LEADER
Civil Engineering and Architecture

Civil Engineering and Architecture Journal Vol 1 No.3 (2023) E-ISSN
DOI 10.37253/leader.v1i3.8297

Evaluation of Vertical Alignment on Copper Smelter Access Road PT Wanhong Nonferrous Recycling Utilization - Sulawesi

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ARTICLE INFO

Keywords:

Copper Smelter
Road Geometry
Vertical Alignment

ABSTRACT

This research paper, based on the Indonesian Standard geometric road guidelines, evaluates the vertical alignment of the access road to PT Wanhong Nonferrous Recycling Utilization in the Palu Special Economic Zone. The objective was to assess the feasibility of the existing road geometry and ensure compliance with safety and comfort standards. The study found that the road falls under the JKC category and is classified as mountainous terrain, with a maximum incline of 12%, while the actual incline measures are 9.37%. The speed plan of the road adheres to the minimum velocity requirement for JKC classification. The study utilized surveying equipment, Google Earth, and AutoCAD Civil 3D®. The findings emphasize the importance of proper road geometry in ensuring safe and efficient transportation infrastructure, particularly in industrial areas.

1. Introduction

Copper is widely used in various industries, including construction, electronics, transportation, and renewable energy. By 2050, the demand for copper is projected to increase by 300% above current levels [1] As economies develop and infrastructure projects increase, the demand for copper continues to rise. In particular, the transition to clean energy technologies in the global market, such as electric vehicles and renewable energy systems, is expected to drive significant demand for copper in the coming years. The need for modern and efficient infrastructure drives the growing demand for copper in the construction industry. Copper's conductivity and durability make it an ideal choice for electrical wiring, plumbing systems, and heating and cooling systems in buildings. As urbanization intensifies and developing countries invest in their infrastructure, the demand for copper in construction projects is set to increase substantially.

The mining industry in Indonesia is experiencing an increase as can be seen from the 2022 Gross Domestic Product (GDP) from 218.7 trillion rupiah in the 3rd quarter to 223.6 trillion rupiah in the 4th quarter and it can reach 230 trillion rupiah in the 4th quarter of 2023 [2]. Increasing the capacity production of Indonesian mining products requires the construction of new mines and smelters with adequate infrastructure conditions. This includes transportation infrastructure such as roads, railways, and ports, as well as energy infrastructure such as power plants and transmission lines. Road infrastructure and transportation are important components of urban areas and have enabled the rapid development of industrialization and urbanization [3]. Without adequate infrastructure, it may be difficult or expensive to transport minerals from the mine site to [4] Indonesian mining products. By processing raw minerals into higher-value products such as metal ingots or concentrates, smelters can help to increase the profitability of the mining industry.

The construction of new mines and smelters with should be accompanied by adequate infrastructure. Roads are infrastructure used to transport people and goods from one place to another [5]. To get adequate and comfortable, following the class of roads that have been determined by the government

Receieved 2 Juli 2023
Available online 1 Agustus 2023
Published by Fakultas Teknik Sipil dan Perencanaan UIB

Civil Engineering and Architecture Journal Vol 1 No.3 (2023) E-ISSN
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(Indonesian Standard), it is necessary to review the geometric aspects as a basis for planning to determine the speed of a feasible plan for the road [6]. Traffic accidents are negative events for road infrastructure and accidents also pose a risk to the safety of road users which also result in damage to vehicles and goods resulting in material losses [7]. Applying the Indonesian Standard code of the road is a must to fulfil safety and comfortable road.

Palu City is a city located in Central Sulawesi Province, which experienced an earthquake and tsunami in 2018. Until now, the city of Palu is still recovering in terms of infrastructure due to the disaster. Palu City experiences continuous development each year, encompassing various aspects of community life, including economic, social, political, and territorial aspects. With this ongoing development, transportation demand naturally increases, significantly affecting transportation facilities and infrastructure [4]. The overall development of Palu City has brought significant impacts on transportation facilities and infrastructure in the region.

