LEADER
Civil Engineering and Architecture Journal

Civil Engineering and Architecture Journal Vol.2 No.5 (2024) 3026-622X
DOI 10.37253/leader.v2i5.10328

Evaluation of Horizontal Alignment Design Using AutoCAD® CIVIL 3D: Case Study of Majalengka-Sumedang (STA 0+000-STA 0+713)

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ARTICLE INFO

Keywords:

Geometric
Alignment
AutoCAD® Civil 3D

ABSTRACT

Road infrastructure is crucial for development, enhancing access to transportation and fostering regional and national growth. Indonesia's mountainous terrain, shaped by tectonic plate activity, creates road construction and maintenance challenges. An example is the Majalengka-Sumedang Road in West Java, which has uneven surfaces that frequently cause traffic accidents. Effective road design must consider cross-sectional features, visibility, vehicle stability, driver comfort, traffic dynamics, and financial aspects. Professionals use AutoCAD® Civil 3D, a BIM software, for precise highway planning, essential for safe, economical, and efficient roads. Data collection is a key initial step in addressing these challenges. For instance, the Majalengka-Sumedang Road, especially around kilometer five, is being evaluated following the 2021 Road Geometric Design Guidelines. These guidelines dictate specific design criteria, including calculations for horizontal alignment factors like Straight Section Length, Bend Radius, Bend Length, and Transition Curve Length. The road section from STA 0+000.00 to STA 0+713, with a 10-25% slope, requires thorough excavation and stockpiling to meet design specifications. Evaluations show this road is a hill type, particularly at mile 5, with five horizontal alignments assessed at a 60 km/h design speed, ensuring compliance with design standards.

1. Introduction

The development of a country or region can be enhanced by providing adequate transportation facilities, particularly through road infrastructure. One of the primary goals to achieve a safe, balanced, and sustainable road transport system is to ensure traffic safety and manage potential risks effectively. **(Mitrović Simić, et al., 2020).** To sustain their economies, several nations have developed sophisticated transportation infrastructure. With the potential to greatly accelerate regional economic growth in Asia, Europe, and Africa, China's Belt and Road Initiative (BRI) is one of the biggest infrastructure investment projects in history (Wang, Lim, Zhang, Zhao, & Lee, 2020).

Because Indonesia is situated among three tectonic plates, it features extensive mountain ranges. Consequently, regions like Bandung in West Java and Lembang experience highly diverse topography, influencing road design. When planning road geometry in these areas, ensuring the safety of all road users is paramount (Nugroho, Rifai, & Akhir, 2022). Unsafe and insufficient road infrastructure is a major contributing factor to road traffic crashes (RTCs) and the injuries they inflict. Road geometry has a significant influence on RTC incidents (Jima & Sipos, 2022).

In contemporary society, ensuring road safety has become a paramount concern due to the significant financial and material losses caused by traffic accidents worldwide each year. One example of a road in West Java Province with uneven or bumpy topography is the Majalengka-Sumedang Road (Ziakopoulos & Yannis, 2020). Steep inclines and sharp curves frequently lead to accidents. Inconsistencies in road geometry near curves can contribute to these incidents. Examining the route's geometry, especially in this regard, helps indirectly control and predict human factors involved in accidents (Islam, Hua, Hamid, & Azarkerdar, 2019).

There are frequent traffic incidents between the Paseh and Tomo sub-districts. The primary causes of these accidents often involve bends that do not adhere to approved guidelines for visibility, road width, and other parameters, or inconsistencies in road design. The winding and curving nature of the roads, especially as they transform into slopes, is the main contributing factor. This configuration makes it challenging to see approaching vehicles from the opposite lane during turns, increasing the risk of accidents when two vehicles attempt to negotiate these curves simultaneously (Targe, Mahajan, Patil, Lilake, & Sonawane, 2018). Drivers who exceed speed limits exacerbate this issue. Traffic accidents are on the rise due to several factors, including population growth, driving behaviors among the affluent, road and environmental conditions, and the state of vehicles and drivers. Violations are almost always the primary cause of accidents, highlighting one of the main challenges in traffic management (Lubis, 2022).

