Planning Strategies for Accident Black Spots

A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree

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by

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under the supervision of

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ABSTRACT

Road traffic accidents continue to pose a significant public health, economic, and urban mobility challenge worldwide. In India, accident black spots—locations exhibiting a high concentration of crashes and safety risks—contribute substantially to fatalities and serious injuries. Despite the existence of national guidelines such as the Ministry of Road Transport and Highways (MoRTH) protocols and IRC:131-2022, the integration of road safety considerations into urban planning processes remains limited, particularly in rapidly growing Tier-II cities. This study addresses this gap by developing planning strategies for the assessment and mitigation of accident black spots through a spatial, risk-based, and planning-oriented approach.

The research was conducted in two phases. Phase I involved a comprehensive review of national and international literature, policy documents, road safety guidelines, and black spot management practices. The review examined conventional and emerging approaches to black spot identification, including crash-frequency methods, severity-based approaches, GIS applications, road safety audits, and risk-based assessment techniques. The analysis highlighted significant gaps in the integration of road safety management within statutory planning frameworks and urban mobility planning processes.

Phase II focused on Bhopal, Madhya Pradesh, as a representative Tier-II city. The study utilized officially identified accident black spots obtained from concerned government authorities under a live project framework. GIS-based spatial analysis was undertaken to map and examine the distribution of black spots across the urban road network. Detailed field investigations and road safety audits were conducted to assess geometric deficiencies, traffic movement characteristics, pedestrian exposure, visibility conditions, roadside environment, and operational conflicts at each location.

A risk-based prioritization framework was developed to evaluate black spots using parameters such as traffic exposure, pedestrian activity, geometric deficiencies, speed-related risks, and strategic importance within the city road network. Based on the assessment, identified locations were classified into priority categories and analysed to determine their dominant safety concerns. The findings indicate that high-speed vehicular movement, inadequate pedestrian infrastructure, geometric deficiencies, visibility constraints, and operational conflicts are the major contributors to unsafe conditions at accident-prone locations in Bhopal.

Based on the diagnostic assessment, location-specific planning and engineering interventions were proposed for priority black spots. The study further developed an integrated framework for accident black spot management incorporating identification, prioritization, road safety audits, intervention planning, implementation, and monitoring. The proposed framework emphasizes the integration of road safety considerations into urban planning instruments such as Comprehensive Mobility Plans, road safety action plans, and city-level transportation planning processes.

The study demonstrates that accident black spot management should extend beyond traditional engineering approaches and be incorporated into broader urban planning and mobility strategies. The findings provide practical guidance for local authorities and planning agencies and offer a replicable framework for improving road safety in Bhopal and other Tier-II cities facing similar urban mobility and road safety challenge

सारांश

सड़क दुर्घटनाएँ दुनिया भर में सार्वजनिक स्वास्थ्य, अर्थव्यवस्था और शहरी आवाजाही के लिए एक बड़ी चुनौती बनी हुई हैं। भारत में, 'एक्सीडेंट ब्लैक स्पॉट'—यानी ऐसी जगहें जहाँ बहुत ज़्यादा दुर्घटनाएँ होती हैं और सुरक्षा का जोखिम होता है—मौतों और गंभीर चोटों का एक बड़ा कारण हैं। सड़क परिवहन और राजमार्ग मंत्रालय (MoRTH) के प्रोटोकॉल और IRC:131-2022 जैसे राष्ट्रीय दिशानिर्देश होने के बावजूद, शहरी योजना बनाने की प्रक्रियाओं में सड़क सुरक्षा को शामिल करने का काम सीमित है, खासकर तेज़ी से बढ़ रहे टियर-II शहरों में। यह अध्ययन एक स्थानिक (spatial), जोखिम-आधारित और योजना-केंद्रित दृष्टिकोण अपनाकर दुर्घटना वाले ब्लैक स्पॉट का आकलन करने और उन्हें कम करने के लिए योजना रणनीतियाँ विकसित करके इस कमी को दूर करता है।

