International Journal of Innovations in Research
ISSN: 3048-9369 (Online)

Permanent Rectification of Road Accident Blackspots: Engineering Investigation, Diagnosis, and Safety Improvement Measures

Shashank Chandra[1]; Chitranjan Kumar[2]; Prof (Dr). Ashutosh Singh[3]; Dr. Praveen Verma[4]; Dr. Mayank Chauhan[5]; Mr. Abhishek Rana[6]
[1]Research Scholar; Department of Civil Engineering, School of Engineering and Technology
[2]Assitant Professor; [3]Dean Engineering; [4,5,6]Assistant Professor
[1]Research Scholar; Department of Civil Engineering, School of Engineering and Technology
[2]Assitant Professor; [3]Dean Engineering
Shri Venkateshwara University, Gajraula (U.P.) India
Email id: mayank.shashank@gmail.com

DOI: https://doi.org/10.5281/zenodo.21713332

Abstract
Road accident blackspots are locations where crashes repeatedly occur due to the combined influence of roadway geometry, traffic operations, pavement condition, visibility, roadside environment, and road user behavior. The present paper develops a journal-style research framework for the permanent rectification of accident blackspots using systematic civil engineering investigation and highway safety analysis. The study integrates historical accident data, field reconnaissance, road inventory surveys, traffic volume studies, spot speed analysis, pavement condition assessment, visibility evaluation, and road safety audit procedures to diagnose recurring crash causes. Selected blackspot categories were examined through accident frequency, severity, traffic conflict patterns, geometric deficiencies, pavement defects, drainage problems, inadequate traffic control devices, and vulnerable road-user exposure. The analysis indicates that blackspot crashes are rarely caused by a single factor; rather, they arise from interacting deficiencies such as restricted sight distance, excessive operating speed, narrow carriageways, weak shoulders, poor drainage, faded markings, inadequate lighting, unsafe intersections, and roadside hazards. Permanent countermeasures are therefore proposed as a package of engineering interventions, including carriageway and shoulder widening, geometric correction, pavement strengthening, improved drainage, retro-reflective signs, thermoplastic markings, crash barriers, speed-calming measures, intersection channelization, pedestrian facilities, and post-implementation monitoring. The paper concludes that a data-driven and standards-based approach, aligned with IRC and MoRTH requirements, can substantially improve road safety, reduce accident severity, enhance traffic flow, lower vehicle operating costs, and support sustainable highway infrastructure management.
Keywords: *Road Accident Blackspot; Permanent Rectification; Road Safety Audit; Traffic Engineering; Pavement Rehabilitation; IRC codes; MoRTH specifications.*

1. Introduction

Road accident blackspots represent concentrated zones of recurring traffic crashes within a road network. These locations are critical from a highway safety perspective because they generate repeated fatalities, serious injuries, property damage, traffic congestion, and avoidable economic losses. Blackspots are generally associated with a combination of engineering, environmental, operational, and behavioral factors, including inadequate road geometry, narrow carriageways, sharp curves, insufficient sight distance, deteriorated pavement surfaces, poor drainage, unsafe intersections, inadequate signs and markings, low visibility, and uncontrolled pedestrian or roadside activity.

In India, the treatment of accident blackspots is a major priority for highway agencies because mixed traffic conditions, rapid growth in vehicle ownership, high proportions of two-wheelers, roadside development, and heterogeneous operating speeds intensify crash risk. Conventional short-term measures, such as temporary warning signs or police deployment, may reduce immediate risk but do not remove the physical causes of crashes. Long-term safety gains require permanent engineering rectification based on systematic data collection, site investigation, design evaluation, and post-implementation monitoring.

This paper presents a structured method for identifying accident-prone locations, diagnosing root causes, and selecting durable rectification measures. The work emphasizes compliance with Indian Roads Congress (IRC) guidelines and Ministry of Road Transport and Highways (MoRTH) specifications so that recommendations are technically reliable, economically feasible, and suitable for implementation by road-owning agencies [2-8].

2. Literature Review

Road safety literature consistently identifies blackspot treatment as one of the most effective engineering strategies for reducing crash frequency and severity [1, 2, 9]. A blackspot is commonly defined as a road section, curve, bridge approach, junction, or intersection that exhibits a crash record higher than comparable facilities over a defined period. Selection criteria normally consider accident frequency, severity, fatalities, grievous injuries, collision type, and exposure to traffic volume. The dissertation reviewed global and Indian road safety practices and emphasized that accident data alone must be supplemented by field investigation because crash records often do not reveal the physical deficiencies responsible for recurring accidents.

