Evidence-based Analysis of Urban Road Accident Causes using Video Footage Data

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Abstract: The increasing number of road accidents, especially in urban areas of low- and middle-income economies, has raised their importance to a global concern. It is imperative that factors responsible for road accidents are identified before planning for strategies aimed to reduce their number. The present study proposes using evidence-based analysis of accident video footage data supplemented with road safety audit to identify causes for road accidents in an urban traffic network. The tier 1 Indian city of Kolkata is the study area considered. The findings from the study highlight the advantage of the proposed methodology and provides evidence of unsafe road user practices as the major cause for urban road accidents. The study findings also suggest need for stricter enforcements, and better safety awareness among road users to improve road safety.

Keywords: Urban road accidents, causes, evidence-based analysis, video footage data, road safety audit

1. INTRODUCTION

Every year road accidents claim over 1.2 million lives and leave over 50 million injured around the world (World Health Organization, 2018). Among the reported fatal accidents, 90% are reported in low income and middle-income economies. India has the highest number of deaths due to accident among the 175 countries included in the study by the World Health Organization. In recent years, the amount invested in India by Ministry of Road Transport and Highways (MoRTH) and other state level agencies to improve road safety by improving road infrastructure and creating road safety awareness has increased. However, the road severity index measured as number of people killed per 100 accidents shows an increasing trend over the years (MoRTH, 2019). Though urban roads comprise of only 9% of the total road network of the country, they contribute to approximately 40% of accidents in terms of total number as well as number of persons involved (MoRTH, 2019). Therefore, an understanding of the factors responsible is the first step before planning strategies aimed to reduce the significant number of urban road accidents.

Several studies attempted to understand the causes for accidents in urban areas. These

studies rely on accident reports by police personnel (Cabrera-Arnau, et al., 2020, Gomes, 2013, Jaroszweski & McNamara, 2014). The factors considered include - (i) *road geometry characteristics* such as road class, number of lanes, and lane width (Gomes, 2013), (ii) *traffic characteristics* like traffic flow, type of control, and speed limits (Mountain, et al., 1996), (iii) *road user characteristics and behavior* such as age, gender, speeding, failure to yield, and running red lights (Al-Ghamdi, 2003), (iv) *inclement weather conditions* such as rain (Jaroszweski & McNamara, 2014) and (v) *other road environment factors* such as pavement conditions and existence of urban heat islands (Zou & Yue, 2017). Also, several studies have adopted techniques such as time-series analysis (Cabrera-Arnau, et al., 2020), Bayesian Networks (Zou & Yue, 2017), K-means clustering (Jain, et al., 2016), generalized linear model with Poisson gamma distribution (Gomes, 2013), conditional probability and contingency table analysis, (Al-Ghamdi, 2003), and regression statistical models (Abou-Qudais, 2001) to predict urban road accidents using these factors. Other than traditional reactive approach of crash data modelling, several researchers attempted to proactively identify potential risks for road users using road safety audits (RSA), expert opinion surveys, road user perception studies and conflict analysis techniques (St-Aubin, et al., 2015, Kamrani, et al., 2017, Sayed, et al., 2010). Furthermore, recent years show significant promises in combining the reactive and proactive strategies for road safety management to derive benefits and promises of both the approaches (Mukherjee & Mitra, 2020, Chatterjee & Mitra, 2019). Road user behavior plays an important role in road safety. To study road-user characteristics often surrogate measures such as time to collision (TTC), post encroachment time (PET), etc. are evaluated through videography or simulation study (Johnsson, et al., 2018). In addition, a few studies have attempted to study the road user characteristics at the time of the accident from real time video recordings. (Park, et al., 2011, Wang, et al., 2021, Prati , et al., 2019). However, studies of this nature remain very limited, especially in developing countries such as India, due to non-availability of video data on real accidents.

