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Research Article

Road Safety in Numbers: Using Data to Illustrate the Nepal's Scenarios

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Abstract

Road Safety is one of the critical issues globally Nepal, with rapid unplanned urbanization and growing road networks, has seen a tremendous rise in road casualties in road accidents. This study is an attempt to reveal the existing road safety situations of Nepal. Using the national dataset gathered by Nepal Government, this study examines the evolving road safety challenges of Nepal, focusing on vulnerable road users (VRUs) and systemic gaps. Using multi-year crash data from 2001 to 2024 and statistical analyses, it reveals that motorcycles account for over 50% of traffic crashes with young and middle-aged male drivers facing the highest fatality rates. Similarly, correlation analyses and severity index show that the vulnerability associated with two and three-wheelers is prevalent with instability and limited inbuilt safety features, whereas male above 25 years consistently followed by children below 6 years age are VRUs in Nepal. Early licensing, limited driver training and weak enforcement contribute to high crash involvement among youth. Pillion riders especially female remain at high risk due to low helmet use and lack of regulation. Child fatalities, proportionally lower than other groups, are linked to preventable conditions such as unsafe pedestrian zones and poor protective measures. The outdated transportation acts, absence of spatial crash data and poor local enforcement hinder targeted interventions. Furthermore, lack of proper road design and construction standards and practices, no road safety audit and safety inspection, little-to-zero communication campaigns on road safety, implementation gaps on road safety actions plans with adequate budget and institutional arrangement have exacerbated the road incidents in the country.

Keywords

Road Safety, Vulnerable Road Users, Severity Index

1. Introduction

With rapid urbanization and growth in road networks road safety has been an important issue in Nepal [1]. Increasing number of accidents each year reflects the declining road safety status of the country. Studies have highlighted that the growth in vehicle ownership and lack of adequate protection to the vulnerable road users (VRUs) further exacerbates the potential risk of traffic fatalities [2, 3]. Nepal has its own action plan, National Road safety Action Plan (NRSAP) 2011-2020 which is further revised and drafted into National Road Safety Action Plan 2020-2030 [4]. The major aim of these plans is to align with the SDG to minimize the road crashes into halve by 2030. However, the trend of RTF has

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been otherwise despite some efforts. In the fiscal year 2024/25, more than 20,000 road accidents were officially reported in Nepal double of what was a decade ago [5]. In comparison to traffic fatalities reported in 2010, there has been 70.7% increment in 2020 [6]. The increment in RTA have resulted in burdening the economy of the country. The economic burden of RTIs tripled since 2007 reaching an estimated 1.52% of gross national product (GNP) of Nepal by 2017 [7].

The number of total traffic fatalities globally was estimated to be 1.19 million on the year 2021 which makes it 12th leading cause of death when all the age groups are considered [2]. Whereas the number was 1.35 million on the year 2016 this highlights that there is 11.85% reduction in traffic fatalities from 2016 to 2021 [8]. Despite this decline, the number remains alarmingly high when considering the fact that these fatalities could have been prevented among vulnerable users. Addressing the rise in road traffic fatalities, the United Nations has emphasized the importance of road safety within its 17 Sustainable Development Goals (SDGs). Specifically, Goal 3-"Ensure healthy lives and promote well-being for all at all ages" includes target 3.6 [9]. It aims to halve the number of global deaths and injuries caused by road traffic accidents by 2030. The increase in the number of road accidents does not just claim the life of an individual but has a huge impact on GDP as well. A study conducted on five countries: China, India, Philippines, Tanzania, and Thailand has estimated that over the 24 years of time period 6 to 32% of the national GDP will be invested to prevent the mortality due to road accidents [10]. Conversely, it has also been found that lower number of Road Traffic Injuries (RTI) leads to a boost in the GDP of the country [10]. Despite global efforts to enhance road safety, Low-and Middle-Income Countries (LMICs) continue to bear a disproportionate burden of road traffic fatalities [11]. In 2021, these countries accounted for approximately 90% of global road traffic deaths underscoring the need for targeted interventions to achieve the objectives set forth in SDG Target 3.6 [11].

European roads are among the safest globally, with the EU reducing road traffic fatalities (RTF) by 22% from 2012 to 2022 [12]. Initiatives like “Vision Zero” aim for zero deaths by 2050 with Norway and Greece achieving over 50% reductions through speed control and motorway upgrades [12]. The USA and Australia also report declines in fatalities due to enforcement of seatbelt laws and alcohol limits. However, alcohol (29%) and speeding (28%) remain major causes of RTF in the USA [13]. In contrast, Africa accounts for 19% of global RTF despite only 15% of the world population with a fatality rate of 19.4 per 100,000 [11].

Whereas in Southeast Asian Region, the regional average of reported road death rate and estimated road injury death rate stands at 9.61 deaths and 16 deaths per 100 000 population [14]. Thailand has the most reported traffic deaths per 100,000 population i.e. 25.9 in the yar 2020 that is 32% increase in RTF from 2010 [2]. The percentage of two-wheelers involving in fatalities is found to be the highest (83.8%) in Thailand as their number is also the highest [2]. It has also been reported that there is a continuation of not wearing helmets by pillion riders and lack of political interest on road safety are some importation reasons for growth in RTF in Thailand [15]. Various studies have concluded that the major cause of the road traffic fatality in almost all part of the world has been identified as speeding [16, 17].

In the case of South Asian Countries, the traffic patterns are similar. The road fatalities of South Aisa estimated in 2019 per 100,000 population was 15.54 [13]. Maldives has its own road safety action plan from 2019-2023 with the aim of reducing the RTF by 50% [18] and has the lowest RTF per 100,000 population i.e. 0.9 which is 47% decrease from 2010 [2]. Similarly, in India there has been decrease in RTF rate from 11.4 in 2010 to 10.4 in 2020, and speed was the major cause of accident accounting for 72% of the total fatalities [19]. Meanwhile, Nepal has seen with the increase of RTF rate by 13% from 2010 to 2021 with 28.8 RTF per 100,000 population [4].

Given the rising incidence of road traffic accidents in Nepal there is a pressing need for empirically grounded studies that support effective and context-sensitive interventions. While national reports have recorded year-on-year increases in road traffic fatalities much of the existing literature remains descriptive relying on aggregate statistics that overlook underlying socio-demographic and spatial disparities. Prior studies have noted the lack of disaggregated crash-level data in evaluating risk patterns and emphasized the urgent need to integrate demographic insights into policy design to improve road safety outcomes in Nepal [20, 21]. Moreover, global meta-analyses [6, 22] have shown that targeted interventions based on age, gender and vehicle type reduce fatalities more effectively than uniform strategies but such stratified approaches remain underutilized in Nepal. There is also minimal assessment of the operational impact of national road safety action plans such as the Nepal Road Safety Action Plan 2021-2030 [23]. This study addresses these critical gaps by formulating and answering the following research questions: (i) What are the current patterns and trends in road traffic fatalities in Nepal across time and demographics? (ii) Which population groups are disproportionately vulnerable to fatal road crashes? and (iii) How do the observed fatality profiles align with existing policy interventions? Through combining national road crash data with demographic profiling, the paper aims to identify high-risk segments and evaluate the mismatch between risk incidence and policy focus. Key indicators explored include fatality rates per 100,000 population, death-to-crash ratios and gender-specific vulnerability. In doing so, the paper contributes to both academic discourse and actionable policy recommendations by filling a well-documented empirical gap in the road safety literature of Nepal.