Previous studies and highway safety manuals show that remedial engineering measures can provide measurable safety benefits when they target the true causes of crashes. Common measures include widening of narrow carriageways, shoulder strengthening, correction of horizontal and vertical alignment, improvement of super-elevation, pavement resurfacing, improved skid resistance, intersection redesign, channelization, access control, lighting, delineation, crash barriers, pedestrian crossings, speed-calming devices, and drainage improvements. These interventions are most effective when implemented as coordinated packages rather than isolated treatments [4-8].

International Journal of Innovations in Research
ISSN: 3048-9369 (Online)

Indian practice is strongly guided by IRC codes and MoRTH specifications, which provide standards for road safety audits, geometric design, traffic signs, road markings, safety barriers, traffic calming, highway construction, and maintenance [3-8]. The Safe System perspective also supports forgiving roads that reduce the consequences of human error. Therefore, blackspot rectification should combine engineering, enforcement, education, emergency response, periodic maintenance, and continuous monitoring.

3. Objectives of the Study

- To identify accident-prone locations using historical accident records and severity-based screening.
- To conduct detailed field investigations covering road geometry, pavement condition, drainage, visibility, roadside hazards, signs, markings, lighting, intersections, pedestrian movement, and traffic operations.
- To evaluate traffic volume, traffic composition, spot speed, and conflict characteristics at selected blackspots.
- To diagnose the engineering and operational root causes responsible for recurring accidents.
- To propose permanent rectification measures in accordance with IRC guidelines and MoRTH specifications.
- To discuss the expected safety, economic, environmental, and operational benefits of blackspot treatment.

4. Materials and Methods

The methodology follows a sequential highway safety investigation process. The process begins with secondary accident data collection and continues through field reconnaissance, road inventory, traffic studies, speed analysis, geometric evaluation, pavement assessment, visibility analysis, road safety audit, root-cause diagnosis, and preparation of engineering recommendations. This integrated approach is important because accident occurrence is generally the result of multiple interacting conditions rather than a single isolated deficiency.

Historical accident records are obtained from the Traffic Police Department, Public Works Department, State Highway Authority, National Highways Authority of India, and other agencies responsible for highway safety management. The database includes date and time of crash, exact location, chainage, collision type, vehicle categories, number of fatalities, injuries, weather condition, road surface condition, probable cause, driver behavior, and traffic condition at the time of occurrence. Accidents are classified as fatal, major or grievous injury, minor injury, and property-damage-only events, consistent with severity-based blackspot screening practice [2].

After the preliminary identification of potential blackspots, field investigations are conducted through multiple site visits. Measurements are taken for carriageway width, shoulder width, median features, pavement condition, curve radius, gradients, super-elevation, stopping sight distance, overtaking sight distance, drainage, bus stops, utility poles, trees, lighting, signs, markings, pedestrian movement, encroachments, and intersection layout. Photographic documentation, videos, GPS location records, and sketches are prepared to support the engineering interpretation.

