Road Traffic Accidents in Prithvi Highway, Nepal: A Spatiotemporal Analysis

Youb Raj Bhatta[1], Kedar Rijal[1]*, Ramesh Raj Pant[1], Rabin Khadka[2], Shashank Bhatta[3], Crimsan S Negi[4], Puja Pali[4], Rajeev Gyawali[5]
[1]Central Department of Environmental Science, IOST, Tribhuvan University, Nepal
[2]Department of Civil Engineering, Indian Institute of Technology Madras, Chennai, India
[3]Institute of Engineering, Pulchowk, Lalitpur, Nepal
[4]School of Engineering, Far Western University, Kanchanpur, Nepal
[5]Department of Survey, Minbhawan, Kathmandu, Nepal
*Corresponding Author: krijal@cdes.edu.np,

Abstract

Road transport networks are vital catalysts for socioeconomic development and connectivity; their rapid expansion is inextricably linked to the critical global challenge of Road Traffic Accidents (RTAs). RTAs constitute a persistent public safety challenge in Nepal, with the Prithvi Highway recognized as one of the country's most hazardous transport corridors due to its complex terrain, geometric deficiencies, and escalating traffic demand. This study employs a GIS-based spatiotemporal analytical framework to examine crash distribution along the highway from 2019 to 2025 AD. Secondary crash records were systematically cleaned, geocoded, and evaluated using Kernel Density Estimation (KDE) to detect spatial clustering, while Global Moran's I statistics were applied to assess spatial autocorrelation across crash attributes. The temporal assessment revealed substantial annual variability, including a distinct peak in 2021 AD, alongside a consistent predominance of daytime crashes across all districts, reflecting higher exposure during active traffic periods. Spatial analysis identified persistent and high-intensity hotspots in the Kathmandu–Thankot, Khairghari–Malekhu, Kurintar–Mugling, and Aabukhaireni–Damauli sections, confirming strong clustering of crash events. Moran's, I result indicated statistically significant spatial dependence for total crashes, injuries, and age-group involvement, whereas fatalities exhibited a random spatial pattern, suggesting the influence of situational rather than locational determinants. Contributing factors were closely associated with geometric constraints, including narrow carriageways, sharp curves, inadequate super-elevation, and restricted sight distances, compounded by environmental stressors such as monsoon-induced landslides, surface runoff, and winter fog. The findings underscore the necessity of targeted, corridor-specific interventions involving geometric upgrades, slope stabilization, enhanced drainage, seasonal risk mitigation, and data-driven enforcement. This study provides a robust scientific basis for developing precise and sustainable road safety strategies along one of Nepal's most critical national highways.

Keywords: *Road Traffic Accidents, Spatiotemporal Analysis, GIS, Hotspot Analysis, Prithvi Highway, Road Safety*

Introduction

Road transport networks are widely recognized as the milestone of critical infrastructure, serving as a fundamental prerequisite for national development and socio-economic advancement. By ensuring universal access for populations, commodities, and services across diverse geographic landscapes, road networks optimize economic efficiency and stimulate national growth (Ng et al., 2019). This connectivity is particularly vital for rural communities, where secure road networks are indispensable for increasing mobility, enabling capital flow, and linking agricultural sectors with global marketplaces (Liu et al., 2024). However, the rapid expansion of such network is indistinguishably compounded with global challenge leading to Road Traffic Accidents (RTAs). RTA refers to any occurrence on a public road where at least one moving vehicle involved and causes injury or death to one or more people. While the evolution of road transport has accelerated human development, the rapid surge in motorization has concomitantly precipitated a significant escalation in traffic-related casualties, creating a "developmental paradox" where economic progress precipitates a public health crisis (Chen et al., 2016).The magnitude of this crisis is evidenced by global mortality data; RTAs claim approximately 1.35 million lives annually, equating to roughly 3,700 fatalities per day. This burden is disproportionately concentrated in Low- and Middle-Income Countries (LMICs), which account for over 90% of global fatalities despite possessing only approximately 50% of the world's vehicle fleet (WHO, 2023),(A. Khadka et al., 2021). This disparity underscores a critical lag in infrastructure safety and regulatory enforcement relative to the pace of urbanization in emerging economies. To address these systemic failures, modern road safety paradigms have shifted toward the Safe System Approach (SSA) (Mooren, n.d.). Unlike traditional models that place sole responsibility on road users, the SSA explicitly acknowledges the unreliability of human physiology and the predictability of human error. It posits that the entire transport system comprising road infrastructure, vehicles, and institutional frameworks must be designed to be "forgiving," thereby mitigating the severity of crashes when errors inevitably occur (World Bank, 2020). This theoretical framework aligns with the Haddon Matrix, which analyzes the interaction of three major factors: the environment, the vehicle, and the human (Davoudi-Kiakalayeh et al., 2023). While human factors such as speeding, non-compliance, and reckless driving are the immediate precipitants in nearly 90% of crashes (Khadka et al., 2025), the road environment acts as a pivotal moderating factor. In developing nations, environmental vulnerabilities such as poor geometric design, hazardous roadside conditions, and inadequate signage often amplify human errors, transforming minor mistakes into fatal outcomes (Khadka et al., 2024).This interaction is particularly acute in Nepal, where the development of road infrastructure faces unique geographical and developmental challenges. As a Least Developed Country (LDC) where two-thirds of the demographic resides in rural communities, the expansion of road networks is a foundational imperative for survival (Bhatta et al., 2024). Yet, this expansion has occurred within a challenging topographic context, resulting in a severe public health crisis on the nation's highways.