2. Methods

Various published materials, relevant documents and data obtained from government, international bilateral and multilateral agencies are the main sources of information for developing this paper. Based on the literature reviewed for identification of the indicators for the study analyses were conducted. The data of road crashes were collected from Nepal police categorized to different provinces of Nepal for the last ten years period. The vehicles registration data were collected from Department of Transport Management (DoTM). The paper has used Nepali calendar date (Nepali calendar BS 2070/71 to 2081/82 is AD 2015-2024) to avoid any ambiguity due to the unavailability of dataset in terms of monthly period data are presented in Nepali date format.

2.1. Goal and Scope

The primary aim of this methodological framework is to examine the patterns, determinants and severity of road traffic incidents in Nepal over a decadal timeframe with a particular focus on identifying vulnerable road user groups based on age, gender vehicle type and geographic distribution (based on road type). This research employs a comprehensive statistical methodology that incorporates both quantitative measures of severity and exploratory data analysis techniques to extract insights pertinent to policy development.

First, correlation analysis is conducted using Pearson's correlation coefficient, Spearman's rank correlation and Kendall's tau coefficient to explore the strength and direction of associations among variables. These techniques offer a rigorous foundation for establishing both linear and non-linear monotonic relationships and are particularly appropriate given the heterogeneity and potential skewness in longitudinal traffic safety data [24, 25]. Second, the Crash Severity Index (CSI) is employed as a composite measure to quantify the seriousness of road traffic outcomes. This index widely used in transportation safety literature [25-27] aggregates fatalities and injuries into a unified metric based on weighted values thereby facilitating comparability across demographic groups and incident types.

Beyond these structured statistical tools, the study also incorporates general descriptive and comparative analysis of disaggregated datasets. This includes trend evaluations, vehicle-type stratifications and province-wise summaries. These components rely on basic percentage share calculations, time-series visualizations and normalized ratios to interpret shifts in accident distribution and vulnerability over time. This triangulated methodological design ensures both granular insight and analytical robustness especially in contexts where incident reporting may be incomplete or injury classification is generalized.

The scope of the methodology extends to identifying high-risk cohorts, temporal fluctuations in road incident metrics and spatial disparities across the provinces of the country. The study builds a comprehensive empirical base to inform evidence-driven road safety interventions, policy design and infrastructure prioritization.

2.2. Correlation Analysis

To examine the interrelationships between key traffic safety indicators such as accident frequency, fatalities, injuries, population and vehicle registrations over time, three correlation techniques were employed: Pearson's correlation coefficient, Spearman's rank correlation coefficient and Kendall's tau. Pearson's correlation was used to measure the strength of linear relationships between continuous variables, relying on the assumption of normal distribution and homoscedasticity. This technique has been widely adopted in traffic safety literature, including the work by Yan et al. (2019) [25] who has applied Pearson's correlation to verify significant relationships between selected factors and traffic injury severity, confirming its efficacy in such analyses.

Given that traffic data often exhibit non-normal distributions and non-linear associations, Spearman's rank correlation was also applied to capture monotonic trends that may not conform to linearity. This rank-based non-parametric method is suitable for ordinal and skewed data, and has been used in behavioral traffic studies to evaluate the strength of associations between perception-based scores and pedestrian behavior variables [28]. To further ensure robustness, particularly considering the relatively small sample size (eleven fiscal years) and potential presence of tied ranks, Kendall's tau coefficient was computed. Kendall's tau is less sensitive to outliers and provides a more conservative measure of ordinal association. Its application in traffic safety research is exemplified in the study by Bina et al. (2006) [24] who have used Kendall's tau to assess driver attitudes and perceptions towards crash causation factors.

1) Pearson's Correlation Coefficient (r)

It measures the strength and direction of the linear relationship between two continuous variables.

$$r = \frac{\Sigma(X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\Sigma(X_i - \overline{X})^2 (Y_i - \overline{Y})^2}}$$

where, X_i, Y_i are individual data points and $\overline{X}, \overline{Y}$ are the means of the respective variables.

2) Spearman's Rank Correlation Coefficient (ρ)

It evaluates the strength and direction of the monotonic relationship between two ranked variables making it suitable for non-parametric data.

$$\rho = 1 - \left(\frac{6\Sigma d_i^2}{n(n^2-1)}\right)$$

where, d_i is the difference between the ranks of each pair, n

is the number of observations.

3) Kendall's Tau Coefficient (τ)

It assesses the ordinal association between two variables by considering the number of concordant and discordant pairs.

$$\tau = \frac{C-D}{\frac{1}{2}n(n-1)}$$

where, C is the number of concordant pairs, D is the number od discordant pairs and n is the number of observations.

2.3. Crash Severity Index (CSI)

The Crash Severity Index (CSI) is a numerical representation of crash seriousness, typically calculated by assigning weights to fatalities and injuries and then normalizing them by the total number of crashes or involved people. This approach aligns with methodologies adopted in previous research. For instance, Li and Bai (2008) [27] developed crash severity index models to evaluate risk levels in work zones emphasizing the importance of weighting injury outcomes to reflect crash severity accurately. Similarly, Samerei et al. (2024) [29] applied a severity index to assess pile-up crash severity using real-time traffic and environmental factors to demonstrate the adaptability of index to varying data contexts. The CSI facilitates comparative analysis across different demographics, vehicle types and road conditions that enables targeted interventions and helps to identify vulnerable areas [26, 30].

A commonly used formula adapted from a several studies [27, 30, 31] is:

$$CSI = \frac{(w_1 \times F + w_2 \times SI + w_3 \times MI)}{N}$$

where,

$F\ is\ number\ of\ fatalities,$

$\frac{SI}{MI} = \frac{serious}{minor}\ inJuries,$

$w = severity\ weights\ and\ N = total\ casualties$

In this study, due to data availability constraints on type of injuries such as serious or minor injuries being reported as ‘injuries’ only above formula is simplified to the version as below:

$$CSI = \frac{(1.0 \times F + 0.5 \times I)}{N}$$

where,

$F\ is\ number\ of\ fatalities,$

$I = total\ number\ of\ injuries$

3. Results and Discussion

3.1. Correlation Analysis

The correlation analysis using Pearson, Spearman and Kendall Tau methods reveals consistent patterns and meaningful divergences in how road accident indicators in Nepal relate to one another. Across all three statistical measures, the relationship between reported fatalities and fatality rate per 100,000 population stands out as exceptionally strong, Pearson (0.98), Spearman (0.99) and Kendall (0.96). This is expected as the fatality rate is a derivative metric calculated directly from the number of fatalities. Even when measured using rank-based or ordinal correlation (Spearman and Kendall), the association remains firmly intact affirming their tightly coupled nature.

