LEADER
Civil Engineering and Architecture Journal

Civil Engineering and Architecture Journal Vol 1 No. 4 (2023) 3026-622X
DOI 10.37253/leader.v1i4.8954

Road Assessment: Analyzing Geometric Standards Compliance With The Power Of Open-Source Google Earth - A Case Study Of Waecicu Road, West Manggarai

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ARTICLE INFO

Keywords:

Road Assessment, Google Earth, Geometric Standards, Effective Road Assessment Techniques, Road Compliance

ABSTRACT

This study conducted a case study on Waecicu Road in NTT to evaluate its compliance with the Indonesian Road Geometric Design Guidelines 2021. It aims to revolutionize the process of road assessment by utilizing the power of open-source Google Earth. The study found that Google Earth's features, such as satellite imagery, 3D modeling, and measurement tools, provide a powerful and cost-effective means to assess road geometry, including lane width, slope, and curvature. Using Google Earth, road engineers and planners can quickly identify problem areas and take necessary measures to improve road safety and compliance with standards. The study's findings could contribute to developing more effective and efficient road assessment techniques, particularly in areas with limited resources and infrastructure.

1. Introduction

Road traffic accidents are a significant public health and safety issue worldwide, with over 1.35 million people dying yearly and between 20 and 50 million injured or disabled. These accidents are most prevalent in low- and middle-income countries, where road safety measures may be inadequate or not enforced effectively, resulting in significant economic and social costs in addition to the human toll.

Indonesia ranks fifth in the world in the number of road accidents. The number of traffic accidents in Indonesia reached 103,645 cases in 2021 resulting in 25 266 deaths and material losses of Rp 246 billion. Road geometric design plays a crucial role in road safety. Poor design, such as narrow lanes, sharp curves, and steep slopes, can increase the risk of accidents. In contrast, well-designed roads with appropriate lane widths, gentle curves, and well-maintained surfaces can reduce the likelihood of accidents and improve overall road safety. Open-source technologies, such as Google Earth, have provided road engineers and planners with powerful tools to evaluate the geometric design of roads more efficiently and accurately, identify problematic areas, and guide improvements that enhance compliance with geometric standards.

Road engineers and planners must consider geometric design principles and leverage new technologies to create safer and more efficient road networks, especially in low- and middle-income countries, where road safety measures may need to be improved or enforced effectively. Road safety is critical for ensuring the safety of road users, minimizing fatalities, serious injuries, and long-term disabilities, and reducing the significant economic and social costs associated with road accidents.

The devastating impacts of road traffic accidents on individuals, families, and communities cannot be overstated. Apart from humans, toll road accidents can significantly impact national economies through lost productivity, healthcare costs, and damage to infrastructure and vehicles. Hence, there is a need for effective measures to mitigate this problem, including better road infrastructure design, effective enforcement of road safety measures, and leveraging new technologies to improve road safety standards.

Road safety is a crucial global issue that requires urgent attention, especially in low- and middle-income countries such as Indonesia. By leveraging new technologies and adhering to geometric design principles, road engineers and planners can create safer and more efficient road networks, ultimately reducing road accidents' economic and social costs.

2. Literature Review

2.1 Evaluating Compliance with Geometric Standards

Many roads in Indonesia need to conform to the established standards for geometric road design (Elfandari & Siregar, 2021). To ensure road safety, engineers incorporate various elements into road design, including measures to enhance hazard visibility, create safe roadway surfaces, implement traffic control measures, encourage responsible behavior among road users, provide guidance for traffic flow, utilize appropriate roadway signs, and consider weather conditions. A proper geometric design can help reduce traffic congestion, increase capacity, and improve safety for all road users. For example, providing reasonable sight distances at intersections and curves can help reduce the risk of accidents, while using suitable lane widths and alignments can help ensure a smooth and efficient traffic flow.
Evaluating compliance with geometric standards is essential to road safety because the design of roads and highways can significantly impact the likelihood of accidents and the severity of their consequences. The influence of geometric road design on accidents is also significant because many segments of road geometry do not meet the standards [1]. Inappropriate geometric design results in discomfort for road users and can lead to accidents [2].

