INDONESIAN JOURNAL OF MULTIDISCIPLINARY SCIENCE

P-ISSN: 2808-5957
E-ISSN: 2808-6724
ijoms.internationaljournallabs.com

THE GEOMETRIC DESIGN OF HORIZONTAL ALIGNMENT: A CASE OF POST-HARVEST INFRASTRUCTURE CORN DRYING CENTER, TUBAN, EAST JAVA

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ARTICLE INFO

Published: January 17th, 2023

Keywords: *Geometric design, Horizontal Alignment, AutoCAD Civil 2D®, Special Road*

ABSTRACT

One of the aspects put forward in modern times is road infrastructure to meet the needs of moving goods, services, and people. As well as road planning for toll roads, connecting roads between regions, and roads in specific areas such as industrial areas, it also requires careful planning to meet the needs of transportation movement in them. This analysis focuses on the geometric road planning for horizontal paragraphs in the Corn Drying Center Post-Harvest Infrastructure industrial area in Tuban, East Java. The planning considers daily vehicle flows, heaviest axis loads, and bend radiuses that adjust for a limited land area. Correspondence to data in the field is obtained from the results of surveys that have been conducted (quantitative data). The result of the calculations is depicted using AutoCAD Civil 2D®.

INTRODUCTION

In modern times, one of the aspects put forward is road infrastructure that functions for the movement of goods and services, and people from one location to another to increase the community's needs. In geometric road planning, things that need to be considered include topographic conditions and the surrounding environment to provide economical, optimal, and efficient road planning. In geometric road planning, two kinds of standards can be used as a reference: national and international. AASHTO (A Policy on Geometric Design of Highways and Streets) in 2001 is a geometric standard of roads used in America, while in Indonesia, several regulations apply, including; Geometric Planning Standards for Urban Roads in 1992, Geometric Planning Procedures for Intercity Roads No. 038/TBM/1997 and Geometric Urban Roads RSNI T-14-2004 (Sinaga, Lerinsah, Sendow, & Waani, 2019).

Because transportation is a common thing in society, the solution to the problem can significantly affect the community's life. This effect affects the constraints currently experienced by society on the development and evaluation of roadblocks that are general and based on analysis, economical, credible in social life, sensitive to environmental issues, politically acceptable, and demonstrable. The combination of all these aspects is produced in a relatively contemporary development in the professional area, namely, transportation engineering. Transportation engineering applies technical and scientific principles to the planning process, functional design, operational, and facility management for all modes of transportation to move people and goods safely, quickly, comfortably, economically, and environmentally friendly. Traffic engineering, which is a branch of transport engineering, takes into account the planning, geometric design, and operation of traffic from roads, networks, terminals, their borders to the ground, and their relationship with other modes of transport (O'Flaherty, A., & ed., 2018).

Based on the location of the road, the planner selects the best corridor through the geometric design of the road and makes an alignment of the main route in the field on the selected corridor. Therefore, the first thing to pay attention to is the road's location, the corridors' selection, and the road's geometry from the corridor's alignment. In addition, the geometric design of the road takes into account the physical condition in the field consisting of; cross-sectional pieces, visibility, paragraphs, arches, superelevations, and other related aspects. Road terrain in Indonesia is classified according to the condition that most terrain is a slope if measured perpendicular to the contour line. Therefore, uniformity to road terrain conditions should take into account the uniformity of terrain conditions according to the road paragraph plan by ignoring changes to small parts of the road plan (Douglas, 2018); (Veer, Raghu, Gupte, & Juremalani, 2018); (Rifai, Talib, Prayogo, & Isradi, 2022).

Roads in this industrial area are categorized as particular roads based on the road designation. Special roads are not intended for general traffic, only for the benefit and direct benefit of specific individuals, community groups, business entities, or certain agencies. Because the roads in this area are intended for significant vehicle traffic, such as transport trucks, it is necessary to analyze the aspects of truck traffic and its safety. Pay attention to the length of the truck body, the large volume, Overspeed, overload, long braking distance, and other driving characteristics, the consequences to traffic accidents and the magnitude of safety hazards (Ministry of PUPR, Directorate General of Highways, 2021); (Bao, Yujie, Wang, & Li, 2020).