यह शोध दो चरणों में किया गया। पहले चरण में राष्ट्रीय और अंतर्राष्ट्रीय साहित्य, नीतिगत दस्तावेजों, सड़क सुरक्षा दिशानिर्देशों और ब्लैक स्पॉट प्रबंधन के तरीकों की व्यापक समीक्षा की गई। समीक्षा में ब्लैक स्पॉट की पहचान करने के पारंपरिक और नए तरीकों की जाँच की गई, जिनमें दुर्घटना की आवृत्ति (crash-frequency) के तरीके, गंभीरता-आधारित तरीके, GIS एप्लिकेशन, सड़क सुरक्षा ऑडिट और जोखिम-आधारित मूल्यांकन तकनीकें शामिल थीं। विश्लेषण से पता चला कि कानूनी योजना ढाँचों और शहरी आवाजाही की योजना बनाने की प्रक्रियाओं में सड़क सुरक्षा प्रबंधन को शामिल करने में काफी कमियाँ हैं।

दूसरा चरण मध्य प्रदेश के भोपाल शहर पर केंद्रित था, जिसे एक प्रतिनिधि टियर-II शहर के रूप में चुना गया था। अध्ययन में एक लाइव प्रोजेक्ट के तहत संबंधित सरकारी अधिकारियों से प्राप्त आधिकारिक तौर पर पहचाने गए दुर्घटना वाले ब्लैक स्पॉट का इस्तेमाल किया गया। शहरी सड़क नेटवर्क में ब्लैक स्पॉट के वितरण को मैप करने और उनकी जाँच करने के लिए GIS-आधारित स्थानिक विश्लेषण किया गया। हर जगह पर ज्यामितीय कमियों, ट्रैफ़िक की आवाजाही की विशेषताओं, पैदल चलने वालों के जोखिम, दृश्यता की स्थिति, सड़क के किनारे के माहौल और संचालन संबंधी समस्याओं का आकलन करने के लिए विस्तृत फील्ड जाँच और सड़क सुरक्षा ऑडिट किए गए।

ब्लैक स्पॉट का मूल्यांकन करने के लिए जोखिम-आधारित प्राथमिकता ढाँचा विकसित किया गया, जिसमें ट्रैफ़िक का जोखिम, पैदल चलने वालों की गतिविधि, ज्यामितीय कमियाँ, गति से जुड़े जोखिम और शहर के सड़क नेटवर्क में रणनीतिक महत्व जैसे मापदंडों का इस्तेमाल किया गया। मूल्यांकन के आधार पर, पहचानी गई जगहों को प्राथमिकता श्रेणियों में बांटा गया और उनकी मुख्य सुरक्षा चिंताओं का पता लगाने के लिए उनका विश्लेषण किया गया। नतीजों से पता चलता है कि भोपाल में दुर्घटना-प्रवण जगहों पर

असुरक्षित स्थितियों के मुख्य कारण तेज़ गति से वाहनों की आवाजाही, पैदल चलने वालों के लिए अपर्याप्त बुनियादी ढाँचा, ज्यामितीय कमियाँ, दृश्यता की समस्याएँ और संचालन संबंधी समस्याएँ हैं।

निदानात्मक मूल्यांकन के आधार पर, प्राथमिकता वाले ब्लैक स्पॉट के लिए जगह-विशेष योजना और इंजीनियरिंग उपायों का प्रस्ताव दिया गया। इस स्टडी में एक्सीडेंट ब्लैक स्पॉट मैनेजमेंट के लिए एक इंटीग्रेटेड फ्रेमवर्क तैयार किया गया है, जिसमें पहचान, प्राथमिकता तय करना, रोड सेफ्टी ऑडिट, इंटरवेंशन प्लानिंग, लागू करना और मॉनिटरिंग शामिल हैं। प्रस्तावित फ्रेमवर्क शहरी प्लानिंग के तरीकों—जैसे कॉम्प्रिहेंसिव मोबिलिटी प्लान, रोड सेफ्टी एक्शन प्लान और शहर-स्तर की ट्रांसपोर्टेशन प्लानिंग प्रोसेस—में रोड सेफ्टी से जुड़ी बातों को शामिल करने पर ज़ोर देता है।

स्टडी से पता चलता है कि एक्सीडेंट ब्लैक स्पॉट मैनेजमेंट को पारंपरिक इंजीनियरिंग तरीकों से आगे बढ़कर व्यापक शहरी प्लानिंग और मोबिलिटी रणनीतियों में शामिल किया जाना चाहिए। इसके नतीजे स्थानीय अधिकारियों और प्लानिंग एजेंसियों के लिए व्यावहारिक मार्गदर्शन देते हैं और भोपाल तथा इसी तरह की शहरी मोबिलिटी और रोड सेफ्टी चुनौतियों का सामना कर रहे अन्य टियर-II शहरों में रोड सेफ्टी को बेहतर बनाने के लिए एक ऐसा फ्रेमवर्क पेश करते हैं जिसे दूसरी जगहों पर भी अपनाया जा सकता है।

