Application and Preliminary Assessment of an Adapted Infrastructure Risk Rating Model on an Urban Road Corridor in Kathmandu, Nepal: A Case Study of the Koteshwor–Kalanki Road Section

Srijan Subedi Chowi[1], Aakansha Thapa[2], Bikas Prasad Yadav[3], Manish Sharma[4], Manisha Shrestha[5], Monika Upadhyay[6]

[1] *Senior Lecturer, Department of Civil Engineering, Kantipur Engineering College, Dhapakhel, Lalitpur, Nepal*

[2,3,4,5,6] *Department of Civil Engineering, Kantipur Engineering College, Dhapakhel, Lalitpur, Nepal*

doi.org/10.64643/IJIRTV13I3-207860-459

***Abstract*—Road-safety assessment in Nepal has largely relied on historical crash information, which is reactive because interventions are generally prioritized after crashes have accumulated. This study examines the application of an adapted Infrastructure Risk Rating (IRR) framework to an urban road corridor in Kathmandu and compares its within-corridor ranking with historical crash indicators. The approximately 9.5 km Koteshwor–Kalanki corridor was represented by six selected homogeneous sections covering 7.87 km in total. Field observations, GPS measurements, photographic documentation, aerial imagery and official crash records were used to assess road stereotype, alignment, carriageway width, roadside hazards, land use, intersection density and access density. In the corrected calculation, the traffic-volume term was assigned a neutral value of 1.00 for all six urban sections because traffic volume was not included as a differentiating input in the applied urban procedure. IRR scores ranged from 1.23 to 1.63, with Koteshwor–Gwarko ranked first. Historical crash records for fiscal years 2077/78 to 2080/81 were summarized using a study-specific Severity Weighted Index (SWI), Average annual Accident Frequency Index (AFI), and Accident Density Index (ADI). IRR showed complete rank agreement with SWI and AFI in the six-section sample, while ADI produced a different middle-order ranking because it normalizes crash frequency by section length. The results provide preliminary evidence for the screening value of an adapted IRR framework, but they do not constitute full predictive validation or Nepal-wide calibration.**

***Index Terms*—Infrastructure Risk Rating, Road Safety, Kathmandu Ring Road, Koteshwor–Kalanki, Roadside Hazards, Severity Weighted Index, Accident Frequency Index, Accident Density Index**

I. INTRODUCTION

Road infrastructure is a fundamental component of urban mobility, economic activity and access to essential services. However, safety performance can deteriorate when geometric characteristics, roadside hazards, access conditions, land use and traffic activity interact under high exposure. Pilot studies have identified narrow carriageways and shoulders, roadside hazards, pedestrian activity, access points and mixed urban land uses as important road-safety concerns along the Koteshwor–Kalanki corridor. Official crash records also indicate substantial crash occurrence within the investigated sections.

Road-safety management can be approached through reactive and proactive methods. Reactive approaches depend on an established crash history to identify locations requiring treatment. Proactive approaches instead assess road and roadside conditions that may create risk before a substantial crash history is established. Infrastructure Risk Rating (IRR) was selected in the source study as a proactive method because it combines infrastructure and surrounding land-use characteristics rather than relying exclusively on historical crashes [1].

Infrastructure-based risk-rating approaches have been applied in Australia and New Zealand and have been used to identify high-risk road environments and support prioritization of safety investments [1, 2, 3]. Previous road-safety studies in Nepal have also emphasized systematic identification and ranking of hazardous locations [13]. However, application and local calibration of IRR in Nepalese urban environments remain limited. The present study therefore examines the feasibility of applying the IRR framework to the Koteshwor–Kalanki corridor and assesses whether its ranking is consistent with historical crash indicators.

1.1 Research Problem

The research problem is whether an infrastructure-based risk score can identify the same broad priority sections indicated by historical crash records while providing a proactive basis for infrastructure improvement.