The rapid economic growth of mining industries has stimulated increased mobility of the population and trade activities. This necessitates enhancing the quality and capacity of existing transportation systems to meet the growing transportation needs. Road infrastructure services well, safely, and smoothly will be fulfilled if they meet the geometric technical requirements of the road. [8]. This is no exception in industrial areas. Therefore, this research aims to evaluate the vertical alignment using geometrics roads guidelines Indonesian Standard at the access road of PT Wanhong Nonferrous Recycling Utilization in Palu Special Economic Zone. By assessing the vertical alignment of the access road, the researchers aim to determine whether it adheres to the recommended standards and guidelines. This evaluation ensures the road's safety, smoothness, and overall functionality.

2. Literature Review

2.1 Roads Geometry

The road geometry consists of vertical and horizontal alignment. Road geometry is an important aspect of planning road development. The purpose of geometric road planning is to produce safe infrastructure, efficient traffic flow services, and maximize the ratio of usage/cost of implementation [9]. In determining the geometric design of a road, one must pay attention to several criteria. User safety is the main criterion in the geometric planning of a road. Geometric features can determine the shape of the driveway, such as curve radius, deflection angle, spiral length, tangent length, and road/lane/shoulder width, and any or all of these can be customized by the designer [10].

Geometric road planning is crucial to establish a well-developed road infrastructure. It is part of road planning that focuses on physical shape planning so that it can fulfill the essential functions of the road, which are providing optimal service to traffic flow and maximizing the ratio of the level of use of implementation costs to give a sense of security and comfort for road users [11]. Furthermore, geometric road planning involves integrating elements customized to accommodate comprehensive and existing primary data from field survey results. This process includes thorough data analysis and references to relevant regulations. By doing so, the planning ensures a well-adapted and efficient road infrastructure.

Road safety issues have become a primary concern worldwide as they are one of the highest causes contributing to the world's most significant mortality rate [12]. Road accidents are among the leading causes of mortality and severe injuries, making it imperative to address them proactively. The consequences of these accidents are not limited to loss of life and physical injuries but also result in immense emotional trauma, economic losses, and strains on healthcare systems. To have adequate road infrastructure, roads must comply with standard codes and regulations.

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2.2 Vertical Alignment

Vertical alignment is one aspect of road geometry, it can be in the form of an incline or slope of the road. The slope of the haul road is directly related to the ability of the conveyance both in overcoming inclines and in braking when the conveyance is loaded or empty. [13]. Vertical alignment planning is divided into procedures, namely determining the initial data, the slope of each vertical curve, the design speed, the type of curve, and the plan length [14]. The vertical alignment of a road is crucial for ensuring a smooth and safe driving experience. It aims to provide sufficient visibility for drivers, minimize steep grades that could impede vehicle movement, and optimize drainage to prevent water accumulation on the roadway.

This paper uses the 2021 Indonesian Standard road geometry guidelines to evaluate vertical alignment. These guidelines provide a framework and recommendations for designing and assessing the vertical alignment of roads in Indonesia. The geometric formula of the highway depends on specific design standards such as visibility, vehicle stability, entertainment driver, drainage, economy, and aesthetics. [15]. By adhering to these standardized guidelines, road planners can ensure that the vertical alignment of roads meets the specified safety, functionality, and efficiency criteria. The evaluation of vertical alignment plays a crucial role in designing roads that cater to the specific requirements of different types of vehicles and provide optimal driving conditions for road users. By considering factors such as initial data, slope determination, and design speed, road planners can create a road geometry that enhances the performance and safety of vehicles while adhering to the established standards and guidelines outlined in the Indonesian Standard Road geometry guidelines. A good design will result in higher speeds and reduced road performance in terms of safety and comfort [16].