Current statistics indicate that Nepal experiences approximately 2,789 fatalities annually, translating to a mortality rate of 29.86 per 100,000 population one of the highest in South Asia (Shrestha et al., 2017). The socio-economic ramifications are devastating, with societal losses estimated at 6% of the national GDP and the direct economic cost per injury case estimated at US$126.2 (Manandhar, 2022). The crisis in Nepal is characterized by a complex interplay of risk factors where human behaviors interact with an unforgiving environment marked by steep gradients, landslide-prone zones, and monsoon hazards (World Bank, 2020a). Despite institutional mandates held by the Department of Roads (DoR) and Department of Transport Management (DoTM), enforcement gaps persist, and previous strategic goals to reduce RTA rates have largely not materialized (Thapa, 2013). Within this national context, the Prithvi Highway stands out as a critical case study for high-risk infrastructure. Spanning approximately 174 kilometers across the districts of Kathmandu, Dhading, Chitwan, Tanahun, and Kaski, it serves as the primary arterial link between the capital, Kathmandu, and the tourist hub of Pokhara (Bener et al., 2009). While it is a lifeline for trade and tourism in central and western Nepal, the highway is notoriously accident-prone. Its geometry is characterized by narrow carriageways, sharp curves, and steep slopes, all of which are heavily burdened by high traffic volumes. Localized assessments, such as those in the Mugling–Kotre section, have identified hazardous "black spots" where geometric deficiencies interact with environmental stressors, such as fog and landslides, to create clusters of high-casualty crashes (Kc et al., 2023). The frequency of mass-casualty bus accidents along this corridor highlights the limitations of current safety management strategies.

Despite the severity of the issue, road safety research in Nepal has traditionally relied on descriptive statistics from police and hospital records. These methods often fail to capture the geographic complexity of crash occurrences or the spatial distribution of risk. To develop effective countermeasures, there is a growing necessity to transition toward spatial and temporal analysis using Geographic Information Systems (GIS) (Mahato et al., 2025; Mohammed et al., 2023). Global research has demonstrated the efficacy of spatial statistical models, such as Moran’s I and Kernel Density Estimation (KDE), in identifying "hotspots" areas where accidents cluster significantly more than would be expected by chance (Mahato et al., 2024). While recent studies in the Kathmandu Valley have utilized these techniques to correlate temporal crash patterns with land-use variables (Chowi et al., 2023), there remains a significant gap in the literature regarding the Prithvi Highway. A comprehensive spatiotemporal analysis that visualizes the evolution of accident patterns and their relationship to specific roadway characteristics is currently lacking (K.C, Pradhananga & Koju, 2024). Therefore, this study aims to conduct a GIS-based spatiotemporal analysis of road traffic accidents along the Prithvi Highway, providing a scientific basis for mitigating the high fatality rates on this strategic corridor.

Objectives

This study employs a GIS-based spatiotemporal analysis to examine road traffic accidents along Prithvi Highway of Nepal. The specific objectives are to: (i) analyze annual and seasonal trends in accident frequency and severity; (ii) map spatial clustering and delineate high-risk zones through hotspot analysis and spatial autocorrelation; and (iii) investigate the correlation between these zones and contributing factors, including roadway geometry and environmental conditions, to guide targeted safety interventions.

Study Area

This study focuses on the Prithvi Highway (NH 17), a strategically vital 174-kilometer corridor that serves as a critical lifeline between Kathmandu and Pokhara. Traversing the five districts of Kathmandu, Dhading, Chitwan, Tanahun, and Kaski, the highway navigates a diverse and challenging topography of steep mountainous terrain, river valleys, and densely populated settlements. The analysis focuses on several high-risk segments of the Prithvi Highway: Kalanki to Thankot, Khairghari to Malekhu, Kurintar to Mugling, Aabukhaireni to Damauli, and the Pokhara entry section. These stretches are consistently identified as accident-prone due to a combination of hazardous geometric features, including narrow carriageways and sharp curves, as well as adverse environmental conditions such as seasonal landslides, fog, and chronic traffic congestion.

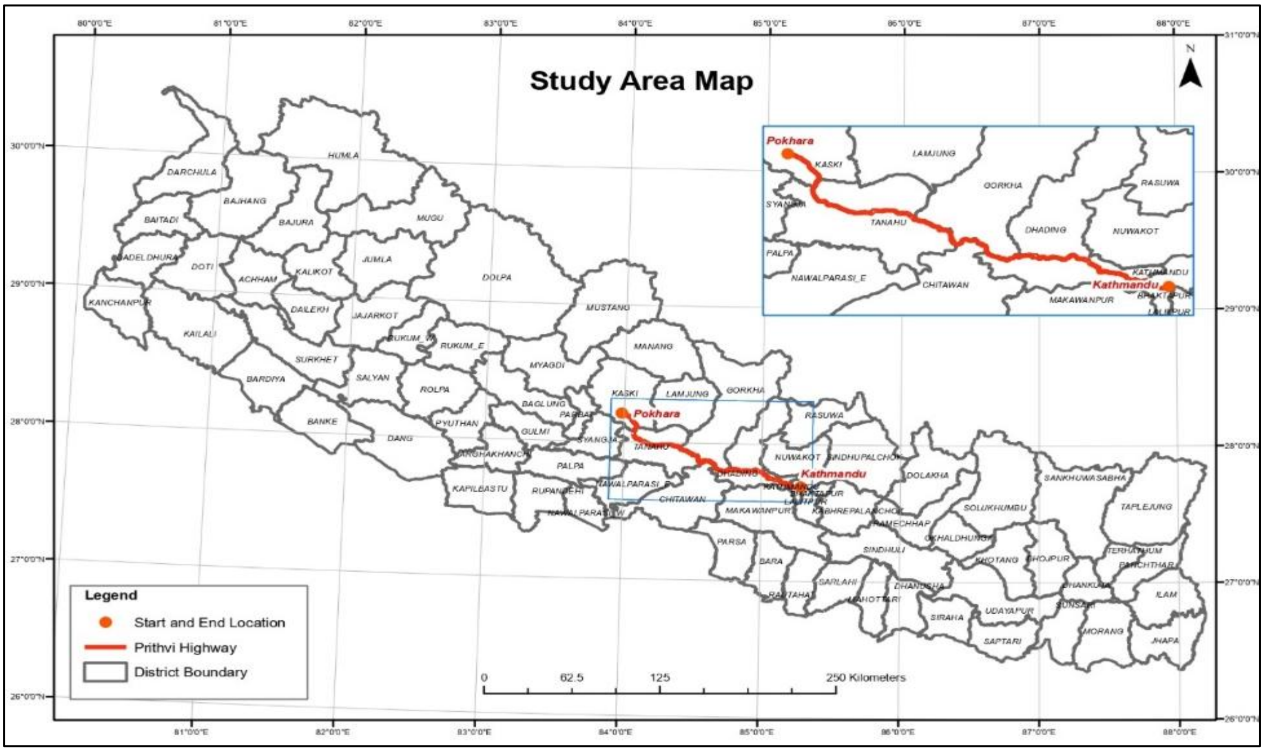

Figure 1:Location map of the study area.