Road infrastructure is one of the instruments that have an essential role in a country's equitable economic development and welfare. In 2016, the Government of Indonesia provided State Capital Participation (PMN) funds to state-owned companies, including Perum BULOG. One of the PMN funds is used by Perum BULOG to build corn processing infrastructure (Corn Drying Center) in Tuban, East Java. The purpose of compiling this paper is to consider the geometric planning of roads in the Corn Drying Center Postharvest Infrastructure Industrial Estate owned by Perum BULOG in Tuban Regency, East Java. A good road geometric planning is expected to meet the traffic flow of the transport passing through it and still prioritize safety. Therefore, road infrastructure design planning must consider all aspects that affect the safety of its users (Rozi, 2022); (Pembuain, Ardilson, Priyanto, & Suparma, 2019).

LITERATURE REVIEW

Road Geometry Planning Design

Road Design is a complex job where assessment and experience play an essential role. Design is selecting and combining the correct elements to develop the right solution to achieve the goal. It is an iterative process that requires designers to practice judgment and experience while practically applying proper technical guidelines and continuously evaluating the design to assist in selecting a decent value for each design element. Based on technical guidance, calculations, and experience, as well as an assessment of a designer, they choose the features of the road, the main design elements, and the dimensions of the design. The impact on safety is an important thing that designers must understand when combining the limiting values of different design elements and under different circumstances (O'Callaghan, McHugh, & Marshall, 2021).

A road must provide safety, comfort, effectiveness, and efficiency for the travel of people and goods. The design of the road itself should be based on the capabilities and habits of all road users, including pedestrians, bicycle users, motorcycle users, and all transportation (including public transport). Road projects are developed to meet the high level of travel, address the problem of accidents, improve the landscaping of roads, create communities that are passable/accessible to pedestrians, and rehabilitate existing infrastructure or a combination of those various purposes. A balanced road planning and design approach can improve operational efficiency, driving safety, and public facilities that minimize environmental impacts, including noise, vibration, pollution, and visual disturbances (Fanning, Veith, Whitehead, & Auman, 2021).

The Geometric Designs of the Road relate to the visible features of the road. Safety is a significant factor in road design. Road geometrics deals with horizontal and vertical arches, visibility, road gradients, and intersections which are also important aspects. Traffic surveys are carried out to determine the number of lanes, the width of roads, and pavement design. The main focus of traffic surveys is to determine the composition of vehicles in traffic flow that affect the geometric features of the planned road (Manda, Manoj, Pawade, & Sandel, 2019).

Road Geometric Design concentrates on physical form planning to fulfill the essential functions of the road and provide optimum road traffic services. Elements that affect the geometry of the road include; horizontal paragraph ends, consistent geometric design of roads, superelevation, volume flow of traffic vehicles, and traffic accidents. The volume of vehicle flow is the number of vehicles passing by in the surveyed area at a given time. Traffic accidents involve three factors, namely, human factors, vehicle factors, and environmental and road factors (Elfandari, Amadea, & Siregar, 2021).

Safety aspects to be considered for large vehicle lanes

The accident rate was relatively high in the Yuanxun Zheng, Huiji Guo, and Xiaobing Wei research on Xiarong and Hexi roads. The three leading causes are human factors, unsafe vehicle conditions, and the shape of the road that is lacking in terms of safety factors. Based on statistical data, it is stated that one of the vehicles that are prone to accidents is trucks. Heavy loads always cause the heavy braking system of the truck. If there is a defect in the truck's braking system caused by periodic maintenance, braking failure can quickly occur in poor road conditions (Zheng, Guo, & Wei, 2017).