2.2 Google Earth

The usual approach for surveying and mapping topographic maps involves aerial photography technology. This method offers several benefits, such as providing high precision, covering extensive areas, and capturing detailed ground information. However, it is a costly technique and can be significantly affected by weather conditions [3] [4] [5] [6] [7].

Google Earth, a popular virtual globe software created by Google, combines satellite photos, aerial photos, and GIS data to create a three-dimensional representation of Earth. It utilizes high-resolution satellite imagery as its primary data source and incorporates diverse information about infrastructures closely connected to everyday life. The introduction of Google Earth has transformed geographic information applications, making them accessible to professionals and regular Internet users as a practical tool [8] [9] [10] [11] [12].

This software is mainly used for infrastructure projects like roads, highways, and railways. Initial site planning becomes very easy with visualization, but Google Earth provides the latest construction site data with the actual surrounding environment that helps boost the visualization of construction sites. In addition, Google Earth offers topographical information that can be used to analyze the terrain along a proposed road alignment, which can help engineers and designers determine the appropriate road grade, alignment, and cross-section.

2.3 Road Geometric Design Guidelines

Geometric roads are one of many factors that can influence how people behave on roads [13]. Several factors must be considered, including geometric road planning [14]. Road geometric design aims to produce safe, efficient, and efficient infrastructure for traffic flow services and maximize the ratio of usage level/implementation costs. The principle of geometric road design is that the alignment of the road should be designed such that its geometric elements optimize the effectiveness and efficiency of meeting the quantity and quality requirements of the vehicle movement that will pass through it, considering the availability of resources, environment, and social factors, as well as referring to applicable regulations.

The road is anticipated to ensure user convenience and safety, permit effective traffic operations, and, at the same time, draw the lowest possible costs for construction and maintenance [15]. Drainage is another crucial aspect that warrants careful consideration during road design. Careful consideration must be given to rainwater runoff during road design. The pavement layer is susceptible to damage owing to water puddling, which is caused by the inherent nature of the materials that form the asphalt mixture. This condition arises because asphalt is not highly resistant to water penetration [16]. Adequate drainage is essential for ensuring optimal pavement management.

3. Method

3.1 Research Location

This research was conducted on Waecicu Road, West Manggarai. The observed location spanned a length of 3.75 kilometers. A research location map is shown in the Figure below.

