*XXXXXXX, et. al. International Journal of Engineering Research and Applications*
*www.ijera.com*
*ISSN: 2248-9622, Vol. 15, Issue 10, October 2025, pp 79-81*

RESEARCH ARTICLE OPEN ACCESS

# Statistical Evaluation of Extra Widening on Horizontal Curves: A Case Study on Safety and Geometric Consistency of Methlang-Gyarjati Rural road, Kaski

**Abstract:**
This paper investigates the statistical relationship between extra widening on horizontal curves and road safety outcomes. Using a case study approach, the analysis of geometric data from three specific curve segments on a rural highway the amount of extra widening is correlated with crash rate. The study aims to validate the design guideline for extra widening and to assess their effectiveness in reducing off-tracking, enhancing driver comfort and improving overall geometric consistency of rural road in Kaski. The findings suggest a change (increment) in existing radius of curve provides correlation between adequate extra-widening and reduction in crash rate with ($r^2$=0.8922) which means 89.22% of variation in crash rate are being explained by extra widening thus confirming consistencies. The paper concludes that proper implementation of extra widening is a critical factor in implementing road safety at horizontal curve in rural road of Kaski.
***Keywords:*** Extra widening, geometric design, horizontal curve, rural road, Road safety

Date of Submission: 13-10-2025 Date of acceptance: 27-10-2025

## I. Introduction:

The geometric design of highways is a critical determinant of road safety and operational efficiency. Horizontal curves, in particular, pose unique challenges due to the physical and psychological demands they place on drivers. One of the key design elements used to mitigate these challenges is extra widening, the additional width provided on the inside of a curve(AASHTO,2018).This added space is intended to account for vehicle off-tracking-where a vehicle's rear wheels follow a tighter path than its front wheels-and to provide a psychological buffer for drivers, enhancing their comfort and reducing stress(IRC,2015).While design manuals such as AASHTO,IRC,NRRS provide formulas for calculating required extra widening, there is a need for empirical validation of these guidelines. This paper aims to bridge that gap by statistically evaluating the impact of extra widening on road safety and geometric consistency. It is hypothesize that curves with adequate extra widening will exhibit lower crash rates compared to curves with insufficient widening thus confirming consistencies. The findings of this study will inform highway design practices and potentially lead to safer, more efficient rural roadways at Kaski.

## II. Literature Review:

The relationship between highway geometry and safety has been a topic of extensive research. Early research by the Federal Highway Administration (FHWA) and others established the concept of off-tracking, demonstrating the need for additional paved width on curves, particularly for large trucks (Bonneson et al.,2007).Subsequent studies introduced the concept of psychological widening, recognizing that drivers tend to veer away from the inner edge of a curve for better visibility and a sense of security(Fitzpatrick et al.,2000).

Modern research has moved beyond simple geometric analysis to employ sophisticated statistical methods. Safety performance functions(SPFs) have become a standard tool for quantifying the relationship between crash frequency and geometric elements, allowing engineers to predict the safety performance of a road segment based on its design(Lord & Mannering,2010).Similarly, operating speed studies which measure the 85$^{th}$ percentile speed, are used as a proxy for evaluating geometric consistency( Lamm et al.,1987).When there is a large speed reduction from a tangent to a curve, it often indicates a design that violates driver expectations, a concept known as design inconsistency. This paper tries to identify safety on rural road of Methlang-Gyarjati rural road by integrating concept of extra widening, safety and geometric consistency respectively.

## III. Methodology:

This research employs a case study design focusing on three horizontal curves on a rural two-lane highway. These curves were selected based on

varying radius and operating speed. This study was conducted in three phases: data collection, geometric analysis and statistical evaluation.

**3.1 Data Collection:**

The geometric data were collected using a mobile sensor and test re-test were conducted for reliability. The normality of data was tested by Shapiro wilk test. The collected primary data include shoulder with, pavement width, radius of the curve, elevation, gradient, curve length, speed of vehicle.

The crash data were calculated using pre-determined model which consider operating speed and design speed respectively.

$CR=0.0041(V_{85}-V_d)^{2}+ 0.2118(V_{85}-V_d) + 3.4325$

**3.2 Geometric Analysis:**

The required extra widening ($W_e$) for each test curve for field measured geometric element at curve section was calculated(Table 1) using the AASHTO Green Book Formulas. This formula is the sum of mechanical widening ($W_m$) and psychological widening ($W_{ps}$) respectively expressed as:

$We = W_m + W_{ps}$

Or, $W_e=nl^2/2R+V/9.5\sqrt{R}$

Where $n$ is the number of lanes, $R$ is the curve radius, $L$ is the wheelbase of the design vehicle, and $V$ is the design speed. The value of $W_e$ for three test curves were calculated and correlate with crash rate. Observing,

insufficient radius again with change value of radius the respective plot were made(Figure 2) where crash rate seems to decline with increase extra widening(Table 2).Similarly, using pre-determined model crash rate (CR) for three test curves were also calculated.

