ROAD ACCIDENT ANALYSIS AND SAFETY AUDIT: A CASE STUDY OF MDR 132

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Resume

Road accident and road safety are the key global concerns and problem for emerging nations like India. It has been attempted to examine the accidents that happened on Major District Road (MDR) 132 (Nuh to Hodal), India in the last five years. The primary objective of this study was to perform the Road Safety Audit for identification of accident-prone areas based on Accident Severity Index (ASI) and provide some improvement measures in order to lower the frequency and severity of accidents. Identified accident prone locations (blackspots) were ranked according to the ASI index. The distribution of accidents based on various parameters were also discussed. Site visit of critical sections of the road to observe road deficiencies were made and safety recommendations, along with the risk associated with them and priority as per IRC: SP: 88-2019, were suggested.

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1 Introduction

In developing nations, there is a severe problem with traffic accidents. In spite of this, several groups are working to mitigate the impact of these tragedies. The results of the efforts show that while accident-related mortality declined by 0.20 %, the number of road accident instances in India was reduced by 3.86 % in 2019 compared to the previous year. This study tries to identify the many causes of traffic accidents and offers suggestions for future accident prevention based on the RSA conducted on the stretch under study.

The stretch used in this investigation was chosen on MDR-132 between Nuh and Hodal, Haryana. From 2017 to 2021, the FIR records from Haryana's official website have been gathered (up to July). The FIR report includes the time, date, day, month and year, as well as the number of injuries, including fatalities, serious and minor wounds and property damage. It also includes some information about the accident's location and the nature of its causes. To ascertain the criticality of the linkages and stretches, the data has been collated and several parameters have been examined. With this study, key junctions, times, types of vehicles etc. are discovered, and the findings are shown in charts.

2 Literature review

Haque et al. (2022) identified blackspots on NH 76 using accident severity index approach. Corrective safety measures to improve identified blackspots were presented in [1]. Minor road junctions of Nuh were analyzed for safety aspects by Asruddin et al. (2022). The FIR accident data from various police stations were collected and analyzed to identify accident prone locations and then safety measures to correct the road features were given in the study [2]. Mir et al. (2022) performed a case study of J&K (Jammu and Kashmir) for accident analysis and presented accident data in terms of month, year, cause of accidents, location of accidents etc. [3]. Khan et al. (2022) compiled and analyzed the FIR data of accidents occurred in three years on the study stretch and concluded that over-speeding is the main reason causing majority of accidents [4]. E-rickshaws are responsible for many minor accidents especially on city roads. Khan and Singh (2021) developed passenger car unit of e-rickshaw so that designated facilities can be provided for e-rickshaws while planning and designing to ensure safety of e-rickshaws and to avoid safety concerns related to e-rickshaw [5]. In their research, Elena et al. (2018) suggested forecasting techniques for

accidents involving vehicles in the Driver-Vehicle-Road-Environment (DVRE) system. A study of effectiveness of the recommended action to increase the traffic safety was conducted using the approach, which allowed for the measurement of the influence on the accident rate [6]. The road safety scenario of the rural roads was studied by Naveen et al. (2017). This article examines variables that influence the safety of rural road and perform road safety audit. The study was based on two different sections of the road. Finally, this project intends to address the issues that arise throughout the rural road implementation process and presents remedies to assist the work of the road safety audit [7]. Tawar and Dass (2017) identified the black spots on NH 65 and analyze the safety measures on the selected section of 19.5 km of NH 65. Safety measures based on the RSA conducted on selected stretch were also presented in [8]. Borole et al. (2017) conducted research on traffic crashes on NH 6 and found that during the last few years, there has been an increase in the number of traffic crashes in Jalgaon. Geospatial data was used to identify crash locations, as well as to examine the pattern of traffic crashes in Jalgaon [9]. Kaur et al. (2017) estimated the severity of accidents on State highways and other district roads. By evaluating the accident severity based on the kind of accident and location of accident using the R tool, this study focused on forecasting the occurrence of accidents on roads. The frequency of traffic crashes on roads was evaluated using the correlation analysis and exploratory visualization approaches, pointing out the traffic collision data on roadways. Finally, a system for analyzing the road traffic accidents has been developed. Improvement in the level and scope of the road traffic safety management can be effectively implemented using this methodology. The current study modeled accident and incident data acquired from traffic data and data pertaining to the construction industry [10]. Singh et al. (2016) predicted the accidents using the M5 tree model and binomial regression model on rural road sections of Haryana state. Data on accidents were obtained from police records. Field studies were used to gather data on geometry, traffic and environment parameters. By separating roadways into parts with specific uniform geometric properties, 222 data points were acquired. It was concluded that minor highway accesses must be properly constructed and managed, service roads must be made functional and speed dispersion must be reduced to improve the highway safety in India [11]. The NH-55 was analyzed for road accidents by Dehury et al. (2013) and a predictive model was proposed to reduce road accidents on the selected stretch. The study depicted that major cases of fatalities involve trucks in road accidents. This study adopted the method of regressions for predicting the future accident growths [12]. The majority of accidents, according to research by Ganveer and Tiwari (2005), involve persons between the ages of 18 and 37. Because of this, the nation is being hurt twice. Risk-taking behaviors among children may be a contributing factor to the greater accident rate in these age groups [13]. The accident scenario of Patna was analyzed by Singh and Misra (2004) and found that pedestrian fatalities were exceptionally high as a portion of all traffic deaths where public transportation facility is not provided properly. It was also found that the new bypass road on NH-38 was determined to be the most accident hotspot in the town [14].