Methodology

This study employed a GIS-based spatiotemporal methodology to analyze road traffic accidents on the Prithvi Highway. The process began with the compilation and cleaning of secondary accident data (2019-2025 AD) from Nepal Police official sources, which was then geocoded and verified using Google Earth Pro. Moreover, filed based assessment across the road has been employed to obtain the physical condition of the road. The validated coordinates were processed in ArcGIS 10.8, where a suite of spatial analyses including Kernel Density Estimation for hotspot mapping and Global Moran's I for spatial autocorrelation was applied to identify high-risk clusters. The final phase involved interpreting these clusters in the context of contributing factors, such as roadway geometry and environmental conditions, through visual inspection and spatial correlation.

Data Collection Methods

Secondary RTA data spanning from 2019 to 2025 AD were sourced from official records maintained by the Nepal Police and the Department of Transport Management. The dataset encompassed key variables, including the date and time of each accident, location descriptors or GPS coordinates, types of vehicles involved, the number of fatalities and injuries, the age of affected individuals, and crash severity classification (fatal, major, minor). To ensure spatial accuracy, each crash location was rigorously verified through a multi-step process: initial coordinate extraction using Google Earth Pro, contextual validation via Google Maps Street View to assess roadway features, and manual correction of any discrepancies. All records were systematically compiled and cleaned in Microsoft Excel before being exported as a comma-separated values (CSV) file for seamless integration into ArcGIS, enabling subsequent geospatial analysis.

Data Analysis

The collected data were analyzed using a multi-faceted approach to examine temporal patterns, spatial distribution, and contributing factors. Temporal analysis was conducted to identify trends in accident occurrence by year (2019–2025 AD), season (Winter, Monsoon, Spring, Autumn), time of day (day vs night), crash types and age group involvement, revealing critical periods of elevated risk and demographic vulnerability. Spatially, GIS tools were applied, including Kernel Density Estimation (KDE) to identify high-density crash corridors, heatmaps to visualize clusters relative to local administrative units, and Global Moran's I spatial autocorrelation to determine whether accident distributions were clustered, random, or dispersed. Finally, contributing factors were assessed through the evaluation of road geometry and environmental influences, such as terrain slope analysis derived from Google Earth elevation data, inspection of curve sharpness and gradient, identification of landslide-prone zones, and consideration of seasonal rainfall and fog patterns.

Results and Discussion

This section presents the spatiotemporal analysis of crash data uncovered several distinct patterns related to time, location, clustering behavior, and contributing factors along the Prithvi Highway. The key findings are from the analysis are.

Temporal Analysis

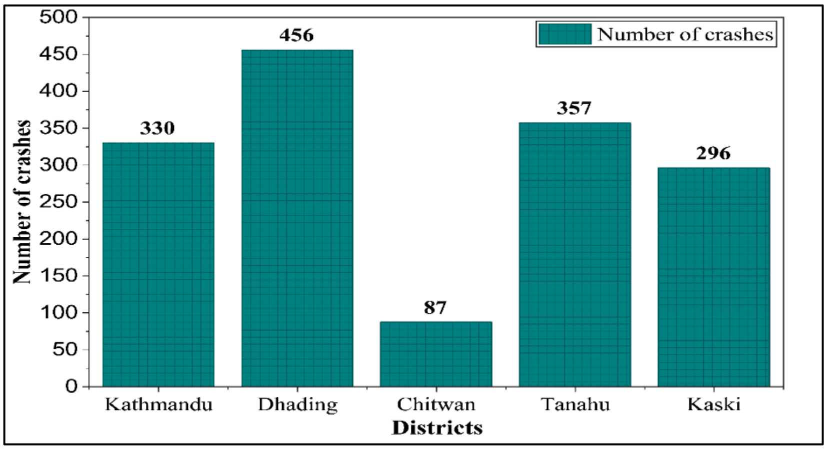

Figure 2: District wise RTA crash distribution in Prithvi highway.

Figure 2 presents the district-wise distribution of road traffic accidents (RTAs) along the Prithvi Highway. The data show that Dhading recorded the highest number of crashes (456), followed by Tanahu (357), Kathmandu (330), and Kaski (296). In contrast, Chitwan reported the lowest number of crashes (87). This pattern reflects variations in highway length, terrain characteristics, traffic volume, and settlement density across the districts. Districts like Dhading and Tanahu have extensive winding sections and steep slopes, contributing to higher crash frequencies.