CONTENTS

CANDIDATE'S DECLARATION iii

CERTIFICATE OF PLAGIARISM iv

ACKNOWLEDGEMENT v

ABSTRACT vi

सारांश viii

LIST OF ABBREVIATIONS xv

LIST OF FIGURES xvii

LIST OF TABLES xviii

CHAPTER 1 19

INTRODUCTION 19

1. 1 Conceptual Basis for Planning Interventions at Black Spots 19

1. 2 Hierarchy of Black Spot Definitions 22

1. 3 Key factors used in the definition and identification include: 25

1. 4 Causes of Accident Black Spots 25

1.4.1 Defective Geometric Design 26

1.4.2 Poor Road Infrastructure and Maintenance 27

1.4.3 Environmental and Contextual Factors 28

1.4.4 Behavioural and Operational Factors 28

Chapter 2 30

Literature Review 30

2. 1 Discussion 32

Inferences from Global and National Case Studies 35

2. 2 Gap Findings 36

2. 3 Need of study 38

Chapter 3 41

Research Design 41
3. 1 Aim 41
3. 2 Objectives 41
3. 3 Methodology 42
3. 4 Correlation between Phase 1 and Phase 2 objectives 43
3. 5 Scope 44
3. 6 Limitation 45
Chapter 4 47
Data and Data Analysis (Primary Data and Site Selection) 47
4. 1 Selection of the Study Area: Bhopal as a Tier-II Urban Model 47
4. 2 Data Considerations. 47
4. 3 Identification of Accident Black Spots 49
4.3.1 Road Network Characteristics of Bhopal 49
4.3.2 Identification of Black Spots 50
4.3.3 Zonal Analysis of Traffic Hotspots 50
Traffic Zone 1 52
Traffic Zone 2 52
Traffic Zone 3 53
Traffic Zone 4 53
List of Priority Black Spots 54
4. 4 Analysis of Primary Data 57
4. 5 Risk-Based Prioritization of Identified Accident Black Spots 59
4.5.1. Need for Prioritization 59
4.5.2. Prioritization Framework 59
4.5.3 Risk-Based Prioritization of Accident Black Spots 60
4.5.4 Priority Categories 61

4.5.5 Key Findings 62
Chapter 5 63
Road Safety Audit and Diagnostic Assessment of Identified Accident Black Spots 63
5. 1 Road Safety Audit Framework 63
5.1.1 Geometric Assessment 63
5.1.2 Traffic Assessment 64
5.1.3 Pedestrian Safety Assessment 64
5.1.4 Traffic Control and Visibility Assessment 64
5.1.5 Environmental Assessment 65
5. 2 Issue-Based Classification of Identified Accident Black Spots 65
Category A: High-Speed Conflict Zones 65
5. 3 Pedestrian Conflict Zones 66
5. 4 Geometric Deficiency Zones 66
5. 5 Congestion and Mixed-Traffic Conflict Zones 66
Chapter 6 68
Inferences 68
6. 1 Inference Chapter Summary 68
6. 2 Implications for Planning Practice 69
6. 3 How the Findings Apply to Tier-II Cities 70
6. 4 Integrated Framework for Accident Black Spot Management in Tier-II Cities 71
Institutional and Stakeholder Analysis 72
Chapter 7 73
Proposed Planning Strategies For Identified Accident Black Spots 73
7. 1 Proposal for Banganga Junction 74
Proposed Interventions 75

Expected Outcomes 75
7. 2 Proposal for Ashima Mall Corridor 75
Proposed Interventions 76
Expected Outcomes 77
7. 3 Proposal for Govindpura Turning 77
Proposed Interventions 78
Expected Outcomes 78
7. 4 Proposal for Bawadiya Kalan Bridge Corridor 78
Proposed Interventions 79
Expected Outcomes 79
7. 5 Proposal for Platinum Plaza Square 80
Existing Issues 80
Proposed Interventions 80
Expected Outcomes 80
7. 6 Proposal for Bawadiya Kalan Bridge Corridor 81
Existing Issues 81
Proposed Interventions 81
Expected Outcomes 81
7. 7 Comparative Assessment of Existing and Proposed Conditions 82
7. 8 Implementation Framework 83
7. 9 Conclusion 84
Chapter 8 85
Conclusion and Recommendations 85
8.1 Summary of the Study 85
8.2 Major Findings of the Study 86
8.3 Planning Implications 86

