Evaluation of the Implementation Status of the Nepal Rural Road Standards (NRRS) Concerning Geometrical Parameters: A Case Study of Morang District of Nepal

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Abstract

Maintaining the effectiveness of the transportation system is essential to economic growth. Poor road upgrading methods in many developing nations, however, are making it impossible for traffic to flow freely. Nepal developed the Nepal Rural Road Standards (NRRS) of 2055, District Transportation Master Plan (DTMP), and Municipality Transportation Master Plan (MTMP) to regulate the construction of rural road infrastructure. These guidelines provide guidelines for rural road planning, design, building, and maintenance, among other aspects. However, each geometric design has certain features, and parameter requirements depending on the region and location to be applied. This study aims to compare the geometrical features of the rural roads that have been built with the Nepal Rural Road Standards (NRRS) 2055, second revision (2071). Using a random sampling approach, six rural roads in the Morang district were selected for the data collection. To gather geometrical data, field observations and measurements were made at random chainages. This study evaluates various geometric parameters using linear and angular field measurements. Mapping conducted via smart road software ensures road geometry compliance, including aspects such as curve radius, shoulder width, gradient, sight distance, carriageway, and additional widening. The findings demonstrate that strict adherence to established standards substantially enhances road safety. Based on the results of the field observation, the geometric elements have been built according to design specifications, except for the additional widening at shoulder width and horizontal.

Keywords: *Rural Roads, Nepal Rural Road Standards, Geometrical Parameters, MTMP, DTMP*

Introduction

The movement of people and goods depends heavily on the transportation infrastructure. However, a fundamental barrier to economic progress in many emerging nations is a weak transportation infrastructure. The idea of a balanced passenger transportation system is to combine various modes of transportation so that prospective passengers have choices (Kampf et al., 2012). The world is shifting toward intelligent transportation systems(Zulkarnain et al., 2021), which use a variety of electronics, communication, control, and vehicle sensing technologies to manage and resolve traffic issues(Singh et al., 2015). Governments and private institutions are investing in technology like electric vehicles (EVs) and intelligent transportation systems (ITS) to improve the sustainability and efficiency of road transportation. However, in developing nations, road infrastructure is essential because it facilitates the efficient movement of people and commodities and makes a wide range of economic and social activities accessible (Ng et al., 2019). The primary means of transportation in Nepal is the road system and the need for automobiles has skyrocketed due to rapid urbanization and rising economic activity (Aryal et al., 2022). The lack of management, improper engineering, inadequate maintenance, inadequate safety infrastructure, and many catastrophe modes all contribute to the perilous state of Nepal's roadways (Pant et al., 2022).

A road's geometric arrangement serves the primary purpose of securely and aesthetically linking two or more destinations while taking user comfort and safety into consideration (Tougwa, 2021). Road conditions, individual decisions, infrastructure, and the surrounding environment all have a significant influence on traffic safety (Dell'Acqua et al., 2011). The road geometry components are carefully chosen, proportioned, and positioned to achieve several design goals, including sight distance, vehicle stability, driver convenience, drainage, economic growth, and aesthetic elements. The design of highways considers the conventional highway design approaches primarily focused on the use of guidelines that provide nominal safety (Afolayan et al., 2022). Since parts of rural highways with inconsistent design have higher collision rates, evaluating the consistency of geometric design is one of the potential approaches to enhancing rural highway safety (Banjara et al., 2023; Jacob et al., 2013).

The rural transport infrastructure plays a pivotal role in promoting several Sustainable Development Goals (SDGs) and providing a significant number of socioeconomic advantages for rural populations globally (Kaiser et al., 2022). It might be challenging for people to move about in rural and sparsely populated places since public transit is not readily available (Šoštaric et al., 2022). However, the old pastoral and agricultural subsistence economy in the rural region has been significantly enhanced by the rural road. Access to agricultural regions and markets is made feasible by rural roads, which often have lower design speeds, little to no traffic, and serve as vital links between local populations which are now owned by the local government of Nepal (Bhandari, 2013). The Nepal Rural Road Standard 2054 (NRS-2054) revised version (Second Revision 2071) and Nepal Rural Road Standards 2054 (NRRS-2054) are a collection of guidelines and regulations that control the building, maintenance, and management of rural roads in Nepal. It offers a comprehensive framework for building rural roads across the country to improve transportation, connectivity, and accessibility in remote and underdeveloped areas (DoLIDAR, 2014).

The NRS and NRRS criteria for the design and construction of rural roads have not been uniformly followed and implemented. The rural roads are constructed without the use of any social safeguarding procedures, environmental safeguarding measures, or industry-standard engineering practices. Technically speaking, as well as principally from an environmental and social standpoint, these impromptu constructions have created a significant number of management and safety challenges in the field of transport infrastructure improvement (Pokharel et al., 2015). Local governments, who oversee developing and managing the road infrastructure on their territory, are severely limited by capacity (Acharya et al., 2022). More capacity is needed to create new partnerships in a changing environment, formalize the process of restructuring local governance, raise citizen participation in the system, improve technical, administrative, and financial capacity for efficient service delivery, and draft the necessary laws, acts, and regulations (Acharya, 2018).

When planning, designing, and constructing geometric roadway elements, three main concepts must be carried out. To start, it provides a minimum level of safety and comfort for the driver by considering factors like sight distance, friction coefficients, and available road space for vehicle motions (Li et al., 2016). Secondly, these principles provide a foundation for economical design for designers (Gasparin, 2018). And lastly, they guarantee ongoing alignment to get lower operating costs (Nimitha et al., 2017; Sudmeier-Rieux et al., 2019). The discipline of highway engineering, particularly the geometric design of highways, is focused on adhering to specific guidelines and limitations to achieve these goals. The primary objectives of geometric design are to maximize safety and efficiency while minimizing costs and environmental consequences to make a road livable. The newly emerging fifth objective, "livability," refers to building roads that support more general community goals such as allowing various modes of transportation, reducing emissions and fuel consumption, and minimizing harm to the environment and jobs, schools, businesses, and residences (Baobeid et al., 2021).