2.3 Roads Geometry Guidelines

Road planning in different countries involves adhering to specific regulations and guidelines that are applicable within each country. For instance, in India, road design follows the standards set forth by the Indian Road Congress (IRC), while in America, road design is based on the guidelines provided by the American Association of State Highway and Transportation Officials (AASHTO). Each country has its unique policies and criteria due to the variations in geographical, climatic, and socio-economic factors. The most widely used method in Indonesia is Directorate General of Hihgway. [17]

The road geometry guidelines used in this study are the Indonesian Standard 2021 road geometry guidelines. These guidelines exist so that roads that are built can be in following applicable rules to achieve the function of a road. Indonesian Standard Road Geometric Design Guidelines 2021 can provide recommendations that are appropriate and able to provide safety and comfort for passing users. [18]. In road design, there are several factors to consider such as terrain, design vehicle, road function, road class, and design speed. It is fundamental research to optimize the road's vertical alignments to improve the safety and economy of design roads geometry.

The Bina Marga method Is outlined in the 2021 Road Geometry Design Guidelines. These guidelines refer to A Policy on Geometric Design of Highways and Streets (AASHTO,2001), Road Design Guidelines (VicRoads,2002), and Guide to Road Design (Austroads,2016) [19]. By incorporating the principles and recommendations from these esteemed sources, including A Policy on Geometric Design of Highways and Streets (AASHTO, 2001), Road Design Guidelines (VicRoads, 2002), and Guide to Road Design (Austroads, 2016), the Bina Marga method outlined in the 2021 Road Geometry Design Guidelines ensures a comprehensive and standardized approach to road planning that encompasses international best practices and expertise in the field.

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2.4 AutoCAD Civil 3D®

AutoCAD Civil 3D® is Autodesk software widely used for 2D and 3D data processing. AutoCAD software itself has various features, namely two-dimensional and three-dimensional visualization images as well as reading dimensions such as length, area, and volume of objects [20]. AutoCAD will be used to create a contour map and analyze vertical alignment. Using AutoCAD Civil 3D software helps in saving time and energy, which results in the completion of a project on time [21]. AutoCAD Civil 3D has become an essential tool for civil engineers and designers in infrastructure and construction.

Three-dimensional (3D) reconstruction is the process of generating a 3D Representation of a 3D view of the output of data collection equipment [22]. This technique enables the generation of a comprehensive and immersive view of the collected data. By reconstructing the data in a 3D format, it becomes possible to visualize and analyze complex structures, objects, or environments with enhanced accuracy and depth. The process typically involves utilizing specialized algorithms and software tools to transform the acquired data into a realistic and interactive 3D model. With the continuous advancements in imaging and sensing technologies, 3D reconstruction techniques are becoming increasingly sophisticated, enabling researchers, professionals, and industries to gain valuable insights, improve decision-making, and enhance overall understanding in their respective domains.

As imaging and sensing technologies advance, 3D reconstruction techniques become increasingly sophisticated, further enhancing decision-making processes in medical imaging, computer graphics, virtual reality, robotics, and more [23] [24] [25]. The combination of advanced software tools like AutoCAD Civil 3D and cutting-edge 3D reconstruction techniques creates a powerful synergy, propelling the fields of civil engineering, construction, and various other industries forward. It is considered faster, more accessible, and more practical, and can provide solutions whether the design is feasible or not [26].

3. Method

Data collection was carried out directly at PT Wanhong Nonferrous Recycling Utilization in October 2022. The research location was taken at coordinates 0°42'41.7"S 119°53'03.1"E. Method of this research uses a qualitative method with the primary data being vertical calculation alignment and the secondary data including road classification, speed plan, and topography contour. The tools used in this study are a set of surveying tools such as measuring tape and GNSS Rover, Google Earth, AutoCAD Civil 3D®, and Microsoft Office® [27] [2] [28] [29] [30]. The materials used in this study are primary data and secondary data, namely the contour maps of PT Wanhong Nonferrous Recycling Utilization.