Heavy vehicles certainly have larger dimensions than cars, usually have low acceleration, and require more space to maneuver and brake, which causes an increase in the capacity of the road itself. The conversion of heavy vehicles to car capacity is essential when analyzing roads with a particular slope grade. Road geometry also plays a vital role in the road system, capacity, safety, and efficiency. Capacity and Level of Service (LOS) are set by road category, number of lanes, plane speed, intersection type, grade percentage, vehicle type, and number. From these parameters, the effect of heavy vehicles' performance should be considered. Although heavy vehicles do not affect the flow of vehicles on flat roads, their effect is quite significant at crossroads or on roads with high-elevation slopes (Srnová, 2017).

Longitudinal road markings are an essential supporting aspect as a guide in driving. The increase in width affects the driving aspect and road safety. Wider road markings form the perception of narrower roads, influencing motorists to reduce speed. The use of wider longitudinal road markings results in a decrease in vehicle speed to reduce the number of traffic accidents. Analysis of speed reductions in day and night driving conditions at moderate traffic density showed a reduction in vehicle speed of 2.24% during the day and 1.96% during the day for light vehicles, and 2.46% during the day and 2.15% at night for heavy vehicles (Calvo-Poyo, de Oña, Garach Morcillo, & Navarro-Moreno, 2020).

Horizontal Alignment

They used Bayesian network analysis to predict the probability of the influence of vehicle traffic and road factors and their effect on traffic accidents. It is emphasized that vehicle speed, horizontal curved radius, vehicle type, coefficient of adhesion, and longitudinal slope are essential factors. Based on the results of the probability of a roadside accident, the horizontally curved radius threshold, adhesion coefficient, and road shoulder width are related to the difference between vehicle speed and vehicle type for accident identification on the blackspot in the curved piece under review. The research results aimed to improve roadside safety with a section of a curve with a small radius. Therefore, it can also be concluded that vehicle speed and horizontal curved radius are critical factors in roadside accidents (Cheng, Cheng, Pei, & Xu, 2020).

The geometric characteristics of the road, including the plane speed, superelevation, and horizontal curved radius, are also set out in the AASHTO regulations. In addition, it also arranges other geometric characteristics of the road, including elongated grade, lateral friction factor, and road width, both full circle and spiral-circle-spiral arch. The dynamic simulation of the procedure analyzes several factors (longitudinal values, minimum radius of horizontal arch, vehicle speed, changes in vehicle length and weight, and differences in driver behavior) where the level of safety is determined based on the curve with the largest radius. This study demonstrated the need for clothed transition curves and proposed a lateral friction analysis methodology for velocities of 50, 80, 110, and 130 km/h (Abdollahzadeh Nasiri, Rahmani, Abdi Kordani, Karballaeezadeh, & Mosavi, 2020).

Technical provisions in a geometric design of roads in general; design criteria, determination of corridors, visibility, horizontal alignment (including visibility and accessible area of side bends), vertical alignment and coordination of horizontal and vertical paragraphs, a cross-section of roads, and coordination of paragraphs. The design criteria, as referred to, are the basis for determining corridor studies, determination of visibility, horizontal paragraph design, vertical alignment design, and typical cross-section of the road, as well as assessing the coordination between horizontal and vertical alignment. On a path along a horizontal line, all lanes of traffic must meet Stop Visibility (JPH). In the case of the length of the horizontal paragraph design, it is necessary to be limited to neutralize the road's monotonous and boring shape. As much as possible, the design of the horizontal paragraph should be made straight with the largest bend radius (Ministry of PUPR, Directorate General of Highways, 2021).

Plan speed and speed limit

As is known, the engineering approach includes two things; the operational speed method and the road risk method. There are two main options to lower the risk; close the flow of the vehicle or lower over speed. Unfortunately, the first option is often inapplicable and challenging to follow and implement. Therefore, a speed limit is required temporarily, and a methodology is needed as the best way out. Although it can be said that planning a new speed limit on the actual conditions of the road is quite challenging because there are many limiting conditions, parameters, and standards/tools that affect the severity value among them; speed, direction, slippage, tires, lubricated or dry conditions, and road surface property (Pratico, 2018).

