknik Jalan Raya: Perencanaan Geometrik Jalan* [*Highways Engineering: Road Geometric Planning*] *1st ed*. Yogyakarta: Lembaga Penelitian, Publikasi, dan Pengabdian Masyarakat UMY.

12. Suraji, A and Mulyono, AT 2022. Accident risk analysis of road geometric components using functional worthiness approach. *Eastern-European Journal of Enterprise Technologies* **3**, 6-14.
13. Popoola, MO et al. 2018. Effect of Traffic and Geometric Characteristics of Rural Two Lane Roads on Traffic Safety: a case study of Ilesha-Akure-Owo road, South-West, Nigeria. *FUOYE Journal of Engineering and Technology* **3**, 125-130.
14. Aldala'in, SA et al. 2023. Road Accident Hotspots on Jordan's Highway Based on Geometric Designs Using Structural Equation Modeling. *Applied Sciences* **13**, 8095.
15. Gangwa, N and Deulkar V 2020. A Review on Effect of Highway Geometric Elements on Accident Modeling. *International Journal of Scientific Research & Engineering Trends* **6**, 153-157.
16. Islam, H, Hua, LT, Hamid, H bin, Azarkerdar, A 2019. *Relationship of Accident Rates and Road Geometric Design*. IOP Conference Series: Earth and Environmental Science, Sustainable Civil and Construction Engineering Conference 25–27 August 2018, University Putra Malaysia, Kuala Lumpur, Malaysia, 1-10.
17. Motalib, J et al. 2024. Assessment of Road Safety Through Geometric Design Analysis: The Case of Sagonsongan Diversion Road in Marawi City. *Journal of Interdisciplinary Perspectives* **2**, 544-550.
18. Yan, J et al. 2023. Relationship between Highway Geometric Characteristics and Accident Risk: A Multilayer Perceptron Model (MLP) Approach. *Sustainability* **15**, 1-15.
19. Zhang, H et al. 2021. Formulating A GIS-Based Geometric Design Quality Assessment Model For Mountain Highways. *Accident Analysis & Prevention* **157**, 1-13.
20. Mahmudah, N et al. 2024. Analysis of the Relationship between Road Geometrics and Potential Accident on Imogiri-Dlingo Road, Bantul, Indonesia. *Media Komunikasi Teknik Sipil* **29**, 271–279.