8.4 Recommendations 87
Engineering Recommendations 87
Planning Recommendations 87
Institutional Recommendations 88
8.5 Contribution of the Study 88
8.6 Scope for Future Research 88
8.7 Final Conclusion 89
References 90
Annexure 92

LIST OF ABBREVIATIONS

Abbreviation	Full Form
AADT	Annual Average Daily Traffic
AHP	Analytic Hierarchy Process
ARI	Accident Risk Index
AU/NZ	Australia / New Zealand
AU	Australia
BCR	Benefit–Cost Ratio
BN	Bayesian Network
BP	Back Propagation (Neural Network)
CCTV	Closed-Circuit Television
CF	Crash Frequency
CFM	Crash Frequency Method
CMP	Comprehensive Mobility Plan
CR	Crash Rate
DTA	Dynamic Traffic Assignment
DP	Development Plan
EB	Empirical Bayes
ELM	Extreme Learning Machine
EPDO	Equivalent Property Damage Only
FIR	First Information Report
FHWA	Federal Highway Administration (USA)
FIS	Fuzzy Inference System
GIS	Geographic Information System
Gi*	Getis-Ord Gi* Hotspot Statistic
GMM	Gaussian Mixture Modelling
GoI	Government of India
IRC	Indian Roads Congress
KDE	Kernel Density Estimation
LISA	Local Indicators of Spatial Association
LMICs	Low- and Middle-Income Countries
MCDM	Multi-Criteria Decision Making
ML	Machine Learning
MLA	Machine Learning Algorithm
MoHUA	Ministry of Housing and Urban Affairs
MoRTH	Ministry of Road Transport and Highways
MP	Madhya Pradesh
MPRDC	Madhya Pradesh Road Development Corporation
NCRB	National Crime Records Bureau
NBSP	National Black Spot Program (Australia)
NMT	Non-Motorised Transport
NHTSA	National Highway Traffic Safety Administration
NSM	Network Safety Management
NUTP	National Urban Transport Policy

Abbreviation	Full Form
OSD	Overtaking Sight Distance
PDO	Property Damage Only (Accidents)
PU Learning	Positive–Unlabeled Learning
PWD	Public Works Department
ROR	Run-Off-the-Road (Crash Type)
RTI	Road Traffic Injury
RTYB	Road Transport Year Book
SAFEPED	Safety Pedestrian Simulation Model
SD	Standard Deviation
SDG	Sustainable Development Goals
SH	State Highway
SVM	Support Vector Machine
SPF	Safety Performance Function
SSD	Stopping Sight Distance
UAT	Urban Arterial Traffic
UCL	Upper Control Limit
UN	United Nations
VRU	Vulnerable Road User
VOSviewer	Visualization of Similarities Viewer (Bibliometric Tool)
WSI	Weighted Severity Index

LIST OF FIGURES

Figure 1Issues wise classification of accident Black Spots (Author) 51

Figure 2: spatial distribution of accident black spots in Bhopal city (Author) 56

Figure 3: the influence zones of the identified black spots through spatial buffering techniques(Author) 58

Figure 4: Integrated Framework for Accident Black Spot Management 71

Figure 5: existing plan of Banganga Junction 74

Figure 6: Existing Plan of Ashima Mall Junction 76

Figure 7: Existing Plan of Govind Pura Turning 77

Figure 8: existing plan of Bawadiya Kalan Bridge Corridor 79

LIST OF TABLES

Table 1: Comparing Parameters Across Levels 24
Table 2: Zonal Analysis of Traffic Hotspots 50
Table 3: Traffic Zone 1 Location Of ABS 52
Table 4: Traffic Zone 2(ABS) 52
Table 5: Traffic Zone 3(ABS) 53
Table 6: Traffic Zone 4 53
Table 7: List of Priority Black Spots 54
Table 8: Prioritization framework for Accident Black spot 59
Table 9: Risk-Based Prioritization of Accident Black Spots 60
Table 10: Institutional and Stakeholder Analysis 72
Table 11: Comparative Assessment of Existing and Proposed Conditions 83
Table 12: Implimentation Framework 84