One of the critical causes of traffic accidents in diverse weather conditions is the lack of precise speed selection (intentional or unintentional driver behavior) or too high a variation in speed. Among the various factors that influence the choice of speed by truck drivers, the driver's perception of the correct speed that should be applied to specific weather is the most significant factor. The traffic management center adjusts and harmonizes speed limits based on the prevailing weather and road conditions, intending to minimize the possibility of accidents on the freeway corridor. Motorists' level of driving experience and knowledge varies between vehicle and truck passengers and considering the severity resulting from truck accidents is usually much higher than accidents caused by non-truck vehicles (Yang, Guangchuan, Ahmed, & Gaweesh, 2019).

In order to study the characteristics of diverse traffic flows, researchers have always carried out the conversion of other classes of vehicles to the equivalent of passenger cars. In different traffic conditions, the equality of passenger cars may be different. For example, in free-flow traffic conditions, the distance between vehicles is usually much larger than the length of the vehicle. Therefore, the influence of heavy vehicles is negligible. Conversely, the effect of heavy vehicles on traffic flow must be addressed in heavy traffic conditions where density is more significant than the critical density. In addition, the distance gaps of different vehicles are also different at different travel speeds. At high speeds, vehicles also need to maintain a long distance to maintain safety (Yu & Fan, 2019).

Drivers of heavy vehicles have a slight chance of a fatal accident. This is because the heavier or longer the vehicle's body can provide Dungandungan to the driver. In addition, due to the stricter rules of heavy trucks, drivers tend to avoid risky behaviors, including avoiding high speeds and paying more attention to the road's surroundings, which then affects the lack of accidental injuries. Higher speed limits carry a higher risk than lower speed limits (Rahimi, Ehsan, & al, 2020).

Seepage visibility is lowered from the minimum required length for the vehicle to pass safely. The provision of visibility reduces the effects of lowering the speed of other vehicles, especially when the vehicle is heavy with steep increases and decreases. The type of vehicle in front affects the visibility of the driver of the vehicle behind it. Larger front vehicles affect the driver's visibility from smaller rear vehicles. Under such conditions, the rear driver following tends to reduce the speed to maintain a long distance from the vehicle in front of him to increase visibility (Mahanpoor, Mohammad, Monajjem, & Balali, 2021); (Zhao, Peibo, & Lee, 2018).

Poor visibility on the horizontal arch affects the increased risk of accidents due to lack of visibility. Engineering principles that consider truck traffic flow similar to reaction time perception and longitudinal friction characteristics to meet appropriate visibility (development of horizontal curved radius for road design) can also be applied to heavy vehicles. (Papadimitriou, Eleonora, & al, 2019); (Bassan, 2017).

METHOD

Data is one of the main strengths in compiling scientific research and modeling. The systematic scientific research process must begin with identifying the right problem. Data processing is the basis for geometric road planning with manual calculations and makes the Highway Design Standard of Indonesia 2021 a reference. Primary Data obtained to analyze the performance of roads and intersections without a signal include; geometric conditions, environmental conditions, traffic data, side drag data, and existing speed data (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, The Data Mining Applied for The Prediction of Highway Roughness due to Overloaded Trucks, 2015); (Rifai, Hadiwardoyo, Correia, & Pereira, 2016); (Isradi, Nareswari, Rifai, & Muhfidin, 2021).

Based on the designation of a road, a particular road is a road that is not intended for public traffic, intended only for the benefit of and for direct benefit to specific individuals, community groups, business entities, or agencies. According to the regulations, the implementation of particular roads is carried out by the non-government. Matters related to coaching, supervision, business, and operation can be carried out by government or government agencies together with the private sector, private sector, individuals, or specific community groups. Individuals, certain community groups, business entities, and certain agencies or government agencies can have the right to ownership (Ministry of PUPR, Directorate General of Highways, 2021).

This research is located in Karangasem Village, Jl. Raya Glondong-Kerek, Jenu District, Tuban Regency, East Java Province. The consideration of choosing this location is because the object of the study is the Post-Harvest Corn Drying Center (CDC) Infrastructure Development Project which was carried out there. The land area reaches 1,350 m2 (±1.3 Ha). Land ownership status is Building Use Rights (HGB) land owned by Perum BULOG. The location of the study is shown in Figure 1.

