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Evaluation of the Suitability of Bend Geometry on Road User Perceptions: Case Study of Bantrangsana Bend on Jalan Raya Siliwangi Majalengka

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ABSTRACT

Road geometric factors, such as curve design, have significantly contributed to traffic accidents. Inappropriate corner design can cause the vehicle to lose control, especially at high speeds. Road geometry plays an important role in traffic safety, with many studies showing that poor geometric design can increase the risk of accidents. In Indonesia, evaluating road geometry is the main focus in improving traffic safety. In Indonesia, evaluating road geometry is the main focus in improving traffic safety. This research focuses on the Bantrangsana corner on Jalan Raya Siliwangi, Majalengka, because it is often reported as a location with a high accident rate. This research aims to evaluate the suitability of bend geometry to the perception of road users at the Bantrangsana Bend on Jalan Raya Siliwangi Majalengka using the Interpretative Phenomenological Analysis (IPA) approach. Results with 20 road users revealed that corner visibility is poor at night. When it rains, the narrow road width adds discomfort, especially when facing vehicles from the opposite direction, in traffic jams or vehicles leaving the road connecting to Bantrangsana village. Also, at the Bantrangsana bend, a road connects to Bantrangsana village; it can be seen on the location plan that the bend is a bend with a T-junction. Therefore, additional improvements are needed, such as improving lighting, adjusting road width, and adding clearer signs to improve the safety and comfort of road users at Bantrangsana Bend. The results of this study demonstrate the importance of considering road user perceptions in evaluating and designing road geometry to ensure a safer and more comfortable driving experience.

1. Introduction

Geometric roads are buildings of road bodies above ground level vertically and horizontally, assuming the ground level is uneven (Rizqi, 2022). In global transportation, road safety is a crucial issue that continues to receive attention. Various reports from the World Health Organization (WHO) show that traffic accidents are one of the main causes of death in the world, especially in developing countries (WHO, World Health Organization. (2019). Global status report on road safety 2018, 2018). Road geometric factors, such as curve design, have significantly contributed to traffic accidents. Inappropriate corner design can cause the vehicle to lose control, especially at high speeds. Therefore, evaluating and improving road geometry, especially curves, is an important agenda in improving road safety globally.

High-traffic accidents require serious attention at the regional level, especially in Asia. In recent years, with the rapid development of highway construction and the emergence of environmental problems, China is gradually studying the establishment of various highway environmental management technical regulations and standards to control or avoid the negative impact of highway construction on the environment (Dong, 2019). Indonesia, one of the countries with the largest population in the region, has big challenges in managing road safety. Inadequate road infrastructure and high traffic density often exacerbate the situation. In certain areas, including West Java, sharp turns and poor road conditions seriously threaten road users. Local and national governments must collaborate to identify and improve these accident hotspots. Our key finding is that road improvements increase ward-level employment and the number of establishments (Gibbons, 2019).

Nationally, the Indonesian government has attempted to reduce the number of traffic accidents through various initiatives. One is through the "Zero Accident" program, which aims to improve road safety through various approaches, including improving road infrastructure (Yahya, 2019). However, despite these efforts, traffic accident rates remain high. More specific data-based evaluations and interventions are needed to achieve desired safety targets. This research evaluates curve geometry as one of the key factors that can improve road safety in Indonesia. Design criteria in geometric planning include cross-sectional elements, visibility, vehicle stability, driver comfort, traffic characteristics, and economic factors (Nurjannah, 2022; Rizqi, 2022).

The case study discussed in this research is Bantrangsana Bend on Jalan Raya Siliwangi, Majalengka. Residents know this bend as a dangerous corner, often the location of traffic accidents. The safety of road users is essential because the after-effects of a traffic accident on accident victims are enormous (Sumantri, 2022). The non-ideal road geometry conditions and high vehicle volumes make this bend an important focus in road safety evaluations. Evaluation of the geometry of these curves is important to understand how road design influences driver behaviour and traffic safety in the area (Ziakopoulos, 2020).