1.2 Research Questions

- Which road and roadside infrastructure characteristics contribute most visibly to infrastructure-related risk along the Koteshwor–Kalanki corridor?
- Can the IRR framework be applied consistently to homogeneous sections of this urban corridor?
- Do sections with higher IRR scores also show higher historical crash severity, frequency and density?
- Which infrastructure deficiencies should receive priority for road-safety improvement?

1.3 Objectives

- To identify major road and roadside infrastructure characteristics associated with infrastructure risk.
- To apply the IRR scoring framework to six selected sections of the Koteshwor–Kalanki corridor.
- To compare IRR rankings with SWI, AFI and ADI derived from four years of official crash records.
- To examine the robustness of the SWI ranking under alternative severity-weighting assumptions.
- To identify infrastructure deficiencies and practical safety interventions for priority sections.

II. LITERATURE REVIEW

2.1 Road Safety and Proactive Risk Assessment

Reactive safety management responds to locations with established crash histories, whereas proactive assessment seeks to identify hazardous infrastructure and operating conditions before severe crash patterns accumulate. Road-safety assessment can therefore benefit from complementary use of historical crash information and infrastructure-based screening [5, 8, 9].

2.2 Infrastructure Risk Rating

IRR is an infrastructure-based road-safety assessment approach that evaluates road and roadside characteristics independently of crash history. The eight attributes applied in this study are road stereotype, alignment, carriageway width, roadside hazard, land use, intersection density, access density and traffic volume [1]. The approach is particularly relevant where road authorities need to screen infrastructure conditions and prioritize safety improvements.

2.3 Crash-Based Indicators and Severity Weighting

Crash frequency and density describe observed historical crash burden but do not provide equal influence to crashes of different severity. A severity-weighted measure can therefore be used to distinguish sections with greater serious-crash burden. However, severity weights are methodological choices rather than universal constants. Accordingly, the present study treats the 10–5–3–1 weights as a study-specific baseline and recommends sensitivity testing rather than claiming that the weighting is uniquely correct.

2.4 Research Gap

The principal research gap is the limited application and testing of infrastructure risk-rating methods in dense Nepalese urban road environments. Kathmandu roads combine mixed traffic, intensive roadside activity, frequent accesses, pedestrian movement, drainage structures, narrow shoulders and other hazards. The study therefore examines an adapted IRR application and its consistency with historical crash indicators on a major Kathmandu corridor.

III. RESEARCH METHODOLOGY

3.1 Study Area and Section Selection

The study corridor extends from Koteshwor to Kalanki on the Kathmandu Ring Road in Kathmandu District, Bagmati Province, Nepal. The corridor is approximately 9.5 km long. Six selected homogeneous sections were used for detailed section-level analysis. Their combined length is 7.87 km; therefore, the excluded corridor portions are not represented in the section-level ranking.

Table 1: Homogeneous Road Sections Included in the Analysis

Section	Road Section	Length (km)
1	Koteshwor–Gwarko	1.40
2	Satdobato Swimming Pool–Fort 270	1.60
3	Fort 270–Nakhu Dobato	1.60
4	Nakhu Dobato–Balkhu Bridge	0.97
5	Balkhu Bridge–Advanced College	1.20
6	Advanced College–Kalanki	1.10

3.2 Data Collection

Primary data were collected through systematic field surveys. Road characteristics, roadside hazards, access points, intersections, pedestrian facilities, barriers and other relevant infrastructure conditions were recorded using field forms, GPS measurements and photographic documentation. Aerial imagery and available road information were used to support section identification and interpretation. Secondary data consisted principally of official crash records for fiscal years 2077/78 to 2080/81.