Figure 1. Case study location (CDC Project Tuban Regency, East Java)

The study was conducted to plan geometric roads in the Tuban Regency CDC industrial area. This project itself is still planning, so correspondence to data in the field is obtained from the results of surveys that have been carried out (quantitative data). In addition, location documentation is obtained from surveys conducted during field visits. The result of the calculations is depicted using AutoCAD 2D.

This study's secondary data processing process and analysis method were obtained from Perum BULOG on topographic data, contours, layout plans, and vehicle traffic flow plans to be served in industrial areas. The capacity of the planned vehicles has a reasonably diverse range, namely passenger car vehicles to transport trucks with a maximum axis load capacity of 8 tons. The chosen road criteria approach is a collector's road with Daily Traffic ranging from 50-500 vehicles. The criteria are based on SNI regulation 8457:2017 Page 4 Table 2 Design Catalog.

RESULT AND DISCUSSION

The regulation used by the author in the calculation of horizontal paragraphs is based on Circular Number: 20 / SE / Db / 2021 concerning Road Geometric Design Guidelines regulated by the Ministry of Public Works and Public Housing Directorate General of Wildlife Development. In addition, to plan road pavement, SNI 8457:2017 is used. The road network system will be used optimally to accommodate the movement of vehicles of people and goods from one place to another, from origin to destination, or according to economic rules from producer areas to consumer areas. The movement of these vehicles through a road network that is continuously connected to one another so as to form connectivity. Handlers of this road network will be efficient if classification is made according to the hierarchy.

Road Grouping/Classification

Based on the concrete road pavement planning in SNI 8457:2017, this road is categorized as equivalent to a collector's road with an average daily traffic of 50-500 vehicles. Therefore, the

Heaviest Axis Payload load is set at 8 tons. The assumptions in this calculation refer to the Highway Design Standard of Indonesia 2021, as stated in Table 1.

Table 1. Road Classification

No.	**Classification of Roads**	
1	Road Network System	Primary Local Road
2	Specifications for Provision of Road Infrastructure	Low traffic roads
3	Road Use	Grade 3
4	Road Field	Flat/ Even

Horizontal Alignments

Horizontal paragraph calculation requires data on road planning assumptions to obtain traffic that can meet the needs and functions and still prioritize road safety. The data on the assumptions taken can be seen in Table 2.

Table 2. Horizontal Alignment Calculation Data

No	**Components**	**Symbol**	**Calculation Result**	**Unit**
1	Design Speed	V_D	40	km/hour
2	Width of one lane	w	3,5	meter/lane
3	Azimuth angle	$\triangle$	90	degree (º)
4	Normal cross slope	En	2	percentage (%)
5	Maximum cross slope	Em	8	percentage (%)

Based on the planning data above, the calculation of horizontal curved components regarding the Highway Design Standard of Indonesia 2021 is described in Table 3. In a horizontal alignment that is relatively straight and long, do not suddenly have a sharp bend because it will startle the driver. In conditions of compulsion, it should be preceded by a blunter curve equipped with suitable signs. Horizontal alignment should be designed following the terrain conditions so that it will support the environment in harmony with nature, as well as economic factors. Avoid using a minimum Radius to facilitate alignment adjustments in the future.