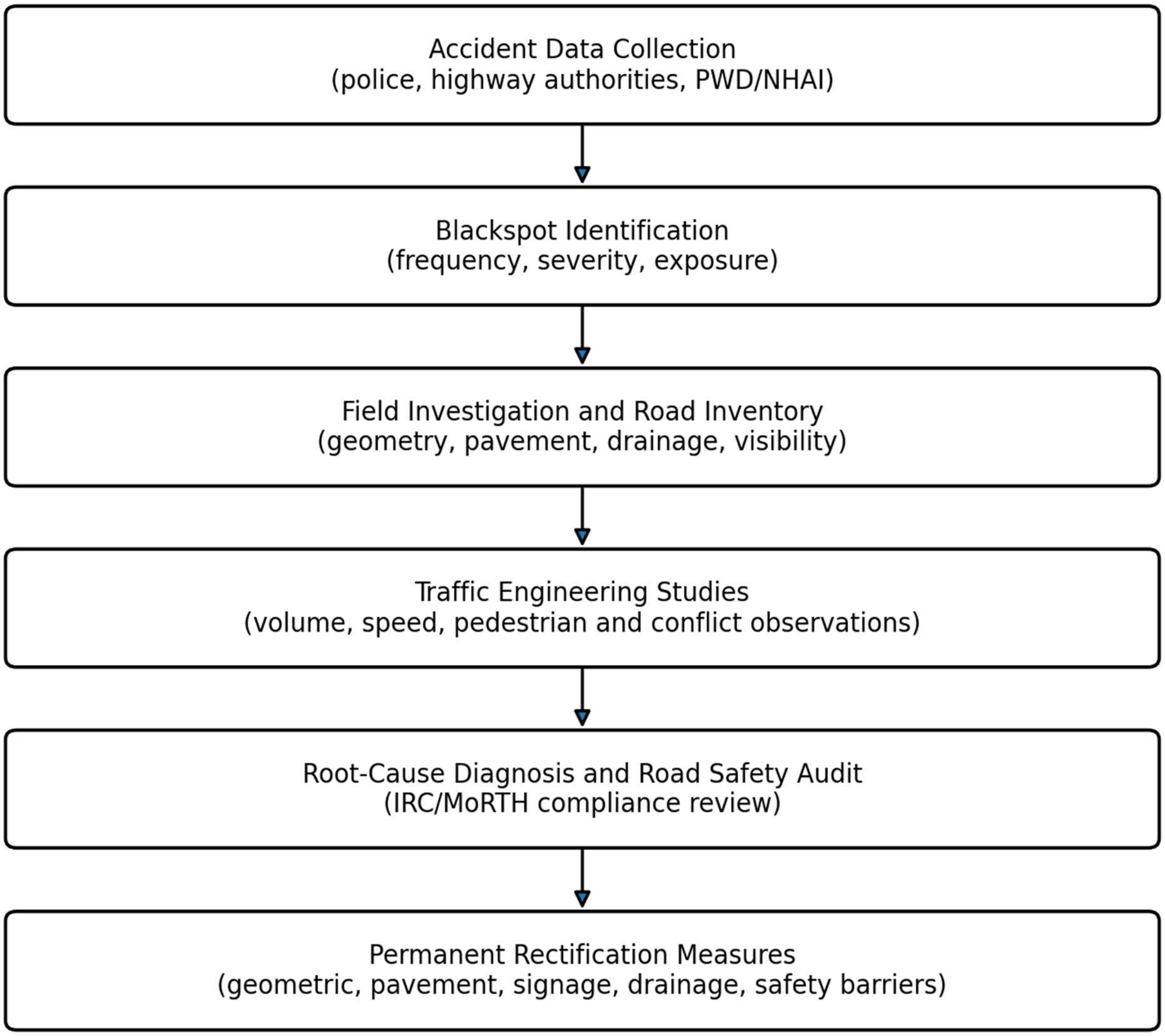

Figure 1: Methodological framework adopted for accident blackspot diagnosis and permanent rectification

Table 1: Data sources and analytical scope used in blackspot evaluation

Investigation component	Primary data collected	Purpose in analysis
Accident record review	Crash location, time, collision type, severity, casualties, weather, vehicle categories	Identification and prioritization of recurring accident locations
Road inventory survey	Carriageway, shoulder, median, alignment, signs, markings, drainage, lighting, roadside features	Detection of physical and geometric deficiencies
Traffic volume study	Classified traffic counts, peak-hour volume, vehicle composition, PCU conversion	Evaluation of demand, capacity, conflicts, and need for widening
Spot speed study	Average speed, median speed, operating speed, 85th percentile speed, speed variation	Assessment of speed-related accident risk
Pavement survey	Potholes, rutting, cracking, edge failure, bleeding, unevenness, skid condition	Selection of resurfacing, strengthening, or reconstruction measures
Visibility and RSA review	Sight distance, obstruction, nighttime visibility, pedestrian and cyclist safety, roadside hazards	Systematic identification of hazards affecting all road users

Traffic volume counts are carried out during morning peak, evening peak, and off-peak periods. Vehicles are classified into two-wheelers, passenger cars, auto-rickshaws, light commercial vehicles, buses, heavy trucks, multi-axle vehicles, tractors, bicycles, and non-motorized traffic. These data are converted into passenger car units where required to evaluate capacity utilization and operational adequacy.

Spot speed studies are conducted under free-flow traffic conditions to estimate operating speed and speed variability. The 85th percentile speed is used as an important safety indicator because locations with excessive speed or abrupt speed changes are more likely to experience severe crashes. Geometric characteristics are compared with IRC recommendations for lane width, shoulders, sight distance, transition curves, super-elevation, gradients, and intersection layout.