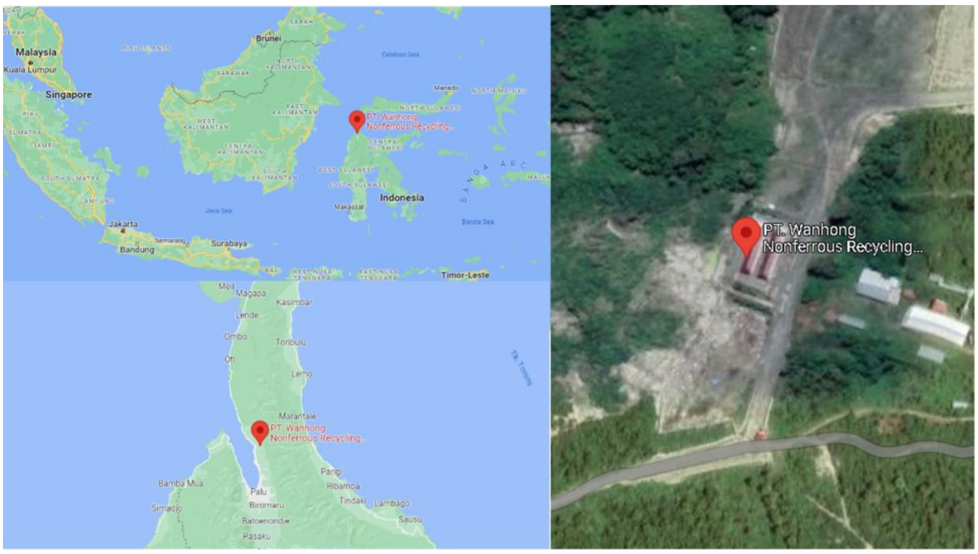

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Figure 1. Location of Reviewed Road

Vertical alignment evaluation is carried out on the PT Wanhong Nonferrous Recycling Utilization using the 2021 Indonesian Standard Road Geometric Design Guidelines to determine the feasibility of the existing road geometry. The first step of this research is to determine the classification of the road, then evaluate the existing roads referring to Indonesian Standard Roads Guidelines 2021. The result will show the entrance roads of PT Wanhong Nonferrous Recycling Utilization according to the Guidelines.

4. Result and Discussion

4.1 Road Classification

This paper aims to evaluate and classify the road at the entrance to the factory smelter area at PT Wanhong Nonferrous Recycling Utilization, which has a length of 224.15 meters. The road in question exhibits specific characteristics and serves a distinct purpose, leading to its classification as a JKC Category Road. The JKC Category classification is based on a comprehensive assessment of various factors, including road design, traffic volume, and intended usage. The road at the factory smelter area meets the criteria for a JKC Category due to its specific features and intended function.

The road is located at the entrance to the factory smelter area at PT Wanhong Nonferrous Recycling Utilization aligns with the characteristics that define a JKC Category Road. Firstly, the road's design and construction have been tailored to accommodate the heavy traffic typically associated with industrial facilities. It is built to withstand the load and frequency of commercial vehicles, such as trucks and lorries, standard in the factory area.

4.2 Contour

The data was collected firsthand at PT Wanhong Nonferrous Recycling Utilization in October 2022.