This research aims to evaluate the suitability of the geometry of the Bantrangsana Bend to the perception of road users. Highways must ensure user comfort and safety for effective traffic movement (Gaikawad, 2020). By conducting in-depth and data-based analysis, it is hoped that this research can make a real contribution to efforts to improve road safety in Indonesia, especially in the Majalengka area. It is also hoped that the results of this research can become a reference for regional and national governments in planning and implementing more effective road infrastructure improvements. Development carried out by a region can reflect the progress of the regional economy, one of which is the improvement of facilities and infrastructure for the community (Rifai, 2021).

2. Literature Review

2.1. Road Geometry and Traffic Safety

The highway is a means or place for vehicles to pass, whether motorized vehicles or the like, that pass through the road (Adiputra, 2022). Road geometry plays an important role in traffic safety, with many studies showing that poor geometric design can increase the risk of accidents. Too sharp turns, inadequate road width, and poor visibility are some geometric factors that can influence driver behaviour and increase the likelihood of accidents. Research by the American Association of State Highway and Transportation Officials (AASHTO) shows that well-designed curves can reduce vehicle speed, improve vehicle control, and reduce accident rates (Hancock, 2019).

In the current era of advanced transportation, it is common for people to mobilize using modes of transportation even though the distance travelled is not too far (Christine, 2022). Furthermore, studies from the World Health Organization (WHO) highlight that improving the quality of road

infrastructure, including good geometric design, can reduce injuries and deaths due to traffic accidents. Road safety has become a major concern affecting countries' socio-economics (Islam, 2019). Countries with strict road design standards tend to have lower accident rates. WHO recommends implementing road design standards considering various factors, including vehicle speed, vehicle type and surrounding environmental conditions.

The main goal of geometric design is to create a safe, efficient, and economical path in maintaining its aesthetics and environmental quality (Zulfa, 2022). Additionally, research in Europe shows that road design that considers road user perceptions can improve safety (WHO, European Regional Status Report on Road Safety 2019, 2020). For example, implementing clear road markings and warning signs at sharp bends can help drivers anticipate road changes and reduce the risk of accidents. Therefore, integration between good road design and an understanding of driver perception is critical to creating a safe road environment.

2.2. Evaluation of Bend Geometry in Indonesia

Road geometry is part of road planning that emphasizes physical form planning to provide optimal service to traffic and access between locations (Gunawan, 2022). In Indonesia, evaluating road geometry is the main focus in improving traffic safety. This condition can be demanding in sample preparation (Han, 2019). Case studies in several areas show that many road bends do not comply with safety standards, resulting in high accident rates. Research by the Indonesian Ministry of Transportation shows that bends with a too small radius and without adequate safety are often the location of accidents.

Geometric road planning aims to produce safe infrastructure and efficient traffic flow services and maximize the ratio of usage level/implementation costs (Lubis, 2019). One case study that stands out is the evaluation of the geometry of bends on highways connecting large cities in West Java. The study found that sharp corners and sudden elevation changes increase the risk of accidents, especially at night or during bad weather conditions. In addition to calculations and analysis, the geometric design of the road included adjustments to the safety and level of service required in a specific terrain (Arifin, 2022). The local government has made various improvement efforts, including widening roads and installing warning signs, but ongoing evaluation is still needed.

Research conducted by universities in Indonesia also supports the importance of evaluating bend geometry. In road geometric design, sharp turns are permitted in geometric standards, but only for certain functional roads with relatively low speeds (Purwanto, 2019). Good geometric design greatly influences road users' perceptions of safe bends. Drivers tend to feel safer and reduce speed when approaching a well-designed corner with sufficient visibility and a less sharp corner.

2.3. Case Study of Bantrangsana Corner, Jalan Raya Siliwangi

This research focuses on the Bantrangsana corner on Jalan Raya Siliwangi, Majalengka, because it is often reported as a location with a high accident rate. This evaluation aims to understand how the geometric design of these bends affects driver behaviour and crash risk. Safety is the main factor of road design, and it is sufficient and easy to move. Geometry deals with horizontal and vertical curves, sight distance, gradient, and intersection, which are also major indicators (Mandal, 2019).