Objectives

This research aims to do a comparative analysis of the geometric characteristics of rural roads as defined by the National Rural Road Standards (NRRS) 2055 and its updated version, NRRS 2071. The research will specifically assess important criteria for local road networks and non-engineered country roads as specified in these standards, including carriageway width, shoulder width, gradient, radius of horizontal curve, extra widening, and sight distance. By examining these discrepancies and revisions, the research hopes to provide light on how the two standards relate to road infrastructure design and adherence to contemporary technical standards.

Methodology

Study Design

The overall condition of rural roads in Morang district was evaluated using a qualitative approach. Additionally, a quantitative method involved examining the geometrical characteristics of these roads. This study compares engineering design specifications according to NRRS 2055 with the construction of rural roads.

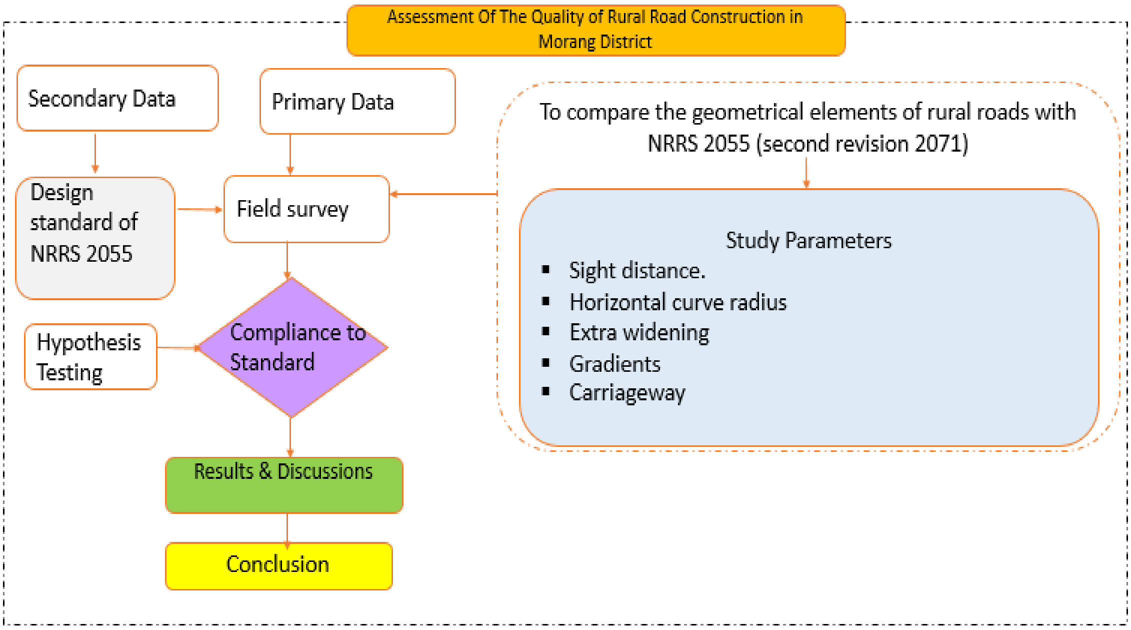

Figure 1: Conceptual Framework of Study

Study Area

The investigation was conducted in Nepal's Morang district along several route segments. The largest city in the district, Biratnagar, is a major commercial and industrial hub in Nepal with heavy traffic. It touches Sunsari to the west, Jhapa to the east, Dhankuta and Panchthar to the north, and India to the south. The following is a list of the precise road segments that were studied:

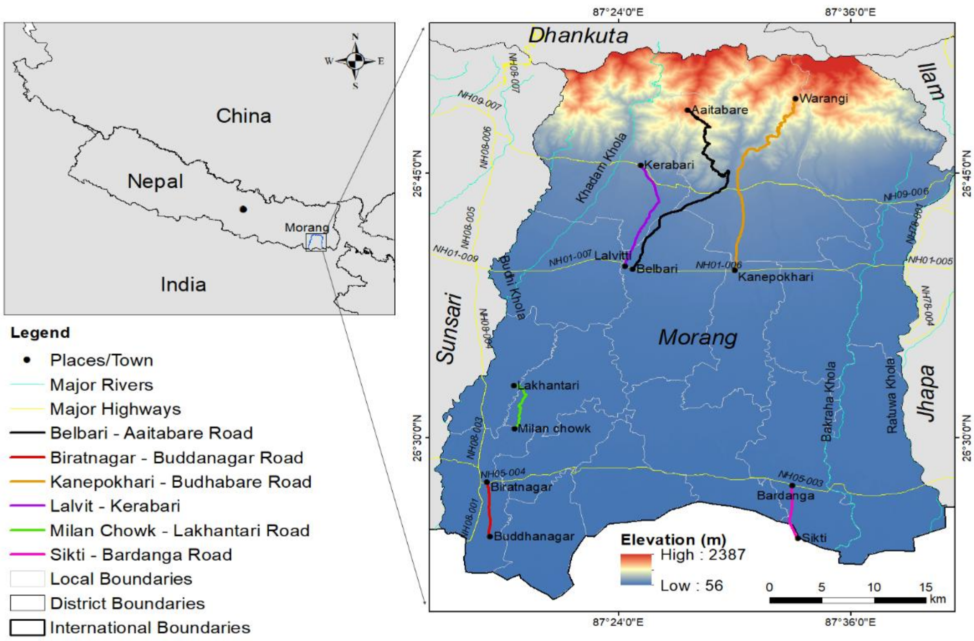

Figure 2 : Location Map of Roads

Kanepokhari-Letang-Warangi-6 No Budhabare Section 1 Road (05DR020A, 10.14 Km Black Top Road)

Lakhantari-Milan Chowk Road (05DR004, 4.4 Km Gravel Road)

Belbari-Lokhara-Bhogteni-Aaitabare Section 2 Road (05DR017B, 14.06 Km Earthen Road)

Biratnagar-Dharambad-Buddhanagar Road (05VR020, 6.91 Km Black Top Road)

Lalbhitti-Devijhoda-Kerabari Road (05VR040, 10.07 Km Gravel Road)

Sikti-Bardanga Road (05VR087, 3.47 Km Earthen Road)

Data Collection

Primary data: A field study was conducted to assess the geometric components of various road segments.