CHAPTER 1

INTRODUCTION

Globally, injuries caused by motor vehicles rank among the most serious issues in Public Health and Economic Development, and have been identified by several major global organizations as being a systemic issue that requires partnerships between multiple disciplines and sectors to solve collectively. Motor vehicle accidents kill approximately 1.3 million people globally every year (World Health Organization, 2021). Most of the victims come from less developed nations that have experienced rapid motorisation trends without the corresponding improvements in road safety mechanisms to support that rapid growth(Dereli & Erdogan, 2017a), Accidents are the result of poor road safety management and all motor vehicle accidents can be avoided through the application of planned evidence based interventions to create a better infrastructure for safe driving and hold agencies accountable for implementing and maintaining those safety improvements. The changing attitudes and ways of thinking globally regarding the issue of road traffic safety are becoming an integral aspect within a larger sustainability agenda that includes the UN Sustainable Development Goals specifically Goal 3 (Good Health and Well-Being). The Goal is to reduce fatalities related to road traffic incidents by 50% by 2030.

1. 1 Conceptual Basis for Planning Interventions at Black Spots

The phenomenon of accident black spots; locations or roadway segments exhibiting a statistically significant higher concentration of road traffic accidents compared to other areas (in a global setting) now represent a fundamental operational tool to assist in reducing fatalities and serious injuries due to accidents. The ability to analyse accident black spots enables decision makers and engineers to focus their funding to improve safety at the few high-risk locations where relatively little financial outlay can provide significant improvements in safety. Countries such as Australia, Sweden, the United Kingdom, and the United States have made accident black spot treatment part of their national road safety programs (with established protocols for identification, diagnosis, engineering intervention, and post intervention evaluation) for many years (WHO, 2021).

Based on the experiences of these countries, reviewing accident black spots represents a highly cost-effective intervention to improve road safety, particularly in countries where resources and institutional capacity are limited.

In recent years, the Ministry of Road Transport and Highways (MoRTH) has recognised the importance of including the identification of black spots in national road safety management systems in India. MoRTH has established a definition of a black spot as the location of a 500-metre segment of a National Highway where: *"five or more crashes involving fatalities or grievous injuries occur within a three-year period*, or *ten or more fatalities occur within the same period"* (Ministry of Road Transport and Highways, 2015).

As supported by this definition of national black spot rectification programme, the key elements of this programme will include the identification of black spots, the proper engineering diagnosis of the type of treatment, the approval of treatment plan(s), the implementation of approved treatment plan(s), and the evaluation of the effectiveness of treatment action(s) after completion of all work. The principles in the IRC:131-2022 document also provide guidance for practitioners in the area of identifying black spots, and contains checklists and recommended countermeasures for various types of crash patterns, as established by the IRC.(*IRC Code 131-2022*, n.d.)

Urban road safety is receiving policy attention as well as highway safety. The Ministry of Housing and Urban Affairs (MoHUA) has developed a National Urban Transport Policy (NUTP) to promote safety, equity, and sustainability in terms of urban mobility, as well as to encourage cities to integrate road safety into their strategic planning documents, such as Comprehensive Mobility Plans (CMP), Master Plans, Area Development Plans and Street Design Guidelines (Ministry of Housing and Urban Affairs [MoHUA], 2014). Although all of these documents highlight safety concerns associated with road use, they do not typically provide specific instructions for identifying or treating black spots. Rather, they are largely focused on promoting broad mobility goals, including enhanced availability and use of public transport systems, enhancing and creating opportunities for non-motorized transport (NMT), and reducing and managing people's demand for vehicular traffic. Therefore, to effectively manage black spots in

urban areas, it is important to develop specific and detailed procedures that will provide for the consistent screening and treatment of identified black spots.

At the subnational level, states have started to develop or change national systems that are suitable for local infrastructure and administration. For example, the state of Madhya Pradesh established road safety action plans at the state level that clearly identify both high-risk areas and the need to apply focused engineering solutions (Madhya Pradesh Government - Transport Department, 2020). District LEVEL black spot assessment guidelines have been created by the Madhya Pradesh Road Development Corporation for instance, where they refer specifically to rural roads and state highways (Madhya Pradesh Road Development Corporation, 2021). The guidelines invite coordination between many departments including the police, health services, Public Works Department (PWD), and the district planning office. Although much has been done to improve road safety, how districts carry out best practices varies dramatically because of inconsistent data quality, different levels of capability within various institutions, and very little ability to integrate black spot procedures into regional city and/or district development plans.