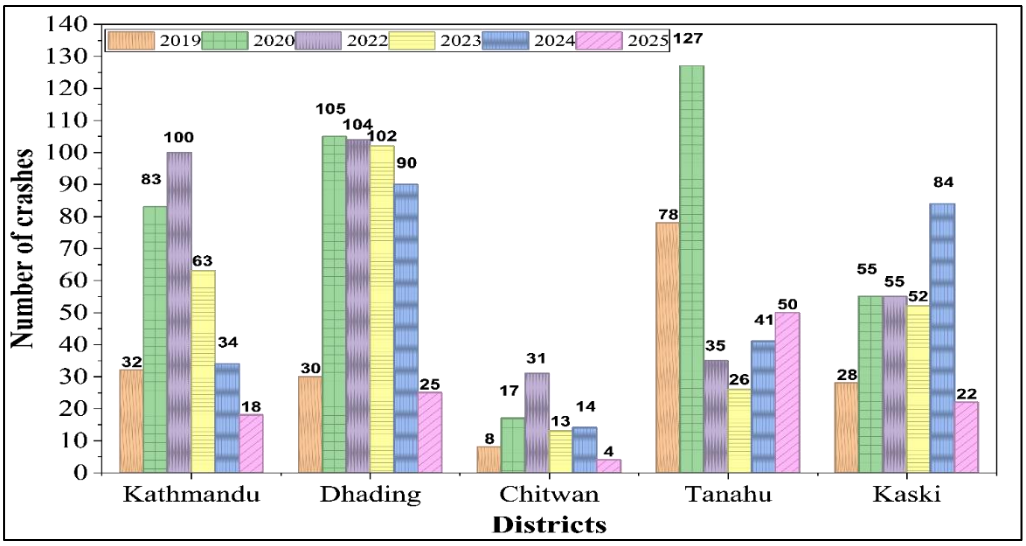

Figure 3: Annual number of crashes by District (2019-2025 AD).

Figure 3 illustrates the annual crash distribution (2019–2025 AD) for each district. The chart shows notable temporal fluctuations, with peak accident counts observed in Kathmandu (127), Dhading (105), and Tanahu (104) during 2078 BS. In subsequent years, crashes generally declined across most districts, except for periodic minor increases in Dhading and Tanahu. Chitwan and Kaski consistently reported fewer crashes compared to other districts throughout the six-year period. These trends may be associated with changes in traffic flow, seasonal road conditions, enforcement activities, and road improvement works undertaken at different times.

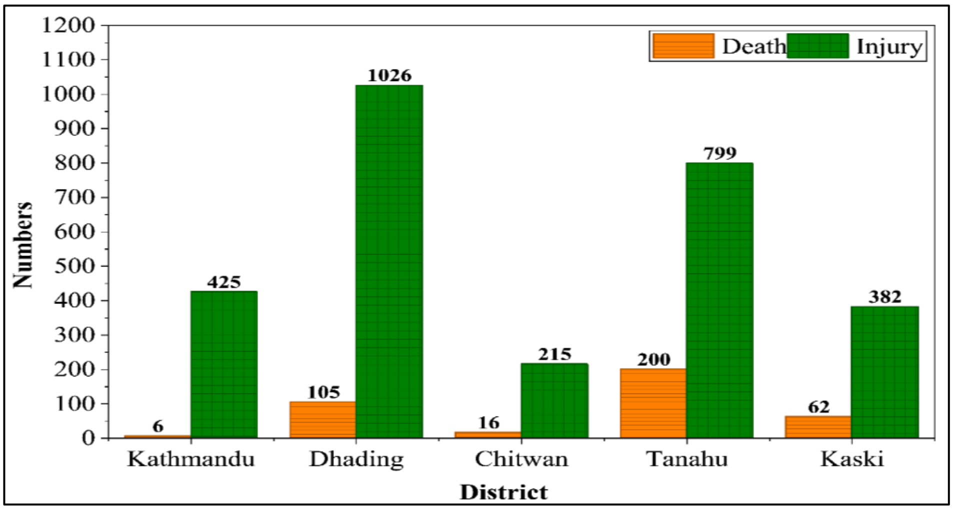

Figure 4: Distribution of crashes by death and injury involved.

Figure 4 shows the number of deaths and injuries from crashes across five districts. Dhading has the highest casualties, with 105 deaths and 1026 injuries, followed by Tanahu with 200 deaths and 799 injuries. Kaski and Kathmandu report moderate injuries (382 and 425) but comparatively fewer deaths (62 and 6). Chitwan shows 16 deaths and 215 injuries. Overall, injuries far exceed deaths in all districts, with Dhading being the most affected.

Figure 5 illustrates the distribution of road traffic crashes during daytime (7 am to 5 pm) and nighttime (5 pm to 7 am) across Kathmandu, Dhading, Chitwan, Tanahu, and Kaski. Overall, daytime crashes are consistently higher than nighttime crashes in all districts. Dhading records the highest number of crashes in both periods, with daytime crashes significantly dominating, suggesting higher traffic volume or increased exposure during working hours. Kathmandu and Tanahu show moderate crash levels, while Chitwan reports the lowest crash frequency for both day and night.

Kaski also shows relatively balanced but lower crash numbers compared to other districts. The chart highlights that most crashes occur during the day, likely due to greater road user activity, commercial transport movement, and peak-hour congestion.

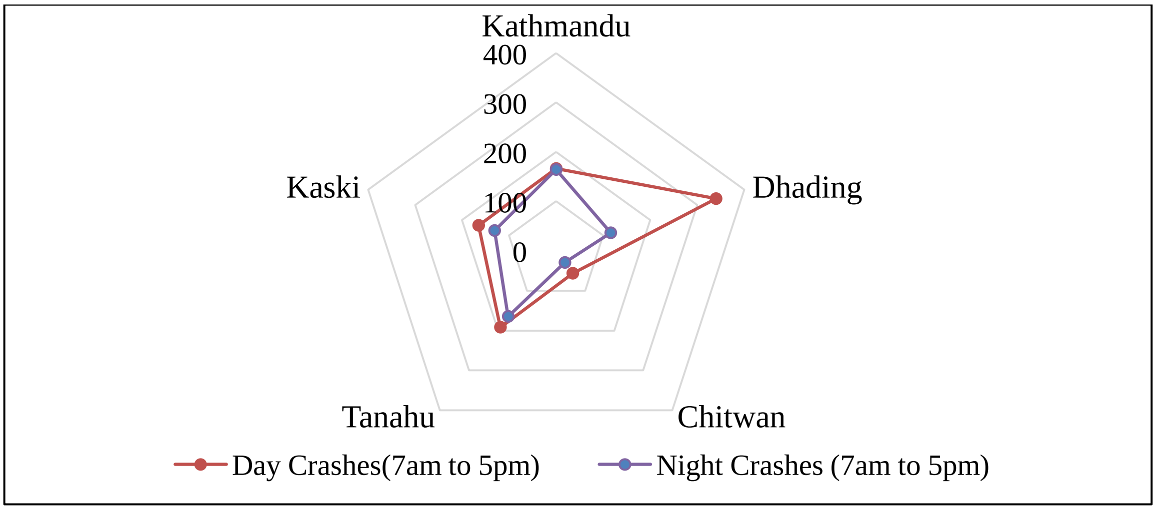

Figure 5: Road traffic crashes during daytime (7am to 5pm) and nighttime (5pm to 7am)