Secondary Data: From secondary sources such as office records or papers, municipality reports, ward profiles, distributed academic or expert reports, and information from the National Statistical Office (NSO) or other recognized offices, current and trustworthy baseline data were retrieved (DoR, 2073).

Study Population and Sampling Techniques

Population: The target demographic for this study is the whole network of rural roads in the Morang area.

Sampling Techniques: Six rural roads in the Morang area were chosen for this study using random sampling. There were three District Road Core Networks (DRCN), one for earthen, gravel, and blacktop roads. The other three were Village Road Core Network (VRCN), which belongs to these three groups.

Analysis of Data

Using smart road software, quantitative analysis was used to examine geometric design features and provide a thorough comparison with NRRS requirements. Both numerical and graphical data were provided for a thorough evaluation. All numerical data, whether above or below predefined levels, were compared with the standards of NRRS 2055 to find percentage-based variances.

Testing of Hypothesis

The t-test is applied in this study to verify the hypothesis. The characteristics of the roads that were examined are:

- Sight distance.
- Horizontal curve radius
- Extra widening
- Gradients
- Carriageway
- Shoulder

The predefined standard established by NRRS 2055 is used to validate the geometric data obtained from field observations.

Null Hypothesis: There is not a significant distinction between the observed data and the implementation of NRSS 2055.

Alternative Hypothesis: There is a significant distinction between the observed data and the implementation of NRSS 2055.

The tests were conducted using the subsequent test statistics:

$$t = \frac{\bar{X} - \mu}{\sqrt{\frac{S^2}{n}}} \qquad (1)$$

i.e. The test statistic t follows t-distribution with n-1 degrees of freedom, and n is the size of samples.

Where,

$\bar{X}$= mean of first sample = $\frac{\sum X}{n}$

μ = The population means

S^2= an unbiased estimate of the common population variance σ2 and its value is computed by the Actual mean method.

$$S^2 = \frac{1}{n-1}\sum(X - \bar{X})^2 \qquad (2)$$

Results and Discussion

Geometric Measurement of Road

Road geometric characteristics are crucial for ensuring safe and efficient transportation. They encompass elements like alignment and cross-section, which are evaluated against design and construction standards to ensure compliance and safety (Jurewicz et al., 2015).

Carriageway Width

The T-test was conducted to assess the significance of carriageway width concerning NRRS 2055 for various road segments at different chainages, utilizing a 5% significance level. The summarized results of the T-test are as follows:

Table 1: Result of T-test for Carriageway width

SN	Name of Road	Calculated value (t_{cal})	Tabulated value (t_{tab})	Result
1	Kanepokhari-Letang-Warangi-6 No Budhabare Section-1(05DR020A)	1.376	1.812	$t_{cal}<t_{tab}$, H_0 is accepted
2	Lakhantari Milan Chowk Road (05DR004)	4.445	1.833	$t_{cal}>t_{tab}$, H_1 is accepted
3	Belbari-Lokhara-Bhogateni-Aaitabare(Section 2) Road (05DR017B)	5.888	1.782	$t_{cal}>t_{tab}$, H_1 is accepted
4	Biratnagar-Dharambad- Buddanagar Road (05VR020)	5.185	1.894	$t_{cal}>t_{tab}$, H_1 is accepted
5	Lalvitti-Devijhoda-Kerabari Road (05VR020)	5.624	1.812	$t_{cal}>t_{tab}$, H_1 is accepted
6	Sikti- Bardanga Road (05VR087)	0.557	1.894	$t_{cal}<t_{tab}$, H_0 is accepted

Table 1 shows that the carriageways of the Kanepokhari-Letang-Warangi-6 No Budhabare Section-1 and Sikti-Bardanga Road are significantly below the standards set by NRRS 2055. In contrast, the other carriageways do not differ substantially from the standard, supporting the alternative Hypothesis.

