

A Review of Strategies for Improving Road Safety Audits for Motorized and Non-Motorized Transportation, Based on Accident Studies

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Abstract:

Road safety is a crucial issue in India, with high rates of road accidents causing fatalities and injuries. Improving road safety requires a comprehensive approach that includes accident studies and road safety audits to identify high-risk areas and develop targeted interventions. This paper presents a methodology for enhancing road safety in Indian cities, involving conducting accident studies, road safety audits, identifying priority areas, developing interventions, implementing and monitoring these measures, and promoting continuous improvement. Through these steps, local government authorities, transportation agencies, and other stakeholders can work together to improve road safety and reduce accidents, fatalities, and injuries on Indian roads. Urban roads typically feature a high number of street entries, are mainly located in urban areas, and have traffic lights spaced at least one kilometer apart. The section of road with control structures at both intersections is called an "Urban Road Segment." Upstream and downstream junctions, which act as key control points, are essential for conducting a Road Safety Audit (RSA) on metropolitan roads where motorized Transport (MT) and non-motorized Transport (NMT) intersect. NMTs are often unstable and sometimes heavily loaded. A main goal of this proposal is to establish and promote a systematic approach to collecting and maintaining traffic accident data, using advanced electronic techniques both at the accident scene and at hospitals where injured individuals are taken.

1. Introduction

India ranks among the countries with the highest number of road accidents worldwide, and most of these involve vulnerable road users such as pedestrians, bicyclists, and motorcyclists (MT & NMT). To improve road safety and reduce accidents involving these users, it is essential to develop a methodology that includes accident studies and road safety audits [1]. This process should begin with analyzing accident data to identify the most common types and locations of incidents involving MT & NMT. This information will help pinpoint areas that need immediate attention and identify where safety measures can be implemented to prevent future accidents. A comprehensive road safety audit of these areas should then be performed to identify specific road design issues, such as inadequate signage, poor surface conditions, or insufficient lighting. Based on findings from the accident data and safety audits, appropriate safety measures can be designed and enacted [2]. These may include infrastructure improvements like road widening, creating separate lanes for different types of road users, installing speed-calming devices, and enhancing road markings and signage [3]. It is imperative to ensure that the entire Road Safety Audit Team is entirely independent from the Design Team and consists of at least two staff members with the appropriate expertise in road safety audits, in addition to the required education and training, as shown in Figure 1



Figure 1. Road Safety Audit Team

Education campaigns and enforcement actions, such as speed cameras, traffic police, and penalties for traffic violations, can also be implemented. It is crucial to involve stakeholders, including traffic police, local government officials, transportation planners, and community groups, in the development and implementation of the methodology.

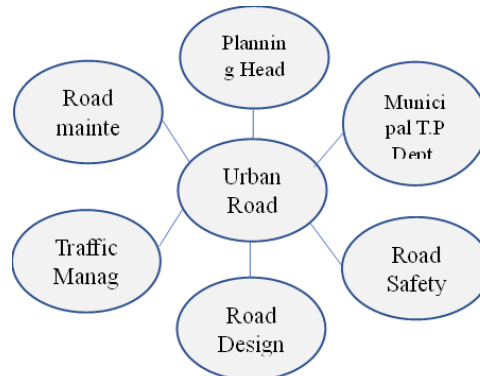


Figure 2. Participation in urban road safety audits

Figure 2 lists several people and groups involved in conducting RSA for urban highways [5].

1.1. Accident Causes

According to information released by the Bhopal Traffic Police, drivers are mainly responsible for all accidents (Source: Office of the Director General of Police, Gujarat State, Gandhinagar). Each year, adverse weather, poor road conditions, mechanical failures, pedestrian errors, passenger mistakes, and inadequate lighting all contribute to a significant percentage of the city of Bhopal's total annual traffic accidents. The data indicate that the data collection process needs improvement to gain a more accurate understanding of the causes of accidents in Bhopal, even though there is no doubt that drivers' irresponsibility plays a significant role in road incidents [6]. The population under 18 years old can be broken down into three main age groups: those under 18, those between 18 and 54, and those over 54 years old. The percentages that each group represents are shown in Figure 3. The majority of people involved in accidents are reported to be between 18 and 54 years old. It highlights the impact these incidents have on the city's economically active population [7].