One of the major differences in terms of how statutory planning is defined to be implemented via documents such as Master Plans, Development Plans, Zonal Plans, etc., is that the chapters and/or step processes for managing black spots are not generally included within these documents. Although these documents do contain statements that identify things such as "safe mobility", "decreasing conflict associated with vehicle movement" or "improving the design of intersections", or "creating a city that accommodates non-motorised transport" (NMT), the planning documents generally do not provide or contain a systematic method for:

i. thresholds for identifying black spots,
ii. workflows for cross-departmental coordination,
iii. funding allocations for site treatments, or
iv. monitoring frameworks for crash reduction.

The lack of this planning information from the planning documents creates a large disconnect between the planning and transportation engineering communities resulting in a large gap between policy and practice; i.e., long-term mobility vision does not lead to the implementation of immediate interventions to reduce the risk of the occurrence of a

crash at a site. Black spots continue to be identified predominantly via department guidelines and approaches to the identification of black spots (i.e., Manual of Roads and Transport Highways (MoRTH), Indian Roads Congress (IRC)) and not by citywide planning processes.

In addition, the emergence of GIS, machine learning, and data analytics has added new methods of examining the location of crashes, allowing for greater sophistication in analyzing patterns of crashes that occur within specific regions. However, due to the limited resources available for implementing these technological advances, as well as the fragmented nature of the national and state-level planning documents that have yet to adopt them, the gap between what technology can do and how it is used in practice continues to grow. As such, there is a need to undertake a thorough review of existing research and create an evidence-based recommendation for planners to identify black spots using these technologies in a manner suitable to the Indian and Madhya Pradesh contexts.

1. 2 Hierarchy of Black Spot Definitions

Accidents black spots have different interpretations on an international, national and state level with a distinct hierarchy of these definitions determined by institutional capacity to gather and manage data, data available to analyse and the policy direction of each country. At the worldwide level, the World Health Organisation (WHO) has developed a conceptual definition for accident black spots as areas or short lengths of roads where there is an unusual number of fatal or serious-injury accidents (compared to other similar situations). WHO does not set specific threshold levels but encourages the identification of systemic risks and evidence-based solutions. On the contrary, there are more specific operational definitions available in some developed countries, where, for example, the Aust roads (Australia-New Zealand) definition for accident black spots includes any road section with three or more casualty accidents within the past five years or for road sections that have a crash rate which is significantly greater than that of comparable roads and for a road section of normally less than one km in length. The Department of Transport in the United Kingdom has defined "sites of concern" as places that have had four or more personal injury accidents within a 100-meter radius over the last three years, with a strong focus on identifying the same pattern of accidents and type of accidents that occur at these

locations. The United States Federal Highway Administration (FHWA) takes a model-based approach, identifying high-risk sites as those with statistically higher predicted crash frequencies relative to expected values generated through Safety Performance Functions (SPFs) and Empirical Bayes (EB) adjustments rather than fixed numerical thresholds.

The Government of India adopts one of the most clearly defined, quantitative National Black Spot definitions based on these international best-practice examples. Specifically, the MoRTH uses two specific definitions for the term Black Spot, which is defined as a segment of roadway comprising 500 meters along which there have been five (5) or more fatal or grievous injured crashes in the past three years or ten (10) or more total fatalities within three (3) years (Ministry of Road Transport and Highways, 2015). These definitions serve as the foundation of the National Black Spot Rectification Programme. The new IRC:131-2022 document also provides additional methods of analysis that could aid in the identification of Black Spots, such as Weighted Severity Index (WSI), Kernel Density Estimates (KDE), empirical-Bayes forecasting methods, and SPF-based modelling while retaining the original MoRTH definitions for Black Spots (Indian Roads Congress, 2022). The existing National Urban Planning Framework, including the National Urban Transport Policy (NUTP) as well as City Master Plans, Development Plans, Zoning Plans, and Comprehensive Mobility Plans, provide general principles of traffic safety but generally do not provide specific definitions or thresholds for Black Spots, thus creating a disconnect between higher-level Urban Planning and Engineering, to the aid of Road Safety (Ministry of Housing and Urban Affairs, 2014).