However, when looking at variables like number of accidents or total casualties in relation to fatality rate a different trend emerges. While Pearson’s linear correlations are modest- Accidents vs. Fatality Rate (0.41), Total Casualties[1] vs. Fatality Rate (0.37)-the Spearman (0.62 and 0.61 respectively) and Kendall (0.49 and 0.45) values are higher. This reflects that while the increase in accident or casualty numbers does not follow a perfectly linear path there is a consistent monotonic upward trend: years with more reported incidents tend to also have higher fatality rates, though not proportionally. Such patterns hint at the complex dynamics of evolving traffic environment of Nepal where exposure grows unevenly with enforcement or potential safety improvements.

Injuries behave similarly to total casualties, again showing stronger rank-based relationships (Spearman: 0.59, Kendall: 0.42) than linear ones (Pearson: 0.34). This reflects how injury counts have risen with urbanization and motorization even if they do not always coincide with proportional increases in fatalities. The nature of urban crashes-often involving motorbikes and pedestrians-could contribute to this trend where injuries increase without a sharp rise in death rates.

Interestingly, fatality per accident shows a weak or even slightly inverse relationship with fatality rate across all methods-Pearson (-0.12), Spearman (-0.03) and Kendall (-0.06). This can be accounted as accident counts grow, many are minor in nature which reduces the average fatality ratio or the increased reporting rate may have also contributed to this factor. Additionally, enforcement in post-crash emergency response, vehicle safety technologies and helmet/seatbelt usage contribute to lower lethality per incident even as total incidents increase.

In general, analysis suggests that while the fatality rate tracks closely with raw fatality counts other indicators such as accidents, injuries, and total casualties show stronger non-linear but consistent associations when analyzed with Spearman or Kendall methods. It further highlights that the traffic accident dynamics of the country are influenced not only by absolute quantities but also by shifting patterns of exposure, infrastructure and potential emergency response capacity. Figure 1 shows the correlation of different road accident factors.

[1] Casualties include both fatal and non-fatal rate.

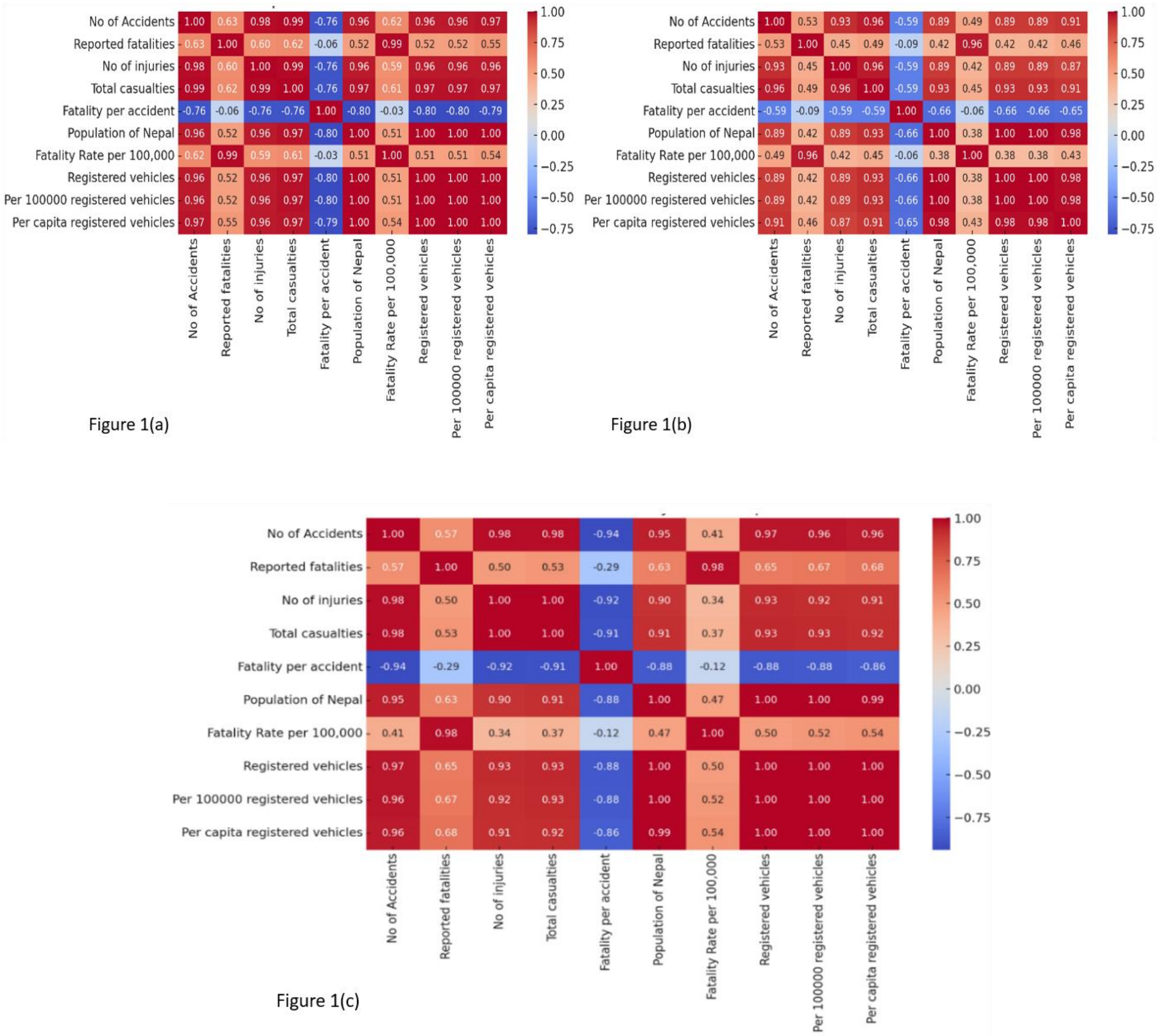

Figure 1. Correlation of Different Accident Parameters a) Pearson b) Spearman and c) Kendall.

3.2. Crash Sensitivity Index (CSI)

The severity index analysis from fiscal year BS 2070/71 to BS 2081/82 (2015-2024) demonstrates a consistent pattern of elevated fatality risk among female road users and young children only second to male group as shown in figure 2. Across all observed years, females in 25+ years age groups recorded a higher ratio of fatalities to injuries comparable to their counterparts even though that age group of male are economically active making them naturally more vulnerable to females. The severity index among females aged 25 and above remains above 0.55 in most years while male counterparts remain closer to 0.65. Children under six years of age also maintained a high severity index often exceeding 0.60 for both boys and girls. The 6–16 age group followed a similar trend with girls again experiencing a higher severity than boys. In contrast, males aged 16–25 consistently held the lowest severity index that reflects a lower fatality-to-injury ratio over the time period. Table 1 shows trend of road incidents in Nepal between male and female.

Table 1. Trend of Road Incidents in Nepal.