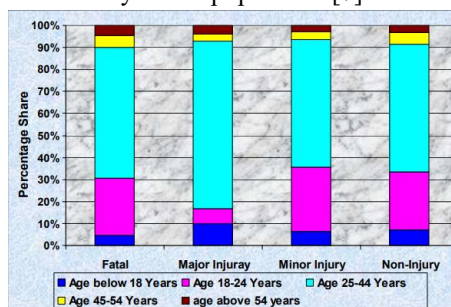


Figure 3. Age breakdown of those killed or injured in accidents in 2022

2. Literature Review

- Several studies have highlighted the need for improved road safety measures in India, especially for vulnerable road users such as pedestrians, bicyclists, and motorcyclists [8]. A review of the literature reveals key insights that can inform the development of a method for enhancing road safety in Indian cities, with a focus on Motorized Transport (MT) and Non-Motorized Transport (NMT), based on accident studies and road safety audits.
- Reviewing Previous Work (Guozhu Cheng, Rui Cheng, Yulong Pei, and Juan Han – 2021) [9]. This study examined various models and approaches for predicting and evaluating roadside accidents. According to their frequency in the literature, the top five risk factors for frequent roadside accidents are small-radius curves, heavy traffic, objects near the lane (like poles and trees), narrow roads, and narrow shoulders. The top five risk factors for fatal roadside accidents are driver age 25 or 65, alcohol use, speeding, failure to use seat belts, and heavy trucks [10].



- As of 2017, (Mrs. Monika and Hitesh Kumar) [11], researchers used FIR data to identify high-accident areas and establish statistical links between those areas and various influencing factors. The study focused on the state of Haryana in India, specifically on Kaithal and Kurukshetra, utilizing comprehensive data to identify the most hazardous regions.
- The study investigated six mid-sized Indian cities—Agra, Amritsar, Bhopal, Ludhiana, Vadodara, and Vishakhapatnam. Overall, in these cities, car occupant deaths account for 2% to 3%, TST fatalities are less than 5%, and deaths among vulnerable road users range from 84% to 93% [12]. Per 100,000 vehicles, there are 2 to 3 times more deaths among Motorized Two-Wheelers (MTW) and 3 to 5 times more among Tricycle, Scooter, and Three-wheelers (TST) than in automobiles. Based on their estimated link to fatal crashes, TSTs pose a slightly lower societal risk than MTWs and cars. Some of these findings will need further validation with more detailed data [13].

Table 1. Literature Review on Road Safety Audit and Accident Study Methodology for Indian Cities

Author(s)	Title	Methodology	Key Findings
Bhalla et al. (2023) [14]	"Pedestrian and motorized transport safety in Delhi: A road user's perspective"	Literature review, surveys, and focus group discussions	Road user behaviour, infrastructure deficiencies, and weak law enforcement contribute to high levels of road accidents in Delhi
Jaiswal et al. (2023) [15]	"Road safety audit for urban roads: A case study of Lucknow city"	Road safety audit	Identification of road safety issues, development of remedial measures, and evaluation of their effectiveness
Mukherjee et al. (2023) [16]	"Development of a road safety audit framework for Indian cities"	Literature review, case studies, expert consultations	The proposed framework includes a three-stage process: data collection, identification of safety issues, and development of remedial measures
Prashanth and Ramesh (2022) [17]	"Road safety audit of urban roads: A case study of Bangalore city"	Road safety audit	Identified safety issues included poor visibility, inadequate signage, and insufficient pedestrian facilities.
Rao et al. (2022) [18]	"Development of a road safety audit framework for Indian cities"	Literature review, case studies, expert consultations	The proposed framework includes a five-stage process: data collection, risk assessment, identification of safety issues, development of remedial measures, and evaluation of their effectiveness
Roy et al. (2022) [19]	"A review of pedestrian safety in Indian cities"	Literature review, case studies	Identified factors contributing to pedestrian accidents, such as inadequate pedestrian infrastructure and road design, and a lack of enforcement of traffic rules

The literature review emphasizes the need for a comprehensive and collaborative approach to improving road safety in Indian cities for MT & NMT. This strategy should include measures such as upgrading infrastructure, raising awareness and education, enforcing traffic laws, incorporating road safety audits into road design, and involving the public in road safety programs. By applying these insights, an evidence-based methodology can be developed that is suited to the local context, ensuring maximum effectiveness in reducing road accidents and fatalities. [22].

2.1. Road safety in India

Road safety is a significant concern in India, given the high number of road accidents that occur each year. According to the World Health Organization (WHO), India accounts for nearly 11% of all road accident deaths worldwide, despite having only about 2% of the world's vehicles. Several factors contribute to India's high accident rate, including poor infrastructure, flawed road design, lack of awareness among road users, and weak enforcement of traffic laws. Most accidents in India involve vulnerable road users like pedestrians, bicyclists, and motorcyclists, who are more likely to be injured or killed in accidents.