Field research was carried out to collect data regarding the physical condition of bends, including road width, bend radius and visibility. This data is then analyzed to determine compliance with applicable road design standards. Many drivers have difficulty controlling their vehicles when negotiating these curves, especially at high speeds. Road traffic accidents occur due to various factors. Driver behaviour, weather conditions, vehicle conditions, other vehicles, road conditions, signs or traffic control devices, other objects on the road, inappropriate road geometry planning, or a combination of the above factors (Sumarsono, 2019). This indicates the need for design improvements to increase safety.

Required sight distances are important inputs in current road design guidelines, especially to determine certain geometric parameters (radiuses of vertical curves, with the clear field in horizontal curves, clear sight fields at intersections, etc.). Autonomous vehicles differ from human-driven vehicles in reaction time and eye (sensor) height. Therefore, reconsidering required sight distances and minimum geometric parameters is relevant (Khaska, 2021).

3. Method

This research aims to evaluate the suitability of bend geometry to the perception of road users at the Bantrangsana Bend on Jalan Raya Siliwangi Majalengka using the Interpretative Phenomenological Analysis (IPA) approach. The IPA approach was chosen because of its focus on an in-depth understanding of individuals' subjective experiences of observed phenomena. This research consists of two main stages: measuring the geometry of the curve and in-depth interviews with road users. In the first stage, researchers collected data regarding the physical dimensions of the bend, including radius, road width and road slope. This data is used to obtain objective information about the curve geometric design and to compare it with existing road geometric design standards.

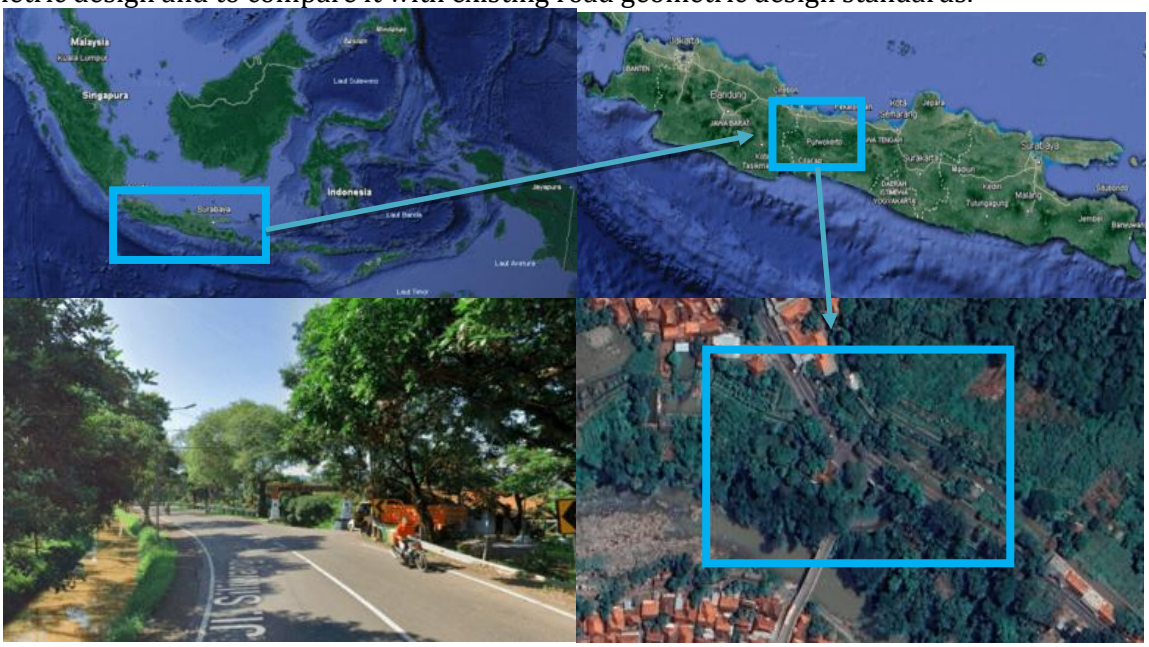


Figure 1 Location Plan

In the second stage, researchers conducted in-depth interviews with road users to explore their perceptions regarding safety and comfort when passing through these bends. These semi-structured interviews allowed the researcher to flexibly explore the subjective experiences and views of road users. The interview data was then analyzed using an IPA approach to identify the main themes of road user experiences and relate them to aspects of curve geometry.