Year	Female		Male	
	Death	Injury	Death	Injury
2080/81	482	8392	1876	22642
2079/80	478	7881	1898	22281
2078/79	520	8202	2363	24798

Year	Female		Male	
	Death	Injury	Death	Injury
2077/78	406	5667	2094	19383
2076/77	428	4293	1823	11871
2075/76	577	4076	2212	10668
2074/75	497	3187	2044	9167
2073/74	468	3277	1917	9225
2072/73	407	3219	1599	9081
2071/72	434	3336	1570	8580
2070/71	424	3074	1363	8294

Note: BS 2070/71 to 2081/82 is 2015-2024. To avoid any ambiguity due to the unavailability of dataset in terms of monthly period data are presented in Nepali date format.

Comparable findings have emerged in global studies. The Global Status Report on Road Safety of the WHO identifies that women and children sustain disproportionately severe outcomes in traffic crashes due to biomechanical disadvantages and reduced access to timely medical intervention [2]. In urban Vietnam, research by Brondom and Florian (2016) [32] documented higher mortality rates among female pedestrians and children in traffic collisions, particularly in zones without pedestrian crossings or speed controls. Studies from sub-Saharan Africa, including Uganda and Ghana, have further recorded a greater likelihood of fatal outcomes among elderly and child pedestrians due to poor traffic segregation and limited enforcement of safety measures [33]. In India, Siddiqui et al. (2013) [34] have identified female pillion riders as a high-severity group in road crashes due to inadequate helmet use and unsafe seating positions on two-wheelers.

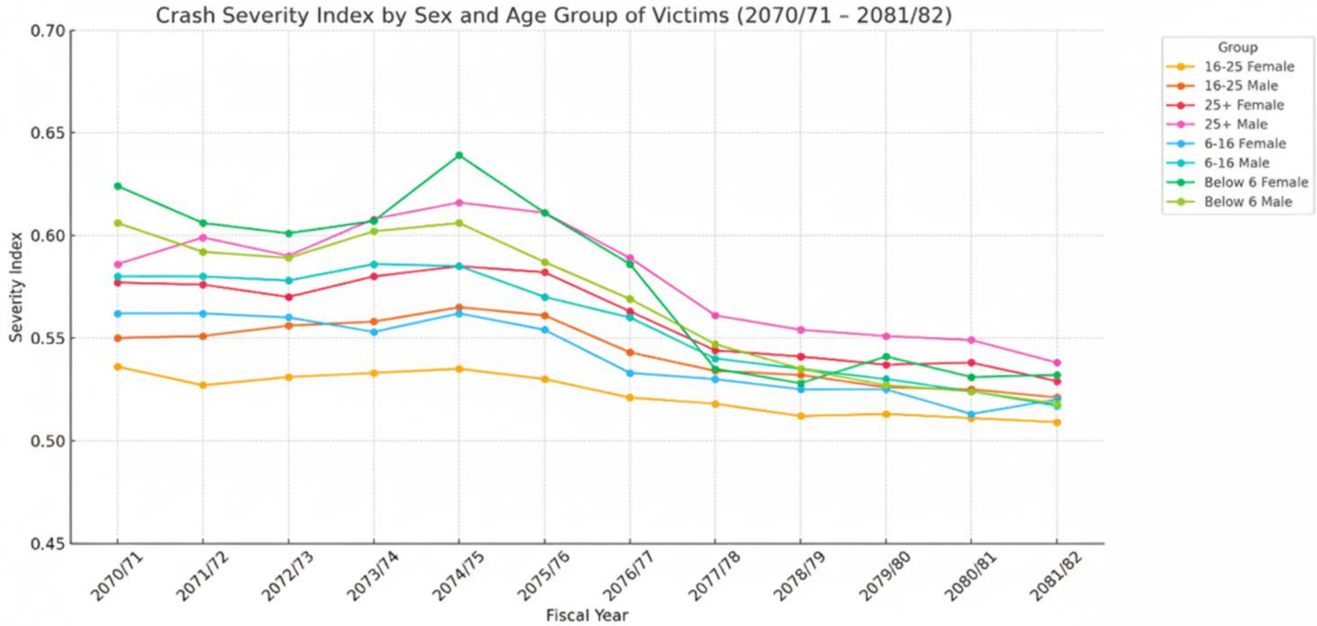

Figure 2. *Crash Severity Index by sex and age group of victims.*

Note: BS 2070/71 to 2081/82 is 2015-2024. To avoid any ambiguity due to the unavailability of dataset in terms of monthly period data are presented in Nepali date format.

3.3. Accident Trend by Provinces

The discrete figure 3 presents a clear visual summary of the total number of vehicle types involved in road accidents across the provinces of Nepal from fiscal year 2076/77 to 2081/82. It reveals that motorcycles are overwhelmingly the most involved vehicle type in Kathmandu Valley, Madhesh and Koshi Provinces each recording over 20,000 motorcycle-involved accidents. Like most of the Southeast Asian countries, the number of registration of motorcycles in Nepal has seen a tremendous increase. Out of 200,000 new vehicles registered in Nepal in 2080/82, around 150000 vehicles were motorcycles as per data available by DOTM [35]. This trend underscores the widespread use and associated risk-of motorcycles in densely populated and urbanizing areas. Jeeps and cars also show significant involvement in Kathmandu Valley followed by moderate figures in Madhesh and Koshi due to their higher rates of private vehicle ownership. Auto rickshaw involvement is especially notable in Koshi and

Madhesh aligning with the fact that their common use in short-distance urban transport. Meanwhile, heavier vehicles such as buses, tankers and tippers display a more moderate and evenly spread pattern across provinces.