A composite index evaluates the safety level of specific entities, such as roadways, to determine the associated risk to road safety. Equation (1) shows the simplest relationship used to assess the danger to road safety. [8],

$$Risk = \frac{Road\ safety\ outcome}{Exposure\ one} \quad (1)$$

2.2. Accident Prevention

The two primary approaches to enhancing traffic safety are accident prevention and mishap reduction. To prevent recurring accidents, we analyze data from past incidents on our current roads to inform improvements in road design or changes in driver behavior. Regardless of the project's specific aims, accident prevention involves



applying knowledge of safe road design to build new infrastructure or modify existing roads. Preventing accidents is essential for road safety, and various measures can be implemented to reduce accidents on Indian roads. Some of these measures include.

- **Improved road infrastructure:** Enhancing road infrastructure, such as adding better lighting, road markings, and signage, can help prevent accidents by increasing visibility and guiding road users.
- **Traffic management:** Effective traffic management, including regulating traffic flow, managing intersections, and enforcing speed limits, can help prevent accidents [24].
- **Education and awareness:** Raising public awareness about safe driving practices and the importance of using safety equipment like helmets and seat belts can help prevent accidents.
- **Enforcing traffic laws:** Strict enforcement of traffic laws, including penalties for drunk driving, speeding, and not wearing safety equipment, can serve as a deterrent and prevent accidents.
- **Technology-based solutions:** Solutions like Intelligent Transport Systems (ITS), which utilize sensors, cameras, and communication networks to improve road safety, can also help prevent accidents.
- **Collaboration and participation:** Involving all stakeholders—including government agencies, civil society organizations, and the public—is essential to preventing accidents. This can involve developing and implementing road safety strategies and programs, sharing information and best practices, and launching public awareness campaigns [25].

Table 2. Year-Wise Road Accident Statistics in India

Year	Number of accidents total	Number of fatal accidents	Number of people killed	Number of people injured	Number of people killed per 100 accidents
2022	469872	158746	80547	405621	20.1
2021	405784	452187	86574	486572	21.3
2020	501367	456328	85426	569821	18.6
2019	423650	785412	45687	753214	17.5
2018	596374	854632	75846	896574	22.5
2017	459821	896574	96580	365897	21.3
2016	403874	235480	456871	856974	20.7

All vehicle users, including those with special needs and those using the surrounding areas, should be considered. The potential risks must be assessed to determine if any traffic safety issues could arise during the work. The model is mathematically presented below for evaluating road safety [26]:

Accident rate calculation: The number of accidents per unit of traffic volume or distance can be determined using the following equation.

$$\text{Accident rate} = \text{Number of accidents} / (\text{Traffic volume or distance})$$

Crash severity index: The severity of crashes can be quantified using a crash severity index (CSI), which is based on the severity of injuries and property damage. The CSI can be calculated using the following equation:

$$\text{CSI} = (\text{Number of fatal crashes} \times W_f) + (\text{Number of injury crashes} \times W_i) + (\text{Number of property damage only crashes} \times W_p)$$

where W_f , W_i , and W_p are weights assigned to each type of crash.

Risk assessment: The risk of accidents can be assessed using various models, such as the Predictive Analytic Model for Multi-Agency Road Traffic Safety (PAM-MARTS), which employs a logistic regression equation to predict the probability of crashes based on factors including road geometry, traffic volume, and weather conditions. The equation is as follows:

$$\text{Risk} = e^{\{(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n)\}}$$

Where:

$\beta_0, \beta_1, \beta_2, \dots, \beta_n$ are coefficients estimated from the data.

$X_1, X_2, \dots, X_n$ are the input variables used to predict the risk of crashes.

These equations are merely examples and may not be directly applicable to the development of a road safety audit and accident study methodology for Indian cities. The methodology would likely involve a more holistic approach that includes qualitative analysis, stakeholder engagement, and local context-specific factors.

$$E_0 = \max \frac{\sum_{r=1}^v v_r y_{r0}}{\sum_{i=1}^m v_i x_{i0}}$$

$$\text{subject to } \frac{\sum_{r=1}^s v_r H_{-j}}{\sum_{i=1}^t \Sigma_1 I_{4j}} \leq 1, \quad j = 1, \dots, n \quad (2)$$

$$u_r, v_1 \geq 0, \quad r = 1, \dots, s, \quad i = 1, \dots, m$$

In this formulation, E_0 represents the objective function that needs to be maximized subject to a set of linear constraints. The objective function involves optimizing the ratio of the sum of outputs to the sum of inputs, where y_{r0} and x_{i0} represent the r th output and i th input of the j th Data Envelopment Analysis (DEA) model, respectively. The variables v_r and v_1 are the weights assigned to each output and input, respectively.

