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A Comprehensive Review of Accident Studies and Road Safety Audit for Urban Road Networks

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Abstract: Road traffic accidents remain one of the leading causes of fatalities and serious injuries worldwide, particularly in rapidly urbanizing regions where increasing vehicle ownership, heterogeneous traffic conditions, and inadequate infrastructure contribute to higher accident risks. Urban road networks experience complex traffic interactions involving motorized vehicles, pedestrians, cyclists, and public transport, making road safety a significant challenge for transportation planners and policymakers. Accident studies provide valuable insights into the causes, patterns, and severity of crashes, while Road Safety Audits (RSA) offer a proactive approach to identifying and mitigating potential safety hazards before accidents occur. This review paper presents a comprehensive analysis of published literature on accident studies and road safety audit practices for urban road networks. The review examines major factors influencing road accidents, including roadway geometry, traffic volume, driver behavior, environmental conditions, vehicle characteristics, roadside features, and pedestrian activities. Various accident analysis techniques such as statistical methods, black spot identification, Geographic Information System (GIS)-based analysis, safety performance indicators, and predictive modeling are critically reviewed. The paper also discusses the principles, procedures, stages, and benefits of Road Safety Audits, highlighting their role in improving transportation safety through systematic identification of infrastructure deficiencies. Furthermore, recent developments in intelligent transportation systems, artificial intelligence, machine learning, drone-based traffic monitoring, and GIS applications for accident prediction and safety evaluation are explored. The review identifies existing research gaps and provides recommendations for integrating accident analysis with proactive safety audit practices to enhance urban road safety. The findings are expected to support researchers, highway engineers, urban planners, and government agencies in developing safer, more sustainable, and efficient urban transportation systems.

Keywords: Road Traffic Accidents, Road Safety Audit, Urban Road Network, Accident Analysis, Black Spot Identification, Traffic Safety, GIS, Intelligent Transportation Systems.

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I. Introduction

Rapid urbanization and continuous growth in vehicular ownership have significantly increased traffic demand on urban road networks across the world. Cities are experiencing severe traffic congestion, increased travel delays, and a growing number of road traffic accidents due to mixed traffic conditions, inadequate road infrastructure, poor traffic management, and unsafe road user behavior. Urban roads accommodate diverse categories of road users, including pedestrians, cyclists,

motorcycles, cars, buses, trucks, and non-motorized vehicles, making traffic operations highly complex and increasing the probability of conflicts and crashes.

Road traffic accidents are recognized as a major public health and socio-economic concern because they result in fatalities, injuries, property damage, productivity losses, and increased healthcare expenditures. Developing countries, particularly India, account for a disproportionately high share of global road accident fatalities despite having a comparatively smaller proportion of the world's vehicles. Factors such as excessive speed, distracted driving, violation of traffic rules, inadequate pedestrian facilities, poor roadway design, insufficient signage, and roadside encroachments contribute significantly to accident occurrence on urban roads.

Accident studies play a crucial role in understanding crash characteristics, identifying accident-prone locations, evaluating contributing factors, and developing effective mitigation measures. Traditional accident analysis methods include statistical analysis of crash data, accident severity assessment, black spot identification, conflict analysis, regression modeling, and Geographic Information System (GIS)-based spatial analysis. Recent advancements have introduced machine learning algorithms, artificial intelligence, and predictive analytics to improve accident forecasting and safety assessment.

While accident studies focus primarily on analyzing crashes after they occur, Road Safety Audit (RSA) represents a proactive engineering approach aimed at preventing accidents by identifying potential safety deficiencies during the planning, design, construction, and operational stages of road projects. An RSA is a formal, systematic, and independent examination of road infrastructure conducted by qualified multidisciplinary teams to ensure that safety considerations are incorporated throughout the project lifecycle. Numerous studies have demonstrated that timely implementation of RSA recommendations significantly reduce accident risks and improves overall road safety performance.

In recent years, researchers have increasingly emphasized integrating accident analysis with Road Safety Audit procedures to develop comprehensive safety management strategies. Such integration enables authorities to combine historical accident information with proactive infrastructure evaluation, thereby supporting evidence-based decision-making and efficient allocation of resources for safety improvements.