The fifth mile of this study focuses on the Majalengka-Sumedang road, spanning from the Tomo sub-district to the Paseh sub-district. Along this route, accidents frequently occur due to irregular or rough road geometry. As the geometric features determine vehicle alignment, curve radius, and speed limits, it is crucial to review them thoroughly to ensure the creation of a safe roadway.

2. Literature Review

2.1 Road

The rising need for transportation must be matched by adequate road construction. Alongside the increasing global demand for passenger movement, there is a continuous market for goods transport. High vehicle density creates a challenging environment, complicating the implementation and management of an efficient traffic flow system. Research institutes worldwide are studying various issues in air, rail, road, and marine transportation to address specific challenges, identify commonalities, and explore future opportunities (Zadobrischi & Dimian, 2021).

A highway is a publicly owned road that links two towns or major cities. Highways are vital to the development of a nation because they facilitate the rapid transportation of commodities and the concentration of people in one area, both of which are known to boost economic activity. Roadways are an important source of transportation that boosts the economy, particularly those that connect locations and are essential for the flow of people and products. Therefore, efforts are undertaken to improve the road to ensure that it operates as intended (Ulchurriyyah, Rifai, & Taufik, 2022).

Given that road transportation inherently involves distances, it is sensible for academics to consider spatial studies. Road safety spatial analysis sometimes involves looking at collisions while taking into consideration their absolute or relative locations (Ziakopoulos & Yannis, 2020). In considering the bigger picture, effective road construction must prioritize transportation needs to reduce accident rates. Therefore, a thorough understanding of these elements is essential for proposing innovative and practical approaches to encourage safe driving behaviors and enhance road safety. (Tselentis & Papadimitriou, 2023).

2.2 Road Geometric

Geometric planning uses a variety of design factors, including cross-sectional features, visibility, vehicle stability, driver comfort, traffic dynamics, and economic considerations. In physical form planning, geometry is utilized to optimize traffic flow and access (Rosaria, Rifai, & Prasetijo, 2022). In the challenging field of road design, sound judgment and experience are crucial. Design involves selecting and combining elements to achieve the best possible solution for completing a task. Therefore, geometric planning of roads is essential to achieve optimal outcomes (Nurjannah, Rifai, & Akhir, 2020).

A subset of road planning known as "geometric road planning" focuses on physical shape planning to help roadways achieve their fundamental goals of maximizing the ratio of utilization to implementation costs and streamlining traffic flow (Maulana, Rifai, & Isradi, 2022). An exact geometric design is necessary due to the Majalengka-Sumedang road's steep terrain, high traffic volume, and abundance of sand trucks, particularly on the Nyalindung road portion.

The objective of evaluating the geometric characteristics of the Nyalindung road segment is to decrease the incidence of accidents in that area. Enhancing road traffic safety is a significant global objective, and all countries must assess and improve their traffic safety measures accordingly (Toriumi, et al., 2022). Traffic bottlenecks frequently arise since this protected road is not utilized to its full potential as a district road that significantly impacts the economy.

AutoCAD® Civil3D

Civil engineering professionals utilize AutoCAD® Civil 3D, a Building Information Modeling (BIM) software, to effectively and accurately design highways. The traditional manual approach, which was once predominant, has been replaced by AutoCAD Civil 3D® software. Manual methods for geometric design are inefficient in terms of cost and time, and they produce designs that are only 2D and less precise (Mandal M. , Pawade, Sandel, & Infrastructure, 2019). Modern technology makes this kind of apprehension easier. One of AutoDesk's products is AutoCAD® Civil 3D. The product was created by a multinational corporation that John Walker and Drake formed in California.