Table 2: Infrastructure Risk Rating Attributes Used in the Study

IRR Attribute	Risk Aspect Assessed
Road stereotype	Road configuration and median characteristics
Alignment	Degree of horizontal curvature and road tortuosity
Carriageway width	Lane and sealed-shoulder width
Roadside hazard	Hazards on both sides of the carriageway
Land use	Commercial, residential and surrounding activity
Intersection density	Number of intersections per kilometre
Access density	Number of accesses per kilometre
Traffic volume	Traffic exposure where applicable

3.3 Infrastructure Risk Rating Procedure

Each homogeneous road section was assigned risk scores for the eight IRR attributes. The overall IRR score was calculated using the logarithmic formulation reproduced from the project implementation [1].

$$\text{IRR Score} = \log_{10}[RSRS \times RSA \times RSCW \times ((RSLRH + RSRRH) \div 2) \times RSLU \times RSID \times RSAD \times RSTV] \quad (1)$$

where RSRS is the road stereotype risk score, RSA is the alignment risk score, RSCW is the carriageway-width risk score, RSLRH and RSRRH are the left- and right-side roadside-hazard scores, RSLU is the land-use risk score, RSID is the intersection-density risk score, RSAD is the access-density risk score, and RSTV is the traffic-volume risk score. For the corrected urban calculation, RSTV was set to 1.00 for all six sections because traffic volume was treated as a neutral/non-differentiating input in the applied urban procedure. The urban risk bands used were High above 2.22, Medium-High from 2.02 to 2.22, Medium from 1.76 to 2.02, Low-Medium from 1.49 to 1.76, and Low below 1.49.

Table 3: IRR Component Scores Used in the Corrected Calculation

Section	RSRS	RSA	RSCW	Left Hazard	Right Hazard	Land Use	Intersection	Access	Traffic
Koteshwor–Gwarko	1.00	1.50	2.01	2.80	2.80	5.00	1.00	1.06	1.00
Satdobato–Fort 270	1.00	1.00	2.01	2.80	2.80	5.00	1.15	1.03	1.00
Fort 270–Nakhu	1.00	1.00	2.01	2.80	2.80	3.00	1.15	1.06	1.00
Nakhu–Balkhu	1.00	1.00	2.01	2.80	2.80	3.00	1.00	1.10	1.00
Balkhu–Advanced College	1.00	1.00	2.01	2.80	2.28	3.00	1.00	1.10	1.00
Advanced College–Kalanki	1.00	1.00	2.01	2.80	2.80	3.00	1.00	1.03	1.00

3.4 Crash-Based Comparative Indicators

Three descriptive crash indicators were used. They are not independent validation datasets because all are derived from the same historical crash records.

$$SWI = \Sigma(10F + 5S + 3M + 1I)t \quad (2)$$

where F, S, M and I represent fatal, severe, moderate and minor crash counts, respectively, as defined in the verified police dataset.The weights 10, 5, 3 and 1 are retained as study-specific baseline severity weights.

$$AFI = \Sigma Nt \div T \quad (3)$$

where Nt is the total number of crashes in year t and T is the number of study years.

$$ADI = \Sigma Nt \div (T \times L) = AFI \div L \quad (4)$$

where L is section length in kilometres. ADI therefore represents observed annual crash density per kilometre and should not be interpreted as an exposure-normalized crash rate per vehicle-kilometre.

3.5 Severity-Weighting Sensitivity

Because severity weights can influence the magnitude and ranking of SWI, the 10–5–3–1 baseline should be compared with alternative monotonic schemes such as 6–3–1–1 and 5–3–2–1. These alternatives are treated as robustness tests rather than universal standards. The purpose is to determine whether the section ranking is sensitive to the chosen severity assumptions.

3.6 GIS and Comparative Analysis

GIS was used to visualize the spatial distribution of the investigated road sections and their rankings. IRR, SWI, AFI and ADI were ranked from highest to lowest and compared descriptively. Spearman rank correlation may be reported as an exploratory statistic because the sample contains only six sections; it is not treated as population-level predictive validation.