This review paper presents a comprehensive synthesis of the available literature on accident studies and Road Safety Audit practices for urban road networks. It examines various accident causation factors, analytical methodologies, safety audit procedures, emerging technologies, and implementation challenges. The review also identifies existing research gaps and outlines future research directions for developing safer, smarter, and more sustainable urban transportation systems.

II. Objectives of the Study

The primary objective of this review paper is to critically analyze the existing literature on accident studies and Road Safety Audit practices for improving safety in urban road networks.

The specific objectives are:

- To review the current status and trends of road traffic accidents in urban transportation systems.
- To identify the major factors influencing road accidents, including roadway characteristics, traffic conditions, human behavior, environmental conditions, and vehicle-related factors.
- To critically review various accident analysis techniques such as statistical methods, black spot analysis, GIS-based analysis, safety performance indicators, and predictive modeling approaches.
- To study the principles, methodology, stages, and implementation process of Road Safety Audits for urban road projects.
- To examine the effectiveness of Road Safety Audits in reducing accident frequency and improving road infrastructure safety.
- To review recent technological advancements, including GIS, Intelligent Transportation Systems (ITS), Artificial Intelligence (AI), Machine Learning (ML), drone-based surveys, and smart traffic monitoring systems used in accident analysis and safety assessment.

- To identify research gaps and challenges in accident studies and Road Safety Audit practices reported in existing literature.
- To provide recommendations and future research directions for developing safer, sustainable, and resilient urban road networks.

III. Review of Literature

Arun S Bagietal (2001) This study had identified accident prone areas on the road from FIR, it studied the effect of roadway geometrics and traffic conditions on the road stretch and development of statistical relationship between accident rates and numerous factors causing accidents. The scope of the study was to reduce accidents on road network, reducing severity of accidents and the need for costly remedial work is reduced. The road selected for the study is Bannerghatta Road (12 km). The accident analysis was done from four years data. The V. F. Babkov's analysis is done by collecting geometric features of the road. Pedestrian safety analysis was also done. Accident prone locations are identified by the all analysis. 8 hours volume count was conducted at 2 locations of the stretch on a weekday covering both peak and off-peak hours of a day. Floating car method survey was conducted to find the speed at every kilometer of the stretch. The accident particulars pertaining to the study stretch was collected from the respective police stations. The accident data form as prescribed by IRC has been prepared to collect the necessary information such as date, time, location, whether the accident was fatal, vehicle damage and injured. The data regarding the road accidents in Bannerghatta Road have been collected for a period of four years, i.e. 2008 to 2011 from the Traffic Police Station. The date, time, approximate place, types of vehicles involved etc., are entered in the First Information Report (F.I.R) and details are recorded in case diaries.

Montella et al. (2011) In this paper, a comprehensive study was carried out to evaluate the effectiveness of Road Safety Audits (RSA) in reducing crash occurrences on urban and rural road networks. The researchers examined several completed road projects where safety audits had been conducted during the planning and design stages. The audit findings were categorized based on geometric design deficiencies, inadequate traffic control devices, roadside hazards, pedestrian facilities, and intersection design. The study concluded that early implementation of RSA recommendations significantly reduced accident risks, improved traffic operations, and proved to be a cost-effective strategy for enhancing road safety. The authors emphasized that Road Safety Audit should become an integral part of every road development project.

Cunto and Saccomanno (2013) In this study, the researchers investigated the relationship between traffic conflicts and accident occurrence at urban signalized intersections. The study employed microscopic traffic simulation and conflict analysis techniques to identify hazardous locations before accidents occurred. Vehicle trajectories, conflict frequency, and conflict severity were analyzed using surrogate safety measures. The results indicated that traffic conflict analysis provides a reliable alternative for evaluating road safety where accident data are insufficient. The study recommended incorporating surrogate safety assessment into Road Safety Audit procedures to proactively improve urban intersection safety.

Yuha Huvarinenetal (2013) The article showed that observance of automobile roads design and construction standards does not guarantee safety of traffic. It studied the experience of the leading countries in the field of the traffic safety audit integration into technological processes of roads lifecycle. It had given the key features of the traffic safety audit methods and the model of its application in terms of the Russia/Finland project for the development of a longrun special purpose program for enhancing traffic safety in the Leningrad Oblast by the experts. In the Russian practice, the cause for an accident which occurred for the combined factor "person – road environment" in an accident card is usually specified as "the driver failed to control the car". Thus, the blame for an accident is fully laid on a road user who consciously or unconsciously violated the rules or committed an error while driving. The practice shows that accidents of such kind occur also on the sections of roads built in compliance to the design, construction, and operation standards. It means that the application of standards is the reasonable and fundamental condition but not absolute for the safety of road network and its users. As the motorization level grows, the share of unprofessional drivers not protected with the industry work and rest codes and often not informed of potential road risks increases.

