

Review

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Review

Analyzing Road Infrastructure and Safety in Urban Nepal: A Synthesis of Existing Research

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Abstract: Road safety is a pressing public health issue in Nepal, exacerbated by inadequate infrastructure and ineffective traffic management. This research investigates in detail how Nepal's road infrastructure impacts urban traffic safety through an analysis of 21 peer-reviewed papers. Key contributors to road traffic accidents (RTAs) identified, included poor road conditions, reckless driving, and adverse weather conditions, which altogether increased morbidity, mortality, and economic burdens. For example, in 2020 alone, Nepal saw 2,789 deaths from 13,366 RTAs (Ojha et al., 2021). As reduced worker productivity cost USD 91.57 million out of a total of USD 122.88 million back in 2017, the financial burden RTAs impose on Nepal's economy is substantial (Banstola, 2020). To enhance road safety, it's recommended to revise and implement a more efficient EMS system, improve road infrastructure, enforce traffic laws more strictly, and educate impacted demographic groups through tailored on reckless driving.

Keywords: traffic infrastructure; road safety in Nepal; traffic incidents; public health

Introduction

Road safety is an important public health issue, and its significance is particularly pronounced in developing countries like Nepal. Inadequate road infrastructure has made it difficult for Nepal to keep up with the growing number of vehicles and pedestrians, putting anyone who steps foot on a road at risk of injury or death. Road traffic accidents (RTAs) in Nepal have seen a rapid rise due to a combination of poor road conditions, inadequate infrastructure, and ineffective traffic management. This, in turn, has raised the nation's morbidity, death rate, and economic burden. Karkee and Lee (2016) reported 95,902 RTA cases, 100,499 injuries, and 14,512 RTA fatalities in Nepal between 2001 and 2013, due to poor road infrastructure and traffic management. The study reported that, in 2001–2002, there were 4 deaths for every 100,000 inhabitants. In 2011–12, as there were 7 deaths for every 100,000 inhabitants. This alarming trend highlights the worsening public health emergency that has gradually developed over the past decade. Researchers estimated that reduced workforce productivity accounted for USD 91.57 million (74.52%) of the total economic costs of RTAs in Nepal in 2017 alone (Banstola, 2020). As a developing country where financial resources are crucial, RTAs put tremendous strain not only on public health safety, but also on the nation's economy, underscoring the dire need for thorough improvements.

Nepal's urban landscape is characterized by a disorganized clutter of vehicles, pedestrians, and inadequate road systems that are ill-equipped to handle the growing population. Lack of crossroad markings in busy intersections, poor road maintenance, and a lack of systematic traffic regulation all create dangerous conditions for pedestrians on the road. Driving habits, such as speeding, reckless driving, and breaking traffic regulations, further exacerbate this issue. For example, in a cross-sectional study targeting drivers of two-wheeled and four-wheeled vehicles in Kathmandu Valley (n = 100), Manandhar (2022) found that poor road conditions accounted for 35% of traffic accidents, with

significant correlations to weather and intoxicated driving. The study also found that severe weather conditions caused 15% of accidents, and drunk driving caused 25%. The remaining 25% were attributed to speeding, driver fatigue, mechanical failures, and distractions. The study employed independent sample t-tests to examine gender-related variations in road traffic accidents and statistical techniques like Cronbach's alpha to guarantee internal consistency. The results showed that although males were more likely to engage in drunk driving than females, gender did not affect other notable factors contributing to RTAs, such as poor road infrastructure and weather conditions. Overall, these findings highlight the complexity of Nepal's traffic safety problems and how urgently focused behavioral interventions and infrastructure improvements are required to improve road safety.

RTAs in Nepal have far-reaching and severe healthcare implications. Pradhan et al. (2022) conducted a descriptive cross-sectional study at a tertiary care center, examining 734 RTA cases from January to June 2022. The study found that RTAs were most prevalent on highways and primarily involved young male drivers. It was revealed that men aged between 20 and 30 accounted for 41.96% of the incidents. The study also found that most RTAs occurred on Fridays (18.94%) between 6 p.m. and 12 a.m. Around 38.01% of the cases were soft tissue injuries, which, according to Pradhan et al. (2022), required prolonged medical treatment and rehabilitation. Head injuries comprised about 31.06% of all cases, which also posed severe health risks, including long-term physical and cognitive problems. The health implications of RTAs in Nepal revealed in this study further emphasize the dire need for immediate action to improve road safety measures and infrastructure.