3 Data collection and data analysis

The research was done on MDR132 from Nuh to Hodal. The study stretch was covering Nuh Bypass, Adbar, Raipuri, Ujina, Chilawali, Bibipur, Thekra Mode, Bhimsika, Malai, Uttawar, Maluka Mode, Mithaka, Kot, Pahari Mode, Bahin, Nangal Jat, Sunder Nagar, Sondh and Hodal village. Accident data were collected from the official website of Haryana police stations, as shown in Table 1. On this route, 63 accidents occurred in 2017, 43 accidents occurred in 2018, 44 accidents occurred in 2019, 36 accidents occurred in 2020 and 23 accidents have occurred until July in 2021.

3.1 Month-wise distribution of accidents

As observed in Figure 1, accident severity follows a complex pattern with the month of occurrence. The figure suggests that month of January followed by August and December are the most unsafe in terms of number of injured persons and their severity levels. The month of May is the month in which the least accidents occurred.

Table 1 *Total accidents recorded on MDR132 from Nuh to Hodal*

Year	Location (Nuh to Hodal)	Total Accidents	Fatalities
2017	MDR-132	62	34
2018	MDR-132	43	27
2019	MDR-132	44	24
2020	MDR-132	36	16
2021 (till July)	MDR-132	23	8
Total		208	109