Accident reporting in India is undertaken by police personnel and follows the guidelines as given in IRC-53 (2012) (Indian Roads Congress, 2012). The report is designed to provide detailed information for *accident identification* (location, date, time, land use, type of accident), *roadway characteristics* (roadway classification, road surface type, presence of median, presence of construction zones), *weather conditions*, and *details of damage* involved in terms of property, vehicles and people affected. However, crash data reports are unlikely to contain accurate information at the time of accident on important aspects such as the *road geometric factors* (e.g. stopping sight distance, and signal visibility), *nature of violation of traffic* (e.g. signal violations), *road user behavior* (e.g. lack of lane discipline, speeding, encroachment of vehicular carriageways), and *traffic operational characteristics* (e.g. signal settings) (Mukherjee & Mitra, 2020). Thus, important factors leading to the accidents are often overlooked by relying solely on accident crash reports. Moreover, data obtained from MoRTH reveals that more than 70% of the accidents are caused due to driver's error, mainly speeding (MoRTH, 2019). Crash data records have limited utility in identifying the precise cause responsible for behavior of road users that caused the accident. On the other hand, accident videos provide detailed and accurate information on road environment, road user behavior, traffic operational characteristics, and possible adverse weather conditions for the durations leading to, during and after an accident. In addition, with most metro cities across India opting to install CCTV across at major intersections and roadways, a unique opportunity is now available to access video data of real accidents.

Video footage data (VFD) provides concrete evidence for inspection and comprehensive accident information; however, it is likely that certain factors such as visibility of signal heads,

adequate sight distance, walkability and other roadway characteristics require additional field investigation. In such cases, it would be beneficial to undertake Road Safety Audits (RSA) to supplement VFD. With this background, the present study adopts an evidence-based analysis using real time Video footage data (VFD) of accidents supplemented with RSA to identify causes for urban road accident. Kolkata, a tier 1 Indian city and capital city of the state of West Bengal, is identified as the study location. The video footage of accidents available from CCTV cameras installed at more than 7000 locations in the urban traffic network of this city is a valuable data source for understanding urban road accidents and their causes.

The remainder of the paper is structured as follows. Section 2 describes the methodology adopted for the study and Section 3 includes details of the study area. Section 4 discusses analysis of data and salient findings of the study. Section 5 concludes the paper highlighting the contributions of the paper, suggestions for improving road safety and scope for future work.

2. METHODOLOGY

In the present study, to identify the causes for urban road traffic accidents, a four-stage methodology was identified. These include (i) extraction of data from available video footage, (ii) road safety audit, (iii) combined analysis to identify causes for road accidents, and (iv) identify and suggest areas for improvement. The following Figure 1 illustrates the methodology adopted for the present study.