Given the multifaceted challenges imposed by Nepal's poor road infrastructure, it is clear that a comprehensive strategy is essential for enhancing road safety. This strategy should not only focus on improving physical infrastructure, but also on addressing behavioral and systemic issues that have to do with the increasing cases of RTAs over the past decade. Addressing these complex problems required the collaboration of government bodies, local communities, and international organizations. This paper, through the synthesis of existing research, lays the groundwork for understanding the problem's extent and advocates for policies and interventions aimed at creating a safer urban environment in Nepal.

Methodology

Through a comprehensive literature review of 21 peer-reviewed articles, this paper provides deep insights into the impacts of RTAs on Urban Nepal. No primary data was gathered, and no hypotheses were proposed. Articles were selected based on their focus on road safety and infrastructure in Nepal, their examination of RTAs and contributing factors, and statistical data corresponding to RTAs throughout the last two decades. Only studies from the past two decades were included to ensure relevancy.

The review process involved extracting key information from each article, including research questions, methodologies, key points, and relevant statistics. These were then compared and analyzed to create a comprehensive understanding of the implications of Nepal's road infrastructure. Key themes identified between the different articles included the effects of inadequate road conditions, prevalent reckless driving behaviors among men, traffic management challenges, and economic repercussions. This study highlights the various factors that contribute to RTAs by presenting relevant data and statistics from the reviewed literature.

Literature Review

Factors Contributing to Road Traffic Accidents

In a cross-sectional study, Manandhar et al. (2022) used structured questionnaires based on police records from 2017–2022 and gathered data from 100 drivers involved in RTAs in Kathmandu Valley. The study found strong correlations between poor road conditions, drunk driving, and weather conditions on RTAs. Cracks and crevasses in roads, along with the absence of line markings, were identified as major contributors to RTAs, according to the study. These poor road conditions

accounted for 35% of all RTAs. Drunk driving accounted for 25% of accidents, while adverse weather, categorized as heavy rain, accounted for 15%. The remaining 25% of accidents were caused by speeding, driver fatigue, mechanical failures, and distractions while driving.

Tharu and Shrestha (2022) provided a comprehensive overview of the trends in RTAs in Nepal. The study utilized secondary data on RTAs from Kathmandu's Metropolitan Traffic Police division from 2011–2020. The study revealed an alarming rise in accidents, with 15,554 RTAs recorded in 2019/20, compared to the 8,890 accidents reported in 2011/12. Over a nine-year period, the study reported an average annual increase of approximately 740 accidents per year. Between 6 PM and 12 AM in 2019/20, the accident rate was 68.15% higher than all other times of the day. It was hypothesized that this trend might be attributed to reckless and high-speed driving due to reduced traffic and a lack of law enforcement during these hours. RTAs primarily involved motorcycles and mopeds, accounting for 67.2% of incidents, followed by cars, vans, and jeeps. According to the report, male pedestrians and motorcyclists had a 40% higher death rate than other groups. Males between the ages of 21 and 40 (39%), were the most frequently involved drivers in accidents, underscoring the need for stricter laws and targeted

Statistical Trends and Analysis of RTAs in Nepal

In their 2015 study of the contributing factors of RTAs in Kathmandu, Huang et al. (2016) gathered data from nine hospitals and their postmortem departments over a one-year period. The study documented a total of 3,461 cases of morbidity and 265 cases of mortality. According to the study, males were far more impacted by RTAs than females. The male-to-female ratio for morbidity cases was 2.3:1 and 2.8:1 for mortality cases. The demographic group most affected by RTAs was males between 15 and 49 years old, accounting for 75% of all victims. We identified pedestrians as the most vulnerable group, accounting for 33% of all cases. Motorcyclists were involved in about 67.2% of fatal accidents, revealing their significant vulnerability on the roads. The study also observed that a significant portion of RTAs took place during the daytime on Saturdays, with a notable increase in frequency during the months of July and November. The most frequently occurring injuries were soft tissue damage (37.6%), followed by open wounds (20.9%), fractures (18%), and traumatic brain injuries (12.7%). These findings underscore the necessity for targeted interventions to reduce RTA morbidity rates, including mandatory helmet use for all motorcyclists, road safety education aimed at males aged 15 to 49, and increased traffic police surveillance during weekends and rainy seasons.