The set of constraints ensures that the solution is feasible and meets certain conditions. The constraint $(\sum_{r=1}^s v_r H_{-j}) / (\sum_{i=1}^t \Sigma_1 I_{4j}) \leq 1$ represents the requirement that the weighted sum of the outputs of all DMUs should be less than or equal to the weighted sum of the inputs, where H_{-j} represents the matrix of weights for the j th output and I_{4j} represents the matrix of weights for the j th input. This constraint is applied for each production, starting from $j = 1$.

The variables v_r and v_1 are also subject to the non-negativity constraints, which require them to be greater than or equal to zero. This formulation is merely an example, and the specific objective function and constraints used in a given optimization problem may vary depending on the situation and its context.

$$\text{Risk} = \frac{\text{Wt. Sum of Outputs}}{\text{Wt. Sum of Inputs}} = \frac{\text{Min. Outputs}}{\text{Max. Inputs}}$$

$$\text{Road Accident Risk Index} = \frac{\text{Min. Outputs}}{\text{Max. Inputs}} = \frac{\text{Safety Outputs}}{\text{Exposure}} \quad (3)$$

In this formula, Wt. Sum of Outputs and Wt. The sum of inputs represents the weighted sum of outputs and inputs, respectively, where the weights are assigned based on the relative importance of each variable. Min (Outputs) and Max (Inputs) represent the minimum of the outputs and maximum of the inputs, respectively. Safety Outputs refer to the minimum of the outputs, while Exposure refers to the measure of risk exposure, such as vehicle miles travelled or person miles travelled. This formula suggests that the risk of road accidents can be measured as a ratio of the safety outputs to exposure. A higher safety output and a lower exposure would result in a lower risk of road accidents. In contrast, a lower safety output and a higher exposure would result in a higher risk.

Risk: The basic concept of DEA-Risk calculation is as follows:

$$\text{Risk} = \frac{U_1(y_{1j}) + U_2(y_{2j}) + \dots + U_k(y_{kj})}{V_1(x_{1j}) + V_2(x_{2j}) + \dots + V_l(x_{lj})} \quad (4)$$

In this equation, U and V represent the weights assigned to the outputs and inputs, respectively, where $U = (u_1, u_2, \dots, u_k)$ and $V = (v_1, v_2, \dots, v_l)$ are the weight vectors. $y_{1j}, y_{2j}, \dots, y_{kj}$ represent the outputs of the DMU j , while $x_{1j}, x_{2j}, \dots, x_{lj}$ represent the inputs of the DMU j . The formula calculates the risk or performance of the DMU j as the ratio of the weighted sum of outputs to the weighted sum of inputs. The weights represent the relative importance of each output and input in the DMU's performance. A higher value of risk or performance indicates better performance relative to other DMUs, while a lower value indicates poorer performance.

2.3. Special Safety Concerns Affecting Road Design

All traffic users should be included in a plan. The safety features of large vehicles, such as lorries and coaches, require extra attention. These vehicles may have different requirements than cars do. Specifically, it may be necessary to examine statistics to help the system safely manage such traffic. Additionally, the unique needs of pedestrians and non-motorized transportation must be considered [27]. Road design plays a crucial role in ensuring road safety, and several essential safety concerns must be addressed when designing roads in India. Some of these concerns include.

- **Vulnerable road users:** As mentioned earlier, vulnerable road users, such as pedestrians, bicyclists, and motorcyclists, face a higher risk of accidents. Therefore, road design should prioritize the needs and safety of these users by providing dedicated and protected lanes for them.
- **High traffic volume:** As the number of vehicles on Indian roads increases, traffic congestion has become a significant safety issue. Therefore, road design should consider traffic volume and allocate enough space for smooth traffic flow.



- **High-speed limits:** High-speed limits on Indian roads are a significant safety concern, and road design should ensure that the road geometry, such as curves and slopes, is designed to promote safety speeds.
- **Roadside development:** Unplanned roadside development can pose safety risks by blocking drivers' views and increasing the chance of accidents. Therefore, road design should provide sufficient clearance for roadside development and ensure it does not compromise road safety.
- **Weather conditions:** India experiences various weather conditions, such as heavy rains, floods, and extreme heat, which can affect road safety. Road design should consider these weather patterns and incorporate infrastructure, such as drainage systems, to ensure protection during adverse weather conditions. [28].

In special safety concerns need to be taken into account while designing roads in India to ensure road safety. Road design should consider the needs and safety of vulnerable road users, traffic volume, speed limits, roadside development, and prevailing weather conditions. By addressing these safety concerns, it is possible to create a safer road environment for all road users in India.