Spatial Analysis

The Kernel Density Estimation (KDE) heatmaps for crash frequency, fatalities, injuries, and age-group involvement collectively reveal a clear spatial organization of road traffic accidents along the Prithvi Highway. Rather than being evenly distributed, crash events demonstrate strong spatial clustering, indicating that accident risk is concentrated within specific segments of the corridor. Across all four indicators, the Kathmandu to Thankot, Khairghari to Malekhu, Kurintar to Mugling, Aabukhaireni to Damauli, and the Pokhara entry section consistently emerge as high-intensity hotspots. The recurrence of these clusters across multiple crash categories general frequency, severity, and demographic involvement highlight their persistent vulnerability and indicates that the underlying causes are structural and systemic. The spatial pattern of crash frequency and injuries shows widespread clustering across mid hill and river valley sections, where geometric constraints, high traffic volumes, and limited maneuvering space converge. These segments are characterized by narrow alignments, repeated curvature transitions, and inadequate shoulder width, conditions that collectively increase the likelihood of collisions even under normal weather conditions. Fatality hotspots, however, exhibit a more localized pattern, primarily around Mugling and Kurintar. This suggests that severe crashes are more sensitive to specific high-risk features such as steep gradients, sudden alignment breaks, limited sight distances, and weather-induced visibility reduction, all of which increase the probability of catastrophic outcomes. Similarly, the spatial distribution of crashes involving individuals in the 18–45 age group closely mirrors the overall crash heatmap. This alignment reflects the dominance of the working-age population among highway users and suggests that the zones with the highest crash exposure also coincide with peak mobility segments for commuters and freight operators. The consistent overlap between demographic involvement and spatial crash intensity further reinforces the systemic nature of risk along these segments.

Taken together, the KDE results demonstrate a robust pattern of spatial dependence in accident occurrence along the Prithvi Highway. The convergence of hotspots across crash types, severity levels, and victim demographics confirms that high-risk segments are shaped by the combined influence of geometric constraints, environmental exposure, and complex traffic interactions. These findings highlight the need for targeted, corridor specific safety interventions focused on geometric correction, slope and drainage management, speed control, and enhanced hazard warning systems within the identified hotspot zones.