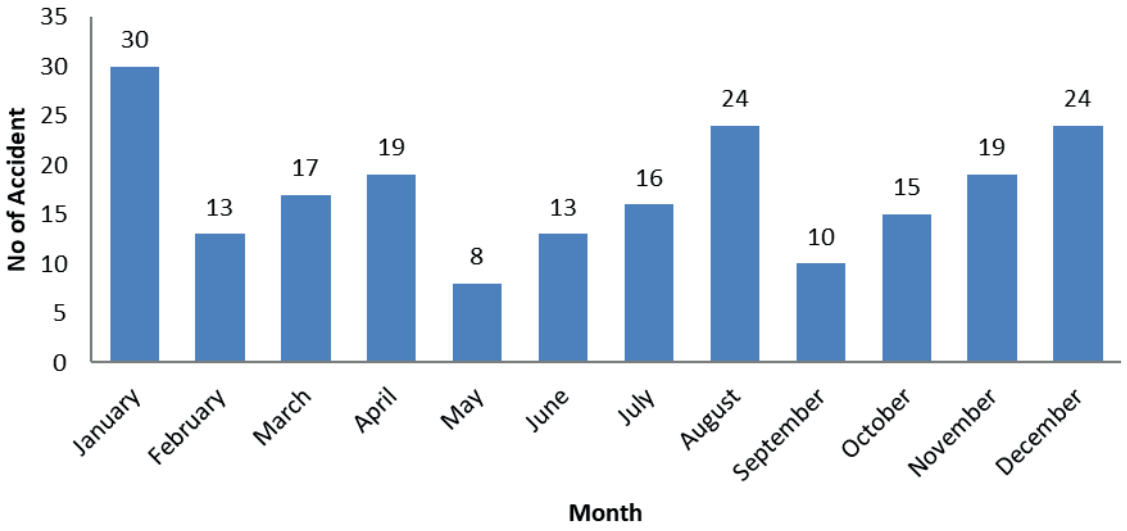

Figure 1 *Classification of the accident according to month*

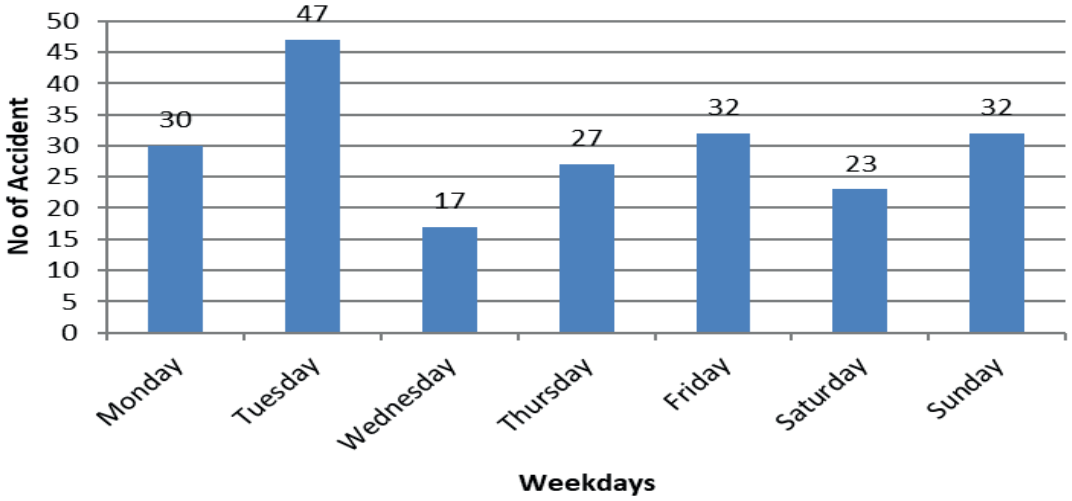

Figure 2 *Classification of accidents according to day of the week*

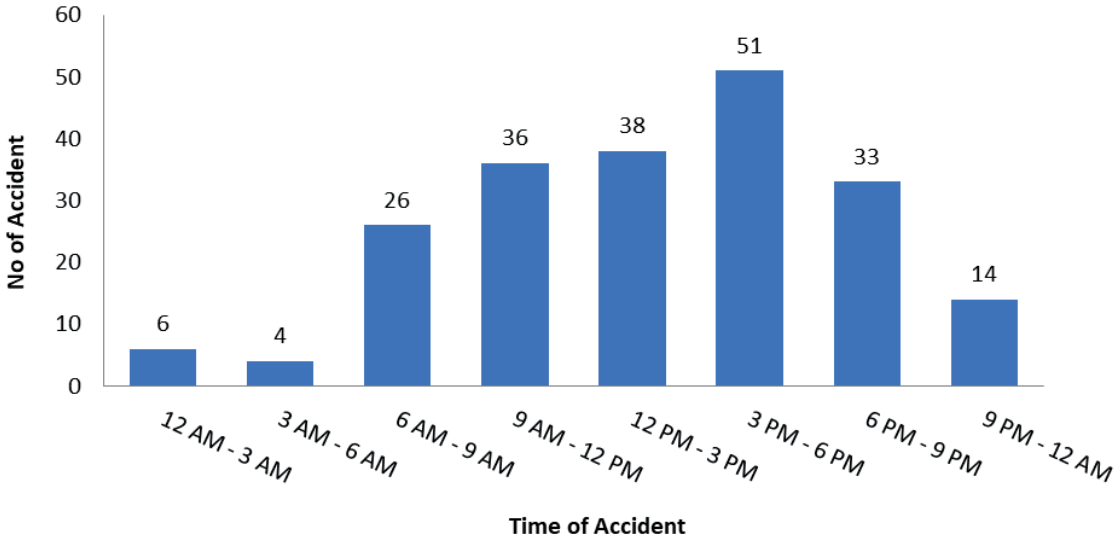

Figure 3 *Time-wise distribution of accidents*

3.2 Day wise distribution of accidents

Figure 2 shows variation of accident severity according to the day of a week. The figure clearly indicates that more severe injuries are taking place on Tuesdays and then Fridays and Sundays. The basic reason behind the observation was that both days are close to weekends when more people travel from and to their homes (extended families) to their workplace. People also break traffic rules due to congestion and hurry, which further leads to higher number of accidents.

The least accident occurred on Wednesday or Saturday as shown in Figure 2.

3.3 Distribution of accidents according to time of occurrence

Figure 3 shows pattern of accident severity according to the time of day. The figure indicates that more severe accidents occurred between 3 PM and 6 PM and then between 12 AM and 3 PM, while during the time between 3 AM and 6 AM least accidents occurred.

Figure 4 presents the combined graph showing the relation between the number of accidents and time, day and month.

3.4 Distribution of accidents according to the nature of accident

According to an FIR assessment of the previous five years, the head-on collision accidents accounted for 65 accidents, rear end collision accidents accounted for 50 accidents and skidding was the cause of just one accident as per records in FIRs (see Figure 5).

3.5 Distribution of accidents according to geometric design of the road

According to statistics from the past five years' FIR reports, there were more accidents on the straight section of the road (68 % of all incidents), followed by 11 % on the stretch's curve, while there were less accidents at the X- and Y-junctions, as shown in Figure 6. Around 75 % of the study stretch is straight, which