2.4. Road Design and Safety Audit

Road design and safety audits help identify potential safety issues and offer recommendations to improve road safety. Some key aspects of these audits include:

- **Design standards:** Road design must follow national and international standards, such as the Indian Road Congress (IRC) guidelines, to ensure safety.
- **Road geometry:** Road geometry, including curves, gradients, and intersections, should be designed to support safe speeds and traffic flow [29].
- **Road markings and signage:** Road markings and signage should be clear, easy to read, and informative to help guide drivers and prevent accidents.
- **Pedestrian facilities:** Adequate pedestrian facilities, like footpaths, pedestrian crossings, and signals, should be provided to ensure pedestrians' safety.
- **Bicycle facilities:** Dedicated bike lanes and facilities should be established to ensure the safety of bicyclists.
- **Roadside development:** Roadside development, including buildings, trees, and utility poles, should be planned and designed to prevent them from creating safety hazards for road users.
- **Lighting:** Proper lighting should be installed to ensure visibility and safety at night.

2.5. Road Accidents – Situation in India

Road accidents are a significant public health and safety issue in India, with a high number of fatalities and injuries reported each year. According to the Ministry of Road Transport and Highways, there were 4,49,002 road accidents in India in 2019, resulting in 1,51,417 deaths and 4,51,361 injuries. Most road accidents in India involve vulnerable road users such as pedestrians, bicyclists, and motorcyclists, who are more likely to suffer injuries or death in accidents. In 2019, two-wheeler riders made up 35% of all road accident deaths, while pedestrians and bicyclists accounted for 15% and 5%, respectively. Several factors contribute to India's high rate of road accidents, including inadequate infrastructure, poor road design, lack of awareness among road users, and weak enforcement of traffic laws [30]. The situation worsens due to the increasing number of vehicles on the roads, leading to congestion and overcrowding. The Indian government has introduced several measures to enhance road safety, such as raising penalties for traffic violations and implementing stricter rules for issuing driver's licenses [14].

3. Research Methodology

This research includes quantitative and qualitative analyses of data, rules, and behaviors related to road safety. It investigates the current situation of road safety in Asian countries, as well as the implementation of relevant policies, action plans, and practices across the region. Additionally, it examines valuable sources of data and researches the topic of road safety, developing several illustrative models tailored to the Asian region. The report utilizes data from the World Health Organization (WHO) and country reports, as well as information and input gathered from major stakeholders in the field of road safety during three sessions held in Kathmandu.



3.1. Data Description and Preparation

Data were gathered from the National Highway Authority (NHA) and the National Motorways and Highway Police (NHMP) for the motorway (MP-Bhopal, 200-300 km) over six years (2018-2022) to create a statistical association between traffic factors and the severity of road accidents. Safety outcomes or outputs included the number of accidents (NOA) and the number of people affected, such as injured or dead. We examined whether there was an isotonic relationship between the data output variables.

3.2. Road infrastructure safety management

At various points in the life cycle of road infrastructure, RISM methods are designed to improve road safety. While some can be applied to existing infrastructure for a more reactive approach (i.e., addressing safety issues that are already present), other procedures are applied in the early stages (e.g., enabling a more proactive approach, such as planning and design).

3.3. Data Envelopment Analysis for Accident Risk Analysis

The idea behind using the DEA model in the area of road safety is to increase exposure to traffic while reducing the number of accidents. The optimization tool DEA has been used to construct the road accident risk index using a similar methodology [31].

Accidents, fatalities, and injuries are considered a successful safety outcome when compared to increases in traffic volume and capacity, vehicle kilometres travelled, and vehicle hours travelled. Highway risk evaluation connection is indicated in Equation (5) by the addition of the actual desired variables to Equation (4) [20]:

$$Risk = \frac{U_2 (NoA) + U_1 (NoAP)}{V_1 (V/C) + V_2 (VKT) + V_3 (VHT)} \quad (5)$$

In this formula, NoA represents the number of accidents, NoAP represents the number of accidents resulting in fatalities or serious injuries, V/C represents the traffic volume, VKT represents the vehicle kilometers travelled, and VHT represents the hours of risk exposure. U1 and U2 represent weights assigned to the inputs NoAP and NoA, respectively. V1, V2, and V3 represent weights assigned to the output's V/C, VKT, and VHT, respectively. The Risk value represents a measure of the level of risk associated with a particular road segment, taking into account factors such as traffic volume, vehicle kilometers travelled, and risk exposure. It is commonly used in road safety audits and accident studies to identify high-risk road segments and inform the development of road safety measures.