How safe do you feel when passing Bantrangsana Bend?	A1
Do you feel visibility around this corner is adequate at night?	A2
How do road conditions (e.g., potholes, road surface) affect your safety when negotiating curves?	A3
Do you feel that the signs or road markings at this corner are clear and easy to see?	A4

Table 2 Indicators of Safety Perception

How comfortable do you feel when passing Bantrangsana Bend?	B1
Is the width of the road at this corner sufficient to accommodate two vehicles passing	B2

each other?	
Do you feel that the slope of the road at this corner affects driving comfort?	B3
Do you feel there is a need for improvement in this corner?	B4

Table 3 Indicators of Perceived Comfort

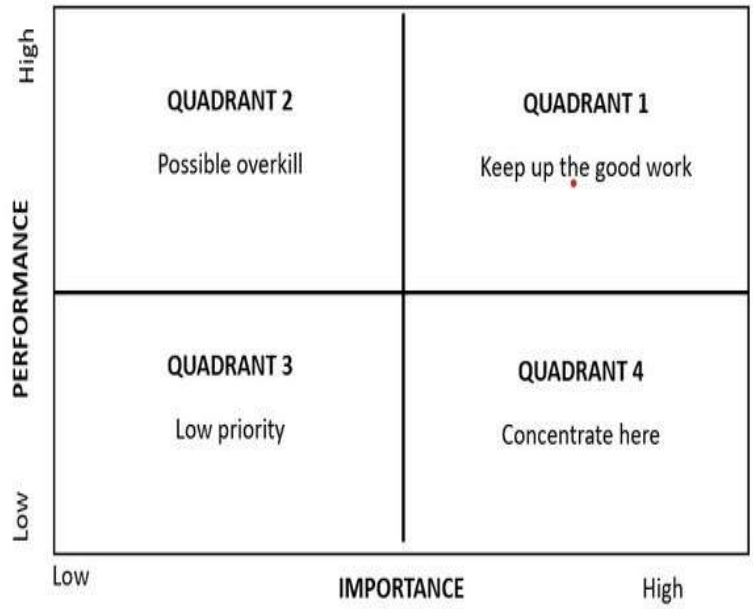


Figure 4 The IPA Method Quadrant

4. Result and Discussion

Bend Radius Calculation

$$R = \frac{v^2}{15(e+f)}$$

$$R = \frac{60^2}{15\ (0{,}05 + 0{,}15)}$$

$$R = 1200 \text{ m}$$

R = Bend Radius (m)
V = Design Speed (km/h)
e = Super Elevation (m/m)
f = Lateral friction coefficient

Super Elevation Calculation

$$e = \frac{v^2}{g.\ R} - f$$

$$e = \frac{16{,}67^2}{(9{,}81\ .\ 1200)} - 0.15$$

$$e = -0.126$$

R = Bend Radius (m)
V = Design Speed (km/h)
e = Super Elevation (m/m)
f = Lateral friction coefficient
g = Gravitational Acceleration (m/ s^2)

Visibility Calculations

$$SSD = \frac{v\ .\ t}{3.6} + \frac{v^2}{254\ (f+e)}$$

$$SSD = \frac{60.\ 2{,}5}{3.6} + \frac{60^2}{254\ (0{,}15+0{,}05)}$$

SSD = Sight Stopping Distance (m)
V = Design Speed (km/h)
e = Super Elevation (m/m)
f = Lateral friction coefficient
t = Driver Reaction Time (s)