A road safety audit is used as a structured check of hazards from the viewpoint of motorists, motorcyclists, cyclists, pedestrians, elderly persons, school children, public transport users, and persons with disabilities. The audit covers junctions, bridges, culverts, bus bays, pedestrian crossings, guardrails, crash barriers, drainage, lighting, markings, median openings, and maintenance condition.

5. Blackspot Analysis

The study identified accident-prone locations by examining accident frequency, severity, collision patterns, and site-specific engineering conditions. Locations with multiple fatal or serious crashes, high operating speeds, deficient geometry, heavy traffic demand, poor visibility, pedestrian activity, and roadside hazards were prioritized for detailed evaluation. The analysis confirmed that the selected locations exhibited recurring safety problems rather than isolated accidents.

The available site summary includes three representative blackspot locations: NH-31 Junction, Sharp Curve Area, and Urban Intersection. The Urban Intersection recorded the highest annual accident frequency, followed by NH-31 Junction and Sharp Curve Area. The dominant causal conditions include traffic conflict, poor visibility, and over-speeding, which correspond to common blackspot mechanisms observed in mixed-traffic highway and urban environments.

Table 2: Summary of accident blackspots considered in the study

Location	Accidents per year	Dominant cause	Severity level	Indicative engineering concern
NH-31 Junction	25	Poor visibility	High	Sight obstruction, insufficient delineation, junction guidance deficiencies
Sharp Curve Area	18	Over-speeding	Medium	Curve geometry, super-elevation, speed transition, warning signs
Urban Intersection	30	Traffic conflict	High	Turning conflicts, pedestrian exposure, channelization and signal control

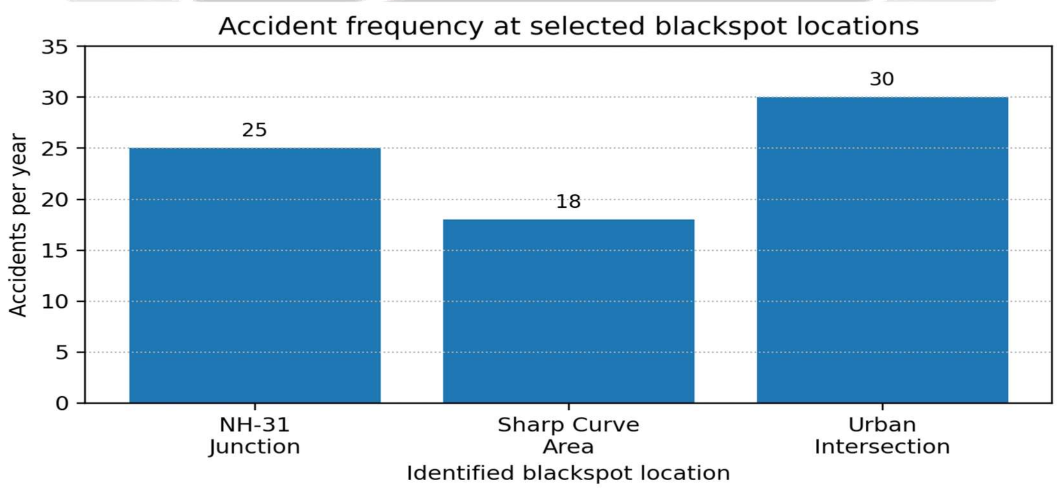

Figure 2: Accident frequency at selected blackspot locations based on the dissertation data

Root-cause identification shows that each blackspot is influenced by a combination of deficiencies. The common engineering factors include narrow carriageways, inadequate shoulders, poor pavement condition, excessive operating speeds, deficient drainage, inadequate traffic signs, faded road markings, restricted visibility, unsafe intersections, roadside hazards, lack of street lighting, and high pedestrian activity. Driver error can aggravate these deficiencies, but the design objective of permanent rectification is to create a safer and more forgiving roadway environment.

6. Proposed Permanent Rectification Measures

Permanent blackspot rectification must directly address the deficiencies identified during accident analysis and field investigation. The proposed measures are not limited to isolated sign installation; instead, they include geometric, operational, pavement, drainage, roadside, and vulnerable road-user improvements. The combination of treatments is selected according to site conditions and expected safety benefit.

Road widening is recommended where the existing carriageway is inadequate for current and projected traffic demand. Additional lane width and shoulder width reduce side-swipe conflicts, improve overtaking safety, provide recovery space, and support emergency stopping. Shoulder strengthening is particularly important at high-speed locations and on road sections with heavy commercial vehicle movement.