Table 3. Horizontal Alignment Forming Components

No	**Components**	**Formula**	**Calculation Result**	**Description**

1	Curve Radius (R)	$\frac{V^2}{(e+f)g}$	48.5 m, considering the limited area, the curve radius being rounded down to 40 m	V: vehicle speed (km/h) e: Maximum cross slope (8%) F: Transverse Friction between Tire and Pavement (0.18) g: gravitation (9.81 m/s^2)
2	Spiral Curve	$\frac{V.T}{3,6}$	33.33 m	Q: traveling time through spiral curve lane (3 secs)
3	Spiral curve angle (θs)	$\frac{90 * Ls}{\pi * R}$	23.88°	π: constant ratio of the circumference of a circle to its diameter (3,14)
4	Circle curve angle (θc)	$\triangle$-2 θs	42.23 °	
5	p	$\frac{Ls\text{^}2}{6R} - R(1 - cos\theta s)$	1,21	
6	p*	$\frac{p}{Ls}$	0.0361	
7	k	Ls - $\frac{Ls\text{^}3}{40.R\text{^}2} - R * sin$ θs	16.56 m	
8	Lc	$\frac{\theta c * \pi * R}{180}$	29.37 m	
9	Xs	Ls ($1 - \frac{Ls^2}{40.R^2}$)	32.75 m	
10	Ys	$\frac{Ls\text{^}2}{6R}$	4.63 m	
11	Ice	(R+p) sec 1/2 $\triangle$ - R	18.27 m	
12	Ts	(R+p) tg 1/2 $\triangle$ + k	57.76 m	

The planning of the horizontal alignment of the radius of the bend is influenced by the values e and f and the specified design speed values. This means there is a minimum radius value for the maximum superelevation value and the maximum cross-friction coefficient. Furthermore, based on the results of the calculations above, the horizontal curved type of Spiral Circle Spiral (S-C-S) as shown in Figure 2.

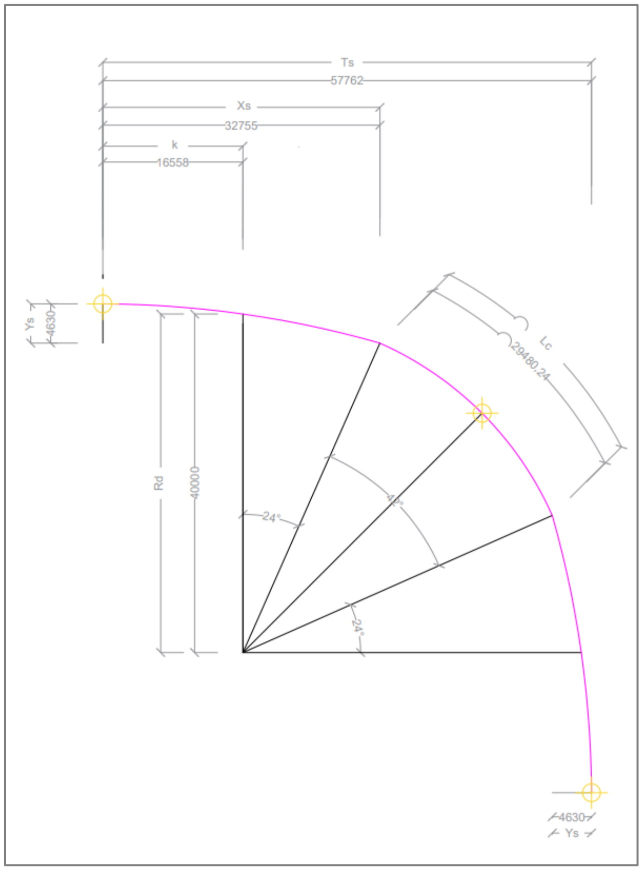

Figure 2. Curved Alignment Horizontal Plan

After obtaining the results of calculating the horizontal arch, the next step is to determine the widening of the pavement. Pointing to the Highway Design Standard of Indonesia 2021 Table 5-43 concerning the widening of bends per lane for design vehicles and the daily flow of vehicles in the form of large vehicles, it is also necessary to add a bend widening for trucks, which is 1.03 m. In addition, based on the Highway Design Standard of Indonesia 2021, Table 5-44 concerning the addition of supporting width (z) on widening is set at 0.63 m.

CONCLUSION

Based on the calculation and analysis results above, the value of the 40-meter plan radius and the plan speed of 40 km/h were obtained. The result of the horizontal arch that can be applied is the Spiral-Circle-Spiral (SCS) arch with a total Horizontal Curve length of 111.83 meters. Horizontal arch illustrations can be drawn using the AutoCAD Civil 2D® program. In addition to the calculation of the horizontal arch, it was also obtained that the widening of the bend pavement by considering large vehicles was 1.03 m and the addition of a supporting width of 0.63 m.

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