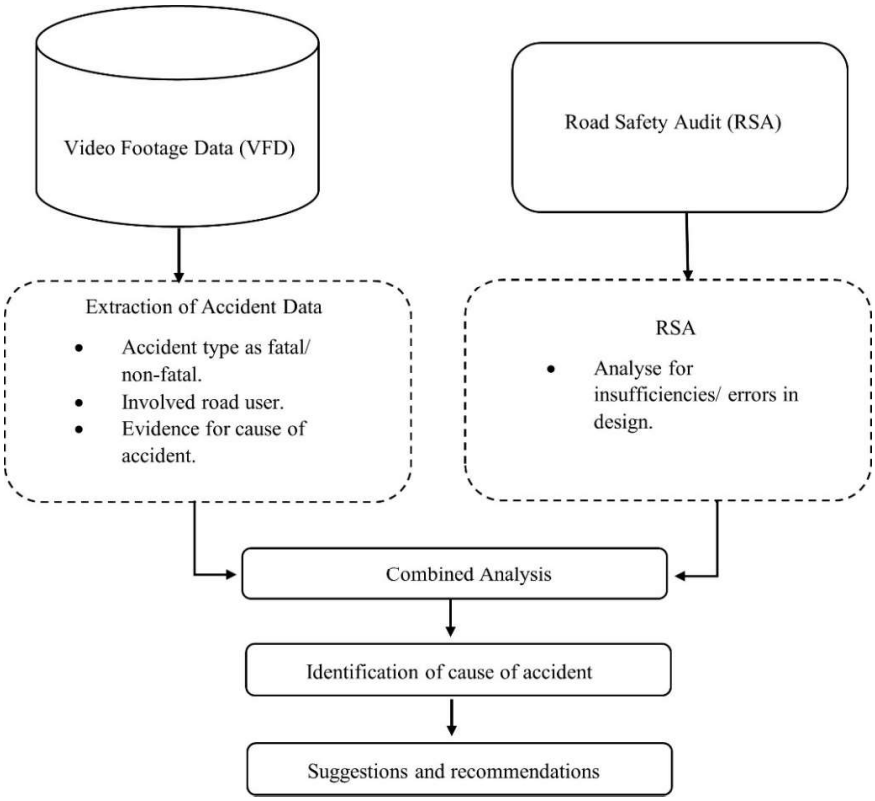

Figure 1Proposed Methodology.

2.1 Video Footage Data

Kolkata traffic police has more than 7000 CCTV cameras installed at different locations in the city. Video data corresponding to accidents for the year 2015-2016 was collected. The month-wise video data for accidents in the city of Kolkata for these years is the primary data source. The video data provides information on road environment during, before and after an accident in addition to providing different views for location of accident. Details of location, date and time are also available with the video data provided by the Kolkata traffic police.

Video data obtained was extracted and arranged in Microsoft Excel to include location and time of accident, type of road section, driver and other road users involved in the accident, and fault leading to accident.

2.2 Road Safety Audit

Video footage data while providing significant information regarding the cause of accidents is insufficient for understanding the road design features. Therefore, road safety audit was also undertaken to supplement VFD with data pertaining to type of roadway, pavement conditions, geometric features, intersection type and existing level of control, movement of traffic, and pedestrian facilities and their movement.

2.3 Combined Analysis

Identification of major factors causing accidents in the considered locations are based on the evidence provided by video footage. In addition, the findings from the RSA are supplemented to VFD evidence for the considered location to identify if road design features or factors such as inclement weather has influenced user behavior leading to the accident. Therefore, while video footage can help clearly identify the nature of violation or unsafe road user practice causing the accident, findings from road safety audits establish the lack of or deficiencies in road infrastructure that may have led to the violations.

2.3 Suggestions and Recommendations

Understanding the causes for accidents help to identify focus or target areas of intervention and enforcement that may help to effectively reduce the occurrence of accidents. Findings from the study can help traffic engineers, government agencies and police personnel to prioritize the areas of education, enforcement and infrastructure maintenance required to enhance traffic safety in their urban road networks.

3. STUDY AREA

The study area comprises of urban areas of the city of Kolkata (Figure 2), a tier 1 Indian city and capital of the state of West Bengal. The Kolkata metropolitan area is spread over 1,886 sq. km and has a population density of approximately 24,306 per sq.km as per the 2011 Census data. The major modes of transport in the city include cycles, motorized two-wheelers, cycle-rickshaws, motorized three-wheelers, cars, taxies, buses and trams. Kolkata reported around 2500 total number of accidents in the year 2019 and more than 250 individuals were

killed in road accidents in the same year. A significant proportion of the victims include pedestrians (Ghosh & Paul, 2013).