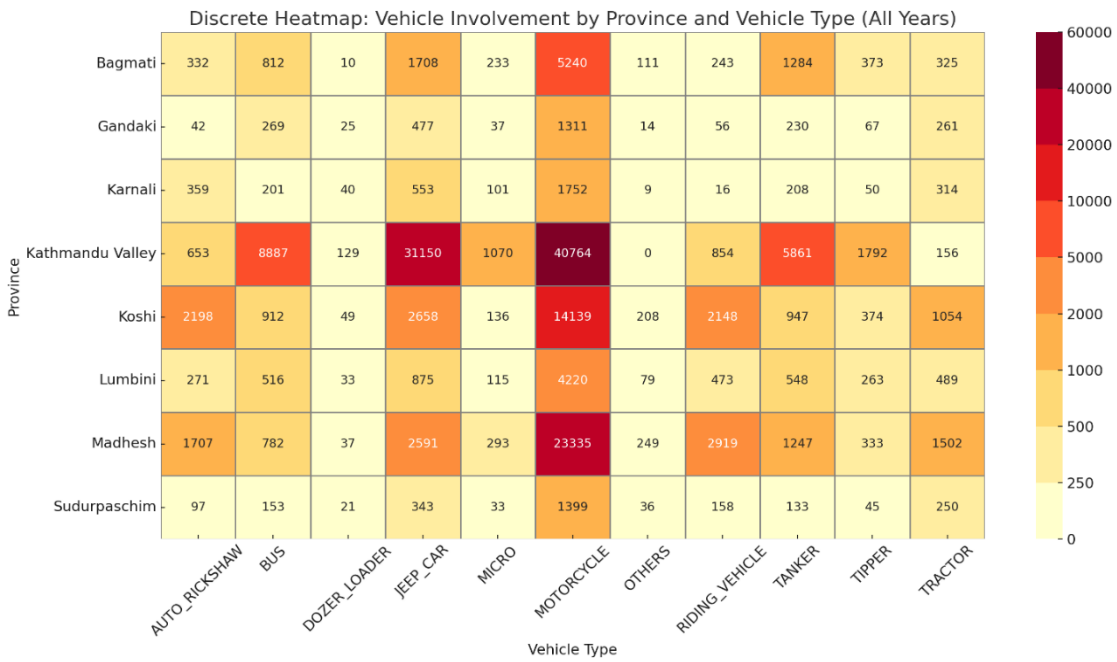

***Figure 3**. Heat Map of Types of Vehicles Involved in Road Incidents in Different Provinces.*

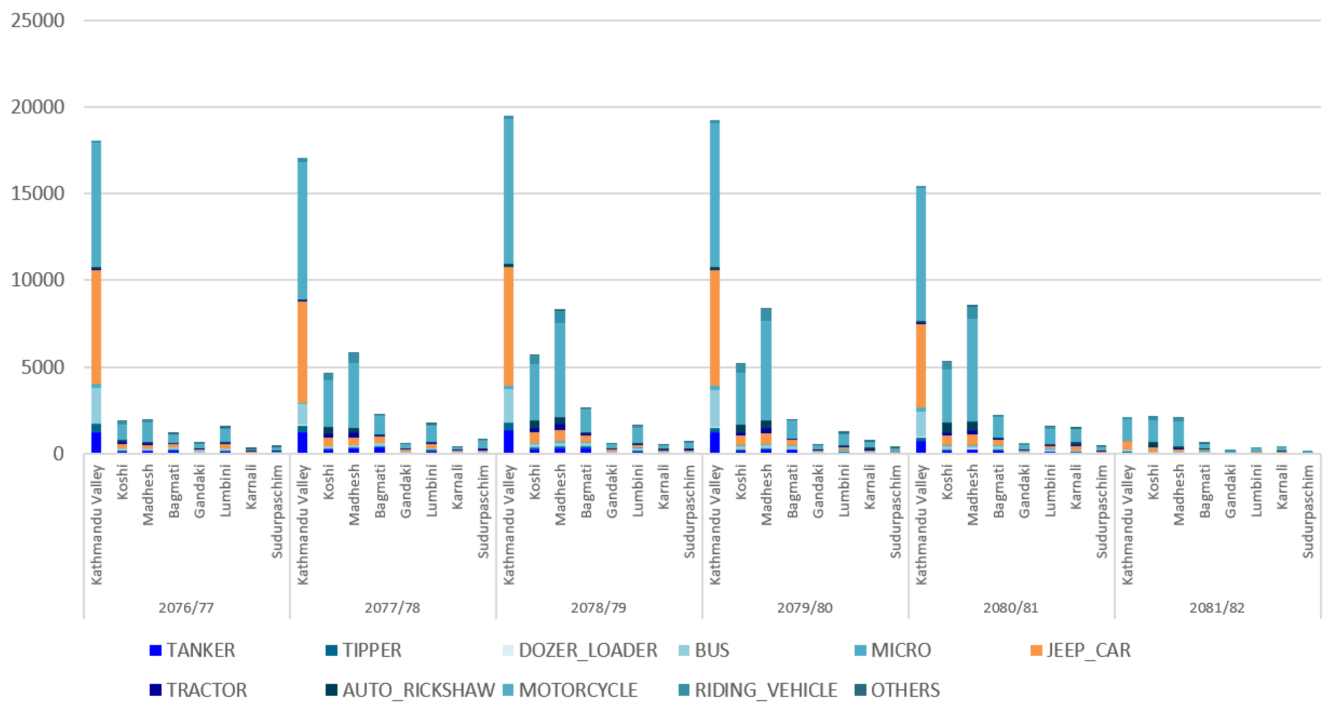

***Figure 4**. Province wise road crash.*

Note: BS 2070/71 to 2081/82 is 2015-2024. To avoid any ambiguity due to the unavailability of dataset in terms of monthly period data are presented in Nepali date format.

The trend analysis as shown in Figure 4 across the provinces of the country from FY 2076/77 to 2081/82 reveals that motorcycles are the dominant vehicle type involved in traffic accidents nationwide, with the highest concentrations in

Kathmandu Valley, Madhesh, and Koshi Provinces. Kathmandu Valley consistently records the largest number of total accidents driven by its dense urban traffic and widespread use of both motorcycles and jeeps/cars, along with significant involvement of buses and micro-buses, reflecting its role as a transport hub. In Madhesh and Koshi, motorcycles are again the leading contributors but there is also a notably high presence of auto-rickshaws due to their crucial role in urban and peri-urban mobility. The high number of motorcycles involvement in accidents also hints their excessive use in mobility. Out of 200000 new vehicles registered in Nepal in 2080/82, around 150,000 vehicles were motorcycles [35]. Bagmati and Lumbini show moderate accident volumes with Lumbini seeing a steady rise in tractors and jeeps likely due to their agricultural relevance. Across all provinces, motorcycles remain the most consistently overrepresented vehicle type while urban areas also see higher shares of rickshaw and private vehicle accidents.

3.4. Accident Trend by Vehicle Type

The trend analysis of vehicle-type involvement as shown in Figure in road accidents also reveals persistent dominance of motorcycles accounting for approximately 40% to 55% of all reported vehicle-related incidents each year. This overrepresentation is a result of several factors: the high volume of motorcycles on Nepalese roads, their affordability compared to four-wheelers and their high exposure to risky driving environments especially in mixed-traffic urban corridors. Motorcycles are widely used not only for personal mobility but also for deliveries, ride-sharing and long-distance commuting-activities that increase road exposure and consequently, risk. These findings align with international evidence from WHO [6], and Mukharjee and Mitra (2022) [36] that place two-wheeler riders among the most vulnerable road users particularly in LMICs where protective infrastructure and enforcement are often inadequate.

The consistent rise in jeep and car involvement correlates with the expanding middle class, urban sprawl and increased access to vehicle financing in Nepal. As private vehicle ownership rises especially in and around Kathmandu, the probability of urban collisions and congestion-related crashes has grown. Literature from Gwilliam (2003) [37] and Litman (2023) [38] links motorization rates to increased urban traffic injuries when not accompanied by proportional investments in infrastructure and traffic management. The existing road infrastructure of the country struggles to safely accommodate this surge in vehicle types.

The upward trend in auto-rickshaws and small vehicles, including bicycles and e-mobility options like e-scooters underscores their growing popularity in the rapidly urbanizing municipalities. Their compact size and low emissions make them attractive for last-mile transport [30]. However, these modes are also under-regulated and poorly integrated into the formal traffic governance frameworks of the country. Case studies from the MoRTH reports of India [19] and BRAC (Bangladesh) [39] highlight similar trends where a rise in micromobility leads to increased collision rates when not supported by designated lanes and protective urban design.