AASHTO (2014) This publication presented comprehensive guidelines for conducting Road Safety Audits on highways and urban road facilities. The manual described the objectives, procedures, audit stages, multidisciplinary audit teams, and reporting mechanisms required for effective safety assessment. The guidelines covered safety considerations during planning, preliminary design, detailed design, construction, pre-opening, and operational stages of road projects. The study highlighted that systematic safety audits help identify infrastructure deficiencies before they result in crashes and contribute significantly to reducing accident severity and improving overall transportation safety.

World Road Association (PIARC) (2015) In this report, the organization reviewed international Road Safety Audit practices adopted in developed and developing countries. Various audit methodologies, implementation frameworks, institutional arrangements, and performance evaluation techniques were compared across multiple nations. The study found that countries implementing mandatory Road Safety Audits experienced considerable reductions in fatal and serious injury crashes. The report recommended integrating Road Safety Audit with road safety management systems, crash databases, and engineering design standards to achieve sustainable improvements in urban road safety.

Shalini Kanuganti et al. (2016) In this paper a study was carried out to determine the priority of safety requirements of a certain category of rural roads, viz., Pradhan Mantri Gram Sadak Yojana (PMGSY) roads in the Jhunjhunu district of Rajasthan, India. Multi-criteria techniques were used to quantify the safety levels. Further analysis was done on the road having the worst safety features to rank various stretches. The parameters vital for safety have been selected and quantified using three multi-criteria decision-making analysis tools: Simple Additive Weightage (SAW), Analytical Hierarchy Process (AHP) and Fuzzy AHP methods and results are compared. The methodology successfully prioritized hazardous road sections and demonstrated the applicability of multi-criteria decision-making techniques in road safety planning.

Zarulazam Eusofe et al (2016) This paper had examined the current institutional arrangements for the management of road safety in Malaysia in a systematic manner. It focused on road safety funding and seemed to provide an insight into how funding factors may affect both the effectiveness and the efficiency or road safety management. The study followed an exploratory approach based on semi-structured interviews targeting key stakeholders in road safety management such as policy makers from various government agencies, private sector representatives and academia. The analysis revealed that the efficiency and effectiveness of the road safety management system in Malaysia may be sustainably improved by addressing the current dependence of funding solely on government sources, the fragmentation of the decision-making process of this de facto multi-disciplinary area, the road safety legislative framework, public awareness, local needs and institutional capacity. An institutional model based on 2nd generation road funds is tentative suggested to this effect. The paper presented a systematic analysis for the assessment of road safety management applicable in countries where financial resources are limited or reduced, focusing on road safety funding and seeking to provide an insight into how appropriately designed funding mechanisms may affect both the effectiveness and the efficiency of road safety management.

Francis John Gichaga (2016) This paper presented the historical and cultural background relating to road improvement and road safety characteristics in Kenya. It discussed two case studies: one on the socio-economic impact following improvements to a 50-km, high-class, high-traffic-volume road and the other on the monitoring and evaluation of road safety aspects along the Northern Corridor in Kenya also following major road improvements. The results of monitoring and evaluation exercises on the Northern Corridor have shown that drivers are the major contributors in causing accidents, with a component ratio of 49.4%; pedestrians are next at 21.7%. Data also showed that 24% of the accidents along the Northern Corridor are fatal, which is of major concern. The study additionally indicated that most road users have not been exposed to education or training on road safety. This study presented many recommendations arising from the road safety study regarding possible improvements in aspects of road safety along the corridor and potential applications of those changes to other roads in general. The study also showed that high truck composition levels contributed to a high rate of accidents and that accident black spots were influenced by factors such as the geometric characteristics of the highway, annual average daily traffic, truck composition, and other random face-tors. Observations also indicated that most road users did not have basic education or training on

road safety.