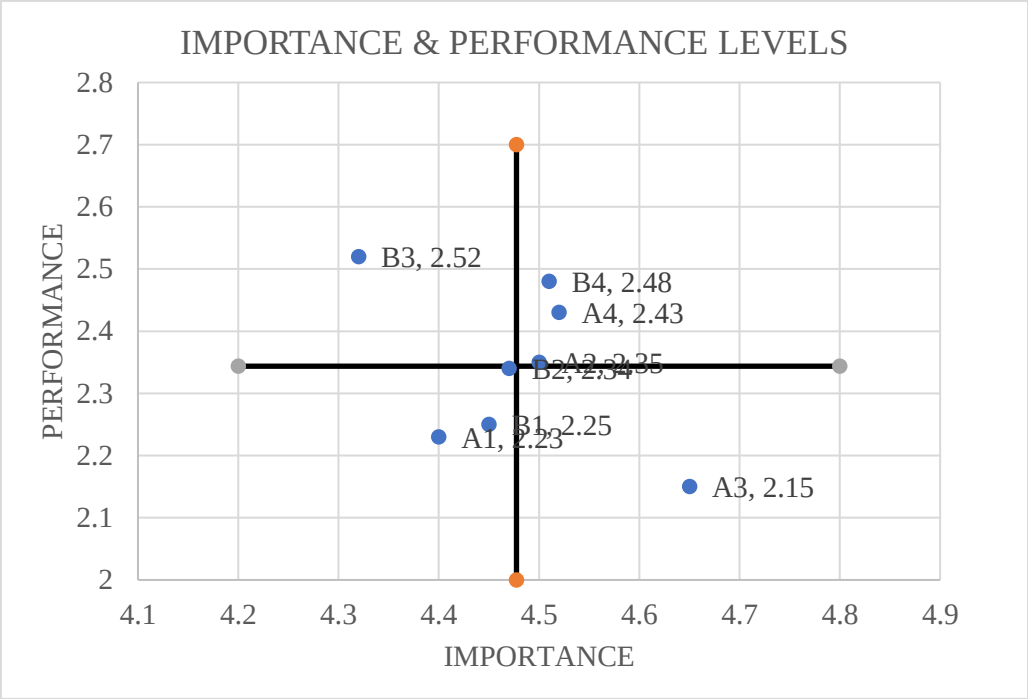
$SSD = 112.53$ m

Based on the 60 km/h design speed, superelevation of 5%, and friction coefficient of 0.15, the calculated bend radius is R=1200 m. With a calculated bend radius of 1200 m, design speed of 60 km/h, and friction coefficient of 0.15, the required superelevation is e=−0.126. This value is negative, indicating that the current super elevation is more than sufficient for that speed or there was an error in setting the initial super elevation value. With a design speed of 60 km/h, driver reaction time of 2.5 seconds, friction coefficient of 0.15, and superelevation of 5%, the calculated stopping visibility is SSD=112.53 m.

NO	Indicators	I	P	G
A1	How safe do you feel when passing Bantrangsana Bend?	4.4	2.23	-2.17
A2	Do you feel visibility around this corner is adequate at night?	4.5	2.35	-2.15
A3	How do road conditions (e.g., potholes, road surface) affect your safety when negotiating curves?	4.65	2.15	-2.5
A4	Do you feel that this corner's signs or road markings are clear and easy to see?	4.52	2.43	-2.09
B1	How comfortable do you feel when passing Bantrangsana Bend?	4.45	2.25	-2.2
B2	Is the width of the road at this corner sufficient to accommodate two vehicles passing each other?	4.47	2.34	-2.13
B3	Do you feel that the slope of the road at this corner affects driving comfort?	4.32	2.52	-1.8
B4	Do you feel there is a need for improvement in this corner?	4.51	2.48	-2.03

Road User Questionnaire Data on Bantrangsana Bend

The research results show that road users feel uncomfortable and unsafe when passing through the Bantrangsana Bend on Jalan Raya Siliwangi Majalengka. Results with 20 road users revealed that corner visibility is poor at night. When it rains, the narrow road width adds discomfort, especially when facing vehicles from the opposite direction, in traffic jams or vehicles leaving the road connecting to Bantrangsana village. Also, at the Bantrangsana bend, a road connects to Bantrangsana village; it can be seen on the location plan that the bend is a bend with a T-junction.