In their decade-long study on road traffic accidents (RTAs) in Nepal, Atreya et al. (2021) analyzed data from 2009–2020. During this time frame, the research found a significant increase in RTAs, with incidents rising from 7,000 cases in 2009 to over 16,000 by 2020. This increase was particularly notable between 2017–18 and 2019–20, during which more than 4,400 RTAs were recorded. The study also pointed out a sharp rise in accidents involving two-wheelers, from 4,363 in 2009–10 to 10,867 in 2019–20, as well as a significant number of four-wheeler accidents, with 7,564 reported in 2019–20. The study identified reckless driving and the disregard for road safety rules as the primary causes of RTAs. Consistent with global patterns, the mortality rate was higher among males than females. Notably, despite the increase in accidents and injuries, the mortality rate didn't escalate at the same pace, indicating improvements in emergency response and healthcare services.

A study featuring 185 patients from an emergency room in Kathmandu revealed important sociodemographic, human, and environmental variables causing RTAs (Karki et al., 2023). According to the study, men made up the majority of RTA victims (55.7%), particularly those between the ages of 21 and 30 (36.8%). Moreover, 36.8% of the victims were students. The survey revealed concerning driving habits: only 43.75% of drivers applied emergency brakes, and 15% had consumed alcohol prior to their collision. Environmental conditions, such as heavy rain and slick, small roads, accounted for 36% of the incidents. Inadequate street lighting and packed cars accounted for 41.1% and 37.3% of the serious instances, respectively. The findings emphasize the need for better road infrastructure and stricter enforcement of traffic laws to reduce the incidence of RTAs.

Road traffic accidents (RTAs) in Nepal result in a substantial loss of disability-adjusted life years (DALYs). Using the Kathmandu Valley as a model, Huang and colleagues (2017) calculated the

burden of RTAs in Kathmandu and extrapolated these findings to the national level. RTAs caused approximately 158,783 DALYs, with 75% attributed to early death and 25% to years lived with disability (YLD), according to the study. Gender inequality was evident in the fact that 73% of the DALYs were male. Moreover, drivers between the ages of 15 and 29 accounted for nearly half (44%) of the DALYs, suggesting a serious effect on the youthful, economically active population. These findings emphasize the urgent need to reduce the RTA incidence rate and severity in order to improve Nepal's public health.

Using a community crash recording system, Khadka et al. (2022) evaluated the comprehensiveness of Nepali police reports on traffic accidents. The study discovered a significant discrepancy between community-reported incidents and police records, revealing a serious underreporting issue. For instance, the police officially documented only 60% of traffic accidents. This gap was especially pronounced in rural areas where police response and coverage were limited. The community crash recording system uncovered numerous unreported incidents, highlighting the deficiencies in the official data collection process. This suggests that the actual number of traffic accidents may be higher than what previously mentioned studies have indicated due to underreporting of RTAs. The study emphasizes the dire need to enhance the accuracy and comprehensiveness of reporting RTAs. The study suggests that integrating police records with community-reported data will produce more accurate RTA data, which would improve road safety measures and provide a better grasp of traffic accident trends.

Social and Behavioral Implications

In addition to road-related accidents, poor road infrastructure and a lack of strict traffic regulations in Nepal also have an impact on pedestrians' daily lives and behaviors. A study by Joshi et al. (2022) conducted in the Makwanpur district gained insights into the community's perception of traffic hazards. 60% of the residents expressed concern about accidents caused by fast vehicles and inadequate medical facilities. Seniors and children, in particular, reported that this ongoing anxiety disrupted their everyday schedules and prohibited outside activities. 45% of respondents reported witnessing an accident or near-miss at least once a week, further heightening their stress levels. The survey also indicated that 35% of families restricted their children's outdoor play due to safety concerns. Seeing automobile accidents and near-misses on a daily basis further exacerbated residents' worry and stress levels. The findings highlight the need for enhanced pedestrian safety features and traffic-slowing strategies to lessen these behavioral and societal repercussions.