IV. RESULTS AND DISCUSSION

4.1 Corrected IRR Results

Table 4: Corrected IRR Scores and Risk Ranking

Rank	Road Section	IRR Score	Urban Risk Band
1	Koteshwor–Gwarko	1.63	Low-Medium
2	Satdobato Swimming	1.50	Low-Medium

	Pool–Fort 270		
3	Fort 270–Nakhu Dobato	1.31	Low
4	Nakhu Dobato–Balkhu Bridge	1.27	Low
5	Advanced College–Kalanki	1.24	Low
6	Balkhu Bridge–Advanced College	1.23	Low

The corrected IRR scores range from 1.23 to 1.63. Koteshwor–Gwarko has the highest score and remains within the Low-Medium band. Satdobato Swimming Pool–Fort 270 is the second-ranked section and is also within the Low-Medium band. The remaining four sections fall within the Low band. The corrected Koteshwor–Gwarko value is approximately 1.63 because RSTV is consistently set to 1.00 rather than using the earlier inconsistent value of 1.06.

4.2 Major Infrastructure Hazards

Field observations identified roadside hazards as an important contributor to the risk scores. Recurrent deficiencies included open deep drainage ditches, missing or damaged barriers, non-frangible poles and trees, vertical cliffs or steep roadside slopes, missing or obstructed footpaths, narrow carriageways and shoulders, and inadequate bus lay-bys. These conditions are important because IRR combines several infrastructure characteristics rather than assessing isolated hazards.

Table 5: Major Infrastructure Deficiencies and Priority Interventions

Observed Deficiency	Related Risk Attribute	Priority Intervention
Open or deep drainage	Roadside hazard	Cover or protect hazards and improve drainage safety
Vertical slope or cliff	Roadside hazard	Install appropriate protective barriers
Non-frangible roadside objects	Roadside hazard	Relocate, shield or replace where feasible
Narrow carriageway or shoulder	Carriageway width	Improve width or shoulder where feasible
Incomplete or obstructed footpath	Land use / roadside environment	Improve pedestrian continuity and accessibility
Frequent roadside accesses	Access density	Consolidate and manage access points
Unsafe bus stopping	Roadside / operational condition	Provide appropriately located bus stopping facilities

4.3 Crash Indicators

Table 6: Crash-Based Comparative Indicators

Rank by SWI/AFI	Road Section	SWI	AFI (crashes/year)	Length (km)	ADI (crashes/km/year)
1	Koteshwor–Gwarko	5460	577.75	1.40	412.68
2	Satdobato–Fort 270	1320	134.25	1.60	83.91

3	Fort 270–Nakhu Dobato	1080	109.75	1.60	68.59
4	Nakhu Dobato–Balkhu Bridge	1035	108.75	0.97	112.11
5	Advanced College–Kalanki	905	90.50	1.10	82.27
6	Balkhu Bridge–Advanced College	700	68.75	1.20	57.29

Koteshwor–Gwarko ranks first for SWI and AFI and therefore has the greatest observed severity-weighted crash burden and annual crash frequency among the six sections. ADI changes the middle-order ranking because it divides annual crash frequency by section length. The very high ADI for Koteshwor–Gwarko reflects both its high annual crash frequency and its relatively short section length.

4.4 Relationship Between IRR and Crash Indicators

Table 7: Comparative Ranking of IRR and Crash Indicators

Road Section	IRR Rank	SWI Rank	AFI Rank	ADI Rank
Koteshwor–Gwarko	1	1	1	1
Satdobato–Fort 270	2	2	2	3
Fort 270–Nakhu Dobato	3	3	3	5
Nakhu Dobato–Balkhu Bridge	4	4	4	2
Advanced College–Kalanki	5	5	5	4
Balkhu Bridge–Advanced College	6	6	6	6

The IRR ranking exactly matches the SWI and AFI ranking sequences in the six-section dataset. ADI produces a different middle-order arrangement because it normalizes annual crash frequency by section length. This agreement should be interpreted as preliminary within-corridor consistency rather than formal predictive validation. The crash indicators are all derived from the same historical crash dataset, and the sample contains only six sections.