In contrast, the decline in accident involvement among buses can be attributed to multiple factors. Nepal has seen the implementation of some stricter public transport regulations. Furthermore, there is a growing decentralization of public transport with minibuses, microvans and ride-hailing platforms offering more agile services. As seen in similar LMIC settings, smaller-scale and tech-integrated mobility tends to reduce exposure for high-capacity public transport vehicles which are increasingly limited to controlled corridors.

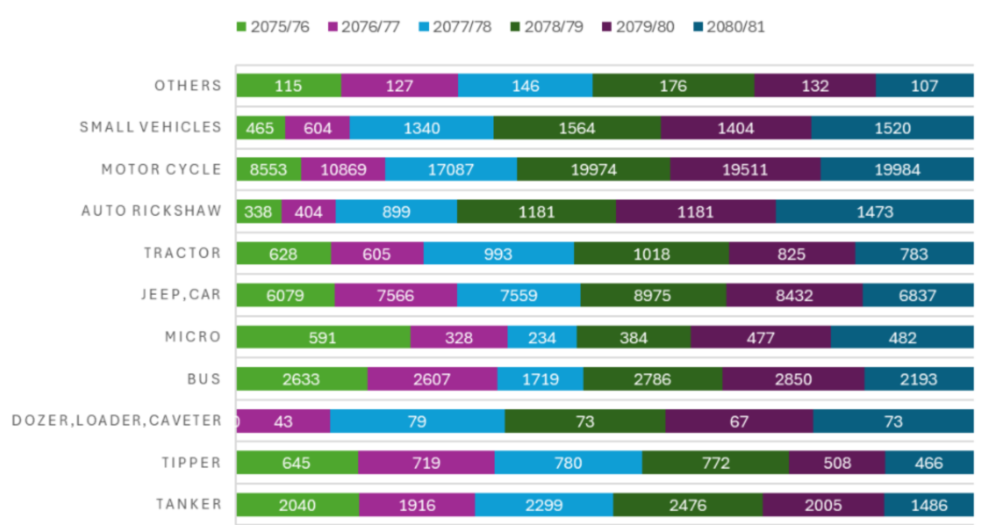

Figure 5. *Trend analysis of vehicle Type.*

Note: BS 2070/71 to 2081/82 is 2015-2024. To avoid any ambiguity due to the unavailability of dataset in terms of monthly period data are presented in Nepali date format.

3.5. Road Accidents by Road Types

While highways historically accounted for the bulk of reported accidents in the country their share has declined in recent years whereas accidents on urban streets and rural roads have surged as shown in 6. Urban street-related accidents have more than doubled over the decade particularly after 2075/76 peaking above 10,000 cases in 2079/80. This increase aligns with rapid urbanization, the proliferation of motorcycles and e-rickshaws and the lack of adequate road planning, traffic regulation and pedestrian infrastructure in growing municipalities [37]. Similarly, rural road accidents began rising steeply after 2074/75-coinciding with the federal restructuring of Nepal which empowered local governments to construct roads rapidly often without engineering standards or road safety protocols. These roads while critical for access have become accident-prone due to poor design, low driver awareness and lack of enforcement. In contrast, highway accident rates began declining after 2077/78 that can be attributed to the potential improved patrol presence, resurfacing efforts and blackspot treatments [4]. Collectively, these patterns illustrate a transition from a highway-centered transport risk landscape to a more decentralized and diversified one that has further emphasized the need for localized safety strategies and capacity-building at the municipal and provincial levels.

Further compounding this trend is the underlying emphasis on rapid road expansion over long-term resilience and safety. A World Bank study (2015–2021) [40] found that the road development in the country during this period was predominantly quantity-driven with local governments prioritizing physical access without sufficient investment in engineering standards, maintenance systems or disaster resilience. This expansion often neglected terrain-sensitive design leading to infrastructural fragility particularly in hilly and mountainous regions. Supporting this Shrestha et al. (2025) [41] demonstrated how unplanned rural road construction at the local level has increased landslide vulnerability caused not only environmental degradation but also heightened crash risk due to unstable road conditions. Despite these risks and the increase in road density, the National Road Safety Action Plan 2021-30 is still not been passed form the cabinet of Nepal [4]. Critical provisions-such as safety audits, crash data systems and mandatory design safety-have remained under-enforced especially at the local level. As a result, while physical connectivity has improved significantly safety outcomes have lagged behind reinforcing the need for a strategic pivot from access-centric planning to safety-integrated road development.

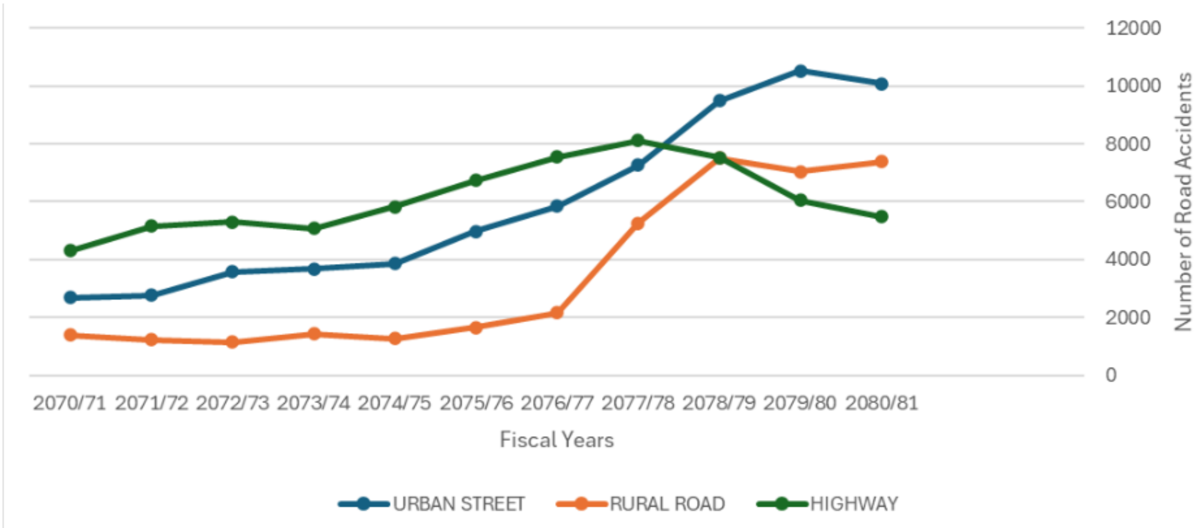

Figure 6. Number of crashes according to road type.

Note: BS 2070/71 to 2081/82 is 2015-2024. To avoid any ambiguity due to the unavailability of dataset in terms of monthly period data are presented in Nepali date format.