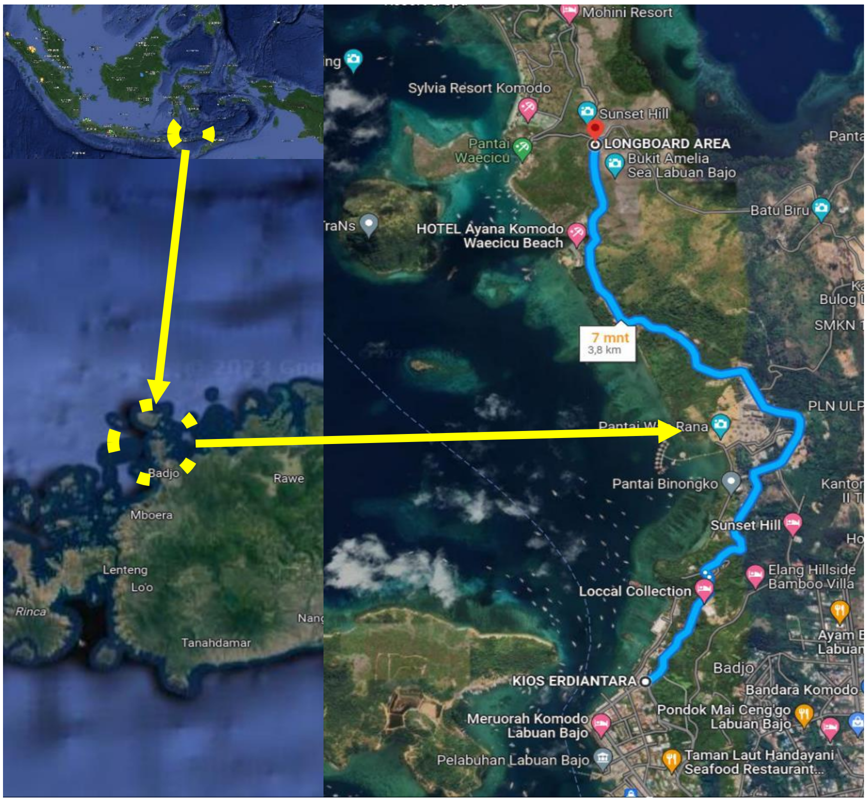


Figure 1. Research Location

3.2. Researched Aspects

3.2.1. Horizontal Alignment

The horizontal alignment is reviewed to determine the parameter values that form the horizontal curves and compared to the regulations specified in Geometric Road Design Guidelines No. 13/P/BM/2021.

3.3. Methodology

Data plays a significant role as a driving force in the compilation of scientific research [17]. The data collection method in a study holds significant importance, as it provides insights into how the research process gathers and incorporates data for analysis. In this study, data obtained from detailed engineering drawings (DED) were compared with the standards of geometric road design. This approach aims to evaluate the compatibility of existing road geometry with established standards.

Primary data are obtained from drawings that include details of the road geometry, such as road width, curve radius, tangent lengths, and other relevant elements [18]. These data are compared with the road geometric design standards of the relevant authorities or applicable regulations.

Secondary data were obtained from Google Earth, which provides satellite imagery and digital maps. These data offer a general overview of the existing road geometry, including road width, curves, and other conditions. The data from Google Earth will also be compared with the relevant road geometric design standards.