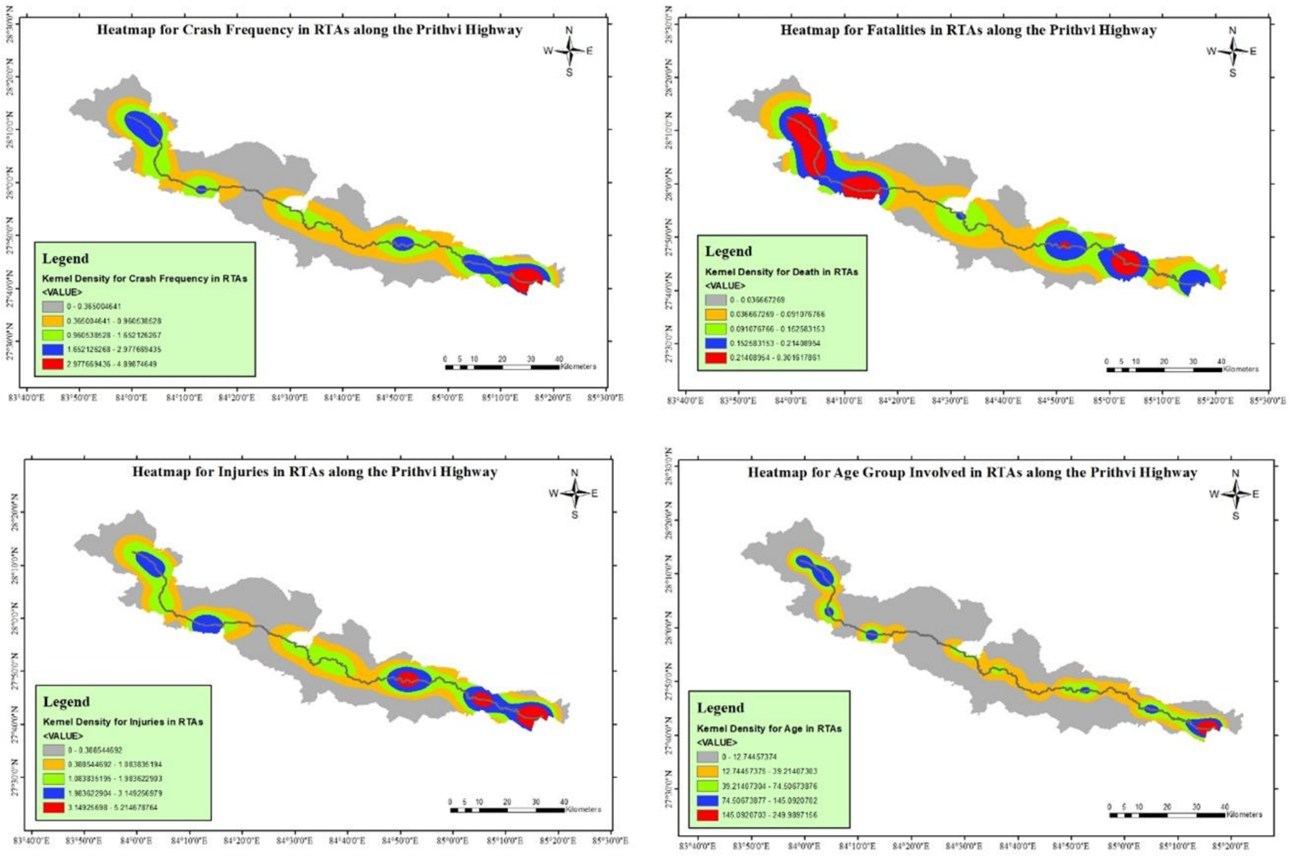

Figure 6: Heatmaps

Moran's Index Analysis

Table 1 shows that the non-random spatial structure of road traffic accidents along the Prithvi Highway. The statistically significant positive autocorrelation observed for crash frequency (I = 0.0216, p < 0.001) and injury cases (I = 0.0263, p < 0.001) indicates that these events are spatially clustered, with crashes tending to occur repeatedly within the same highway segments. This aligns with the KDE-derived hotspots around Mugling–Kurintar, Aabukhaireni–Damauli, and Kathmandu–Thankot, confirming that these locations represent consistent high-risk zones shaped by underlying geometric and traffic conditions. The age-group involvement (I = 0.0190, p < 0.01) also displays significant clustering, suggesting that the working-age population (18–45 years) is disproportionately affected in the same hotspot areas, likely due to higher mobility and greater exposure during peak traffic periods. In contrast, fatality cases do not exhibit significant spatial autocorrelation (I = 0.0147, p = 0.183), implying that the severity of crashes is not strongly tied to specific locations. Instead, fatal outcomes are more likely influenced by situational factors such as collision type, vehicle speed, mechanical failure, or safety-device non-use rather than by the geometric characteristics of a particular segment. Overall, the spatial autocorrelation results complement the hotspot analysis by demonstrating that while crash occurrence and injury burden are highly concentrated in structurally constrained segments, fatality severity is more dispersed and event-dependent. This distinction underscores the need for targeted geometric and operational interventions in clustered hotspots, alongside broader behavioural and enforcement measures to reduce severe crash outcomes.

Table 1: Moran' s Index

Inputs	Moran's Index	Z Score	p-value
Vehicle Crash Frequency	0.021639	3.648286	0.000264
Fatalities	0.014661	1.332389	0.182732
Injuries	0.026347	4.327037	0.000015
Age Group Involved	0.019052	3.162224	0.001566

Contributing Factors

The geometric assessment shows that crash risk along the Prithvi Highway is strongly influenced by terrain-driven design constraints. Straight segments account for many crashes, indicating speed-related and inattentive-driving tendencies where the roadway appears less demanding. In contrast, curved sections particularly in Naikap, Benighat, and Aabukhaireni exhibit elevated risk due to limited sight distance, inadequate super-elevation, and abrupt alignment changes that increase loss of control events. Narrow carriageways in confined valley sections further reduce lateral clearance, heightening side swipe and run off road crashes, especially in locations lacking shoulders or guardrails. Steep gradients, though less common, contribute to severe crashes where long descents impose heavy braking loads on trucks, increasing the likelihood of brake failure and lane departure. Overall, the distribution of crashes across geometric types indicates that speed behavior, constrained width, and curvature-induced control demand collectively shape the spatial concentration of accidents.

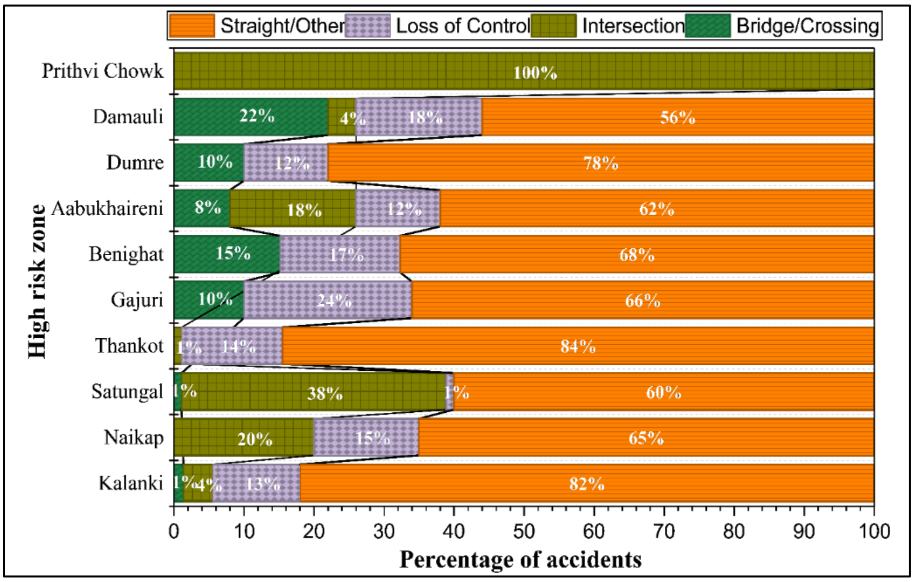

Figure 7: Distribution of roadway geometry risk by zones.