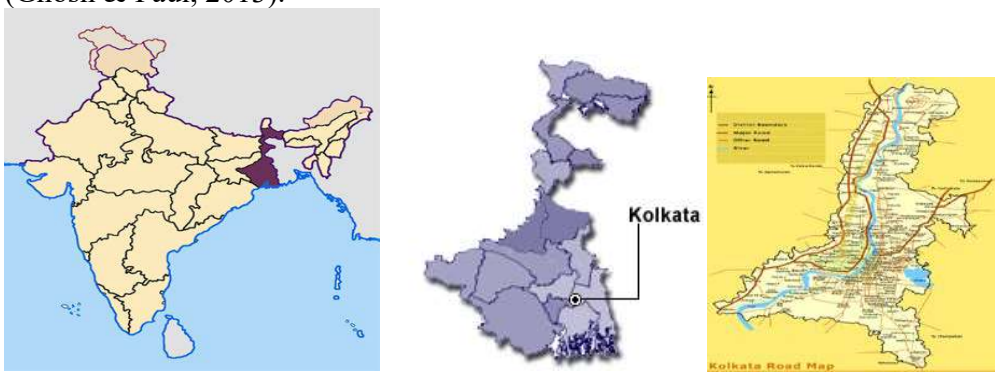

Figure 2 Location of Kolkata

4. ANALYSIS AND SALIENT FINDINGS

Video data for 251 accidents in the year 2015-2106 was analyzed and salient findings from the study are presented here. Of the study data, 26% were fatal accidents while the remaining 74% were non-fatal accidents. An accident shall be classified as fatal accident if one or more persons were killed. The time of occurrence of the accidents was also considered and it was observed that highest number of accidents happened during the morning hours between 6 am and 10 am (Figure 3).

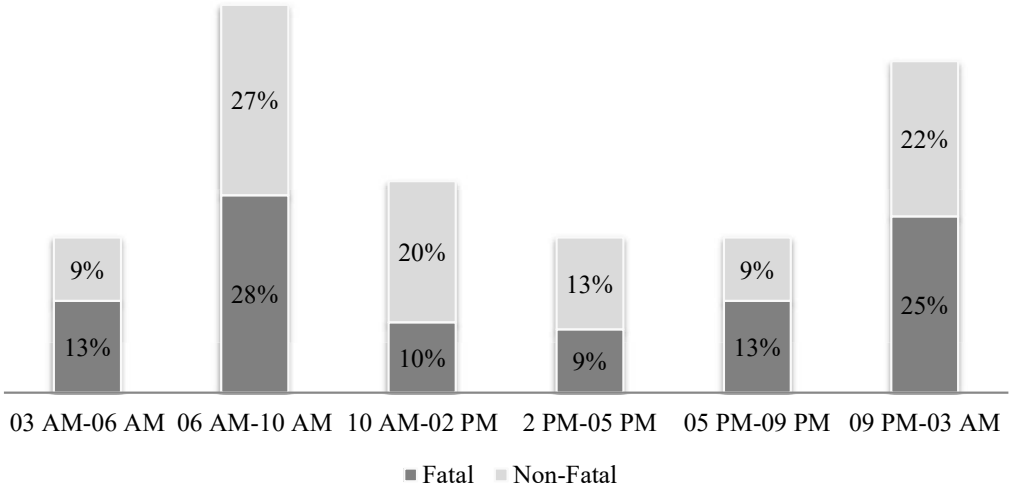

Figure 3 Time of the day statistics for accidents

Analysis of the location of accidents indicated that most of the accidents, as high as 59%, occurred at the signalized intersections followed by 23% at the midblock segments. (Figure 4). A statistical comparison of proportions indicated that intersections had a higher proportion of fatal accidents as compared to mid-block sections (Table 1). In addition,

proportion of fatal accidents were higher at unsignalized intersections as compared to signalized intersections (Table 2).

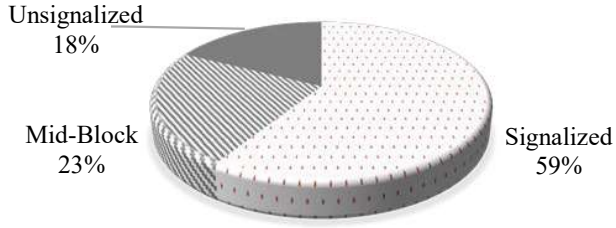

Figure 4 Distribution of accidents based on location.