Shalini Kanugantietal (2016) In this paper a study was carried out to determine the priority of safety requirements of a certain category of rural roads, viz., Pradhan Mantri Gram Sadak Yojana (PMGSY) roads in the Jhunjhunu district of Rajasthan, India. Multi-criteria techniques were used to quantify the safety levels. Further analysis was done on the road having the worst safety features to rank various stretches. The parameters vital for safety have been selected and quantified using three multi- criteria decision-making analysis tools: Simple Additive Weightage (SAW), Analytical Hierarchy Process (AHP) and Fuzzy AHP methods and results are compared. Analysis has been done in two phases. In the first phase the prioritization of roads for safety provision was carried out considering the total length of each road as an alternative and the most critical road was identified. The parameters in the road were measured and rated (on a scale of 1-5). In the second phase, the road found critical from the first phase was considered for detail analysis. The entire stretch of the road was divided into stretches of 1 km and the stretch-wise prioritization of roads for safety provision was determined. The average values per km for the severity score of the parameters were obtained like the first phase. The methodology suggested can be used to determine the level of contribution of parameters towards safety hazard.

Xuchun S. Tu (2016) A review of the crash history has identified that the run-off-road crash is one of key crash types in Queensland, Australia. Hazards on both sides of a carriageway are identified a potential risk exposed to road users. This study says that, a proper roadside design plays an indispensable role to ensure a more forgiving road environment to reduce the likelihood and severity of run-off-road crashes. To assist road engineering practitioners in roadside design, the Queensland Department of Transport and Main Roads (TMR) developed a software application - the Roadside Impact Severity Calculator (RISC), however the applicability of RISC for developing the road safety improvement program needs to be evaluated through gaining a greater understanding of the correlation between the severity index and the crash reduction factor. The existing historical crash data indicates that run -off-road and head-on type crashes account for most of the serious crashes occurring on the roads in Queensland. Hazards on both shoulder and median sides are identified as a major risk to motorists involving run-off-road crashes. Managing road side hazards in a proper manner is key to reduce the likelihood and/or severity of run-off-road crashes. The effectiveness of a road safety treatment can be expressed as either a crash reduction factor (CRF) or a crash modification factor (CMF).

Athanasios Galanis et al. (2016) The paper presented an analysis of the relationship between pedestrian road safety, urban road type and motorists‟ traffic flow. The researchers examined six urban streets of several types in the city of Volos (a medium-sized Greek city, 130,000 inhabitants). They collected data of the pedestrian traffic flow and their legal or illegal walking behavior for each road segment of the examined streets. Furthermore, they collected data of motorists‟ traffic flow in the same road segments of the streets in the study area. The combination of those data with the administrative ranking of each road can indicate a walkability level of an examined street or a specific route and reveal pedestrians‟ mobility and safety issues.

Chen et al. (2017) In this study, Geographic Information System (GIS) techniques were integrated with spatial statistical analysis to identify accident black spots within urban road networks. Historical accident records, traffic volume, roadway geometry, and land-use characteristics were incorporated into a GIS platform for hotspot analysis. Kernel Density Estimation (KDE) and spatial autocorrelation methods were employed to determine accident-prone locations. The findings demonstrated that GIS-based visualization greatly improves accident analysis and assists transportation agencies in prioritizing safety improvement projects and resource allocation.

Elvik (2018) In this review, the author critically evaluated the effectiveness of various road safety measures implemented worldwide. The study synthesized evidence from numerous before-and-after accident studies involving traffic calming measures, speed management, roadway improvements, pedestrian facilities, and Road Safety Audits. Statistical meta-analysis was used to estimate crash reduction factors for different interventions. The review concluded that engineering improvements combined with systematic Road Safety Audits consistently produce significant reductions in both accident frequency and severity, particularly in urban environments with high traffic volumes.

Borsos et al. (2019) In this research, Road Safety Audit techniques were applied to evaluate accident-prone urban

intersections in Hungary. Detailed field inspections, accident records, traffic observations, and geometric evaluations were conducted to identify safety deficiencies affecting all categories of road users. The study revealed that inadequate pedestrian crossings, poor visibility, improper lane markings, and insufficient traffic control devices were major contributors to crashes. The authors recommended implementing corrective engineering measures identified through Road Safety Audits to improve urban traffic safety.