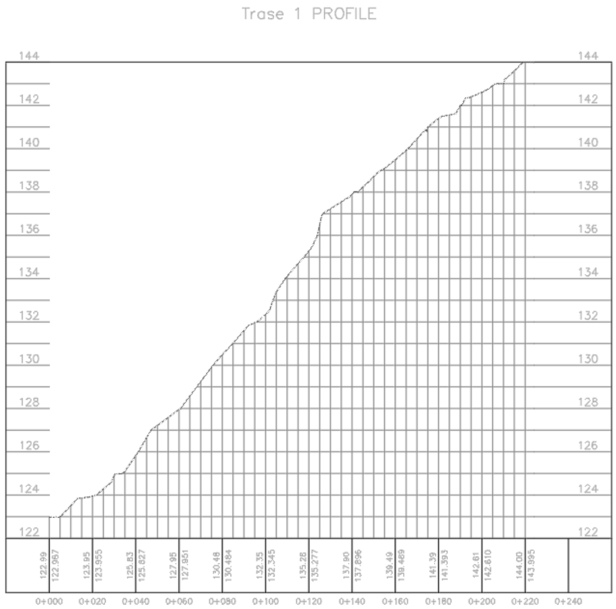

Figure 2. Contour Section of The Roads.

Table 2 represents a cross-section of the road taken from contour map data using the Civil 3D application, providing a detailed visual representation of the road's elevation changes and the corresponding terrain features encountered along the route.

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Table 1. Contour Table

Contour Table						
No	**Station**	**Elevation Left**	**Elevation Right**	**Slope**	**Elevation**	**Slope Average / 50 m**
1	0+000,00	123,005	123,003	0,020%	8%	
2	0+010,00	123,859	123,734	1,250%	2%	
3	0+020,00	124,054	124,02	0,340%	9%	
4	0+030,00	124,986	124,892	0,940%	9%	
5	0+040,00	125,92	125,806	1,140%	13%	
6	0+050,00	127,216	127,023	1,930%	9%	41,2%
7	0+060,00	127,868	128,171	3,030%	12%	
8	0+070,00	129,101	129,385	2,840%	12%	
9	0+080,00	130,336	130,612	2,760%	11%	
10	0+090,00	131,352	131,738	3,860%	8%	
11	0+100,00	131,749	132,967	12,180%	17%	
12	0+110,00	134,062	134,151	0,890%	13%	60,9%
13	0+120,00	135,531	135,278	2,530%	19%	
14	0+130,00	137,831	136,712	11,190%	6%	
15	0+140,00	138,211	137,433	7,780%	10%	
16	0+150,00	138,78	138,815	0,350%	7%	
17	0+160,00	139,454	139,509	0,550%	7%	
18	0+170,00	139,838	140,468	6,300%	12%	47,5%
19	0+180,00	141,723	141,042	6,810%	6%	
20	0+190,00	141,997	142,004	0,070%	8%	
21	0+200,00	142,712	142,826	1,140%	2%	
22	0+210,00	142,994	143,011	0,170%	9%	
23	0+220,00	143,87	143,995	1,250%	1%	
24	0+224,15	143,998	143,996	0,020%		26,1%
Average						43,9%

Based on the available topographic data, it has been revealed that the average elevation increase per 50 meters is 43.9%.

Table 2. Terrain Category

Terrain Category	**Notation**	**Average Slope per 50 m (%)**
Flat	D	<10
Hill	B	10-25
Mountain	G	>25

The result is 43.9% according to the Table 2 Terrain Category the average slope per 50m > 25%. This result indicates that the classification of the road is the mountainous category. The notation of the category is G. Calculate the gradient according to Table 1. Contour Table Contour Table data in the following way:

$$Gradient = \frac{Elevation\ End - Elevation\ Start}{Lenght\ of\ The\ Road}$$

$$Gradient = \frac{143.998 - 123.005}{224.15}$$

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Civil Engineering and Architecture Journal Vol 1 No.3 (2023) E-ISSN
DOI 10.37253/leader.v1i3.8297

$Gradient = 9.37\%$

The result of the calculation reveals a nominal of gradient the road is 9.37%.

4.3 Speed Plan

According to Geometric Roads Guidelines Indonesian Standard table 5-1, secondary collector road with JKC classification is 20-40 km/h, and the minimum speed for JKC classification is 10 km/h.