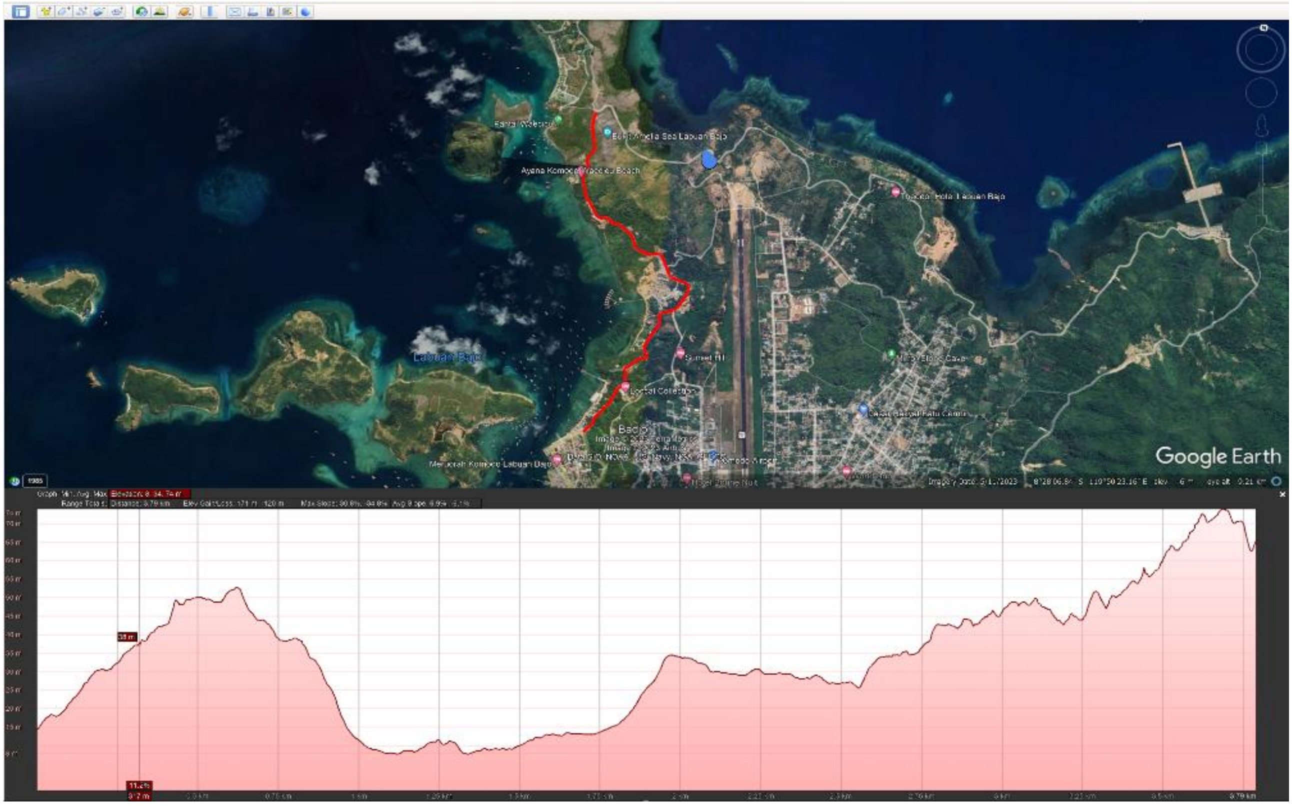


Figure 2. Secondary data from Google Earth

The compatibility of the existing road geometry with the established design standards was examined during the comparison process. If significant differences were found between the obtained data and the design standards, the researcher identified areas for improvement to meet the established criteria.

This research can better understand how well the existing road geometry complies with the applicable design standards by utilizing this comparative method [19]. The findings of this research can serve as a basis for recommending necessary improvements or further development of the road geometry under investigation to enhance safety and traffic efficiency.

4. Result and Discussion

According to Indonesia's 2021 Geometric Road Design Guidelines, roads are categorized based on various factors, including their classification, the system to which they belong, their status, function, the entity responsible for their infrastructure, and the class of users utilizing the roads. Waicecu Road is classified as a Secondary Road (Urban Road) and falls under the Secondary Collector and medium road category. Additionally, the minor type of road, 2/2-TT, was not segregated or separated according to the Highway Design Guideline of Indonesia.

4.1. Data Processing

Obtaining data from Google Earth involves creating a road path, which is then saved as a KMZ file containing coordinates and elevation data. This KMZ file can be further processed using an application called TCX Converter, resulting in an Excel file that can be used for better data analysis.

4.2. Terrain Analysis

According to Indonesia's 2021 Highway Design Guideline, road terrain is categorized into three classifications based on topographic cross-section or contour [20]. These are flat terrain, hill terrain, and mountain terrain. The flat terrain is denoted by (D), with a slope of less than 10%. The hill terrain is represented by (B) with a slope ranging from 10% to 25%, whereas the mountain terrain is indicated by (G) with a slope exceeding 25%. The classification of road terrain is based on terrain slope conditions [21]. The slope value of the landscape was calculated as the average per 50 m within a kilometer. Waicecu Road is classified as flat terrain owing to its average slope of 4.62% from DED and 6.55% from Google Earth; both are less than 10%.