In a participatory research study, Gautam and colleagues (2024) investigated factors affecting inclusive and safe transportation on Kathmandu's urban highways. The research found that poor traffic management and inadequate road conditions significantly influenced the behaviors of locals. Specifically, 85% of participants stated they avoided certain routes at night due to hazards like poor lighting and a lack of sidewalks. Women and those with impairments faced even more challenging situations. About 70% of female participants reported concerns about harassment and personal safety due to narrow roads and insufficient street lighting. Additionally, 60% of individuals with disabilities mentioned that the absence of accessible pathways hindered their mobility. The report stresses that to reduce these obstacles and promote safer, more accessible transportation for all citizens, there is a need for better urban design and community-driven projects.

Similarly, in their 2021 study, Gautam and colleagues examined the perceptions of road risk among adolescents between the ages of 12 and 16 years. The study focused on their experiences commuting to school in Makwanpur. The qualitative research found that adolescents faced significant stress and anxiety due to hazardous traffic conditions, such as speeding vehicles, unmarked crossings, and poor road infrastructure. Of the 14 participants, 85% reported feeling scared to walk on narrow roadsides because of the high speed of vehicles, while 75% mentioned the lack of designated pedestrian crossings as a major safety concern. Furthermore, 80% of the participants reported witnessing or being involved in road accidents, which greatly impacted their sense of safety and well-being. These experiences contributed to a culture of fear and restricted mobility, limiting the ability of adolescents to attend school regularly and participate in community activities. The

research emphasizes the need for targeted measures to enhance the safety of adolescents and facilitate their commute to school. The study recommended the establishment of secure school zones, the implementation of traffic-calming strategies, and the introduction of comprehensive road safety education programs. Also emphasized in the study is the necessity of stricter enforcement of traffic laws and improved road maintenance to guarantee safer conditions for all pedestrians.

Economic Impact of Road Traffic Accidents

In 2023, Rizal and colleagues conducted a thorough examination of the financial repercussions of RTAs being in Kathmandu Valley. The study found that the cost of each RTA is approximately NPR 1.2 million (equivalent to USD 10,000). The costs included NPR 500,000 (USD 4,200) for medical expenses, NPR 300,000 (USD 2,500) for lost productivity, and NPR 400,000 (USD 3,300) for property damage. According to the study, victims and their families were responsible for the majority of these expenses. Only 20% of RTA victims in 2023 received insurance compensation, according to reports. The research also emphasized that low-income households were the most severely impacted, as they had limited access to financial and medical resources. Rizal & Tiwari (2023) compelled about 70% of these households to sell assets or borrow money to cover accident-related expenses. These findings underscore the pressing need for enhanced insurance policies and financial aid to mitigate the financial strain on affected families.

RTAs in Nepal have trickling impacts on the nation's economy, as highlighted by Banstola et al. (2020). In 2020, the study anticipated that the country's annual expenditure on road traffic injuries would amount to 0.8% of its gross domestic product (GDP). This equates to approximately NPR 28 billion (USD 240 million). The direct costs of RTAs include medical expenses, emergency services, and rehabilitation. Indirect costs include lost productivity and income due to injury-related disabilities or fatalities. Together, these factors are the direct causes of this substantial financial strain on the nation's economy (Banstola et al., 2020). In addition, RTAs cause significant financial hardships for many families, leading to increased medical bills and lost income, further impoverishing them. For example, around 60% of families affected by RTAs in 2020 reported a decline in their living standards because of the financial strain (Banstola et al., 2020). In a developing country where it's essential to maintain the economy, the financial strain induced by RTAs highlights the urgent need for effective road safety measures and policies to alleviate these costs and improve public health.