AutoCAD® Civil 3D is a versatile software tool used for designing buildings, roads, and various industrial structures. This dynamic and innovative software is utilized by civil engineering professionals to plan and design road engineering projects, as well as developments in ports and dams(Rizqi, Rifai, & Bhakti, 2022). AutoCAD Civil 3D® is one Building Information Modeling (BIM) system application that can expedite the design, analysis, and implementation of improvements. With AutoCAD® Civil 3D, design programs operate fast and intelligently. Based on a 3D model, the application dynamically modifies the designs of the civilian elements to adapt to environmental changes. (Arifin & Rifai, 2022). This geometric design evaluation reduces research time and produces the best results when using AutoCAD Civil3D.

Gathering detailed information from various studies is crucial for designing a road that is safe, cost-effective, efficient, and easy for traffic to navigate. Each road has a distinct geometric layout, which significantly influences its alignment. Civil engineering professionals rely on AutoCAD® Civil 3D software to plan and design their projects. This project utilizes AutoCAD® Civil 3D to generate comprehensive geometric road designs (Gaikawad, 2020). Usually, AutoCAD® Civil 3D is used to evaluate several scenarios and save time. Road network planning and land use planning are fundamental concepts for efficient transportation systems, and they should be handled together (Gaikawad, 2020).

3. Method

Begin with identifying relevant issues. Therefore, suitable data collection was carried out from the planning this time (Ulchurriyyah, Rifai, & Taufik, 2022). This study uses qualitative data. Thus, it can be interpreted that the qualitative research method is research carried out directly or from the file (Firmansyah, Rifai, & Taufik, 2022).

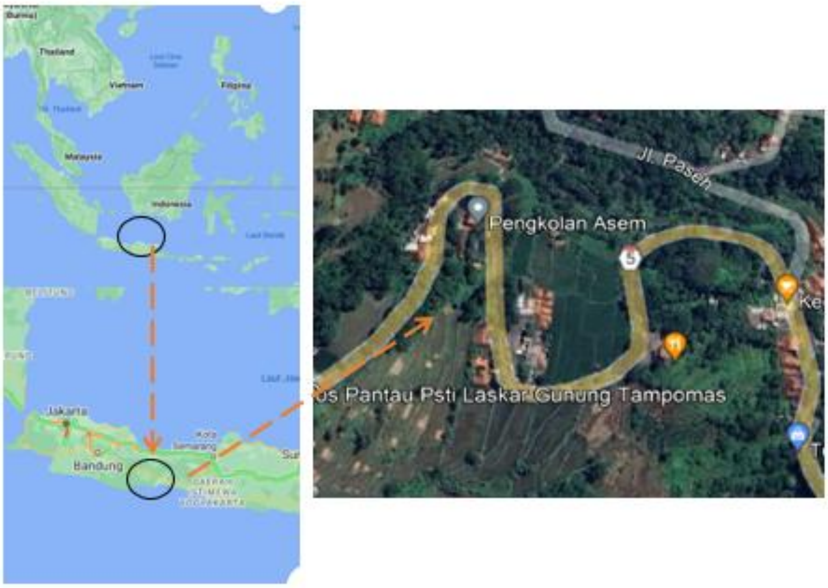

Figure 1 Location

The first step in this research is to get a map of Jalan Majalengka-Sumedang more precisely at kilometer 5 obtained from Google Maps. After that, road geometric planning is carried out using AutoCAD Civil 3D® to plan horizontal and vertical alignments (Rizqi, Rifai, & Bhakti, 2022). Then determine the road design criteria that will be inputted into AutoCAD Civil 3D® for analysis which will later fulfill the required horizontal and vertical alignments as well as excavations and embankments.

4. Results and Discussion

4.1 Design Criteria

Majalengka-Sumedang Road, located at kilometer five, is the route under evaluation. The 2021 Road Geometric Design Guidelines state that good road planning must adhere to the design requirements (Road Geometric Design Guidelines, 2021).