Geometric correction is required at locations with sharp horizontal curves, inadequate transition curves, poor super-elevation, steep gradients, and insufficient sight distance. Improvements may include increasing curve radius, correcting super-elevation, improving vertical profile, clearing sight obstructions, and redesigning median openings or junction approaches. Intersection channelization, dedicated turning lanes, roundabouts, or traffic signals may be warranted where turning conflicts are high.

Pavement rehabilitation is recommended where potholes, rutting, cracking, edge failures, polished aggregates, and surface undulations contribute to unsafe vehicle movement. Bituminous overlay, crack sealing, pothole repair, shoulder reconstruction, and high-friction surface treatment can improve skid resistance, reduce braking distance, and enhance riding quality.

Traffic control measures include retro-reflective signs, chevron boards, object markers, hazard markers, direction signs, thermoplastic markings, lane lines, edge lines, stop lines, zebra crossings, raised pavement markers, road studs, and delineators. These measures improve driver guidance, lane discipline, nighttime visibility, and advance recognition of hazards. Locations with high operating speeds require transverse rumble strips, speed tables, optical speed bars, gateway treatments, speed warning signs, and enforcement support.

Drainage improvements are essential because water stagnation reduces pavement friction and accelerates pavement deterioration. Side drains, cross-drainage structures, culverts, catch pits, shoulder slopes, and pavement cross slopes should be improved to ensure rapid removal of runoff. Roadside safety measures such as crash barriers, guardrails, parapet walls, median barriers, impact attenuators, and protective fencing are required near embankments, culverts, bridges, rigid roadside objects, and deep drains.

Pedestrian and cyclist safety measures are necessary at urban and semi-urban blackspots. Continuous footpaths, zebra crossings, refuge islands, pedestrian guardrails, bus bays, lighting, and warning signs reduce conflicts between vulnerable road users and motorized traffic. Locations near schools, markets, hospitals, and bus stops require special attention because pedestrian exposure is high.

Table 3: Deficiency-measure-effectiveness matrix for permanent blackspot rectification

Observed deficiency	Recommended measure	Expected safety effect
Poor visibility at junctions and curves	Vegetation clearance, relocation of obstructions, reflective signs, delineators, lighting	Improved hazard perception and reduced angle/rear-end collisions
Excessive operating speed	Rumble strips, speed tables, speed-warning signs, optical bars, enforcement support	Reduced approach speed and lower crash severity
Narrow carriageway and weak shoulders	Carriageway widening, paved shoulder strengthening, edge line marking	Reduced side-swipe risk and improved recovery area
Unsafe intersection layout	Channelization, turning lanes, signalization or roundabout where warranted	Reduced conflict points and improved traffic discipline
Poor pavement condition	Overlay, pothole repair, crack sealing, skid-resistant surfacing	Improved vehicle stability and braking performance
Roadside hazards	Crash barriers, guardrails, clear-zone treatment, impact attenuators	Reduced severity of run-off-road crashes
Waterlogging and drainage failure	Side drains, cross drains, culverts, pavement and shoulder slope correction	Reduced skidding, hydroplaning, and pavement deterioration
High pedestrian activity	Footpaths, zebra crossings, refuge islands, pedestrian guardrails, bus bays, lighting	Reduced pedestrian conflicts and vulnerable road-user casualties

7. Results and Discussion

The results indicate that blackspot rectification should be treated as a diagnostic engineering process rather than a routine maintenance exercise. The three sample locations demonstrate different dominant crash mechanisms: the NH-31 Junction is associated with visibility-related risk, the Sharp Curve Area is associated with speed-related risk, and the Urban Intersection is associated with turning and crossing conflicts. This variation confirms that uniform treatments are inadequate; site-specific packages are required.

The expected benefits of geometric improvements include reduction in head-on crashes, side-impact crashes, run-off-road crashes, and sudden braking events. Wider carriageways and stronger shoulders improve maneuverability, while curve correction and improved super-elevation reduce lateral instability. Better intersections reduce conflicting movements and improve decision-making for drivers and pedestrians.

Pavement and drainage treatments improve safety by restoring surface friction and maintaining roadway stability during rainfall. Proper drainage prevents waterlogging, reduces pothole formation, and extends pavement service life. Signage, marking, delineation, lighting, and road studs improve visibility and driver guidance, especially at night and in adverse weather. Crash barriers and roadside safety devices do not necessarily prevent every crash, but they reduce crash severity by controlling vehicle trajectory and shielding fixed hazards.