Yaseen et al. (2020) In this paper, machine learning techniques were employed for predicting road traffic accidents using traffic, weather, roadway, and driver-related variables. Several predictive algorithms, including Random Forest, Artificial Neural Networks, Support Vector Machines, and Decision Trees, were compared to determine the most accurate accident prediction model. The study found that ensemble learning methods significantly outperformed conventional statistical models in forecasting accident risk. The researchers suggested integrating predictive analytics into intelligent transportation systems for proactive road safety management.

Abdel-Aty and Zheng (2021) In this study, advanced data-driven approaches were used to develop proactive road safety assessment models for urban road networks. High-resolution traffic data, connected vehicle information, roadway geometry, and historical accident records were combined using machine learning and real-time monitoring techniques. The proposed framework enabled transportation agencies to identify emerging safety risks before crashes occurred. The study concluded that integrating Road Safety Audits with intelligent transportation technologies and predictive safety models can substantially enhance accident prevention strategies in rapidly growing urban areas.

Paliotto et al. (2024) In this study, a systematic review and comparative evaluation of different road network safety analysis approaches was conducted to support road safety management. The researchers examined several methodologies, including network screening, crash prediction models, Road Safety Inspection (RSI), Road Safety Audit (RSA), and risk-based assessment techniques. The study compared their applicability, data requirements, strengths, and limitations for identifying hazardous road sections. The review concluded that combining crash-based and risk-based approaches provides more reliable safety assessments than using a single method. The authors recommended integrating proactive Road Safety Audits with network safety analysis to improve decision-making and optimize investments in road safety improvements.

Goel et al. (2024) **I**n this paper, an evidence and gap map was developed to evaluate the effectiveness of road safety interventions worldwide. The study synthesized hundreds of published research articles covering engineering measures, enforcement strategies, educational programs, vehicle safety technologies, and post-crash care. The findings indicated that engineering interventions, including safer road infrastructure, traffic calming measures, and Road Safety Audits, consistently produced significant reductions in road crashes and fatalities. The authors also identified substantial research gaps in low- and middle-income countries and recommended further evidence-based studies on urban road safety interventions.

Sarkar, Rao and Chatterjee (2024) In this review, the authors systematically examined surrogate safety measures (SSMs) for evaluating road safety at unsignalized intersections in developing countries. Using the PRISMA review methodology, the study analyzed recent research on traffic conflict indicators such as Time-to-Collision (TTC), Post-Encroachment Time (PET), and Deceleration Rate to Avoid Collision (DRAC). The review found that surrogate safety measures enable proactive identification of hazardous locations even when accident data are limited. The authors emphasized the need to validate these measures under heterogeneous traffic conditions and suggested incorporating them into Road Safety Audits and intelligent transportation systems for improved urban road safety assessment.

Jena et al. (2024) In this paper, the effectiveness of Road Safety Audits in improving road infrastructure and reducing accident risks was evaluated using Indian road projects as case studies. The researchers examined various roadway deficiencies, including inadequate signage, poor geometric design, insufficient pedestrian facilities, and roadside hazards. The study demonstrated that timely implementation of Road Safety Audit recommendations significantly enhanced operational safety and minimized crash potential. The authors concluded that mandatory Road Safety Audits at all stages of highway and urban road development can substantially improve transportation safety and reduce accident severity.

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Endashaw et al. (2025) In this systematic review, the authors investigated the application of Geographic Information Systems (GIS) in road traffic accident analysis and Road Safety Audits. A total of 75 peer-reviewed studies published between 2009 and 2025 were reviewed to evaluate GIS-based techniques such as Kernel Density Estimation (KDE), Getis–Ord Gi* hotspot analysis, Empirical Bayes methods, and machine learning for accident blackspot identification. The review concluded that GIS is an effective decision-support tool for identifying accident-prone locations, analyzing spatial and temporal crash patterns, and prioritizing safety improvement measures. The authors recommended integrating GIS with real-time traffic data, artificial intelligence, and Road Safety Audit procedures to achieve more proactive and data-driven urban road safety management.