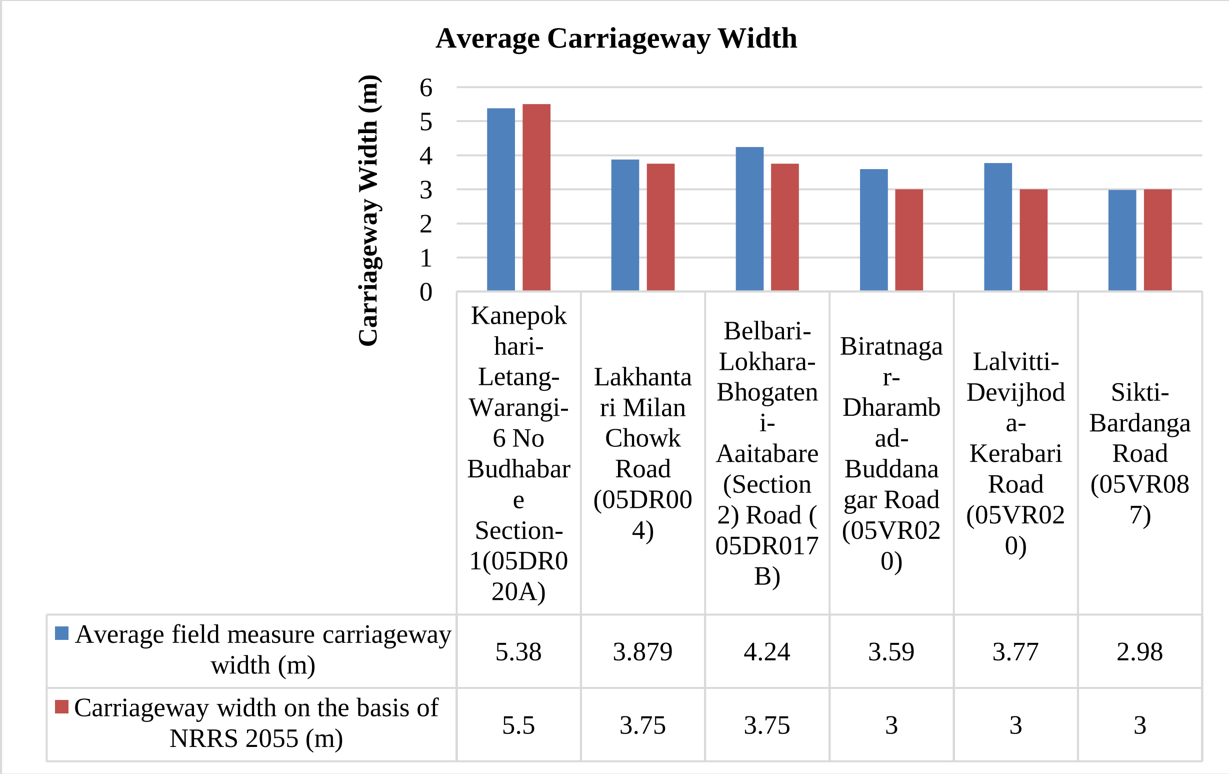

Figure 3: Average Carriageway width

Figure 3 illustrates that the average carriageway width of four roads, excluding the Kanepokhari-Letang-Warangi-6 No Budhabare Section 1 and Sikti-Bardanga roads, significantly exceeds the NRRS 2055 standard. This finding is corroborated by the hypothesis test results presented in Table 3.1. The average carriageway widths were measured at random intervals of 500 meters.

Shoulder Width

Shoulder widths on both sides are measured at the chainage where the carriageway width was recorded, and their significance is tested at a 5% level. To ensure compliance with shoulder width regulations, measurements are taken on both sides. The average width is then calculated and compared to the standards specified by NRRS.

Table 2: Result of T-test for Shoulder width

SN	Name of Road	Calculated value (t_{cal})	Tabulated value (t_{tab})	Result
1	Kanepokhari-Letang-Warangi-6 No Budhabare Section-1(05DR020A)	2.457	1.812	$t_{cal}>t_{tab}$, H_1 is accepted
2	Lakhantari Milan Chowk Road (05DR004)	2.832	1.833	$t_{cal}>t_{tab}$, H_1 is accepted
3	Belbari-Lokhara-Bhogateni-Aaitabare(Section 2) Road (05DR017B)	1.248	1.782	$t_{cal}<t_{tab}$, H_0 is accepted
4	Biratnagar-Dharambad- Buddanagar Road (05VR020)	0.246	1.894	$t_{cal}<t_{tab}$, H_0 is accepted
5	Lalvitti-Devijhoda-Kerabari Road (05VR020)	0.434	1.812	$t_{cal}<t_{tab}$, H_0 is accepted
6	Sikti- Bardanga Road (05VR087)	2.229	1.894	$t_{cal}>t_{tab}$, H_1 is accepted

For road types DRCN and VRCN, three roads—Biratnagar-Dharambad-Buddanagar, Lalvitti Devijhoda-Kerabari, and Belbari-Lakhantari-Milanchowk Road—show no discernible variation in shoulder widths from NRRS 2055. The remaining roads, however, do not adhere to the necessary shoulder width regulation.