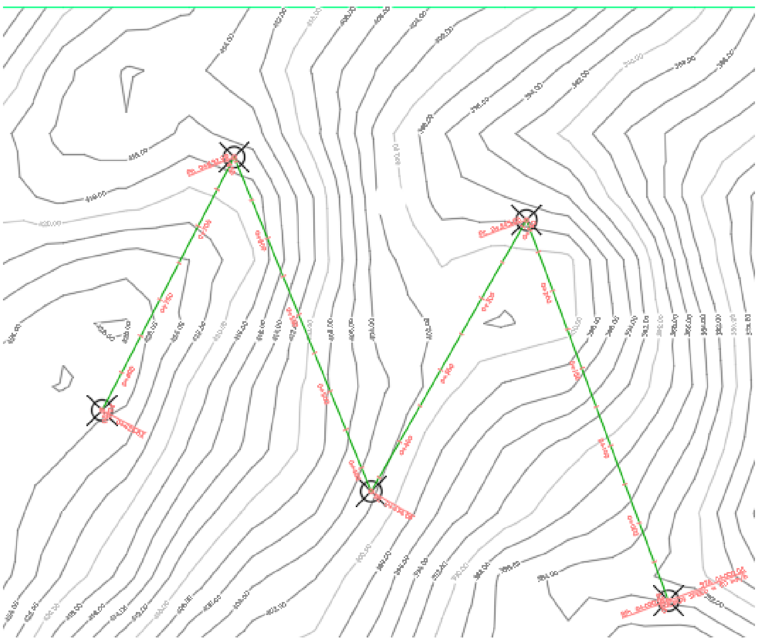

Figure 2 Road alignment

Then based on the calculation results, the bend angle on the Majalengka-Sumedang ring road is shown in Table 1.

Table 1 Angle Calculation

TITIK	KOORDINAT		JARAK			Azimuth	Sudut Tikungan
	X	Y	ΔX (m)	ΔY (m)	d (m)	α	Δ
A	170720,000	9248349,000					
			-86	230	245,5524	159,4986	
PI1	170634,000	9248579,000					**129,679**
			-94	-164	189,0291	29,82007	
PI2	170540,000	9248415,000					**127,843**
			-83	202	218,3873	157,6627	
p3	170457,000	9248617,000					**130,059**
			-80	-153	172,6528	27,60398	
b	170377,000	9248464,000					

By calculating the distance to the coordinates of each point, the angles of the eight horizontal alignment points are obtained.

4.2 Horizontal Alignment

After determining the design criteria and road alignment, in calculating the horizontal alignment, the Straight Section Length (L_L), the Bend Radius (R_C), Bend Length (L_c), and Transition Curve Length (L_S) are then calculated. Based on the design criteria, the velocity design used is 60 km/hour, so the following calculation is obtained:

Table 2 Calculation Result of Horizontal Alignment Criteria

L_L	L_C	L_S
$L_L \leq 2{,}5\ minute\ x\ V_D$ $L_L \leq 2{,}5\ minute\ x\ 60\ km/hour$ $L_L \leq 2{,}5\ km$ $L_L \leq 2500\ m$	$L_C \leq 6\ second\ \ x\ V_D$ $L_C \leq 6\ second\ \ x\ 60\ km/hour$ $L_C \leq 0{,}1\ km$ $L_C \leq 100\ m$	$L_S \leq 1/2\ x\ 6\ second\ \ x\ V_D$ $L_S \leq \frac{1}{2} x\ 0{,}1\ km$ $L_S \leq 0{,}05\ km$ $L_S \leq 50\ m$

The route connects from point A to point B, connecting Jalan Majalengka-Sumedang. From these results it can be seen that on the track there are 3 bends with the Spiral-Circle-Spiral bend type.

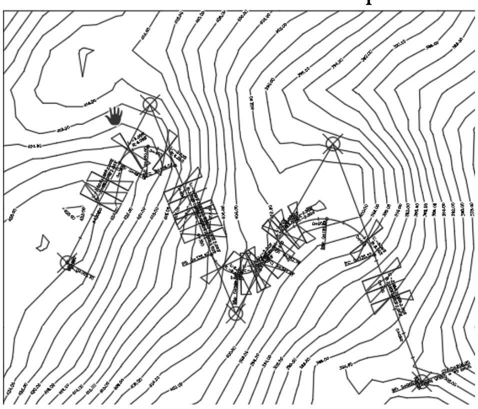

Figure 3 Horizontal alignment

4.3 Vertical Alignment

In planning the design of the road to the Panyaweuyan terracing area, it has the length of the STA. 0+000.00 to STA 0+000-STA 0+713, the hilly area has a slope of 10-25%. The vertical alignment is shown in Figure 4.