IPA Method Diagram Image

These findings indicate that although the corner radius complies with design standards, visibility problems and narrow road widths reduce the comfort and safety of road users. Poor visibility and inadequate road width at curves indicate the need for improvements such as better lighting and possible adjustments to the road design. This shows that design standards must consider road users' perceptions to ensure driving safety and comfort.

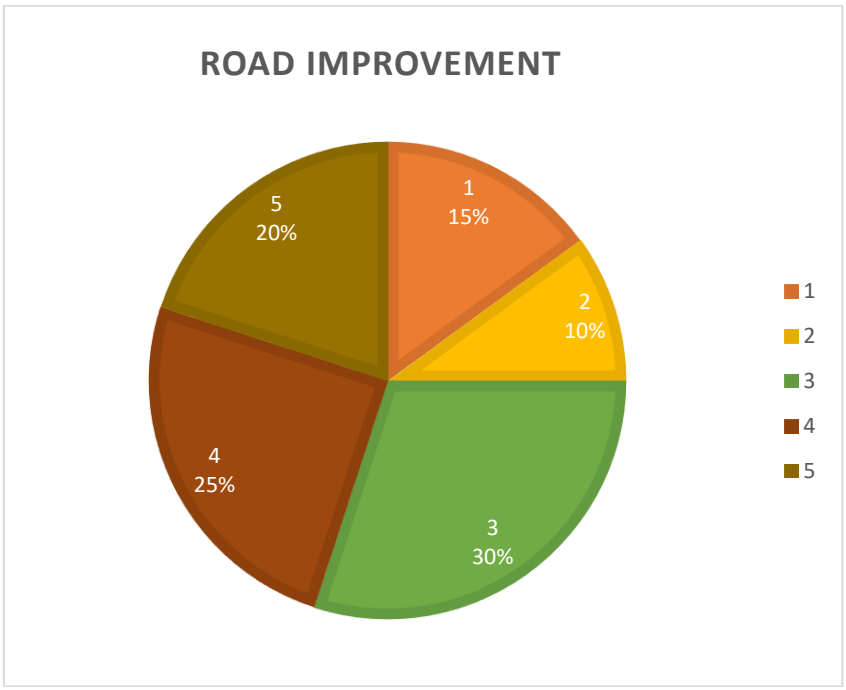


Image of scale diagram of repair needs

5. Conclusion

A bend radius of 1200 meters is sufficient for a design speed of 60 km/h with the given super elevation and friction coefficient. This shows that bends provide a safe and comfortable driving experience if

road conditions and visibility are maintained properly. A negative result from the superelevation calculation indicates that a superelevation of 5% is sufficient or perhaps too large for the given bend radius and speed. A review is needed to ensure that the superelevation meets the needs of the field. Stopping visibility of 112.53 meters shows that for a speed of 60 km/h, the driver needs at least that much visibility to stop safely. This indicates that visibility around corners must be maintained and increased by this stopping visibility to ensure driver safety.

This research evaluates the suitability of the Bantrangsana Bend geometry for road users' perceptions regarding safety and comfort. The measurement results show that, in general, it meets technical standards. However, the interviews with 20 road users revealed that many road users felt unsafe and uncomfortable when passing through this bend. Road users report limited visibility on this corner, especially at night and during rain, leading to unsafe conditions. The narrow width of the road also adds discomfort, especially when passing vehicles suddenly leave the road that connects to Bantrangsana village. These findings suggest that although curves meet some geometric design standards, subjective factors such as perceived visibility and road user comfort are critical in determining safety and comfort.

Therefore, additional improvements are needed, such as improving lighting, adjusting road width, and adding clearer signs to improve the safety and comfort of road users at Bantrangsana Bend. The results of this study demonstrate the importance of considering road user perceptions in evaluating and designing road geometry to ensure a safer and more comfortable driving experience.

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