Table 1 Statistical comparison of proportion of fatal and non-fatal accidents based on location.

	Intersections	**Mid-block sections**	
Fatal	61 (32%)	4 (7%)	
Non-Fatal	131	55	
Total	192	59	
Standard Error	0.07		
Z stat	3.83	*p-value*	0.00

Table 2 Statistical comparison of fatal and non-fatal accident based on intersection type.

	Signalized Intersection	**Unsignalized Intersection**	
Fatal	42 (28%)	19 (43%)	
Non-Fatal	106	25	
Total	148	44	
Standard Error	0.08		
Z stat	-1.85	*p-value*	0.03

The role of road user in accidents was investigated by considering two aspects, namely, (i) involvement and (ii) being the cause for the accident. Cars and motorized two-wheelers constitute a major share of urban traffic composition in the city. Trucks and slow-moving traffic are restricted access during the peak hours of the day. The pedestrian density remains high during peak hours in the city. The analysis indicated that four wheelers ranked first in the involvement (27% of total accidents) and were also the major cause for the same (27% of total accidents). Pedestrians were identified as the second major factor for accidents (25% of total accidents). The following Figure 5 indicates details of the road user involvement and cause for other modes of travel.

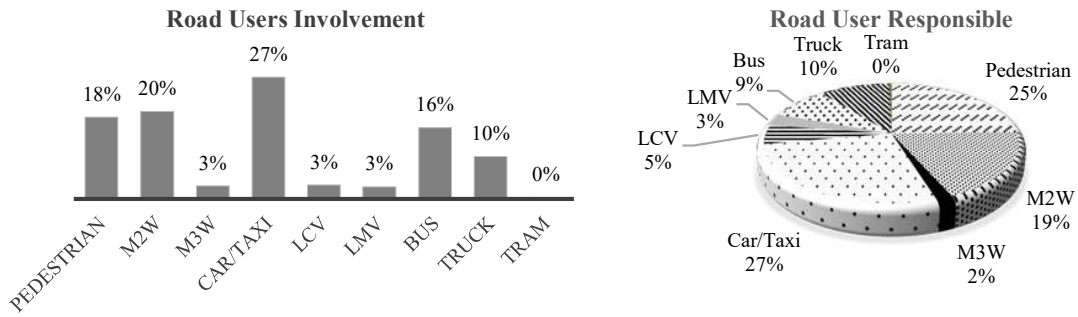

Figure 5 Distribution of road user involvement and responsibility for accident

A similar analysis was done for fatal and non-fatal accidents separately. The statistics indicated that while pedestrians were the major road user involved and contributing to fatal accident (Figure 6), four wheelers like cars and taxis were the main cause for non-fatal accidents (Figure 7).