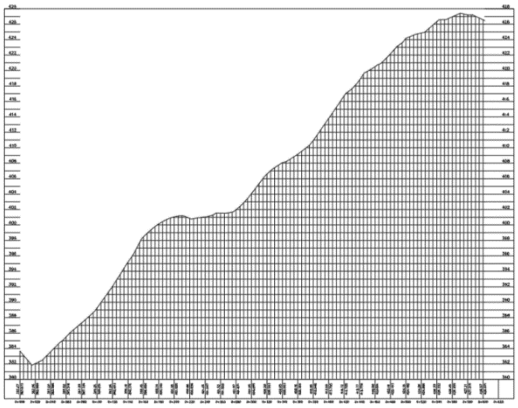

Figure 4 Vertical alignment

From Figure 5 it can be calculated the need for excavation and stockpiling with trend planning. Construction planning, especially road evaluation planning, really needs excavation and stockpiling so that the planned road is following the specified level. From the results of the AutoCAD® Civil 3D analysis, it can provide an overview of the number of excavations and the number of overhangs per 50 meters. For example, in Table 4 there are details of cut and fill from STA 3+300.00 to STA 3+750.00.

Table 1 Example of Volume Cut and Fill Results

Station	Cut Area	Cut Volume	Reusable Volume	Fill Area	Fill Volume	Cum. Cut Vol.	Cum. Reusable Vol.	Cum. Fill Vol.	Cum. Net Vol.
	(Sq.m.)	(Cu.m.)	(Cu.m.)	(Sq.m.)	(Cu.m.)	(Cu.m.)	(Cu.m.)	(Cu.m.)	(Cu.m.)
0+050.000	0,48	0	0	2,27	0	0	0	0	0
0+100.000	0,66	28,51	28,51	2,18	111,28	28,51	28,51	111,28	-82,78
0+150.000	0	16,57	16,57	15,93	452,74	45,07	45,07	564,03	-518,95
0+200.000	0	0,04	0,04	42,81	1468,5	45,12	45,12	2032,53	-1987,41
0+250.000	0	0,02	0,02	38,95	2044,01	45,14	45,14	4076,54	-4031,4
0+300.000	0	0,02	0,02	21,44	1509,82	45,16	45,16	5586,36	-5541,2
0+350.000	0	0	0	25,53	1174,28	45,16	45,16	6760,64	-6715,48
0+400.000	0	0	0	14,84	1009,32	45,16	45,16	7769,96	-7724,8
0+450.000	0	0	0	0	371,02	45,16	45,16	8140,98	-8095,83
0+500.000	0	0	0	13,09	327,25	45,16	45,16	8468,23	-8423,08
0+550.000	0	0	0	50,22	1582,82	45,16	45,16	10051,05	-10005,89
0+600.000	0	0	0	27	1930,54	45,16	45,16	11981,58	-11936,43
0+650.000	0,03	0,69	0,69	12,1	977,4	45,85	45,85	12958,98	-12913,13
0+700.000	7,3	183,07	183,07	0,96	326,47	228,92	228,92	13285,46	-13056,53

5. Conclusion

The computation results indicate that Jalan Majalengka-Sumedang is a hill road type, particularly around mile 5. Additionally, the outcomes of five horizontal alignments—all of which are S-C-S alignment types—were evaluated through the assessment of the design requirements for horizontal alignment with a design speed of 60 km/h. It was also discovered during the evaluation that all alignments' straight section, bend, and transition curve lengths satisfied the requirements, negating the need for the horizontal alignment design to be improved.

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