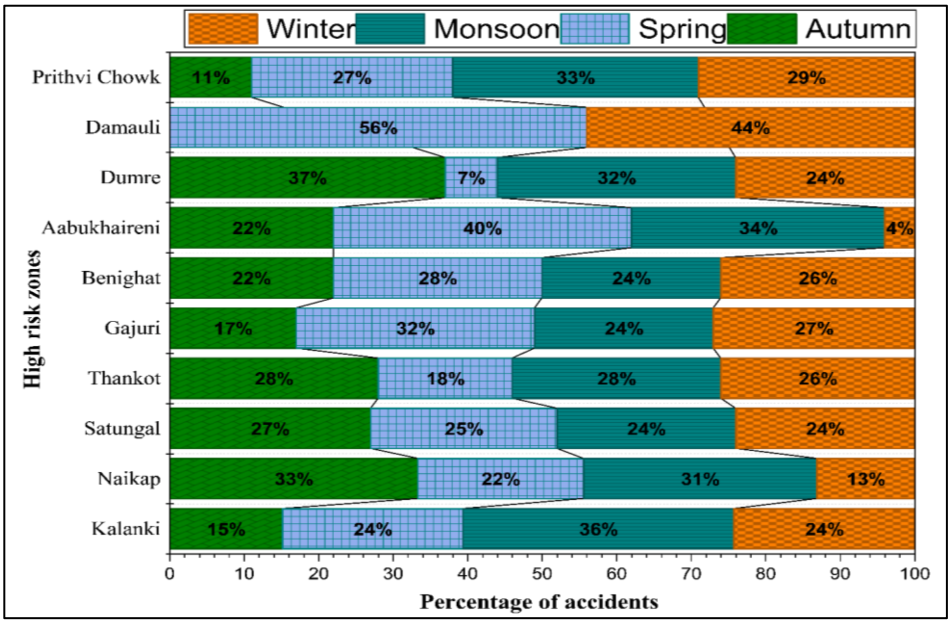

Figure 8: Distribution of risk zone by seasonal trend.

Figure 8 shows that the seasonal variation is typically another key driver of Prithvi Highway crash patterns. Monsoon season rains that are heavy may trigger landslides and other slope failures. Surface runoff lowers the friction coefficient of highway roadways. These effects may create sudden barriers. The barriers lead to crashes. Skidding in these conditions, loss of control in these conditions, and collisions with other vehicles in these conditions can occur. Fog hazards the highway in winter months, particularly from Kurintar to Mugling and inside the section from Aabukhaireni to Damauli, and very poor visibility causes rear-end and lane departure collisions. Despite this, increased visibility and faster speeds on straight sections during the dry season still create a higher proportion for more severe crashes. This indicates that seasonal factors like the monsoons and winter conditions are an important factor in determining the number of crashes and crash severity. This must be addressed by safety improvements along the corridor.

Conclusion

This study provides a comprehensive spatiotemporal assessment of road traffic accidents along Nepal's Prithvi Highway using an integrated GIS-based analytical framework. The findings clearly demonstrate that crash occurrence along the corridor is not random but is governed by a complex interaction of temporal fluctuations, spatial clustering, geometric constraints, and environmental conditions. Temporal analysis revealed distinct yearly variations, including a notable peak in crashes during 2020 AD, and a consistent predominance of daytime accidents, reflecting the influence of traffic volume and operational road use patterns. Spatial analyses using Kernel Density Estimation and Moran's I identified persistent accident hotspots in the Kalanki–Thankot, Kurintar–Mugling, and Aabukhaireni–Damauli segments. These locations exhibited strong spatial autocorrelation for crash frequency, injuries, and age-group involvement, indicating that they possess inherent structural vulnerabilities. In contrast, fatalities displayed a random spatial pattern, suggesting that the most severe outcomes are driven by situational factors such as vehicle speed, collision type, mechanical condition, or driver behavior rather than segment-specific geometric features. The investigation further confirmed that hazardous geometric characteristics sharp and unbanked curves, narrow carriageways, limited sight distances, and constrained valley alignments substantially contribute to crash concentration. These risks are intensified by environmental stressors, including monsoon-induced landslides, surface runoff, and winter fog, which significantly elevate crash likelihood and severity during specific seasons.

Given these insights, road safety interventions must transition from generalized highway-wide approaches to precise, location-specific strategies. Priority measures include geometric improvements in identified hotspots, installation of guardrails and advanced warning systems, slope stabilization, improved drainage, and the adoption of dynamic speed control mechanisms in high-risk zones. Complementary actions such as targeted driver education for the 18–45 age group, seasonal safety campaigns, and stricter enforcement are essential to address high-severity crashes influenced by behavioral and situational factors. Overall, the study underscores the value of spatiotemporal analysis as a robust scientific tool for guiding evidence-based, cost-effective, and sustainable road safety interventions. The findings provide a strong foundation for policymakers, engineers, and transport authorities to develop targeted solutions that can substantially reduce crash frequency and severity along one of Nepal's most critical transportation corridors.

Recommendation

Infrastructure and Geometric Improvements in Identified Hotspots: To systematically address the pronounced spatial clustering of accidents, targeted infrastructure and geometric interventions must be prioritized in high-risk segments such as Kalanki–Thankot, Kurintar–Mugling, and Aabukhaireni–Damauli. Engineering improvements should include widening narrow carriageways, optimizing super-elevation on sharp curves, and constructing additional shoulders and emergency pull-over bays to mitigate lane-departure and loss-of-control incidents. Complementing these measures, the strategic installation of advanced road safety hardware such as crash barriers and guardrails along steep slopes and gorges, high-visibility signage and reflective markings ahead of critical curves and intersections, and rumble strips on approaches to alert inattentive drivers will substantially reduce both the frequency and severity of accidents in these persistently hazardous zones.

Enhanced Traffic Management and Enforcement: Building on the temporal patterns of accidents, dynamic traffic management and strategic enforcement are critical. This includes implementing variable speed limit systems in high-risk zones such as fog prone areas and steep gradients, supported by the strategic placement of automated speed cameras to deter over speeding. Furthermore, increasing traffic police presence during peak accident seasons especially the monsoon and winter periods will enable stricter enforcement of traffic rules, routine vehicle safety inspections, and proactive management of congestion, directly addressing the situational factors that lead to severe crashes.

Public Awareness and Driver Education Initiatives: To reduce human factor related accidents, targeted public awareness and education campaigns must be developed and disseminated. These should focus on the demographic most involved in crashes individuals aged 18 to 45 through driver training programs specifically addressing the challenges of the Prithvi Highway, such as navigating sharp curves and managing speed during descent. Additionally, installing variable message signs at key highway entry points to provide real-time alerts on weather, road conditions, and accident black spots can significantly enhance situational awareness and encourage safer driving behavior. Data-Driven Institutional Planning and Monitoring: For sustainable long-term safety, institutionalizing data driven approaches is essential. This involves establishing a dedicated GIS-based monitoring unit within the Department of Roads to enable continuous accident data analysis, regular hotspot updates, and evidence-based evaluation of safety measures. Simultaneously, formalizing mandatory road safety audits for all highway development and maintenance projects will ensure that geometric and environmental risk factors are systematically identified and mitigated during the planning phase, fostering a proactive rather than reactive safety culture.