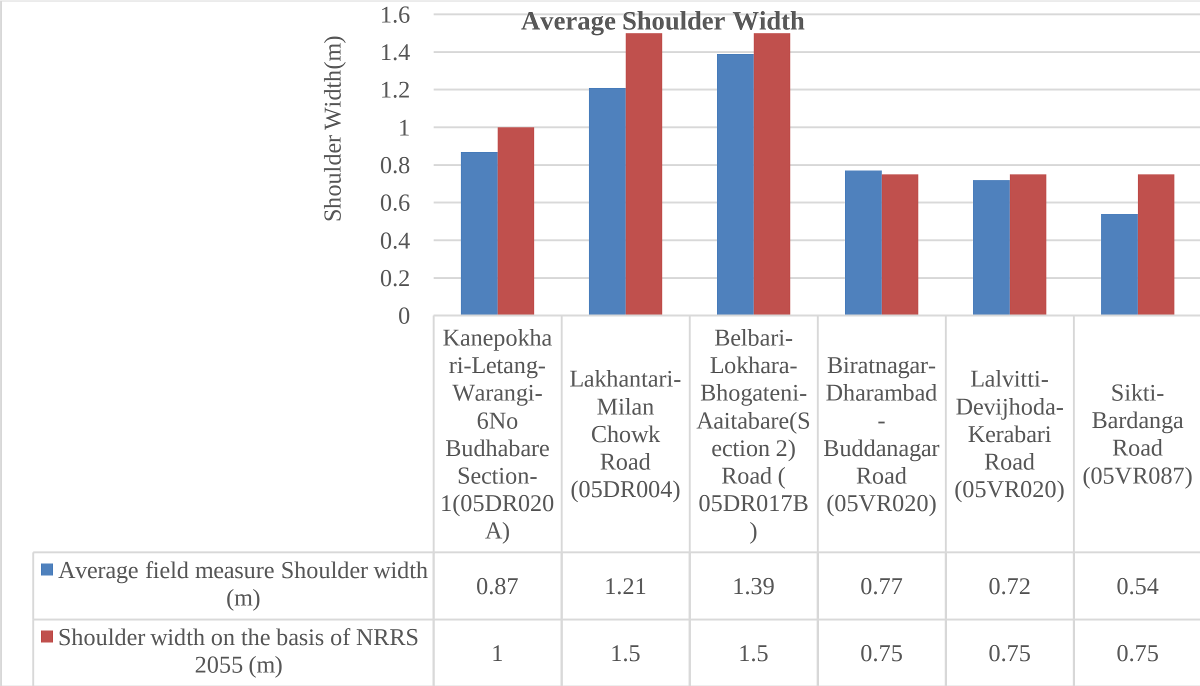

Figure 4: Average Shoulder Width

Only the Biratnagar-Dharambad-Buddanagar Road meets the NRRS standard shoulder width requirements, as indicated in Figure 4 above. The remaining five roads have slightly narrower shoulders than the prescribed norms.

Gradients

The significance of the road gradient is assessed through hypothesis testing with a 95% confidence level. Gradients are measured by calculating the elevation difference over 500-meter intervals of the road using a Level machine instrument with the fly levelling method.

Table 3: Result of T-test result for gradient

SN	Name of Road	Calculated value (t_{cal})	Tabulated value (t_{tab})	Result
1	Kanepokhari-Letang-Warangi-6 No Budhabare Section-1(05DR020A)	19.244	1.859	$t_{cal}>t_{tab}$, H_1 is accepted
2	Lakhantari Milan Chowk Road (05DR004)	41.810	1.894	$t_{cal}>t_{tab}$, H_1 is accepted
3	Belbari-Lokhara-Bhogateni-Aaitabare(Section 2) Road (05DR017B)	47.926	1.782	$t_{cal}>t_{tab}$, H_1 is accepted
4	Biratnagar-Dharambad- Buddanagar Road (05VR020)	85.499	1.894	$t_{cal}>t_{tab}$, H_1 is accepted
5	Lalvitti-Devijhoda-Kerabari Road (05VR020)	51.560	1.812	$t_{cal}>t_{tab}$, H_1 is accepted
6	Sikti- Bardanga Road (05VR087)	136.469	1.943	$t_{cal}>t_{tab}$, H_1 is accepted

According to NRRS 2055, the limiting gradient for rural roads is set at 7%. Upon reviewing Table 3 above, it is evident that all six roads exhibit gradients that are lower than the prescribed standard. As a result, there is no significant deviation in the gradient values. During the summer season, gradient drainage issues frequently occur, particularly on Tarai roads in Nepal.

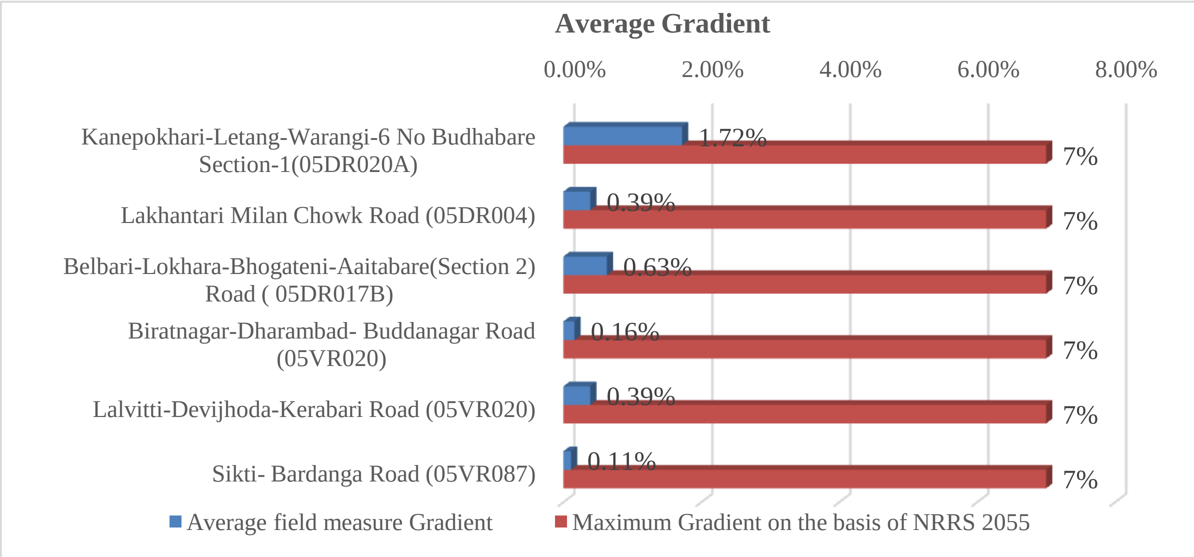

Figure 5: Average Gradient

All six roads have gradients below the standard value of 7%. These roads are situated in the Tarai region of Morang district. However, the Kanepokhari-Letang-Warangi-6 No Budhabare Section 1 Road starts from the Tarai and ascends towards the northern part of Morang district, beginning at the base of a hill with a gradient of 1.72%, as depicted in Figure 5 above.

Sight distance

The T-test is used to evaluate whether sight distances meet compliance standards at a 5% level of significance. Sight distances are measured along curves using vehicle velocities, with specified minimums such as 40 km/h for DRCN and 30 km/h for VRCN on Tarai roads.