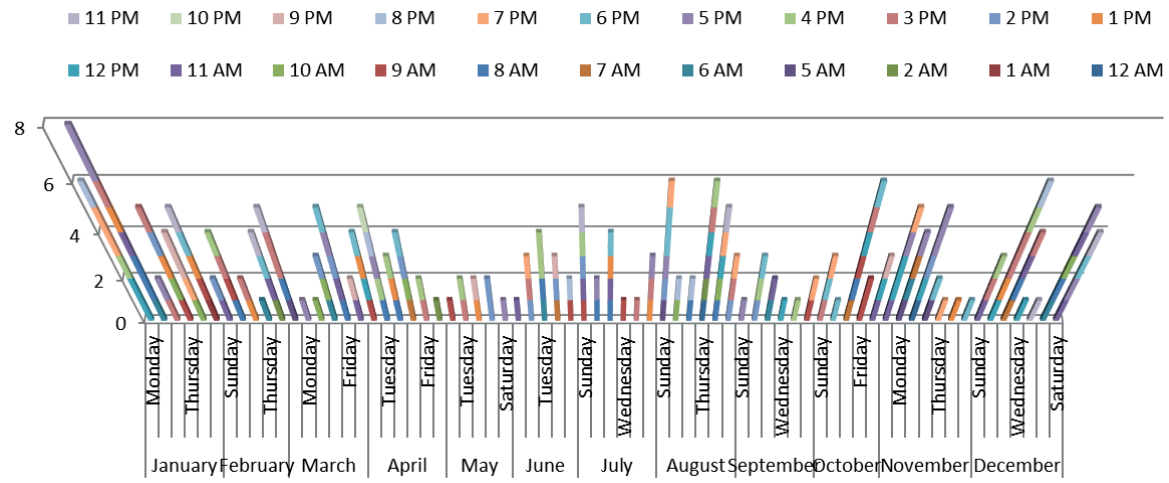

Figure 4 *Distribution of accidents according to time, day and month*

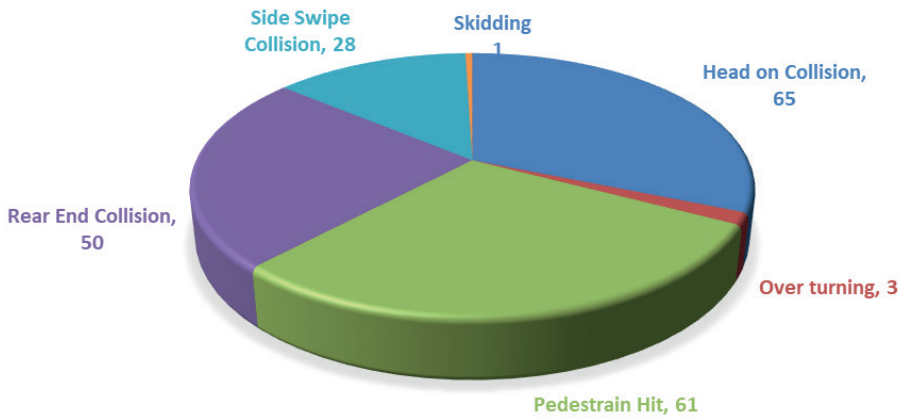

Figure 5 *Distribution of accidents according to their nature*

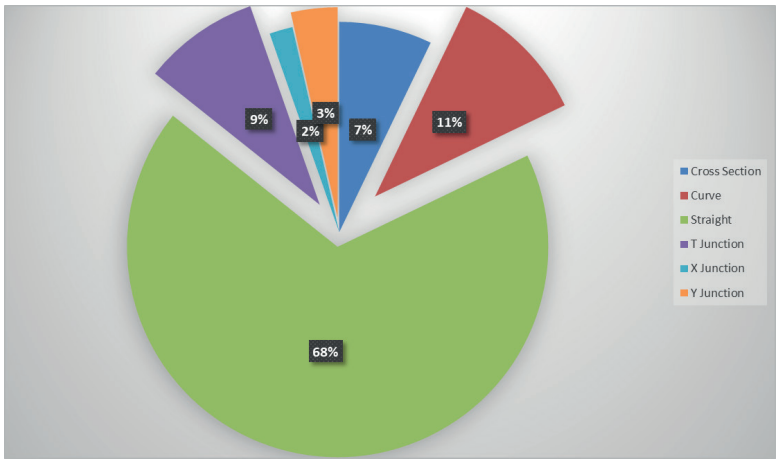

Figure 6 *Distribution of accidents according to the geometric design of the road*