Table 1. Comparison Table

S. No.	Author(s)	Year	Methodology	Major Findings
1	Montella et al.	2011	Evaluation of Road Safety Audits (RSA) conducted during planning and design stages of road projects.	Early implementation of RSA significantly reduced crash risks, improved traffic operations, and proved to be a cost-effective safety measure.
2	Cunto and Saccomanno	2013	Traffic conflict analysis using microscopic traffic simulation and surrogate safety measures.	Traffic conflict analysis effectively identified hazardous intersections where accident data were limited and supported proactive safety assessment.
3	AASHTO	2014	Development of comprehensive Road Safety Audit guidelines covering all project stages.	Standardized RSA procedures improve roadway safety by identifying infrastructure deficiencies before accidents occur.
4	World Road Association (PIARC)	2015	Comparative review of international Road Safety Audit practices and implementation frameworks.	Countries implementing mandatory RSAs experienced significant reductions in fatal and serious injury crashes.
5	Shalini Kanuganti et al.	2016	Multi-Criteria Decision Making (SAW, AHP, and Fuzzy AHP) for prioritizing road safety requirements.	Successfully prioritized hazardous road sections and demonstrated the effectiveness of multi-criteria techniques in road safety planning.
6	Chen et al.	2017	GIS-based spatial analysis using Kernel Density Estimation (KDE) and hotspot mapping.	GIS effectively identified accident black spots and supported prioritization of safety improvement measures.
7	Elvik	2018	Meta-analysis of international road safety interventions and crash reduction studies.	Engineering improvements and Road Safety Audits consistently reduced accident frequency and severity on urban roads.

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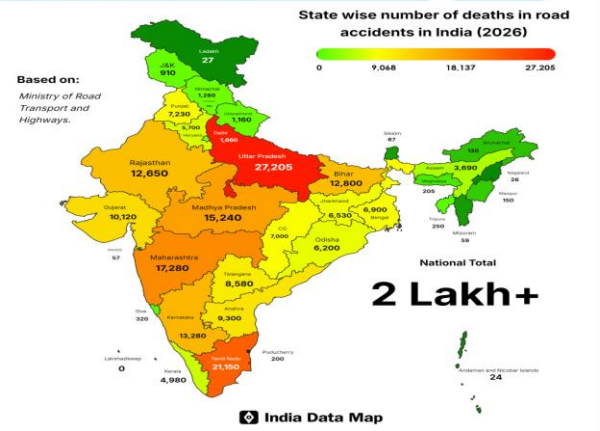
8	Yaseen et al.	2020	Machine Learning models including Random Forest, ANN, SVM, and Decision Trees for accident prediction.	Ensemble machine learning techniques outperformed conventional statistical models in predicting accident risk.
9	Abdel-Aty and Zheng	2021	Data-driven safety assessment using machine learning, connected vehicle data, and real-time traffic information.	Integration of predictive models with intelligent transportation systems enabled proactive identification of road safety risks.
10	Endashaw et al.	2025	Systematic review of GIS applications, hotspot analysis, Empirical Bayes, and machine learning for accident analysis.	GIS integrated with AI and Road Safety Audit provides an effective framework for data-driven urban road safety management and accident prevention.

IV. Road Traffic Accidents: An Overview

Road traffic accidents (RTAs) are one of the leading causes of death, serious injuries, and economic losses across the globe. According to the World Health Organization (WHO), approximately 1.19 million people die each year due to road traffic crashes, while millions more suffer non-fatal injuries that often result in long-term disabilities. The burden of road accidents is particularly severe in low- and middle-income countries, where rapid urbanization, increasing motorization, and inadequate road infrastructure have significantly increased crash risks. In India, road traffic accidents have emerged as a major public safety concern due to the continuous growth in vehicle ownership, mixed traffic conditions, insufficient enforcement of traffic regulations, and deficiencies in road infrastructure. Urban road networks experience higher accident frequencies because they accommodate heterogeneous traffic comprising cars, buses, trucks, motorcycles, bicycles, pedestrians, and non-motorized vehicles sharing the same roadway. High traffic density, frequent intersections, roadside commercial activities, illegal parking, and pedestrian movements further increase the probability of conflicts and crashes.

Road traffic accidents not only result in loss of human lives but also impose substantial economic and social costs through medical expenses, property damage, productivity loss, traffic congestion, and environmental impacts. Therefore, understanding accident characteristics, identifying accident-prone locations, and implementing appropriate engineering and management measures have become essential components of urban transportation planning.