3.6. Road Accidents by the Age Group of Driver

The statistics presented in Figure show consistent dominance by the 25-40 age group of drivers whose share remained above 50% for most of the years due to drivers in this productive and high-mobility age range being the most exposed to road risk-due to work-related and urban commuting patterns. The 16-25 age group contributed steadily around 30–32% of total accidents each year. Their share slightly declined in some mid-years but rose again in FY 2081/82 (2024) to 31.3% due to continued entry of inexperienced or new drivers into the road system. The above 40 age group showed a gradual increase in their share rising from 17.68% in FY 2070/71 (2015) to 22.45%

in FY 2081/82 (2024) due to aging populations continuing to operate vehicles and their increasing presence in rural or long-route driving roles. Overall, the share of accidents among the 25–40 age group is slowly declining while the share among drivers above 40 is rising. The 16–25 group remains stable with slight year-to-year variation.

The current driver licensing policies of Nepal and enforcement practices help explain the consistently high share of traffic accidents among younger and middle-aged drivers. Individuals are legally allowed to acquire a motorcycle license at age 16 and a four-wheeler license at 18 which grants early road access to relatively inexperienced drivers. The licensing process primarily tests basic vehicle control but lacks a comprehensive assessment of hazard perception, decision-making under stress or understanding of defensive driving. As a result, young drivers in the 16–25 age group often begin driving without adequate preparation for real-world traffic risks. This issue is compounded by the presence of loopholes in the licensing system-particularly the influence of intermediaries who help applicants bypass proper procedures [42]. These procedural gaps explain the consistent overrepresentation of young drivers in accident statistics. For the 25–40 age group, which accounts for the largest share of accidents across most years; the explanation lies in their high exposure to road environments. This group is the most economically active and often uses two-wheelers and light vehicles for work, delivery services and commuting.

Numerous studies have established a strong correlation between driver age and traffic accident risk especially in low-and middle-income countries. According to the WHO [6] young drivers aged 15–29 are disproportionately involved in road crashes due to inexperience, risk-taking behavior and inadequate driver education systems. This trend aligns with the findings of Khadka et al. (2024) [43] who analyzed traffic accident data in Nepal and found that motorcyclists in the 16–25 age group accounted for a significant proportion of fatal and non-fatal crashes. The study attributed this to minimal training and weak regulatory enforcement during license acquisition. Furthermore, the licensing system suffers from procedural inefficiencies and corruption which allow unqualified individuals to obtain licenses often through middlemen. The absence of a graduated driver licensing (GDL) system, as promoted by the Global Road Safety Partnership (GRSP), has also been identified as a key policy gap in Nepal. International literature such as by McCartt et al. (2010) [44] shows that GDL systems significantly reduce crash rates among new drivers by introducing phased driving privileges and mandatory supervised driving periods. Additionally, older driver safety research such as from Oxley & Whelan (2008) [45] emphasizes the importance of periodic medical and cognitive testing during license renewal, a component missing in the current framework of Nepal. These studies provide robust support for the observed accident trends across driver age groups in Nepal and point toward systemic gaps in licensing policy and enforcement that contribute to them.

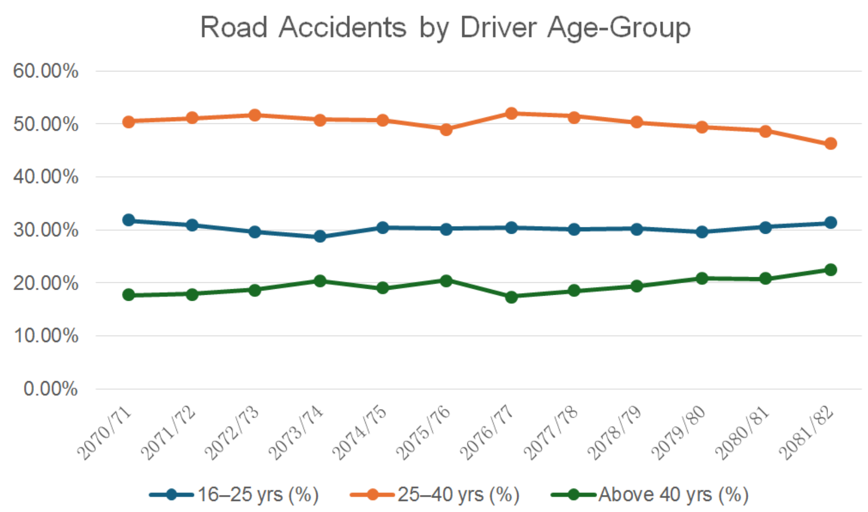

Figure 7. *Road accident by the age group of drivers.*

Note: BS 2070/71 to 2081/82 is 2015-2024. To avoid any ambiguity due to the unavailability of dataset in terms of monthly period data are presented in Nepali date format.

3.7. Discussion

This study has uncovered alarming patterns and enduring difficulties in the road safety environment of Nepal. Due to the lack of legal requirements, pillion riders are particularly at risk because helmet compliance is so low. Similarly, operational delays continue to plague emergency response systems in both urban and rural areas increasing the risk of morbidity and fatality following crashes. Vulnerable populations are disproportionately affected by these tendencies especially women and children who suffer more severe consequences in traffic accidents. In addition to physical vulnerability, systemic flaws in road design, lax enforcement and insufficient post-crash care procedures all contribute to this increased risk.

Nepal has a number of legislative and institutional guidelines including the Nepal Road Standard (2013) [46], Nepal Rural Road Standard (1999) [47] and Nepal Urban Road Standard (2019) [48]. Although these frameworks set standards for structural design road safety is not given express priority in many modern legislations. Crucially, a large number of current laws have not been updated in years and do not take into account changing trends in road usage. Although it remains the statutory foundation, the Motor Vehicle and Transport Management Act (1993) [49] is vague in addressing the distinct safety requirements of commercial transport operators, two-wheelers and micromobility users. It is vital that policies address the lack of vehicle-specific training modules, required helmet use for pillion riders and segregated infrastructure especially in light of the exponential growth in two-wheeler registrations and their domination in crash statistics.

Additionally, the spatial disaggregation of crash data across the seven provinces of the country shows that the type of vehicle involved in accidents varies. Although motorbikes are the most common vehicle in every province three-wheeler, jeep and bus crashes have increased in provinces like Madhesh and Sudurpashchim. Thence, decentralized policymaking that is adapted to the risk profiles of individual provinces is required. Furthermore, underreporting, incorrect categorization and the absence of geographic integration in accident documentation limit the present data environment of the country *(discussed in the next section)*. These restrictions make it more difficult to identify high-risk areas and implement focused interventions.

The demographic analysis of road traffic deaths over the last ten years reveals distinct patterns by age and gender. Adult males over the age of 25 regularly account for the highest proportion of fatalities often reaching 40% owing to their overrepresentation in high-risk vocations such as long-distance driving and considerable daily road exposure. Studies have discussed the absence of frequent health screening or re-certification at license renewal leading to ongoing risk in this age group [50, 51]. Males aged 16 to 25 are the second-highest fatality group due to risk-taking attitudes early access to licenses (motorcycles at age 16, cars at age 18) and a general underestimating of hazards. In contrast, females continuously have lower fatality rates across all age groups. While this may imply lesser risk, it really reflects lower exposure as women in Nepal are less likely to engage in commercial driving and long-distance trips. However, as urban female mobility grows, the related danger is projected to escalate unless infrastructural and policy frameworks change. Research on gender mobility by Uteng & Cresswell (2008) [52] shows that the women travel is frequently confined, more localized and route-specific currently minimizing the exposure but may evolve with increased access and independence.