Table 4: Result of T-test for SSD

SN	Name of Road	Calculated value (t_{cal})	Tabulated value (t_{tab})	Result
1	Kanepokhari-Letang-Warangi-6 No Budhabare Section-1(05DR020A)	6.998	1.894	$t_{cal}>t_{tab}$, H_1 is accepted
2	Lakhantari Milan Chowk Road (05DR004)	3.101	1.859	$t_{cal}>t_{tab}$, H_1 is accepted
3	Belbari-Lokhara-Bhogateni-Aaitabare(Section 2) Road (05DR017B)	4.882	1.795	$t_{cal}>t_{tab}$, H_1 is accepted
4	Biratnagar-Dharambad- Buddanagar Road (05VR020)	7.533	1.859	$t_{cal}>t_{tab}$, H_1 is accepted
5	Lalvitti-Devijhoda-Kerabari Road (05VR020)	5.736	1.812	$t_{cal}>t_{tab}$, H_1 is accepted
6	Sikti- Bardanga Road (05VR087)	5.913	1.894	$t_{cal}>t_{tab}$, H_1 is accepted

Table 4 demonstrates that for all sampled DRCN and VRCN roads, the average sight distance exceeds the minimal value of requirements in which the specified SSD for DRCN is 45 m and for VRCN is 30 m.

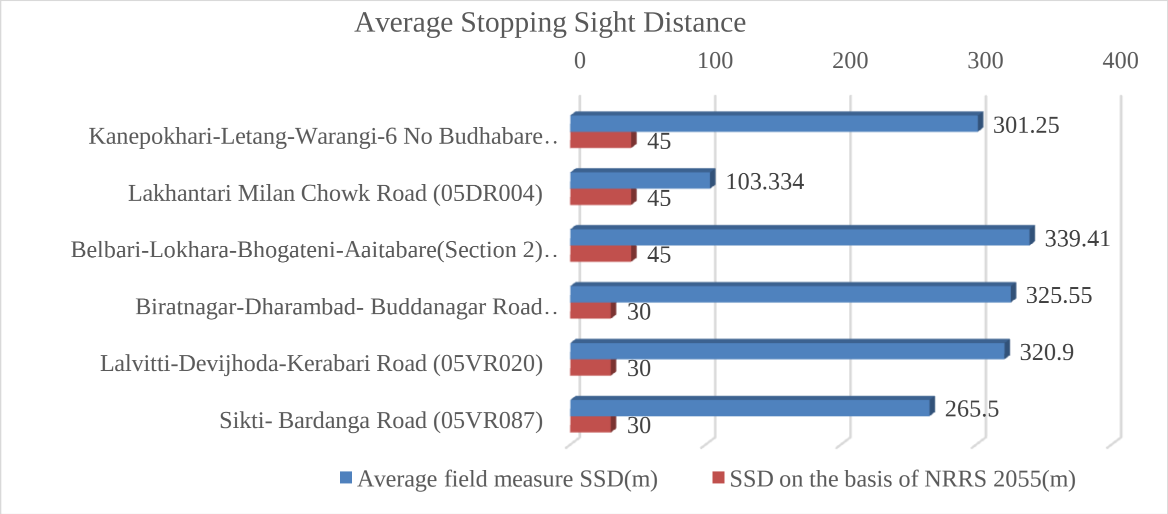

Figure 6: Average SSD

As seen graphically in Figure 6, every road in the Tarai area has stopping sight distances (SSD) that are far above the guidelines established by the Nepal Rural Road Standards (NRRS).

Horizontal curve radius

At a 95% confidence level, the T-test hypothesis endeavors to establish whether the lowest horizontal radius of the curve observed at the road bend in the actual field meets the requisite standards.

Table 5: Result of T-test for horizontal curve

SN	Name of Road	Calculated value (t_{cal})	Tabulated value (t_{tab})	Result
1	Kanepokhari-Letang-Warangi-6 No Budhabare Section-1(05DR020A)	3.066	1.894	$t_{cal}>t_{tab}$, H_1 is accepted
2	Lakhantari Milan Chowk Road (05DR004)	2.272	1.895	$t_{cal}>t_{tab}$, H_1 is accepted
3	Belbari-Lokhara-Bhogateni-Aaitabare(Section 2) Road (05DR017B)	4.430	1.795	$t_{cal}>t_{tab}$, H_1 is accepted
4	Biratnagar-Dharambad- Buddanagar Road (05VR020)	8.718	1.859	$t_{cal}>t_{tab}$, H_1 is accepted
5	Lalvitti-Devijhoda-Kerabari Road (05VR020)	2.831	1.812	$t_{cal}>t_{tab}$, H_1 is accepted
6	Sikti- Bardanga Road (05VR087)	2.982	1.894	$t_{cal}>t_{tab}$, H_1 is accepted

The above table 5 shows the minimum radius of curve is higher value than the standard provided by NRRS for all six sampled road, i.e. There is no significant different between design parameters and field measurement.