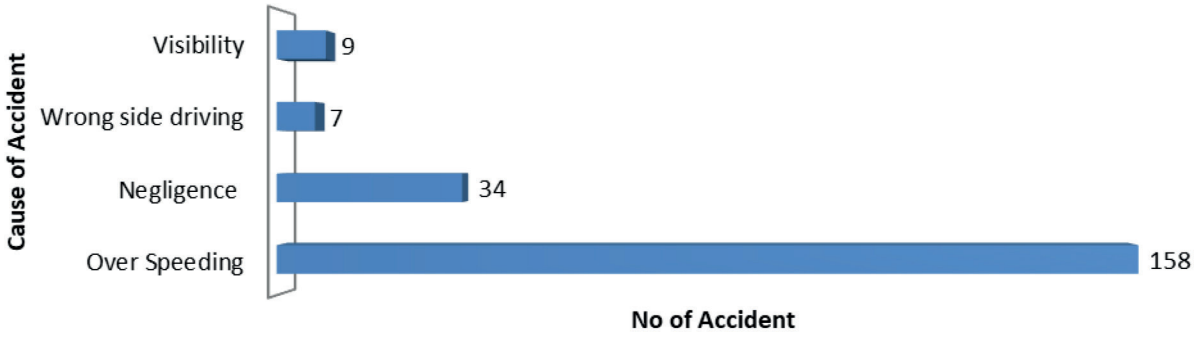

Figure 7 *Cause wise distribution of accidents*

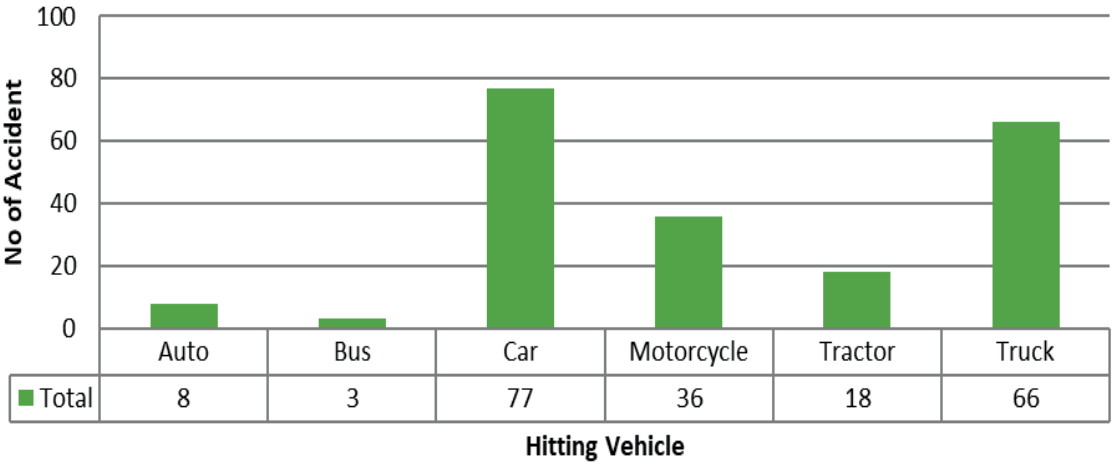

Figure 8 *Distribution of accidents according to the hitting vehicle*

is why 68 % of accidents have occurred on the straight sections. This stretch lacks traffic control devices.

3.6 Distribution of accidents according to the cause of an accident

According to the number, speeding contributed to 158 accidents. On this route, excessive speeding is the leading cause of collisions, followed by carelessness on the part of other drivers. While the FIR data of the previous five years, as shown in Figure 7, indicates that the least accidents were caused by the wrong-side driving and visibility. Heavy vehicles like truck and tractor ply significantly in numbers without following the rules and regulations. There is the absence of speed control devices like speed hump, rumble strips on this stretch and there is no enforcement there. To reduce the number of accidents and to minimize the impact of accidents, it is recommended to install speed limit sign boards, speed hump and rumble strips at the locations where accidents frequently occur. It is also recommended to maintain