Though proportionally lower child fatality remains a pressing concern in terms of preventability. Most fatalities in this group occur due to inadequate pedestrian infrastructure, unprotected school zones, and poor helmet usage among child passengers. International guidelines from WHO (2018) [53] and the Global Road Safety Partnership (GRSP) [54] identify children as high-priority VRUs necessitating localized interventions such as speed-calming infrastructure, designated crossings, and improved vehicle restraints. A pilot assessment using the Star Rating for Schools (SR4S) tool in Nepal reported that only 3 of 14 schools scored above 3 stars all situated within the Kathmandu Valley [55]. This reveals the acute safety gap in peri-urban and rural school zones where road infrastructure is often non-existent or unsafe. Despite such findings, Nepal still lacks enforceable national guidelines tailored to school zone safety.

Another often overlooked institutional challenge pertains to the licensing system. Widespread evidence suggests that intermediaries can subvert official procedures, enabling unqualified applicants to obtain licenses. This not only compromises the validity of licensure but also allows underprepared drivers onto the roads. Investigative reports have documented individuals paying substantial bribes sometimes over NPR 100,000 to bypass formal testing [56]. While the Department of Transport Management (DoTM) has introduced digital platforms to enhance transparency, structural loopholes remain undermining the integrity of the system and increasing public health risk.

Collectively, these findings point to a multidimensional crisis. The rise in crashes and fatalities particularly among VRUs and high-risk demographic groups raises substantive concerns regarding the progress of the country towards achieving SDG Target 3.6. The lack of updated legislation, poor infrastructure, weak data systems and insufficiently targeted safety measures underscore the urgent need for a more comprehensive, disaggregated and equity-driven approach to road safety governance. Without such reforms, Nepal risks continued preventable deaths and a growing burden on its health and economic systems.

4. Benchmarking Limits

This study acknowledges several structural and methodological constraints that may affect the precision and generalizability of its findings. Foremost among these is the nature of crash data collection in Nepal. The Nepal Police, which is the primary agency responsible for managing road traffic incident records, lacks a dedicated institutional unit or standardized protocol for crash data collection and management. Field officers responsible for recording incidents have not received specialized training in crash investigation or forensic classification nor is there a uniform digital infrastructure in place to support real-time reporting. Consequently, inconsistencies in data quality-particularly in terms of injury classification, accident location precision and missing demographic details, pose potential limitations to the empirical validity of statistical outputs of this study.

Furthermore, while this study aims to analyze road crash trends in the context of the evolving transportation infrastructure of the country, it is constrained by the absence of a comprehensive, publicly available database on road length and classification, especially at the provincial and local levels. The exponential expansion of rural and peri-urban road networks following the democratic transition in 1990 followed by federalism in 2015 has been driven more by political and electoral imperatives than by technical planning or engineering assessments. As a result, reliable spatial datasets delineating the rate of road extension or its quality (e.g., paved vs. unpaved, arterial vs. feeder) are unavailable or fragmented across agencies. This hinders the capacity of this study to perform robust benchmarking of accident incidence per kilometer of road particularly in rural and hilly terrains where connectivity has outpaced oversight.

In addition, the geographical categorization of road crashes: urban, rural or highway remains loosely defined and dependent on subjective field assessment at the time of the incident. This lack of standardization in spatial and contextual classification introduces further variability into severity assessment models. Notably, the development of the CSI within this study was constrained by the absence of stratified injury data such minor, serious and critical. Given the lack of clinical or parametric verification of injury types in the field a uniform weight was assigned to all injury cases. While this approach ensures methodological consistency, it may underrepresent or overrepresent the true burden of certain incident types, particularly those involving vulnerable road users such as children, the elderly, or female pillion riders.

Taken together, these limitations do not negate the findings of this study but rather contextualize them within the realities of data governance, infrastructure planning, and institutional capacity in Nepal. Future research would benefit from the establishment of a centralized crash data repository, standardized injury classification protocols, and geospatially tagged road inventories maintained collaboratively by all three tiers of government.

5. Conclusion and Recommendations

This study serves as a data-based road safety approach toward assessing, changing landscape of Nepal in the past decade. It integrates multiple datasets from different years and statistical tools, including correlation matrices and the Crash Severity Index and severity of road traffic incidents by age groups, vehicle types, road types, and provinces of Nepal.

There has been a major rise in road traffic deaths and injuries, with motorcycles representing more than 50% of vehicles involved in road traffic crashes, and male adults between 25 and 40 years, constituting the majority in cases of deaths. Similarly, the study shows a concerning involvement in road crashes for young and middle-aged drivers. The road safety of the country keeps worsening with increased road networks and mobility access, but with limited road safety concerns, especially for vulnerable road users such as women, children, pedestrians, and pillion riders. While the number of male road users involved in crashes is high, females and children have a severe impact in any crash. The number of motorcycles involved in crashes is notably high in Kathmandu, Koshi, and Madhesh provinces, given the fact that they are the most registered vehicle type in Nepal. The vulnerability associated with two and three-wheelers is prevalent with instability and limited inbuilt safety features. However, the impact of the crashes could be prevented to some extend if the use of helmet by both the rider and pillion rider was emphasized. It has been found that pillion riders are significantly less likely to wear helmets compared to riders which increases their risk of serious injury or fatality in the event of a crash. The rapid pace in roadway development across rural Nepal has brought forth haphazard and unsafe roads. The lack of road safety audits and monitoring along with the inconsideration of road safety infrastructure has made these roads to be increasingly perilous during the rainy season taking many lives with it. The analysis also exposes systemic problems that feed into these concerns, out-of-date policies and acts, weak enforcement capacity, lack of protective infrastructures and poor data integration in identifying high risk zones. Crashes are on the increase both in urban and rural areas stressing the urgent need to decentralize interventions for road safety while enhancing the capacity of local governments to plan and develop transport infrastructure where safety is of paramount concern.

Abbreviations

CSI	Crash Severity Index
DoTM	Department of Transport Management
EU	European Union
FY	Fiscal Year
GDL	Graduated Driver Licensing
GDP	Gross Domestic Product
GNP	Gross National Product
GRSP	Global Road Safety Partnership
LMICs	Low-and Middle-Income Countries
NRSAP	National Road safety Action Plan
RTI	Road Traffic Injuries
RTF	Road Traffic Fatalities
SDG	Sustainable Development Goals
SR4S	Star Rating for Schools
USA	United States of America
VRUs	Vulnerable Road Users
WHO	World Health Organization

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Conflicts of Interest

The authors declare no conflicts of interest.

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