Viable Solutions for Road Safety

Road safety remains a pressing issue in Nepal, with the country recording 13,366 RTAs between 2018-2019, and 2,789 deaths (Ojha et al., 2021). In all peer-reviewed papers, the major contributors to these incidents were identified as poor road conditions, reckless driving, and vehicle issues. As a response to the rise in RTAs, the government initiated a road safety strategy that ran from 2013 to 2020 (Tiwari et al., 2023). The project aimed to construct safer road infrastructure and services backed by effective post-crash responses. Among the notable initiatives was the Nepal Road Safety Action Plan 2013 to 2020, which focused on the "Three Es"—Education, Engineering, and Enforcement. Efforts to improve road safety included public awareness campaigns, tightening of traffic laws, and infrastructure improvements such as designated lanes for different kinds of vehicles. Despite these actions, the number of traffic fatalities haven't significantly decreased, highlighting the need for continuous and enhanced efforts. The high number of traffic accidents in Nepal and the resulting public health impact highlights the need for a revised implementation of the action plan and adequate funding for road safety initiatives.

First and foremost, it is essential to invest in and improve Nepal's road infrastructure. To prevent accidents that are caused by poor road conditions, it is essential to ensure that roads are maintained and repaired in a timely manner to address craters, fractures, and other hazards. In urban areas with high traffic density, the implementation of international best practices in road design and construction can significantly enhance road safety, as Tiwari and Luitel (2023) emphasize. In order to enhance the safety of road users, the study recommended the implementation of bicycle lanes, dedicated pedestrian pathways, and well-marked crosswalks. Further, the implementation of traffic-

reducing measures, such as speed bumps, roundabouts, and adequate road signage, can further reduce RTA incidents by enhancing overall traffic management.

Stricter enforcement of traffic regulations is essential to guarantee compliance and reduce RTAs. Detering irresponsible driving behaviors and reducing violations can be achieved by implementing automated traffic enforcement systems, such as red-light cameras and speed cameras. Conducting routine patrols and increasing the presence of traffic police can further improve compliance. Furthermore, implementing severe penalties for violations of traffic rules, including substantial fines and license suspensions for repeat offenders can also serve as an effective deterrent. Research by Pandey et al. (2021) emphasized the need for enhanced collaboration between government agencies and traffic police to guarantee law enforcement effectiveness and adherence to road safety regulations. It was suggested that rather than handling separate aspects of road safety independently—such as road infrastructure, enforcement, and public education—a unified approach where all entities worked together was deemed essential for improving overall road safety.

Another option for reducing the incidence of RTAs in Nepal is to implement public education and awareness campaigns that are intended to encourage safe driving habits. Various peer-reviewed papers discussed all revealed that the rate of RTAs disproportionately impacts varying demographic groups. Therefore, community outreach events should be established and tailored to impacted demographic groups, emphasizing the significance of adhering to speed limits, wearing helmets and seat belts, and avoiding drunk driving. Research by Pant and colleagues (2022) highlighted the importance of road safety education programs in promoting safe practices and raising public awareness. They suggested that public education campaigns could effectively spread safety messages through various channels, including social media, television, radio, and community outreach programs. These efforts aim to create a safer road environment and reduce the number of RTAs. By utilizing multiple communication platforms and involving the community, these programs have the potential to enhance road safety awareness and practices.

In addition to public education, enhancing emergency response systems is equally as essential to improve outcomes for RTAs. Nepal's emergency response times are currently subpar, mostly as a result of inadequate infrastructure and a shortage of skilled individuals. For instance, a year-round research carried out at Patan Hospital found that 53.6% of patients arrived in taxis, significantly delaying critical care, while only 9.9% of patients arrived in ambulances. Moreover, ambulance utilization was limited to 13.5% of the most critical situations, indicating the shortcomings of the current EMS system. Ensuring prompt and efficient treatment following RTAs may be achieved by the improvement of current emergency medical services, such as trauma care units and ambulances, that are well equipped and supervised. Recommendations include increasing the number of trained EMT personnel, upgrading and increasing the availability of well-equipped ambulances, establishing a centralized emergency response system, and improving trauma care facilities. Additionally, public awareness campaigns and securing government funding and policy support are crucial for the continuous enhancement of emergency medical services.