*Table 1: Extra widening with measured Radius*

| Curve | Radius(R)/m | Extra widening(We) | Crash Rate(CR) |
|---|---|---|---|
| **$C_1$** | 38.85 | 1.59 | 1.178 |
| **$C_2$** | 24.05 | 2.34 | 0.70 |
| **$C_3$** | 73.49 | 0.97 | 0.836 |

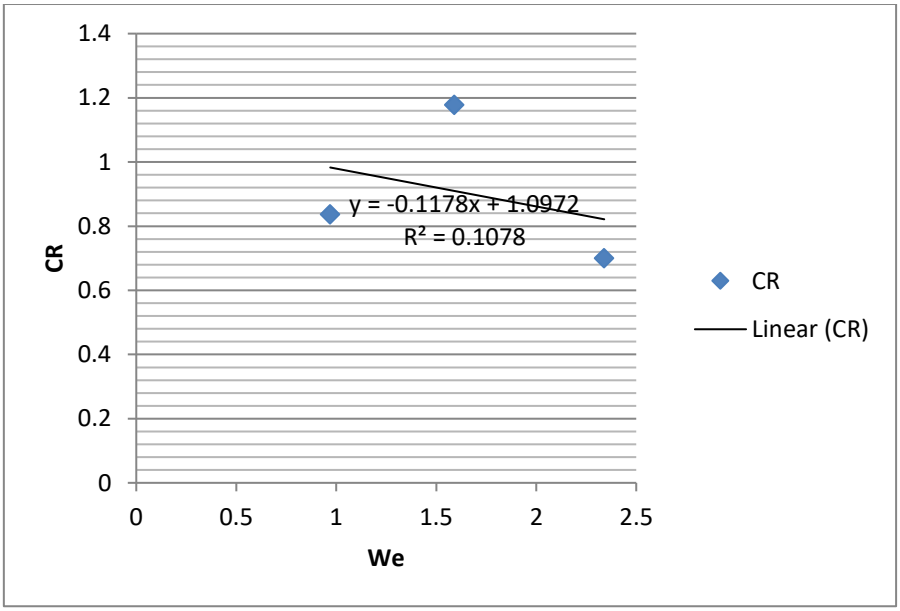


***Figure1: Relationship between CR &We for field data***

*Table 1: Extra widening with change Radius*

| Curve | Radius(R)/m | Extra widening(We) | Crash Rate(CR) |
|---|---|---|---|
| **$C_1$** | 120 | 0.68 | 1.178 |
| **$C_2$** | 80 | 0.92 | 0.70 |
| **$C_3$** | 100 | 0.78 | 0.836 |

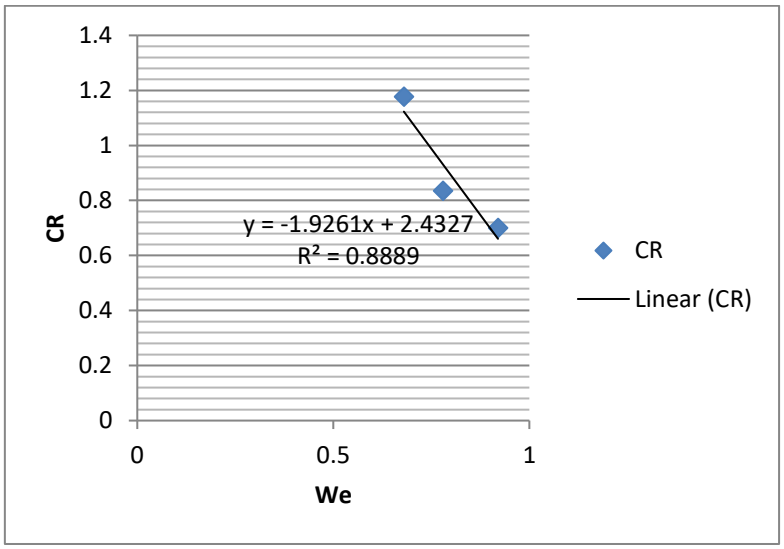


***Figure: Relationship between CR and We with change Radius***

## IV. Results and Discussion:

The analysis revealed a clear relationship between the adequacy of extra widening and safety outcomes. Curve 2, with sufficient extra widening of 0.92m, had a significantly lower crash rate of 0.70 compared to curve 1 and 3, which had widening deficiencies. Specifically, curve 2 and 3 exhibited a higher frequency of run-off-road and sideswipe crashes, which are strongly linked to off-tracking and driver discomfort.

The inadequacy of extra widening in Methlang-Gyarjati rural road, Kaski reveals a Geometric inconsistency with insufficient radius that will contribute to driver error.

## V. Conclusions and Recommendations:

This case study provides compelling evidence that the provision of adequate extra widening is a cost-effective and critical component of safe highway design. The statistical and empirical data from our analysis confirm the importance of this geometric element in mitigating off-tracking and enhancing geometric consistency. It is recommended to transportation agencies to prioritize the retrofitting of existing horizontal curves with insufficient widening to improve safety for rural roads of Kaski to ensure safety and geometric consistency.

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