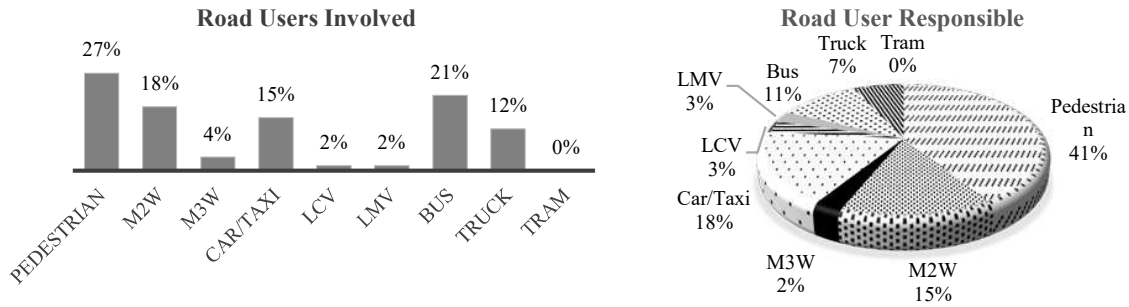

Figure 6 Distribution of road user involvement in fatal accidents

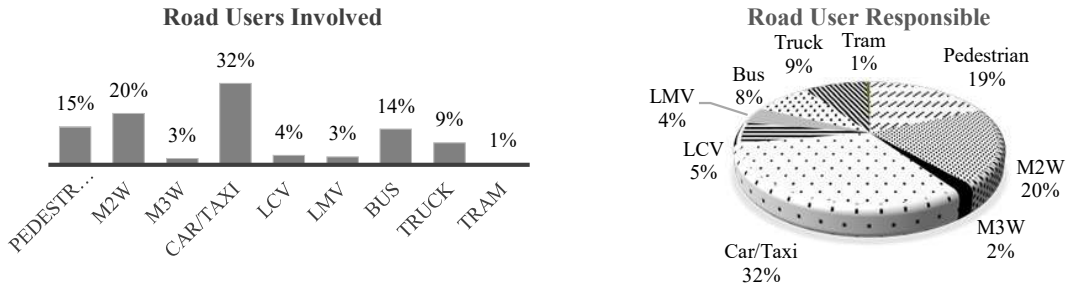

Figure 7 Distribution of road user involvement in non-fatal accidents

The road safety audit helped identify engineering deficiencies, if any, at the accident locations. The identification of deficiencies, such as improper signal design, lack of adequate sight distance, and signal visibility to list a few, can help identify if driver's faulty behavior is a result of negligence or engineering deficiency.

4.1 Causes of Road Accidents

The combined analysis of video footage data of accidents and road safety audit indicated that about 56% of the total accidents were due to fault of the road user and 39% due to deficiencies in road design. The faults or negligence of the road user contribute to about 53%

and 58% of fatal and non-fatal accidents, respectively. Only about 5% of the accidents were due to inclement weather conditions, stray animals, vehicular breakdown and other miscellaneous factors. A similar pattern was observed for both fatal and non-fatal accidents too.

4.1.1 Road User Factors

Further investigation indicated that among various road user factors considered, while safety violations by pedestrians were the main cause leading to fatal accidents, traffic signal violations caused maximum number of non-fatal accidents. However, for both fatal and non-fatal accidents traffic signal violations, pedestrian violations, over-speeding and rash driving were the main factors responsible for road accidents (Figure 8) in comparison to other considered factors such as ignoring road signs, driving on the wrong lane, sudden stopping on the road, tailgating, and stopping at no stopping zones to list a few.

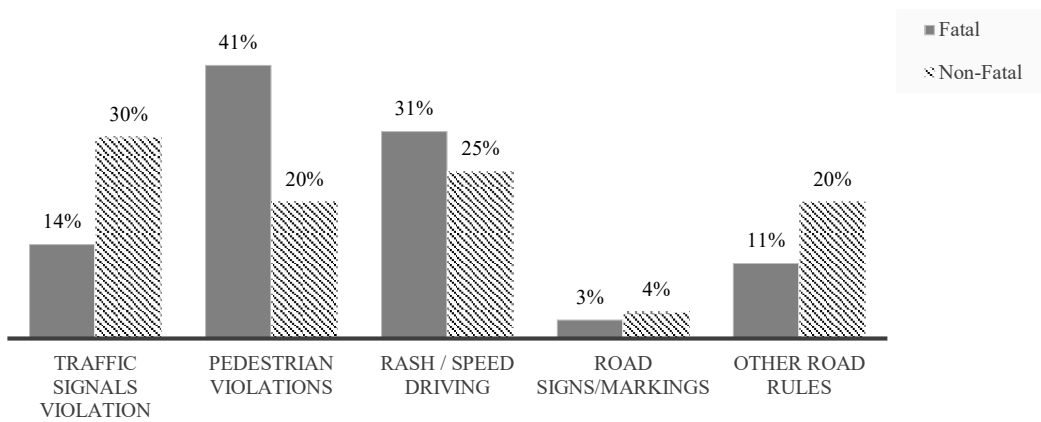

Figure 8 Road user faults causing fatal and non-fatal accidents.