3.4. Accident Severity Index (ASI)

Black spot management by Popli Sudarshan K. report, available online at Uttar Pradesh Public Works Department website, states that "ASI is calculated using the following expression $ASI = (Nf * Wf) + (Ng * Wg)$ (6)

Where

Nf = Number of fatal accidents there

Ng = Number of terrible accidents

Wf = Weightage allocated to the deadly accident is 7

Wg = Grievous is assigned a weight of 3.

Then

$$TH \text{ Value} = \text{Average ASI} + 1.5 * SD \quad (7)$$

$$TH \text{ Value} = \bar{V} + 1.5 \frac{\sqrt{\sum(V - \bar{V})^2}}{(N - 1)} \quad (8)$$

In this formula, the TH Value represents the threshold value for identifying high-risk road segments based on the Aggregate Safety Index (ASI). The average ASI represents the average safety performance of all road segments, while the SD (standard deviation) represents the degree of variation in the ASI among all road segments. The TH Value is calculated by adding 1.5 times the SD to the average ASI. Here, $\bar{V}$ represents the sample mean or average of the values. By dividing the sum of squared deviations from the mean by (N-1) instead of N in the denominator, the resulting value is an unbiased estimate of the variance or standard deviation of the population from which the sample was drawn. Road segments with an ASI higher than the TH Value are considered high-risk and may require special attention in terms of road safety measures. [21].

$$\bar{V} = \frac{V1 + V2 + \dots + Vn}{N} \quad (9)$$



This equation calculates the average value of a set of values $V_1, V_2, \dots, V_n$. In this formula, N represents the number of values in the set. The average value provides a measure of the central tendency of the set of values, representing a typical value that is representative of the set.

The formula is commonly used in statistical analysis. It can be applied in various contexts, such as calculating the average speed of vehicles on a road segment or the average distance between two points.

Risk: The fundamental idea behind DEA-Risk assessment about Equations (1) and (4) is as follows:

$$\text{Risk} = \frac{\text{Weighted sum of output}}{\text{Weighted sum of input}} \quad (10)$$

In this formula, the Weighted sum of output represents the sum of the individual outputs, each multiplied by a corresponding weight. In contrast, the Weighted sum of input represents the sum of the individual inputs, each multiplied by a corresponding weight.

The Risk value represents a measure of the overall effectiveness or efficiency of a particular system or process, taking into account the relative importance or impact of each output or input factor. It is commonly used in multi-criteria decision-making and performance evaluation studies to evaluate and compare different systems or processes based on multiple performance criteria or factors. The weights assigned to each factor are typically based on their relative importance or priority, as determined by experts or stakeholders.

$$\text{Risk} = \frac{\text{Minimize output}}{\text{Maximize input}} \quad (11)$$

In this formula, minimize output represents the desired minimum level of production or performance, such as the number of accidents or fatalities. In contrast, Maximize input represents the maximum level of input or resources, such as traffic volume, vehicle kilometers travelled, or hours of risk exposure.

$$\text{twoRisk} = \frac{\text{Road Safety output}}{\text{Exposure}} \quad (12)$$

In this formula, Road Safety output represents the measure of the effectiveness of road safety measures or interventions, such as the number of accidents prevented or the reduction in severity of accidents. Exposure refers to the level of risk to which an individual is exposed, such as traffic volume, vehicle kilometers traveled, or the number of hours of risk exposure. The Risk value represents a measure of the level of risk associated with a particular road segment or area, taking into account the effectiveness of road safety measures or interventions and the level of risk exposure. It is commonly used in road safety audits and accident studies to evaluate the effectiveness of roads.

Safety measures and inform the development of new measures to reduce the level of risk further.

Even though the fundamental model has been described in the literature review, Equation (6) can be expressed simply as follows:

$$\text{Risk} = \frac{u_1 y_{1j} + u_2 y_{2j} + \dots + u_k y_{kj}}{v_1 y_{1j} + v_2 y_{2j} + \dots + v_l y_{lj}} \quad (13)$$

The overall number of traffic fatalities in India's major cities is shown in Table 2 and Figure 5. It is possible to comprehend the issues with traffic crashes in urban settings, given that less than one in 40 Indian families currently own a car and that both motorized and non-motorized vehicles use metropolitan streets. The death rates per million inhabitants for Indian cities with populations larger than 1 million. These figures show that most city rates in India are higher than the country's average (80 fatalities per million).