The economic benefits are substantial because accident costs include emergency medical treatment, vehicle damage, police and legal processes, insurance claims, travel delay, freight disruption, lost productivity, and infrastructure repairs. Reducing accident frequency and severity produces long-term savings that can exceed the initial cost of engineering improvements. Improved traffic flow also reduces fuel consumption, vehicle wear, and travel time unreliability.

Environmental benefits arise from smoother traffic flow and reduced accident-related congestion. Lower idling and fewer stop-and-go movements reduce fuel use, carbon dioxide emissions, nitrogen oxides, hydrocarbons, particulate matter, and traffic noise. Efficient drainage also protects pavement foundations and reduces erosion. Therefore, permanent blackspot rectification contributes not only to road safety but also to sustainable infrastructure management.

The study also confirms that engineering measures must be supported by enforcement, education, emergency response, maintenance, and periodic audits. Speed enforcement, helmet and seat-belt compliance, control of overloaded vehicles, driver awareness, and intelligent transportation technologies can reinforce infrastructure improvements. Post-implementation monitoring is necessary to verify whether crash patterns reduce and whether new safety issues emerge.

8. Conclusions

- Accident blackspots are multi-causal safety problems that require systematic investigation of accident records, traffic operations, roadway geometry, pavement condition, visibility, drainage, roadside hazards, and vulnerable road-user exposure.

- The selected locations demonstrate distinct crash mechanisms, including poor visibility at NH-31 Junction, over-speeding at the Sharp Curve Area, and high traffic conflict at the Urban Intersection.
- Permanent rectification should be designed as an integrated package of geometric correction, carriageway and shoulder improvement, pavement rehabilitation, drainage improvement, traffic control enhancement, roadside safety protection, speed management, and pedestrian facilities.
- Standards-based design using IRC guidelines and MoRTH specifications improves technical reliability, construction quality, maintainability, and long-term safety performance.
- The proposed interventions are expected to reduce accident frequency and severity, improve traffic flow, reduce travel delays, lower vehicle operating costs, decrease fuel consumption and emissions, and promote safer and more sustainable highway infrastructure.
- Future work should include before-and-after crash analysis, benefit-cost evaluation, GIS-based blackspot mapping, quantitative speed and conflict modeling, and periodic road safety audits after implementation.

9. Limitations and Future Scope

The research uses the available blackspot summary data. Detailed chainage-specific crash records, turning movement counts, sight-distance measurements, speed samples, and cost estimates were not fully tabulated. Future research should collect larger multi-year accident datasets, carry out GIS-based mapping, quantify severity indices, and conduct before-and-after evaluation after the implementation of recommended treatments.

A further extension may include road-user behavior surveys, video-based conflict analysis, pavement skid-resistance testing, illumination measurement, and safety performance functions. Such additions would strengthen the statistical basis of blackspot prioritization and enable more precise estimation of crash reduction factors and economic returns.

Acknowledgement

The author acknowledges the Department of Civil Engineering, School of Engineering and Technology, Shri Venkateshwara University, for academic support during the dissertation work from which this paper has been prepared.

References

[1] World Health Organization. Global Status Report on Road Safety 2023. Geneva: WHO.
[2] Ministry of Road Transport and Highways. Guidelines for the Identification and Rectification of Road Accident Black Spots. Government of India, New Delhi.
[3] Ministry of Road Transport and Highways. Specifications for Road and Bridge Works. Government of India, New Delhi.
[4] Indian Roads Congress. IRC:SP:88, Manual on Road Safety Audit. New Delhi: IRC.
[5] Indian Roads Congress. IRC:67, Code of Practice for Road Signs. New Delhi: IRC.
[6] Indian Roads Congress. IRC:35, Code of Practice for Road Markings. New Delhi: IRC.

[7] Indian Roads Congress. IRC:99, Guidelines for Traffic Calming Measures in Urban and Rural Areas. New Delhi: IRC.
[8] Indian Roads Congress. IRC:119, Guidelines for Traffic Safety Barriers. New Delhi: IRC.
[9] AASHTO. Highway Safety Manual. Washington, DC: American Association of State Highway and Transportation Officials.
[10] PIARC. Road Safety Manual: Recommendations from the World Road Association. Paris: World Road Association.