The agreement also does not establish that infrastructure conditions are the sole causes of crashes. Driver behaviour, traffic exposure, vehicle mix, enforcement, speed, pedestrian activity and crash-reporting practices can influence observed crash outcomes. In addition, the four-year period includes years potentially affected by changes in mobility associated with Gwarko Overpass construction.

4.5 Sensitivity of Severity Weighting

The 10–5–3–1 weighting provides a transparent severity hierarchy, but it should not be described as an internationally established or uniquely correct weighting. Alternative monotonic weighting schemes should be used to determine whether the relative ordering of the six sections changes. If the highest-ranked sections remain stable across reasonable alternatives, the interpretation of the SWI comparison is strengthened. The verified police definition of the fatal-crash category permits this sensitivity analysis to be performed on a consistent crash-event basis.

V. RECOMMENDATIONS

- Priority should be given to treatment of open deep roadside and median drainage ditches, particularly where vehicles or pedestrians could enter the hazard.
- Safety barriers should be repaired or installed at locations with vertical cliffs, steep slopes, exposed roadside hazards and other non-frangible objects.
- Footpaths and pedestrian facilities should be improved, particularly in commercial and residential areas and near bus stops.
- Appropriately designed bus stopping facilities should be provided so that buses do not stop directly on the through carriageway where avoidable.
- Narrow carriageways and shoulders should be improved where physical and right-of-way conditions permit, with priority given to high-risk sections.
- Unauthorized or closely spaced roadside accesses should be controlled and intersection/access management improved in active urban areas.
- Road markings, signs, pedestrian crossings and other traffic-control devices should be maintained, particularly near intersections and curves.
- Speed management, parking enforcement and monitoring of heavy vehicles should be strengthened in congested and high-risk areas.
- IRR assessments should be repeated periodically and combined with updated crash records, traffic conditions and behavioural observations.
- Before wider application in Nepal, the IRR framework should be locally calibrated using a larger multi-corridor dataset and additional variables such as drainage, terrain, pavement condition and operational factors.

VI. LIMITATIONS AND FUTURE RESEARCH

- The analytical sample contains only six homogeneous road sections from one corridor.
- The six sections cover 7.87 km of a corridor described as approximately 9.5 km; excluded portions are not represented in the section-level ranking.
- Consistent historical traffic exposure was unavailable; therefore AFI and ADI describe observed crash burden rather than exposure-normalized crash risk.
- The 10–5–3–1 SWI weighting is study-specific and requires sensitivity analysis rather than being treated as a universal standard.
- The study period may include ongoing construction of an overpass at Gwarko Intersection-related changes in mobility and exposure.
- The IRR framework has not been locally calibrated for Nepal, and the adopted risk bands should therefore be interpreted as source-method thresholds rather than Nepal-specific calibrated thresholds.
- The applied model does not explicitly represent every potentially important factor, including driver behaviour, enforcement, detailed pavement condition and some drainage or terrain variables.

Future research should extend the analysis to multiple Kathmandu Valley and interurban corridors, collect consistent traffic-exposure measures such as AADT where appropriate, establish a standardized Nepal-specific IRR coding protocol, assess inter-rater coding reliability, test attribute-level sensitivity and calibrate IRR against crash exposure using a substantially larger number of homogeneous sections.

VII. CONCLUSION

The study examined the application of an adapted Infrastructure Risk Rating framework to six selected homogeneous sections of the Koteshwor–Kalanki urban corridor. The IRR scores range from 1.23 to 1.63, with Koteshwor–Gwarko ranked first and Satdobato Swimming Pool–Fort 270 ranked second.

The crash comparison shows complete rank agreement between IRR and both SWI and AFI in the six-section dataset, while ADI produces a different middle-order arrangement because section length is incorporated into the measure. The result supports the preliminary screening value of IRR in the investigated corridor, but it should not be interpreted as proof of predictive validity or as Nepal-wide calibration.