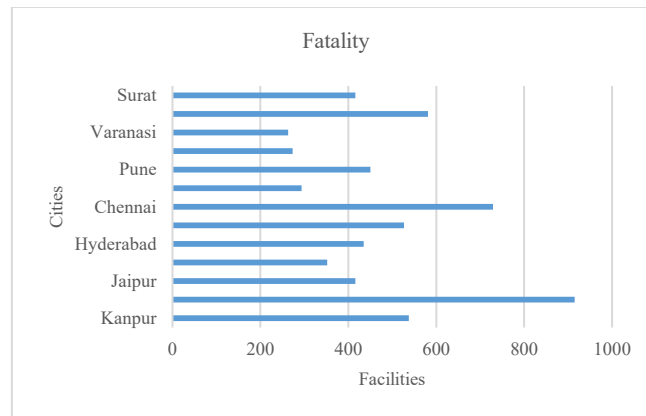


Figure 5. Fatalities in 2000 in metropolitan

Table 3. Traffic fatalities in the metro city of Indian in 2022

City	Fatality
Kanpur	538
Delhi	915
Jaipur	416
Nagpur	352
Hyderabad	435
Lucknow	527
Chennai	729
Bhopal	294
Pune	450
Vadodara	273
Varanasi	263
Mumbai	581
Bhopal	416

4. Results and Discussion

In a perfect world, there wouldn't be any fatalities caused by automobile accidents. Some of the world's wealthiest countries are moving toward "vision zero" rules and other stringent safety measures. According to a study that looked at road safety in Asia, some countries are reporting a rise in the number of people dying on the roads rather than a decrease.

Table 4 compares the number of fatalities in various nations

Countries	Number of Fatalities in 2010	Number of Fatalities in 2016	Difference
Afghanistan	1526	53254	-19%
Bangladesh	1352	26574	48%
Bhutan	960	152	49%
India	23658	4526	31%
Maldives	9	8	-34%
Nepal	48563	2541	-5%
Pakistan	3674	26854	-9%
Sri Lanka	3524	3654	7%
Cambodia	2384	2015	16%
Indonesia	4057	34957	-26%
Laos	1985	16735	-13%
Malaysia	7542	41850	5%
Myanmar	7014	10687	48%
Philippines	8452	10235	50%
Singapore	2365	198	-41%
Thailand	21024	27964	-16%
Vietnam	25096	27968	16%

The following sections offer a detailed review of progress, policies, and practices related to road safety, vulnerable road users, urban road safety, data, investment, and governance. Table 3 shows the percentage of fatal traffic accidents involving different types of drivers and passengers. In South-East Asia, VRUs are responsible for 75.2% of fatalities, whereas in the Asia-Pacific region overall, they account for 54.8% of incidents deaths.

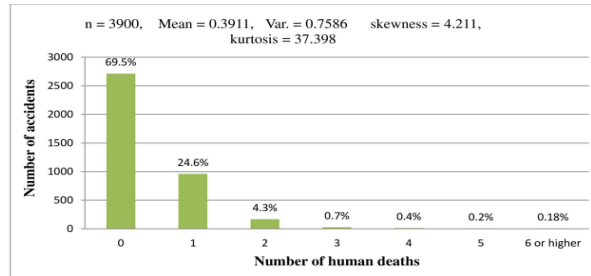


Figure 6.A bar graph of the response variable's distribution, along with the number of fatalities due to traffic accidents.

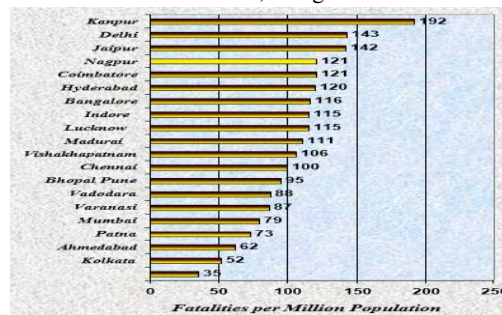


Figure 7. Indian cities' mortality rates per million

The number of collisions involving motor vehicles that occurred in Bhopal during each of the years listed in Table 5 is presented.

Table 5. Shows a year-by-year breakdown of traffic accidents in Bhopal city

Year	Accidents with Fatalities Nos.	Accidents with Serious Nos.	Accident with minor injuries Nos.	No injuries	Total Accidents	
2022	321	276	546	591	236	1183
2021	112	226	328	564	156	858
2020	317	249	656	618	184	1174
2019	501	929	336	565	213	1150
2018	641	315	637	696	244	1517
2017	310	540	563	586	213	1379
2016	471	857	583	648	214	1434
2015	814	504	561	575	233	1440
2014	713	543	492	498	339	1437
2013	358	343	496	546	295	1210
2012	611	327	331	372	639	1506
2011	319	483	308	435	825	1764
2010	414	435	309	459	462	1409
2009	681	437	331	497	438	1484
2008	129	594	430	486	248	1427
2007	235	546	340	402	222	1347
2006	501	241	160	179*	15*	513*
Average	155	415	480	534	314	1348

The percentage of accidents resulting in fatalities is displayed in Figure 9. Specifically, 11% of accidents result in deaths, 30% of accidents cause victims to sustain substantial injuries or impairments, and 35% of accidents result in less severe injuries or no injuries at all.