4.1.2 Road Design Factors

The factors considered under deficiencies in road design include lack of or improperly designed pedestrian facilities and crossings, improper signal design, lack of adequate sight distance, and improper road markings or signs. In the case of fatal accidents, lack of adequate pedestrian facilities and improper signal design were the main causes identified (Figure 9). On the other hand, lack of adequate sight distance and improper signal design was the major reasons for non-fatal accidents (Figure 10).

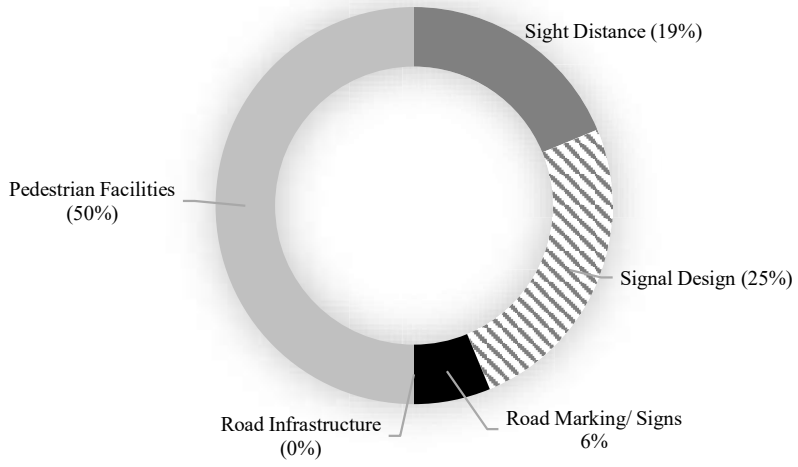

Figure 9 Road design attributes as factors for fatal accidents

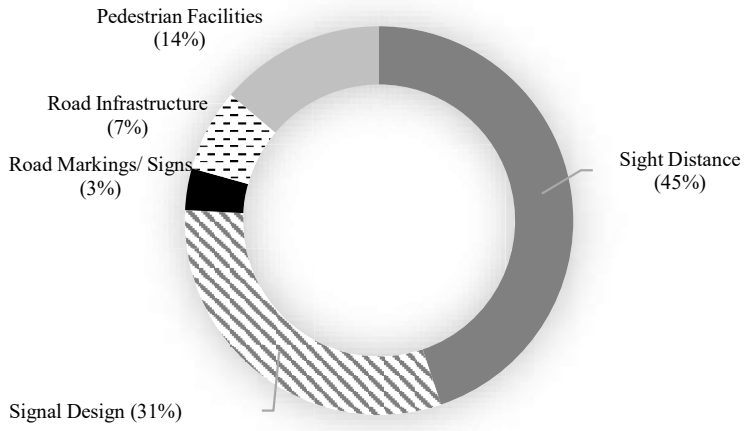

Figure 10 Road design attributes as factors for non-fatal accidents

4.2 Salient Findings

The study and analysis of video data for the 251 accidents in the city of Kolkata for the year 2015-16 identifies unsafe behavior of road users as the main cause for road accidents. The following Table 3 summarizes the main findings of the study.

Table 3 Major causes of road accidents identified by study.

Sl. No.	Identified cause of road accident	Percentage
1	Rash Driving and/or over-speeding	27%
2	Traffic Signal Violation (Red signal)	26%
3	Unsafe pedestrian behavior	24%

Sl. No.	Identified cause of road accident	Percentage
4	Violation of other traffic rules	15%
5	Other factors (inclement weather, breakdown)	8%

As indicated in Table 3, the main cause of accidents identified by the study was the over-speeding and/or rash driving behavior of drivers followed by traffic signal violations. Traffic signal violations as considered above includes violation of the red signal as well as refusal to yield during blinking amber. Most of these instances also included drivers who showed rash driving behavior. The next main cause of accidents identified was the unsafe pedestrian behavior such as walking on carriageways, pedestrian signal violations, not using zebra crossings, boarding/alighting from moving buses, and crossing at blind spots of vehicles like buses and trucks.