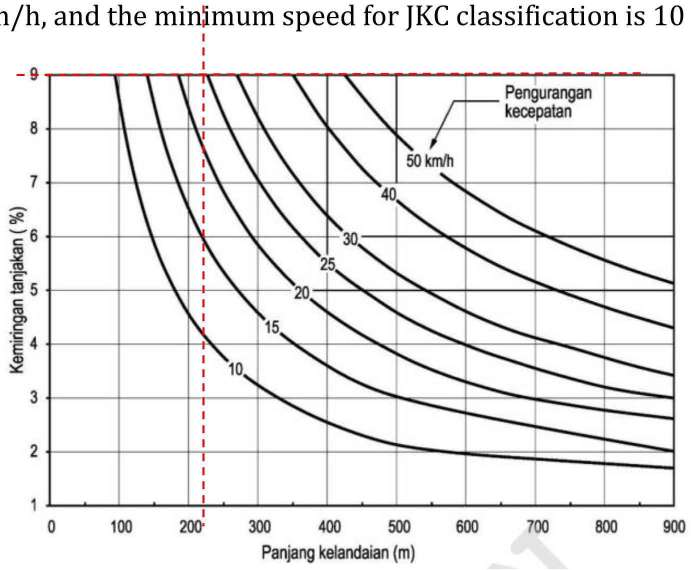

Figure 3. Velocity speed plan reducer

In Figure 3. Velocity speed plan reducer Figure 3 velocity of the speed, plan is reduced by 25 km/h with a velocity speed plan of 40 km/h. The final speed plan for this road is 15 km/h. The final speed plan is greater than the minimum speed plan velocity.

4.4 Vertical Alignment

Table 3. Maximum inclining (Fig 5-48)

Category	Maximum Slope (%)		
	Flat Terrain	Hill Terrain	Mountain Terrain
JBH	4	5	6
JRY	5	6	10
JSD	6	7	10
JKC	6	8	12

The road falls under the JKC classification and is categorized as mountainous terrain, characterized by a maximum incline of 12%. However, upon closer examination, it is crucial to note that the actual incline of the road is slightly lesser, specifically measuring 9.37%. This distinction is significant as it indicates that while the road is still considered to be within the mountainous terrain category, it features a slightly more manageable gradient compared to the maximum allowable incline.

5. Conclusion

In conclusion, this paper focused on evaluating the vertical alignment of the access road to PT Wanhong Nonferrous Recycling Utilization in the Palu Special Economic Zone. The study aimed to assess the feasibility of the road's geometry and ensure its compliance with safety and comfort standards based on Indonesian Standard guidelines. The findings indicated that the road falls under the JKC category and is classified as mountainous terrain, with a maximum incline of 12%. However, the actual incline was measured at 9.37%, within acceptable limits. The research utilized surveying tools, Google Earth,

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Available online 1 Agustus 2023
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Civil Engineering and Architecture Journal Vol 1 No.3 (2023) E-ISSN
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AutoCAD Civil 3D®, and analyzed primary and secondary data. AutoCAD Civil 3D® was valuable for creating contour maps and analyzing vertical alignment. The evaluation of the road's speed plan showed that the final speed plan of 15 km/h complied with the minimum velocity requirement for JKC classification according to the Indonesian Standard guidelines. Overall, the study underscores the significance of proper road geometry in ensuring safe and efficient transportation infrastructure, particularly in industrial areas like PT Wanhong Nonferrous Recycling Utilization. Adhering to recommended guidelines enables the optimization of vertical alignments, thereby enhancing safety and economic considerations in road design.

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Receieved 2 Juli 2023
Available online 1 Agustus 2023
Published by Fakultas Teknik Sipil dan Perencanaan UIB

Civil Engineering and Architecture Journal Vol 1 No.3 (2023) E-ISSN
DOI 10.37253/leader.v1i3.8297

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Receieved 2 Juli 2023
Available online 1 Agustus 2023
Published by Fakultas Teknik Sipil dan Perencanaan UIB