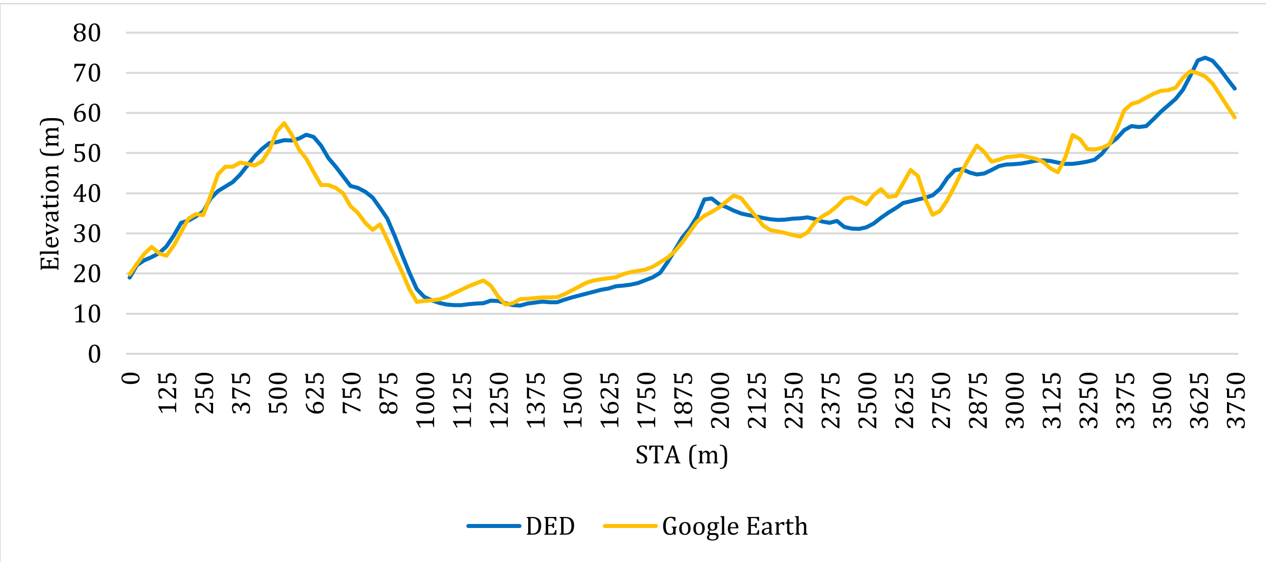


Figure 3. Elevation Profile

No.	STA	Average Slope (%)	
		DED	Google Earth
1	0+000 – 1+000	7.61	9.15
2	1+000 – 2+000	3.29	3.52
3	2+000 – 3+000	2.71	7.09
4	3+000 – 3+750	4.87	6.44
	Average Slope (%)	**4.62**	**6.55**

Table 1. Terrain Slope

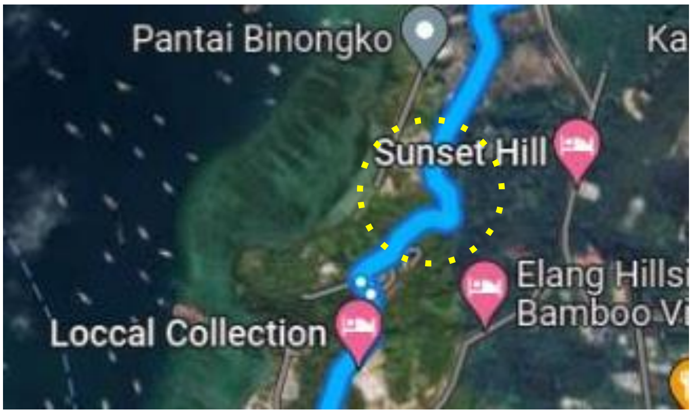
4.3. Design Speed (VD)

The main design criterion for roads is design speed. The road network system determines the relationship between classifications, considering function, status, class, road type, and designated speed range (VD). For instance, Waicecu Road has a fixed speed range of 20-40 km/h. The chosen design for this road was at a speed of 40 km/h.

4.4. Horizontal Alignment

The main objective of geometric design consistency is to reduce the occurrence of unexpected events for road users as they travel along different road segments [22]. Waicecu road spans a distance exceeding 3.75 kilometers and requires careful road geometric design. Lack of proper coordination between the geometric elements of horizontal alignment can result in unsafe driving speeds [23]. The horizontal alignment of a road consists of interconnected straight lines and curved lines. [24]. It is essential to have a completely straight alignment with horizontal curves, as this can lead to monotony and potentially cause road users to feel drowsy. The road was designed to incorporate some horizontal arches into its layout to address this issue. However, the researcher only analyzed this study's three most considerable arches, as shown in the figure below.

Figure 4. Curve Location



No.	Point	Coordinate	
		X	Y
1	Start	817188.957	9061240.701
2	PI.16	817235.750	9061276.332
3	PI.17	817280.629	9061257.259
4	PI.18	817279.222	9061311.232
5	Finish	817241.084	9061350.225