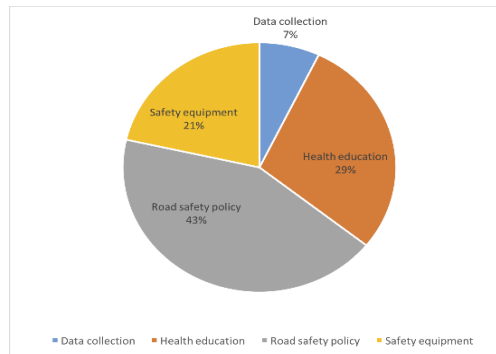


Figure 9 shows the severity-based distribution of traffic accident facilities.

Because the Bhopal traffic police cannot record every minor collision on the city's roads, the accident severity index may have increased somewhat over the past few years. Figure 10 shows the number of fatalities in Bhopal City during the specified years. The death rate has decreased from 0.27 per 100,000 people to 0.22 in the past decade. The decrease in deaths suggests that, despite a significant increase in the number of vehicles, the total number of accidents does not fluctuate greatly. Fewer fatalities were reported in 2012 and 2022 compared to the higher overall number of accidents in those years.

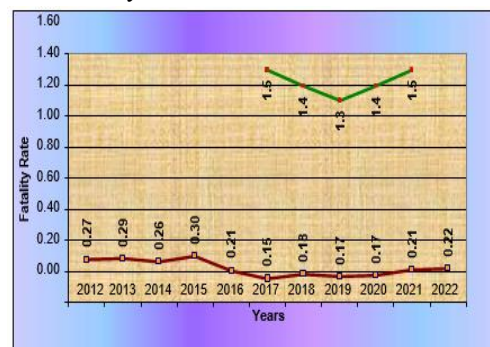


Figure 11. compares the national and local rates of road accident fatalities in Bhopal.

Accidents are distributed over time, as shown in Figure 12, which clearly illustrates the timing of these incidents. With the correct data set and regular records, it is possible to analyze accidents on specific road sections during particular periods, enabling quick identification of hazardous areas in the city. The table clearly shows that two-thirds of accidents happen during the day, while one-third occur at night. The relatively high percentage of evening accidents indicates substantial midnight traffic. It was found that 60% of fatalities occurred.

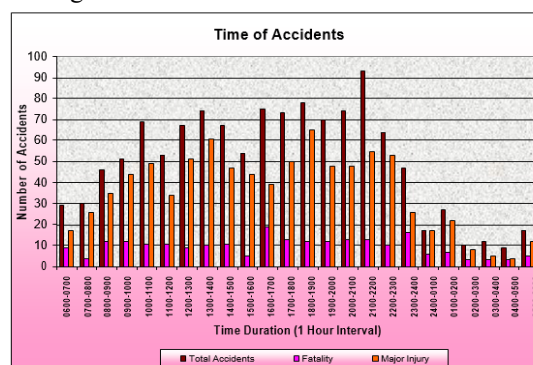


Figure 12. Distribution of accidents by time of occurrence

5. Conclusions

- In conclusion, enhancing road safety in Indian cities for both motorized and non-motorized transport is a vital challenge that demands a comprehensive approach. Developing a methodology based on accident analyses



and road safety audits can help pinpoint key factors contributing to accidents, enabling the implementation of targeted measures to enhance road safety.

- Improvements in road design, traffic management, public awareness campaigns, enforcement of traffic laws, and better data collection and analysis are some interventions to enhance road safety in Indian cities. It is crucial to prioritize the safety of all road users, especially the most vulnerable ones, to reduce the number of accidents and fatalities on Indian roads.
- Developing a methodology to improve road safety in Indian cities for MT & NMT, based on accident studies and road safety audits, is a crucial step toward reducing accidents and fatalities on Indian roads.
- In India, road safety remains a significant challenge caused by factors such as poor infrastructure, lack of awareness, and non-compliance with traffic rules. The approach discussed in the conclusion emphasizes improving road design, traffic management, public awareness, enforcement of traffic laws, and the collection and analysis of data to enhance safety.
- These interventions are not only essential but also work together. Improvements in road design, such as better intersection layouts, the addition of pedestrian crossings, and the separation of bicycle lanes from traffic, can help prevent accidents.
- Similarly, traffic management improvements like better signage, road markings, traffic calming measures, and setting speed limits can help control traffic flow and prevent accidents.

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