Conclusions

This comprehensive review has highlighted the urgent need to address road safety issues in Nepal. 21 peer-reviewed papers identified poor road conditions, a lack of road markings, inadequate pedestrian crossings, speeding, drunk driving, and ineffective traffic management as major contributors to RTAs. Over the past decade, from 2009 to 2020, RTAs in Nepal have grown dramatically. By 2020, there were approximately 16,000 RTA incidents, up from 7,000 back in 2009 (Atreya et al., 2021). During this time, there was a concerning rise in vehicle-specific accidents: 4,363 occurrences involved automobiles and 7,564 incidents involved motorcycles.

Further analysis of RTAs' impacts in Nepal revealed significant economic repercussions. In the Kathmandu Valley, each RTA is estimated to cost roughly NPR 1.2 million (USD 10,000) by Rizal and colleagues (2023). This amount includes NPR 500,000 (USD 4,200) for medical expenditures, NPR 300,000 (USD 2,500) for lost production, and NPR 400,000 (USD 3,300) for property damage. Just 20% of the victims and their families get insurance reimbursement, leaving them to bear the majority of

these costs. Low-income families were particularly affected, often having to borrow money or sell assets to cover expenses (Rizal & Tiwari, 2023). These financial burdens highlighted the urgent need for better insurance policies and financial aid to help affected families.

Additionally, the broader economic impact of RTAs was significant. An estimated NPR 28 billion (USD 240 million), or 0.8% of Nepal's GPA, is lost each year due to RTAs (Banstola et al., 2020). Direct expenditures included emergency room visits, medical bills, and rehabilitation. Indirect expenses included revenue and production losses brought on by the injuries or deaths of workers involved in RTAs. All in all, the findings highlight the need for comprehensive road safety measures and regulations to lessen the financial burden of RTAs and improve public health outcomes in Nepal.

Analysis of existing literature also revealed devastating social and behavioral implications of RTAs. Joshi and colleagues (2022), through a survey, found that 60% of all residents in the Makwanpur district were concerned about accidents caused by overspeeding vehicles and inadequate medical facilities. Around 45% of all respondents witnessed accidents or near-misses on a weekly basis, increasing their doubts about the effectiveness of current road safety measures and overall traffic management. The prevailing anxiety and safety risks disrupted daily routines and restricted outdoor activities for adolescents and elderly individuals.

In another study by Gautam et al. (2024), it was revealed that 85% of participants in the Kathmandu Valley avoided certain routes at night because of risks such as inadequate lighting and narrow sidewalks. 70% of women reported avoiding roads due to a higher likelihood of harassment, while 60% of individuals with disabilities were impeded by the absence of accessible routes. Furthermore, Gautam et al. (2021) noted the high levels of tension and anxiety that adolescents felt from dangerous traffic conditions on their commute to school. Speeding cars and the absence of pedestrian crossings added to a culture of anxiety that reduced school attendance and community involvement. Ultimately, these different findings highlight the need for easily accessible and illuminated sidewalks, enhanced pedestrian safety features, and comprehensive road safety education programs.

To address the multifaceted issues induced by RTAs in Nepal, a comprehensive approach was discussed. Proposed solutions included investing in and upgrading existing road infrastructure, creating dedicated lanes for various types of vehicles, ensuring easily accessible sidewalks, and clearly marking traffic lines on roads (Tiwari & Luitel, 2023). Additionally suggested were stricter traffic law enforcement using automated systems and harsh punishments, as well as coordinated efforts between traffic police and government organizations (Pandey et al., 2021). Campaigns for public education aimed at high-risk demographic groups may encourage safer driving habits (Pant et al., 2021). Furthermore, increasing trained personnel, upgrading ambulance services, and establishing centralized response networks are critical for timely and effective accident response (Patan Hospital study). These multifaceted strategies are essential to reducing RTAs and their significant public health and economic impacts in Nepal.

Author Contributions Aryan Bhattarai conducted the literature review, analyzed the data, and drafted the paper. Dr. Shira Safer provided mentorship, supervision, and assistance with editing and reviewing the paper. The research project was approved by the Department of Public Health.

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