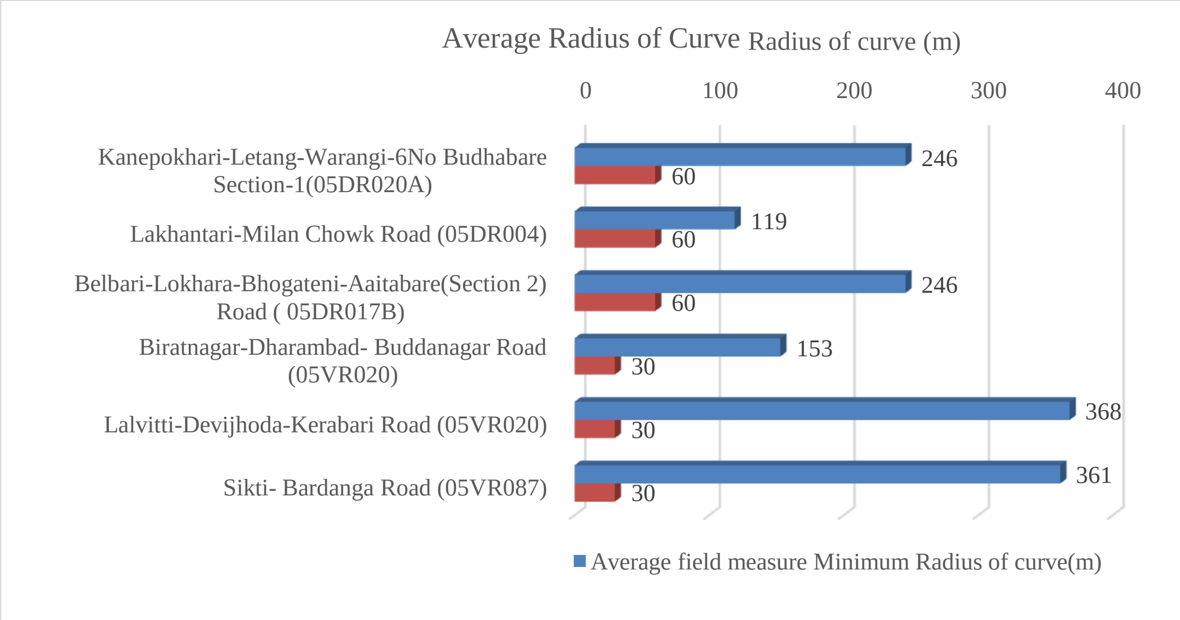

Figure 7: Average Radius of the curve

All of the examined roadways have minimum DRCN and VRCN radiuses of 60 and 30 meters, respectively.

Extra widening

During the field measurement, none of the six routes provide any further widening. As a result, no test is performed to ascertain if the additional widening complies, even though curves with radii of more than 60 m do not require widening under NRRS, but curves with radii of 21 to 60 m do require 0.6 m of widening.

Table 6: Field Measurement sheet of extra widening

SN	Name of Road	Minimum Radius of curve (m)	Average field measure extra widening (m)	Minimum extra widening of curve based on NRRS 2055 (m)
1	Kanepokhari-Letang-Warangi-6 No Budhabare Section-1(05DR020A)	60	0	0
2	Lakhantari Milan Chowk Road (05DR004)	60	0	0
3	Belbari-Lokhara-Bhogateni-Aaitabare(Section 2) Road (05DR017B)	60	0	0
4	Biratnagar-Dharambad-Buddanagar Road (05VR020)	30	0	0.6
5	Lalvitti-Devijhoda-Kerabari Road (05VR020)	30	0	0.6
6	Sikti- Bardanga Road (05VR087)	30	0	0.6

Based on Table 6, no road sample received any additional widening during the measurement of the inserted curve using the linear measurement method.

Conclusions

This study's result emphasizes how crucial it is to maintain adherence to geometrical characteristics of roadways to improve overall road safety and transit effectiveness. It is clear from a thorough examination of several geometrical characteristics, including Carriageway, Shoulder width, Gradient, Sight Distance, Radius of curve, and Extra widening, that rigorous adherence to set rules and norms considerably lowers the likelihood of accidents and enhances traffic flow. Road authorities may reduce risks, ease traffic, and even save lives by identifying non-compliance locations and conducting focused actions. To further improve road geometry and ensure the development of safer and more sustainable transportation networks for all road users, ongoing research and proactive initiatives are necessary. Based on field observations and measurements conducted at random chainages on various sampled rural roads, the following conclusions have been drawn:

- Considering the categorization of the rural roads, the average carriageway width of the DRCN road Kanepokhari-Letang-Warangi-6 No Budhabare Section-1 (05DR020A) and the VRCN road Sikti-Bardanga Road (05VR087) is 5.38 m and 2.98 m respectively. These widths are below the minimum values specified by the Nepal Rural Road Standards (NRRS), which are 5.5 m for DRCN roads and 3 m for VRCN roads. However, the other sampled roads are in acceptable condition according to the NRRS standards.
- The Biratnagar-Dharambad-Buddanagar (05VR020) VRCN road has an average shoulder width of 0.77 m, which is deemed suitable by the Nepal Rural Road Standards (NRRS) however the other shoulder widths are deemed insufficient.
- The radius of the curve, SSD, and gradient that was provided during construction meets the requirements of Nepal Rural Roads Standards.
- No additional road widening has been implemented or planned for any road sections.

Acknowledgement

All those individuals and organizations whose efforts were essential to the accomplishment of our study are deeply appreciated.

Competing Interests Disclaimer

In assessing rural road geometry for compliance, it is important to acknowledge that different stakeholders may have conflicting interests or objectives. These interests might include community needs, environmental concerns raised by conservation organizations, or financial advantages for building corporations. We guarantee transparency and integrity in our research by mentioning these possible conflicts of interest. This allows readers to think about the perspectives and possible impacts of various stakeholders on the study's findings.

Data Availability

The primary author has reasonable access to the data supporting the study's conclusions.

References

Acharya, K. K. (2018). Local Governance Restructuring in Nepal: From Government to Governmentality. In *Dhaulagiri Journal of Sociology and Anthropology* (Vol. 12).