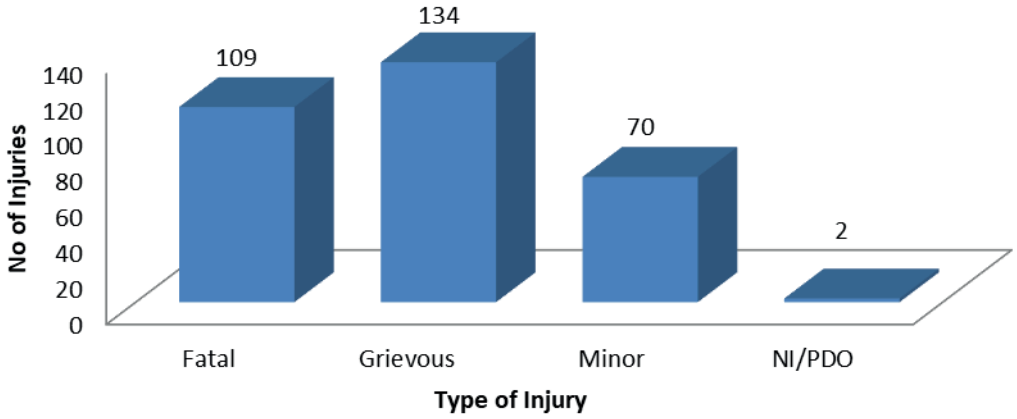

Figure 9 *Distribution of accidents as per the type of injury*

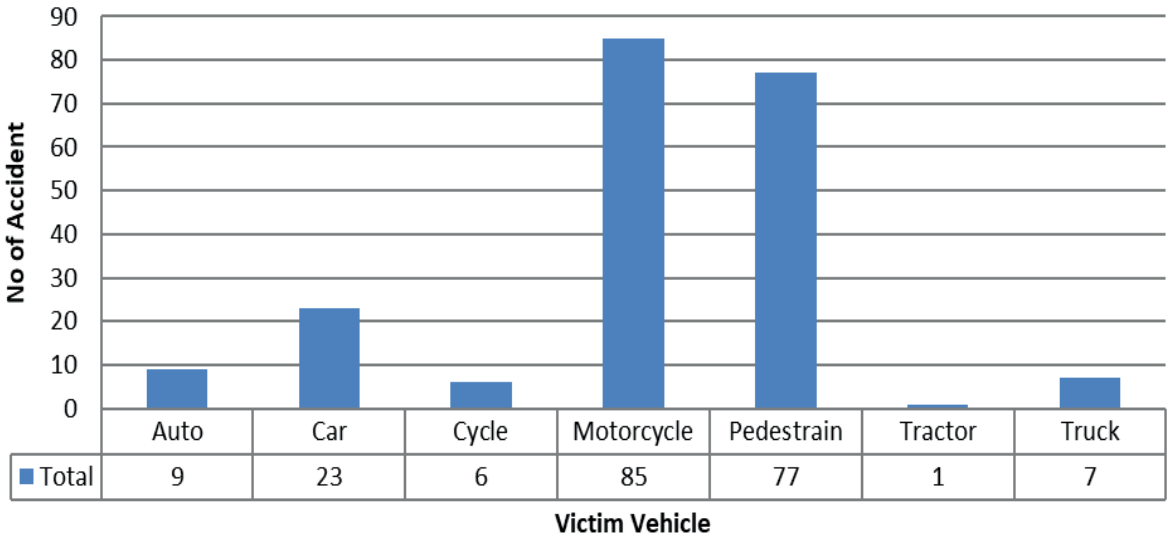

Figure 10 *Distribution of accidents as per types of victim's vehicle*

proper enforcement and to educate the people about the road safety and the negative impacts of speeding.

3.7 Distribution of accidents according to the hitting vehicle

It was discovered that most collisions involved cars. As seen in Figure 8, those vehicles account for 77 of the 208 incidents reported by FIR, followed by trucks, while buses and three-wheelers are less commonly involved in road accidents.

3.8 Distribution of accidents according to the type of injury

From Figure 9, it can be stated that the share of grievous injuries is more as compared to other types of injuries followed by the fatalities while no injury share is the least. The fact that the majority of situations were resolved without being reported may be the cause of the low rate of reported incidents in police records.

3.9 Distribution of accidents according to type of victim's vehicle

Motorcycles, followed by pedestrians, were the most common victims of the accidents that happened on this route during the research period. Figure 10 demonstrates that incidents involving tractors and bicycles are less common.

3.10 Distribution of accidents according to location wise

From the Figure 11, identified accident prone locations are Uttawar Chowk, Jaisinghpur junction,

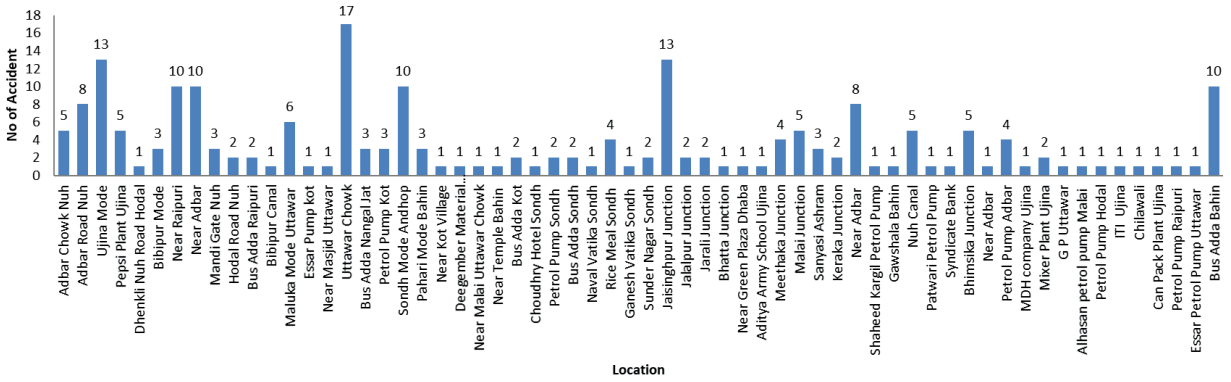

Figure 11 *Identified accident prone locations*

Ujina Mode, Bus Adda Bahin etc. Total of 17 accidents occurred at Uttawar Chowk, then 13 at Jaisinghpur junction and Ujina Mode.

4 Identification of black spots

Blackspot locations can be identified by various methods. Accident severity index (ASI) and MoRTH method are the most widely used methods.

According to the Popli Sudarshan K. study titled "Black Spot Management," Equation (1) is utilized to determine ASI [15].

$$ASI = (Nf * Wf) + (Ng * Wg), \quad (1)$$

where:
Nf = Number of fatal accidents at the spot
Wf = Weightage assigned to the fatal accident is 7
Ng = Number of grievous accidents
Wg =Weightage assigned to grievous is 3.