Acknowledgment

Authors would like to thank to all respondents, officials and colleagues those directly and indirectly contributed and their valuable supports during the research.

Conflict of Interest

The authors declare that no conflict of interest.

References

Bener, A., Burgut, H. R., Sidahmed, H., AlBuz, R., Sanya, R., & Ali Khan, W. (2009). Road traffic injuries and risk factors. *Californian Journal of Health Promotion*, *7*(2), 92–101. https://doi.org/10.32398/cjhp.v7i2.2017

Bhatta, S., Pathak, P., Khadka, A., Parkin, J., Pilkington, P., Joshi, S. K., & Mytton, J. (2024). Injury risks for different road users in Nepal: a secondary analysis of routinely collected crash data. *Global Health Research*, 77–87. https://doi.org/10.3310/dwtr9883

Chen, T., Zhang, C., & Xu, L. (2016). Factor analysis of fatal road traffic crashes with massive casualties in China. *Advances in Mechanical Engineering*, *8*(4), 1–11. https://doi.org/10.1177/1687814016642712

Chowi, S. S., Shahi, P. B., & Thapa, S. (2023). Identification and Ranking of Road Safety Hazardous Locations: Case Study of Kotre-Aabhukhaireni Section of Prithvi Highway. In *International Journal on Engineering Technology (InJET) www.kec.edu.np/journal* (Vol. 1, Issue 1). www.kec.edu.np/journal

Davoudi-Kiakalayeh, A., Barshan, J., Emami Sigaroudi, F., Mirak, H. M., & Naseri Alavi, S. A. (2023). The application of the Haddon matrix in identifying drowning prevention solutions in the north of Iran. *Heliyon*, *9*(6). https://doi.org/10.1016/j.heliyon.2023.e16958

Global status report on road safety 2023. (n.d.).

Kc, N., Joshi, B. R., Gurung, R., & Aryal, R. (2023). Number 1; 31-43 Rajan Gurung. *Rajendra Aryal*, *4*.

Khadka, A., Gautam, P., Joshi, E., Pilkington, P., Parkin, J., Joshi, S. K., & Mytton, J. (2021). Road safety and heavy goods vehicle driving in LMICs: Qualitative evidence from Nepal. *Journal of Transport and Health*, *23*. https://doi.org/10.1016/j.jth.2021.101247

Khadka, R., Singh Negi, C., Pali, P., Giri, L., Badal, D., Bhandari, K., & Mahara, R. (2025). An Analysis of Road Crash Black Spots on the East-West Highway in Kanchanpur District, Nepal. In *International Journal on Engineering Technology and Infrastructure Development (InJET-InDev) www.lec.edu.np/journal* (Vol. 2, Issue 1). www.lec.edu.np/journal

Khadka, R., Tiwari, B., Acharya, U. P., BC, U. B., Adhikari, R., & Thapa, K. (2024). Trends, Causes, Morbidity, and Mortality Analysis of Road Traffic Accidents in Karnali Province, Nepal: A Three-Year Retrospective Study. *Asian Journal of Population Sciences*, *3*, 70–82. https://doi.org/10.3126/ajps.v3i1.61832

Liu, G., Shan, Z., Meng, Y., Akbar, T. A., & Ye, S. (2024). RDPGNet: A road extraction network with dual-view information perception based on GCN. *Journal of King Saud University - Computer and Information Sciences*, *36*(3). https://doi.org/10.1016/j.jksuci.2024.102009

Mahato, R. K., Htike, K. M., Kafle, A., Gewali, V., Kafle, A., & Sharma, V. (2025). Spatial distribution and cluster analysis of road traffic accidents in Nepal. *PLOS ONE*, *20*(8 August). https://doi.org/10.1371/journal.pone.0331333

Mahato, R. K., Htike, K. M., Sornlorm, K., Koro, A. B., Kafle, A., & Sharma, V. (2024). A spatial autocorrelation analysis of road traffic accidents by severity using Moran's I spatial statistics: a study from Nepal 2019–2022. *BMC Public Health*, *24*(1). https://doi.org/10.1186/s12889-024-20586-7

Manandhar, R. B. (2022). Factors Affecting Road Traffic Accidents in the Kathmandu valley. *International Research Journal of MMC*, *3*(3), 82–90. https://doi.org/10.3126/irjmmc.v3i3.48639

Mohammed, S., Alkhereibi, A. H., Abulibdeh, A., Jawarneh, R. N., & Balakrishnan, P. (2023). GIS-based spatiotemporal analysis for road traffic crashes; in support of sustainable transportation Planning. *Transportation Research Interdisciplinary Perspectives*, *20*. https://doi.org/10.1016/j.trip.2023.100836

Mooren, L. (n.d.). *Safe System-Comparisons of this Approach in Australia*. https://www.researchgate.net/publication/237046059

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). https://doi.org/10.1088/1757-899X/512/1/012045

K.C., A., Pradhananga,R & Koju, U. (2024.). *IOE Graduate Conference Spatial Analysis of Road Traffic Crash Hotspots in Kathmandu Valley, Nepal*.

Shrestha, V. L., Bhatta, D. N., Shrestha, K. M., GC, K. B., & Paudel, S. (2017). Factors and Pattern of Injuries Associated with Road Traffic Accidents in Hilly District of Nepal. *Journal of Biosciences and Medicines*, *05*(12), 88–100. https://doi.org/10.4236/jbm.2017.512010

Thapa, A. J. (2013). *Status Paper on Road Safety in Nepal 2013 AJT i 2013 Status Paper on Road Safety in Nepal*.

World Bank (2020). *Global Road Safety Facility-2020*