The following Figure 11 illustrates some of the common unsafe road behavior observed such as stop mark violation at red signal (Figure 11-A), violation of pedestrian signals (Figure 11-B), stopping of buses in no-stop zones (Figure 11-C), pedestrians using vehicular carriageways (Figure 11-D), and improper signal designs (Figure 11-E) giving right of way to conflicting streams of traffic.

Accidents resulting from inclement weather conditions or violation of other traffic rules such as ignoring road signs, driving on wrong lanes, and stopping at no-stopping zones, together constitutes less than a quarter of the observed accidents.

Furthermore, the study investigated if unsafe road user behavior was influenced by deficiencies in the road design and lack of adequate infrastructure. For this purpose, video footage of such accidents (excluding accidents due to environmental factors) were examined. However, analysis of these video footage indicated that about 87% percentage of them were results of specifically unsafe road user behavior such as speeding, and violation of traffic rules (signal jumping, alighting/ boarding moving vehicles, and unsafe crossings). These unsafe practices are observed in pedestrians as well as drivers. Only 14% of these accidents had evidence for the likely influence of design deficiencies (such as inadequate sight distance, signal visibility concerns, absence of road signs and lane markings), and inadequate pedestrian crossing and walking facilities. Thus, the study provides evidence for unsafe road practices as the primary cause of urban road accidents, only some of which may be overcome by catering to deficiencies in road engineering design such as the lack of adequate sight distance, improper signal designs and provision of adequate pedestrian facilities.

Figure 11 Examples of unsafe road behavior

5. CONCLUSIONS

Study findings confirm the advantages of using evidence-based analysis using VFD supplemented with RSA to identify key behavioral aspects of road users responsible for accidents which are usually unavailable from traditional crash data records. The proposed methodology can be effectively used to identify areas of intervention for improving road safety and thereby, is a useful tool for transport planners, policy makers and police personnel to prioritize resources in education, enforcement, and development of safe infrastructure for road users.

A major finding of the present study is the role of negligent road user behavior as the primary cause for urban road accidents. While road user behavior alone accounts for more than 70% of the total number of accidents, this increases to 90% when combined with deficiencies in road engineering design and lack of adequate infrastructure. Rash driving and/or speeding together with traffic signal violation was identified as the major unsafe

behavior by drivers causing majority of accidents. More than 50% of the observed accidents were a result of either or both the factors. Pedestrians were also identified as a major cause for as well as risk group during accidents. More than a quarter of the accidents were due to unsafe pedestrian road behavior such as unsafe crossings and boarding /alighting from moving vehicles.

The study findings justify the need for identification and implementation of priority enforcement measures targeting both drivers and pedestrians to restrain unsafe driver behavior. This would be extremely beneficial for police personnel especially in countries like India. Moreover, traffic planners and policy makers must organize road safety awareness programs designed for all users to educate them on road safety. Proper training of drivers and creating safety awareness among pedestrians is vital to improve the current scenario. However, evidence from the present study also implies that drivers are inclined to make errors and therefore, it would be beneficial for highway engineers to design safe and forgiving road environments. Additionally, correcting deficiencies in road engineering design, ensuring good pavement conditions and safety measures for inclement weather conditions are suggested to further reduce risk of accident.

The available data, however, does not adequately represent urban road accidents occurring in low light conditions such as night times or adverse weather conditions. Therefore, the present study does not include the same. The study also does not attempt to investigate the reasons for the observed unsafe road behavior from the user perspective, deficiencies observed in road design, and the possible interactive effects of the two factors together with adverse weather conditions. Future works aim to investigate the above aspects in addition to possible changes in these factors over the years.

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