Note: When conducting a safety audit of NHAI PPP projects, the values Wf = 7 and Wg = 3 were recently adopted for determination of the black spots

Table 2 *List of identified Blackspots in the study area*

S. No	Location	Number of affected persons				Average	Standard Deviation	Threshold Value	ASI
		Fatal	Grievous	Minor	Non-Injured				
1	Adbar Road Nuh	1	2	3	0				13
2	Pepsi Plant Ujina	2	2	3	0				20
3	Maluka Mode Uttawar	2	0	0	0				14
4	Uttawar Chowk	2	0	0	0				14
5	Sunder Nagar Sondh	3	0	3	0				21
6	Bus Adda Raipuri	2	1	0	0				17
7	Sondh Mode Andhop	2	0	0	0				14
8	Bus Adda Bahin	2	0	0	0				14
9	Bus Adda Nangal Jat	2	0	0	0				14
10	Bhatta Junction	2	0	0	0	5.70	4.17	11.95	14
11	Aditya Army School Ujina	2	0	0	0				14
12	Maluka Mode Uttawar	2	0	0	0				14
13	Sondh Mode Andhop	2	0	0	0				14
14	Near Adbar	1	2	0	0				13
15	Jaisinghpur Junction	3	0	0	0				21
16	Near Adbar	3	0	0	0				21
17	Rice Meal Sondh	2	0	0	0				14
18	Petrol Pump Kot	2	0	0	0				14
19	Near Adbar	2	0	1	0				14

Table 3 *Ranking of blackspots*

Rank	ASI	Location
1	21	Sunder Nagar Sondh Jaisinghpur Junction Near Adbar
2	20	Pepsi Plant Ujina
3	17	Bus Adda Raipuri Maluka Mode Uttawar Uttawar Chowk Sondh Mode Andhop Bus Adda Bahin Bus Adda Nangal Jat Bhatta Junction Aditya Army School Ujina
4	14	Maluka Mode Uttawar Sondh Mode Andhop Rice Meal Sondh Petrol Pump Kot Near Adbar Adbar Road Nuh
5	13	Near Adbar

Table 4 *Locations' specific safety observations and recommendations*

Image	Observations	Recommendation	Risk and Priority
	• Pavement edge marking missing. • Speed breaker and its marking missing at entry of junction • Speed breaker sign missing on the entry of junction. • Information Sign Missing in all directions.	• Pavement edge marking should be provided towards both edges. • Provide speed breaker sign board before intersection in all the incoming directions to alert the drivers • Provide light reflecting tape/paint on all such poles. • Provision of cat eyes at the entry of junction on both carriageways. • Provide information sign in all directions to guide the road user.	Risk: High Priority: Highly desirable
	• Pavement edge marking missing. • Electrical poles laying on main carriage way obstructing the traffic without marking.	• Road marking should be painted properly on the road. • The electric pole should be removed from the carriageway to avoid safety hazards. At least the retro-reflective tape should be pasted on both sides of the pole.	Risk: High Priority: Highly desirable

and the findings were quite good. Minor and non-injury accidents are sometimes considered and given a weight of 1. However, since they are typically not reported in India, they may not be considered when determining the "black spots".

5 Black spot recognition

According to MoRTH, "a Road Accident Blackspot is a stretch of National Highway of around 500 meters in length where either 5 road accidents (including fatalities/grievous injuries) occurred in the previous three calendar years, or 10 fatalities occurred in the previous three calendar years." The Hazardous Spots are ranked using the ASI and SD (standard deviation). Dangerous regions, known as "Black Spots", have an ASI higher than the TH (threshold value). Following formulas are used to calculate threshold value TH [16]:

$$\text{TH value} = \text{Avg of ASI} + 1.5 * \text{SD}, \tag{2}$$

$$\text{TH value} = \bar{\text{V}} + 1.5\sqrt{\frac{\Sigma(\text{V} - \bar{\text{V}})^2}{(\text{N} - 1)}}, \tag{3}$$

where, $\text{V} = \text{V}_1, \text{V}_2, \ldots \text{V}_n$ is the ASI values of locations 1, 2…. N, respectively; $\bar{V}$ is the average ASI value and N is the total number of ASI values.

$$\bar{\text{V}} = \frac{\text{V}_1 + \text{V}_2 + \cdots + \text{V}_n}{\text{N}}. \tag{4}$$

As seen in Table 2, the black spots are mentioned from all accident-prone areas in the study where the ASI estimates are higher than the threshold value. Out of many locations where accidents occurred, 19 locations were identified as potential black spots using ASI, according to the data provided from January 2017 to July 2021, as shown in Table 2.