Acharya, K. K., & Scott, J. (2022). A study of the capabilities and limitations of local governments in providing community services in Nepal. *Public Administration and Policy*, 25(1), 64–77. doi: 10.1108/PAP-01-2022-0006

Afolayan, A., Abiola Samson, O., Easa, S., Modupe Alayaki, F., & Folorunso, O. (2022). Reliability-based analysis of highway geometric Elements: A systematic review. In *Cogent Engineering* (Vol. 9, Issue 1). Cogent OA. doi: 10.1080/23311916.2021.2004672

Al-kassab, M. (2022). The Use of One Sample t-Test in the Real Data. *Journal of Advances in Mathematics*, 21(September), 134–138. doi: 10.24297/jam.v21i.9279

Aryal, T. R., Ichihashi, M., & Kaneko, S. (2022). How strong is demand for public transport service in Nepal? A case study of Kathmandu using a choice-based conjoint experiment. *Journal of Economic Structures*, 11(1). doi: 10.1186/s40008-022-00287-3

Banjara, B. P., & Gautam, G. (2023). A Case Study on the Effect of Geometric Design Consistency on Road Crashes on Narayanghat-Muglin Road Section. *SCITECH Nepal*, 17(1), 58–63. doi: 10.3126/scitech.v17i1.60469

Baobeid, A., Koç, M., & Al-Ghamdi, S. G. (2021). Walkability and Its Relationships With Health, Sustainability, and Livability: Elements of Physical Environment and Evaluation Frameworks. In *Frontiers in Built Environment* (Vol. 7). Frontiers Media S.A. doi: 10.3389/fbuil.2021.721218

Bhandari, S. B. (2013). Overview of Rural Roads. *Journal of Rural Infrastructure Society of Engineers' for Rural Development*, Nepal (SERDeN), 4(4), 88–92.

Dell'Acqua, G., & Russo, F. (2011). Road performance evaluation using geometric consistency and pavement distress data. *Transportation Research Record*, 2203, 194–202. doi: 10.3141/2203-24

DoLIDAR. (2014). *Nepal rural road standards* (p. 42).

Gasparin, M. (2018). Role of designers in developing new products: an innovation turn in transformational economies. In *Journal of Asian Business and Economic Studies* (Vol. 25, Issue 2, pp. 206–220). Emerald Publishing. doi: 10.1108/JABES-10-2018-0065

Jacob, A., Dhanya, R., & Anjaneyulu, M. V. L. R. (2013). Geometric Design Consistency of Multiple Horizontal Curves on Two-lane Rural Highways. Procedia - Social and Behavioral Sciences, 104, 1068–1077. doi: 10.1016/j.sbspro.2013.11.202

Jurewicz, C., Aumann, P., Bradshaw, C., Beesley, R., & Lim, A. (2015). Road geometry study for improved rural safety (Issue June). doi: 10.13140/RG.2.1.4144.3605

Kaiser, N., & Barstow, C. K. (2022). Rural Transportation Infrastructure in Low-and Middle-Income Countries: A Review of Impacts, Implications, and Interventions. In *Sustainability* (Switzerland) (Vol. 14, Issue 4). MDPI. doi: 10.3390/su14042149

Kampf, R., Gašparík, J., & Kudláčková, N. (2012). Application of different forms of transport in relation to the process of transport user value creation. *Periodica Polytechnica Transportation Engineering*, 40(2), 71–75. doi: 10.3311/pp.tr.2012-2.05

Li, P., & He, J. (2016). Geometric design safety estimation based on tire-road side friction. Transportation Research Part C: *Emerging Technologies*, 63, 114–125. doi: 10.1016/j.trc.2015.12.009

Ng, C. P., Law, T. H., Jakarni, F. M., & Kulanthayan, S. (2019). Road infrastructure development and economic growth. *IOP Conference Series: Materials Science and Engineering*, 512(1). doi: 10.1088/1757-899X/512/1/012045

Nimitha, P., Fahad, M., Ahmed, M. A. D., Sindhu, C., & Mounika., G. (2017). Design of Highway Alignment. *IOSR Journal of Mechanical and Civil Engineering*, 14(03), 01–11. doi: 10.9790/1684-1403060111

Pant, P. R., Rana, P., Pradhan, K., Joshi, S. K., & Mytton, J. (2022). Identifying research priorities for road safety in Nepal: A Delphi study. BMJ Open, 12(4). doi: 10.1136/bmjopen-2021-059312

Pokharel, R., & Acharya, S. R. (2015). Sustainable Transport Development in Nepal: Challenges, Opportunities and Strategies. In *Journal of the Eastern Asia Society for Transportation Studies* (Vol. 11). Retrieved from https://www.researchgate.net/publication/304734740

Qureshi, K. N., & Abdullah, A. H. (2013). A survey on intelligent transportation systems. *Middle East Journal of Scientific Research*, 15(5), 629–642. doi: 10.5829/idosi.mejsr.2013.15.5.11215

Shaffer, J. P. (1995). *Multipl e hypothesis testing.*

Singh, B., & Gupta, A. (2015). Recent trends in intelligent transportation systems: a review. *Journal of Transport Literature*, 9(2), 30–34. doi: 10.1590/2238-1031.jtl.v9n2a6

Šoštaric, M., Ševrovic, M., Jakovljevic, M., & Švajda, M. (2022). Sustainability of public transport in rural areas - Case study city of Jastrebarsko. *Transportation Research Procedia*, 64(C), 372–377. doi: 10.1016/j.trpro.2022.09.044

Sudmeier-Rieux, K., McAdoo, B. G., Devkota, S., Chandra Lal Rajbhandari, P., Howell, J., & Sharma, S. (2019). Invited perspectives: Mountain roads in Nepal at a new crossroads. *Natural Hazards and Earth System Sciences*, 19(3), 655–660. doi: 10.5194/nhess-19-655-2019

Tougwa, F. N. (2021). A Review of Highways Geometric Design to Ensure Road Health and Safety. In *International Journal of Scientific Engineering and Science* (Vol. 5, Issue 8). Retrieved from http://ijses.com/

Zulkarnain, & Putri, T. D. (2021). Intelligent transportation systems (ITS): A systematic review using a Natural Language Processing (NLP) approach. Heliyon, 7(12). doi: 10.1016/j.heliyon.2021.e08615