Road traffic accidents are generally classified based on severity (fatal, grievous injury, minor injury, and property damage only), collision type (rear-end, head-on, side-impact, rollover, pedestrian collision, etc.), and location (intersection, mid-block, highway, urban street, or rural road). Such classifications assist researchers and transportation agencies in identifying accident patterns and selecting suitable safety improvement measures.



Causes of Road Traffic Accidents

Road traffic accidents occur due to the interaction of multiple factors associated with road users, vehicles, roadway conditions, and the surrounding environment. Understanding these factors is essential for developing effective accident prevention strategies and conducting comprehensive Road Safety Audits.

Human Factors

Human error contributes to the majority of road accidents worldwide. Common human-related factors include:

- Over-speeding
- Drunk driving
- Distracted driving (mobile phone use)
- Driver fatigue
- Aggressive driving
- Violation of traffic rules
- Lack of driving experience
- Improper overtaking
- Failure to wear seat belts or helmets

Studies indicate that over-speeding remains one of the most significant contributors to fatal accidents because it reduces reaction time and increases crash severity.

Roadway Factors

The physical characteristics of roads greatly influence traffic safety. Important roadway-related causes include:

- Poor geometric design
- Inadequate lane width
- Sharp curves
- Poor sight distance
- Defective intersections
- Lack of medians
- Inadequate road signs and pavement markings
- Poor pavement condition
- Insufficient street lighting

Engineering deficiencies increase driver workload and often lead to higher accident rates.

Vehicle Factors

Mechanical failures also contribute to road accidents. Major vehicle-related factors include:

- Brake failure
- Steering defects
- Tyre burst
- Lighting failure
- Poor vehicle maintenance
- Overloaded vehicles

Regular vehicle inspection and maintenance can significantly reduce such accidents.

Environmental Factors

Weather and environmental conditions directly affect driver performance and roadway visibility. Examples include:

- Rainfall
- Fog
- Dust storms
- Poor visibility
- Night-time driving
- Wet or slippery pavement

Adverse environmental conditions reduce vehicle control and increase stopping distances.

Roadside Factors

Urban roads often experience additional risks due to roadside activities. These include:

- Illegal parking
- Street vendors
- Roadside encroachments
- Utility poles
- Trees close to carriageway
- Bus stop congestion
- Pedestrian crossings without proper facilities

Such roadside obstructions reduce effective roadway width and increase vehicle-pedestrian conflicts.

Road Safety Audit (RSA)

Road Safety Audit (RSA) is a formal, systematic, independent, and multidisciplinary examination of the safety performance of existing or proposed road facilities. Unlike accident investigations, which analyze crashes after they occur, Road Safety Audits aim to identify potential safety deficiencies before accidents happen.

The primary objective of RSA is to ensure that safety considerations are incorporated throughout the planning, design, construction, and operational stages of road projects.

Objectives of RSA

The major objectives include:

- Identifying potential safety hazards.
- Reducing accident frequency and severity.
- Improving road user safety.
- Enhancing pedestrian and cyclist facilities.
- Ensuring compliance with safety standards.
- Providing cost-effective engineering recommendations.

Stages of Road Safety Audit

Road Safety Audits are generally conducted during six stages:

- Planning Stage
- Preliminary Design Stage
- Detailed Design Stage
- Construction Stage
- Pre-opening Stage
- Existing Road Safety Audit

Conducting audits at multiple stages ensures that safety deficiencies are detected before becoming costly to rectify.

Road Safety Audit Team

A typical audit team consists of:

- Highway Engineer
- Traffic Engineer
- Road Safety Expert
- Transportation Planner
- Pavement Engineer
- Police Representative (if required)

The audit team should remain independent of the project design team to ensure unbiased evaluation.

Road Safety Audit Procedure

The general procedure involves:

- Collection of project information.
- Site inspection during daytime and nighttime.
- Identification of safety deficiencies.
- Risk assessment.
- Preparation of audit report.
- Submission of recommendations.
- Implementation and follow-up.

Benefits of Road Safety Audit

Road Safety Audits offer numerous advantages, including:

- Reduction in accident risks.
- Improved roadway design quality.
- Better pedestrian and cyclist safety.
- Reduced long-term maintenance costs.
- Cost-effective infrastructure improvements.
- Increased public confidence in transportation systems.