Table 5 *Locations' specific safety observations and recommendations*

Image	Observations	Recommendation	Risk and Priority
	• Road marking/Speed breaker marking is missing, which can cause visibility problems for road users at night-time as it can lead to the road crashes.	• Provide speed breaker along with the sign board before the intersection to alert the drivers. • Pavement edge marking should be provided.	Risk: High Priority: Highly desirable
	• The shoulders are covered under vegetation.	• The tree branches have come on the carriageway at very low height require pruning along with removal of weeds/ plants from roadside.	Risk: Medium Priority: Desirable
	• The information and direction signages are not provided	• To warn residents of habitation, a standard village signboard should be installed (as per IRC-67,99). • Speed Limit signboard should be provided.	Risk: High Priority: Highly Desirable

6 Ranking of black spots

Black spots are ranked according to the accident severity index of the location. Ranks of the black spots of the study location are shown in Table 3. Locations under rank 1 type are the most severe in terms of accidents and hence priority should be given to such locations. "Adbar road nuh" is the least severe accident blackspot.

7 Safety observations and adequate recommendations

Location specific safety observations and recommendations along with priority as observed from the Road Safety Audit during the field visit are shown in Tables 4 to 7. Identified blackspots were audited to identify the potential safety concerns and to suggest the corrective measures to improve those locations. The risk, along with the priority, is also given in Tables 4 to 7. The road safety manual IRC: SP:88-2019 was used for the road safety auditing. The format and content of Tables 4-7 is in accordance with IRC: SP:88-2019.

8 Discussion and conclusions

The road safety audit and accident analysis are carried out to identify the probable cause of accidents and to identify the accident-prone locations. In this study, accident study was carried out on a 67 km stretch of MDR - 132 from Nuh to Hodal. The FIR data of the last five years from the year 2017 to the year 2021 (July) were

Table 6 *Locations' specific safety observations and recommendations*

Image	Observations	Recommendation	Risk and Priority
	• Road side green areas and trees abutting are not properly maintained. • Retro-reflective tape is missing on the electric pole.	• Formation land along with footpath should be free from vegetation/ weeds. • Retro-reflective tape should be provided on both sides of the electric poles placed close to the carriageway as per IRC-35	Risk: High Priority: Highly desirable
	• Truck drivers are parking their trucks in no parking zone approx. 1 km near Ujina mixture plant.	• Unauthorized parking on the carriageway must be removed	Risk: Medium Priority: Desirable
	• Speed hump is not visible. It can lead to road crashes.	• All marking should be reinstalled and maintained properly and kept clean of dust at all times for the proper visibility.	Risk: High Priority: Highly desirable

Table 7 *Locations' specific safety observations and recommendations*

Image	Observations	Recommendation	Risk and Priority
	• Text is missing on Signboard	• Text on signboard should be placed as per IRC-67-2012.	Risk: Medium Priority: Desirable
	• Uncontrolled Junction: Due to the traffic entering and leaving and heavy pedestrians crossing, this is a safety hazard. • Signboards and speed humps are missing.	• The junction should be improved as per IRC SP 73-2015 standard. • Provide speed breaker along with sign board before the intersection to alert the drivers. •	Risk: Very High Priority: Essential

collected from the Haryana police website. Distribution of accidents, according to various parameters, like month, time, year, vehicle involved, location, cause of accidents etc. were classified after interpretation of FIR data. The main interpretations of accidental the FIR data are as follows:

1. In the month of January and December, more accidents occurred. Probable reasons might be foggy conditions during the winter season.
2. Head-on collision (65 accidents) was found as contributing type of accidents for this stretch due to undivided nature of road and lack of enforcements.
3. Out of 208 accidents, 158 accidents are due to speeding according to the collected FIR data. Flow of truck is significant in this stretch and many accidents occurred due to negligence and speeding of trucks. Motorcyclists too ply with over speed in this stretch. In 84 accidents, truck and tractor combined were hitting vehicles.

Accident prone locations (blackspot) were identified using the accident severity index method in which accident severity index of locations where accidents occurred were calculated along with the threshold value for these locations. Any location having higher ASI value than the threshold value is termed as blackspot. A total of 19 such locations were identified and those locations were ranked accordingly. Those 19 locations were audited to find out safety concerns and to provide safety measures with the help of road safety manual IRC: SP:88-2019. The main observations with the suggestive measures are as follows:

1. The major victims of the accidents were seen to be motorcyclists and pedestrians (Vulnerable Road Users) (VRU), while cars and trucks were observed as the main hitting vehicles causing accidents. Monotony of drivers should be broken on longer sections having considerable VRU movements. Separation of the VRU from vehicular traffic with adequate pedestrian facilities on service roads

ensures less chances of pedestrian from entering the carriageway as mentioned in IRC 103:2012.
2. All informatory signage, road marking, hazard marking must be provided as per IRC 67-2012 & IRC 35.
3. Provide proper signboards, retro reflective markings on all the fixed obstructions and cat eyes as edge marking and central line for the night vision.
4. Remove all unauthorized hoardings from lighting and electricity poles.
5. The unauthorized encroachments in the form of street vending, parking and material storage must be removed.
6. Regular cleansing and removal of debris and aggregates from carriageway is a must.
7. Trees and bushes on the edge of road and median obstructing the carriageway should be trimmed regularly on all roads.

These safety measures are location specific and can be applied for the roads having similar safety issues across India.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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