Table 2. Horizontal Alignment Coordinate

4.4.1. Distance Between Points

$$D = \sqrt{\Delta x^2 + \Delta y^2}$$

D1 (Start – PI.16) $= \sqrt{46.793^2 + 35.631^2}$ = 58.814 m

D2 (PI.16 – PI.17) $= \sqrt{44.879^2 + (-19.073)^2}$ = 48.763 m

D3 (PI.17 – PI.18) $= \sqrt{-1.407^2 + 53.937^2}$ = 53.991 m

D4 (PI.18 – Finish) $= \sqrt{-38.138^2 + 38.993^2}$ = 54.543 m

4.4.2. Azimuth Angle (α)

$$Z = Arc\ tg \frac{\Delta x}{\Delta y}$$

α1 (Start – PI.16) $= Arc\ tg \frac{46.793}{35.631}$ = 52.712°

α2 (PI.16 – PI.17) $= Arc\ tg \frac{44.879}{-19.073}$ = 113.025°

α3 (PI.17 – PI.18) $= Arc\ tg \frac{-1.407}{53.937}$ = 181.493°

α4 (PI.18 – Finish) $= Arc\ tg \frac{-38.138}{38.993}$ = 224.365°

4.4.3. Total Angle (β)

β = α1 – α2

β1 = 52.712° - 113.025° = 60.313°

β2 = 113.025° - 181.493° = 68.468°

β3 = 181.493° - 224.365° = 42.872°

Point	Coordinate		Coordinate Difference		Distance	Azimuth	Total
	X	Y	ΔX	ΔY	(m)	Angle	Angle
Start	817188.957	9061240.701					
			46.793	35.631	58.815	52.712	
							60.313
PI.16	817235.750	9061276.332					
			44.879	-19.073	48.764	113.025	
PI.17	817280.629	9061257.259					68.468
			-1.407	53.973	53.991	181.493	
PI.18	817279.222	9061311.232					42.872
			-38.138	38.993	54.543	224.365	
Finish	817241.084	9061350.225					

Table 3. Coordinate Calculation

Referring to Table 5-18 of the 2021 Indonesian Highway Design Guideline, when planning for a speed of 40 km/h (VD), a side roughness of 0.17 (f), and a maximum superelevation level of 8% (e max), the minimum radius (R min) is 50 meters. Additionally, the maximum equivalent gradient is 1:143. Considering a limited space, the radius taken (R plan) of 50 meters and a lane width of 3.0 meters (b); we can consult Table 5-24 of the 2021 Indonesian Highway Design Guideline. For R = 50 meters and a design speed (VD) of 40 km/h, the length of the transitional arch (Ls) is 35 meters, and the superelevation rate (e) is 8.0%

The result is clearly different from the data in the detailed engineering drawing (DED), which plans for a radius of 8 meters with a superelevation of 8%.

4.4.4. Shift Value Corner (P)

$$P = \frac{Ls^2}{24xR} = \frac{35^2}{24x50} = \frac{1225}{1200} = 1.02\ meter$$

Since the P value is more significant than 0.25 meters, the horizontal alignment of the curve uses Spiral – Circle – Spiral (SCS)

5. Conclusion

In conclusion, comparing data from geometric road design detailed engineering drawings (DED), Google Earth, and design guidelines offer valuable insights and contributes to road design projects' accuracy and effectiveness.

With satellite imagery and mapping data, Google Earth complements engineering drawings by providing a broader context for road projects. It offers a visual representation of the surrounding terrain, existing infrastructure, and geographical features, aiding the identification of potential challenges or opportunities for improvement. This information can enhance the overall design process and facilitate a more comprehensive understanding of road integration within the environment.

Design guidelines establish standards and recommendations for geometric road design to ensure safety, efficiency, and regulation compliance. Discrepancies or deviations can be identified by comparing data from the design guidelines with the information gathered from engineering drawings and Google Earth, enabling the necessary adjustments to align the design with the established standards.

The comparison of data from these three sources allows for a comprehensive assessment of the road's design feasibility, accuracy, and adherence to the design requirements. It helps identify potential conflicts or discrepancies early in the design process, minimizing the risk of costly construction delays.

Integrating data from geometric road design detailed engineering drawings, Google Earth, and design guidelines promote a more robust and informed decision-making process. This enhances the quality of road design, fosters efficient planning, and ultimately contributes to the successful implementation of road projects that meet the needs of road users and the surrounding environment.

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