Many studies have demonstrated that implementing Road Safety Audit recommendations significantly reduces crash frequency and severity while improving overall operational efficiency of urban road networks. Consequently, RSA has become an essential component of modern road safety management and is widely adopted in both developed and developing countries.

IV. Conclusion

Road traffic accidents continue to be one of the most significant challenges to urban transportation systems worldwide, resulting in substantial human, economic, and social losses. This review paper comprehensively examined the existing literature on accident studies and Road Safety Audit (RSA) practices for urban road networks. The review highlighted that road accidents are influenced by multiple interacting factors, including human behaviour, roadway geometry, traffic characteristics, vehicle conditions, roadside environment, and adverse weather conditions. Effective road safety management therefore requires a multidisciplinary approach that combines engineering, enforcement, education, and technological innovations.

The review revealed that traditional accident analysis methods, such as statistical analysis, black spot identification, Weighted Severity Index (WSI), and crash rate analysis, remain valuable tools for identifying accident-prone locations. However, recent advancements in Geographic Information Systems (GIS), Artificial Intelligence (AI), Machine Learning (ML), Intelligent Transportation Systems (ITS), and big data analytics have significantly improved the accuracy of accident prediction, hotspot identification, and safety assessment. These technologies enable transportation agencies to adopt proactive rather than reactive safety management strategies.

Road Safety Audit has emerged as one of the most effective preventive engineering tools for identifying potential safety deficiencies during the planning, design, construction, and operational stages of road projects. The reviewed studies consistently demonstrated that systematic implementation of RSA recommendations reduces crash frequency, minimizes accident severity, enhances pedestrian and cyclist safety, and improves overall roadway performance. Furthermore, integrating accident analysis with Road Safety Audit provides a comprehensive framework for identifying hazardous locations, prioritizing corrective measures, and ensuring safer road infrastructure.

The literature also identified several research gaps, including limited studies under heterogeneous traffic conditions, inadequate integration of GIS and AI with Road Safety Audits, lack of standardized urban safety audit procedures, and insufficient attention to vulnerable road users such as pedestrians and cyclists. Addressing these gaps will contribute to the development of more reliable and sustainable road safety management systems.

Overall, this review emphasizes that improving urban road safety requires continuous monitoring, scientific accident analysis, proactive Road Safety Audits, and adoption of emerging technologies. The findings of this review provide valuable guidance for researchers, transportation planners, highway engineers, and policymakers in developing safer, smarter, and more sustainable urban transportation networks.

V. Future Scope

The review of previous studies suggests several promising directions for future research and practical implementation:

- Development of Artificial Intelligence and Machine Learning models for real-time accident prediction and early warning systems.
- Integration of Geographic Information Systems (GIS), Global Positioning Systems (GPS), and Road Safety Audits for spatial identification and monitoring of accident black spots.
- Application of Intelligent Transportation Systems (ITS), Internet of Things (IoT), and connected vehicle technologies for continuous road safety monitoring and traffic management.
- Development of standardized Road Safety Audit procedures specifically designed for urban roads under heterogeneous traffic conditions in developing countries.
- Utilization of drone technology, remote sensing, and computer vision techniques for automated road safety inspections and traffic data collection.
- Implementation of digital twin technology to simulate traffic operations and evaluate the safety impacts of roadway design alternatives before construction.
- Greater emphasis on pedestrian, cyclist, elderly, and differently-abled road user safety through inclusive road design and dedicated safety audits.
- Integration of accident databases with real-time traffic, weather, and infrastructure information to support data-driven safety decision-making.
- Evaluation of the effectiveness of smart city initiatives, adaptive traffic signal systems, and intelligent surveillance in reducing urban road accidents.
- Investigation of the long-term effectiveness and cost-benefit analysis of Road Safety Audit recommendations using before-and-after accident studies.
- Development of predictive risk assessment models that combine traffic conflicts, crash history, roadway geometry, and driver behavior to identify potential accident-prone locations.
- Promotion of multidisciplinary research involving transportation engineering, data science, urban planning, public health, and behavioral sciences to develop sustainable and resilient urban road safety strategies.

The adoption of these advanced technologies and integrated safety management approaches will significantly contribute to achieving safer urban road networks, reducing accident rates, and supporting the vision of sustainable and intelligent transportation systems.

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