The most important infrastructure deficiencies include roadside drainage hazards, inadequate barriers, non-frangible roadside objects, narrow carriageways and shoulders, pedestrian-facility deficiencies, frequent accesses and unsafe bus stopping conditions. These conditions provide practical targets for safety improvement.

The study therefore supports continued investigation of IRR as a proactive infrastructure-screening tool in Nepal while emphasizing that wider application requires local calibration, consistent traffic-exposure data, larger samples and sensitivity testing of methodological assumptions.

VIII. ACKNOWLEDGEMENT

The authors acknowledge Kantipur Engineering College, the Department of Civil Engineering, the Department of Roads, Nepal Police and other concerned authorities for support and access to data and information used in the study. The authors also acknowledge the field-survey team and individuals who assisted with data collection and documentation.

IX. AUTHORS' BIOGRAPHY

Srijan Subedi Chowi is a Senior Lecturer in the Department of Civil Engineering, Kantipur Engineering College, Dhapakhel, Lalitpur, Nepal.

Aakansha Thapa, Bikas Prasad Yadav, Manish Sharma, Manisha Shrestha and Monika Upadhyay were undergraduate students in the Department of Civil Engineering, Kantipur Engineering College, Dhapakhel, Lalitpur, Nepal, at the time of the study.

REFERENCES

[1] Zia H., Anderson W., Infrastructure Risk Rating Manual for Australian Roads, Austroads, Sydney, Australia, 2019.

[2] Arris Z., Durden P., Harris D., Automated Process of Identifying High-Risk Roads for Speed Management Intervention, Journal of the Australasian College of Road Safety, 2016.

[3] Chhanabhai V., Beer K., Johnsen M., Calibrating Infrastructure Risk Rating for Victoria Road, Safe System Solutions Private Limited, Perth, Australia, 2017.

[4] Noman et al., Risk Management and Construction, Blackwell Scientific, Oxford, England, 1993.

[5] Department of Roads, Road Safety Audit Manual: Road Safety Note 4, Department of Roads, 1997.

[6] The Kathmandu Post, Nepal’s Unsafe Roads, The Kathmandu Post, May 18, 2024. https://www.kathmandupost.com

[7] Bryden J.E., Andrew L.B., Fortuniewicz J.S., Work-Zone Traffic Accidents Involving Traffic Control Devices, Safety Features, and Construction Operations, Transportation Research Record: Journal of the Transportation Research Board, 1998, 1650, 71–81.

[8] Traffic Engineering and Safety Unit, Department of Roads, Road Safety Audit Manual, Kathmandu, 2053.

[9] World Health Organization, Global Status Report on Road Safety, World Health Organization, 2018.

[10] Paudyal D.P., Access Improvement and Sustainable Development: Rural Road Development in Nepal, Discussion Paper Series No. MEI 98/6, International Centre for Integrated Mountain Development, 1998.

[11] Mulmi A.D., Green Road Approach in Rural Road Construction for the Sustainable Development of Nepal, Journal of Sustainable Development, 2009, 2 (3), 149–159.

[12] Bhandary N.P., State of Road Disasters and Experiences from the Current Road Building Practices in Nepal, Graduate School of Science and Engineering, Ehime University, unpublished.

[13] Chowi S.S., Shahi P.B., Thapa S., Identification and Ranking of Road Safety Hazardous Locations: Case Study of Kotre–Aabhukhaireni Section of Prithvi Highway, International Journal on Engineering Technology, 2023, 1 (1), 102–128.

[14] Federal Highway Administration, Local and Rural Road Safety, Federal Highway Administration, 2014. https://safety.fhwa.dot.gov/local_rural/training/fhwasa14072/sec4.cfm

[15] Federal Highway Administration, Accident Analysis Methods, Federal Highway Administration, 2012. https://safety.fhwa.dot.gov/local_rural/training/fhwasa1210/s5.cfm