In accordance with the MoRTH definition, states use the same definition of the MoRTH. However, states apply the MoRTH definition to their own transportation network of state highways, district roads, and rural road transportation networks, thereby broadening the application of the MoRTH definition to these four (4) state transport types(Madhya Pradesh Transport Department, 2020). Madhya Pradesh also enhances the MoRTH definition with a localized approach to creating operational guidelines through the organization of testing procedures for identifying risk-taking behaviours and the development of Mapping Geographic Information Systems (MapGIS) in order to assist with identifying hazardous the hazardous areas of both the urban and rural networks

across the state (Madhya Pradesh Road Development Corporation, 2021). While Madhya Pradesh recognizes a state's compliance with the national crash count criteria, it also acknowledges the limitations of solely using crash counts to assess crash patterns in jurisdictions with low numbers of reported crashes. Therefore, the organization relies on a pattern-based analysis, similar in theory to the UK practice. Overall, the hierarchy presented in this comparison illustrates how International organizations establish the initial framework and overall structure for determining how crashes should be categorized. Additionally, developed nations provide mixed models of both frequency and model-based categories of fatal crashes, India, through the creation of its National Definition of a Fatal Crash, formalizes the most severe numerical definition in the world and Madhya Pradesh develops operationalizing procedures in order to ensure the defined requirements are implemented in the operationalization of local road networks. Furthermore, the lack of any official definition or framework defining a black spot zone in the statute of any of the current Urban Development Board (UDB) documents of India is a significant institutional deficiency and indicates necessitates improvements in the coordination of transportation engineering practices, GIS-based analyses, and Urban Planning framework developments.

Table 1 shows the comparison between the global definitions and parameters of Accident black Spot.

Table 1: Comparing Parameters Across Levels

Level	Stretch Length	Time Period	Crash/Fatal Criteria	Method Basis	Notes
WHO (Global)	Not specified	Not specified	Conceptual – high concentration	Conceptual Risk	Emphasis on systemic causes, no numeric rule
Aust roads (AU/NZ)	≤1 km	5 yrs.	≥3 casualty crashes OR high-risk score	Frequency + Risk Score	Allows EB, SPFs
UK (DfT)	~100 m	3 yrs.	≥4 PIAs	Frequency + Pattern	Emphasis on collision-type patterns
USA (FHWA)	Flexible	Flexible	Statistically higher than SPF	EB + Model-Based	No fixed threshold

Level	Stretch Length	Time Period	Crash/Fatal Criteria	Method Basis	Notes
MoRTH (India)	500 m	3 yrs.	≥5 fatal/grievous crashes OR ≥10 fatalities	Frequency–Severity	One of the most explicit definitions globally
IRC:131 (India)	Same as MoRTH	Same as MoRTH	Same thresholds	Adds KDE, EB, WSI tools	Strong engineering focus
MP (State)	500 m (NH/SH/DR)	3 yrs.	Follows MoRTH	Frequency + Field Audit	Applied to more road classes

(*IRC Code 131-2022*, n.d.)

1. 3 Key factors used in the definition and identification include:

- **Accident Frequency**: The total number of accidents over a specific time frame (e.g., three or five years). A common definition, such as one used by India's Ministry of Road Transport and Highways (MoRTH), identifies a black spot as a 500-meter stretch of highway with five or more road accidents or 10 fatalities in the last three years.(*IRC Code 131-2022*, n.d.)
- **Accident Severity**: This considers the seriousness of the accidents. Fatalities and grievous injuries are often given greater weight than minor injuries or property damage-only collisions. A "severity index" is often calculated to quantify the hazardousness of a location.
- **Accident Rate:** This method relates the number of accidents to the traffic
- **volume at that location:** It helps to account for the fact that busier roads will naturally have more accidents, but it's the rate of accidents that indicates a problem with the road itself.

1. 4 Causes of Accident Black Spots

Accident black spots generally emerge due to the combined influence of road design deficiencies**,** maintenance failures**,** environmental constraints**,** vehicular factors, and road user behaviour**.** According to the Indian Roads Congress (IRC) and MoRTH's Black Spot Identification Guidelines (2019)**,** most black spots are attributed to systemic engineering

shortcomings that compromise visibility, speed consistency, and decision-making by road users. These causes can be expanded as follows:

1.4.1 Defective Geometric Design

The majority of accident black spots can be attributed to defective Geometric Design. Faulty geometry adversely impacts the driver's ability to see hazards, estimate distance and control their vehicle.

- **Sharp curves or corners which hide oncoming traffic -** The poor design of horizontal curves (those with radii less than those recommended by the IRC) "hide" (obscure) the oncoming vehicles from the driver's view. Because of the sharpness of the curve (sharper than that which would be necessary at the design speed), the driver will have to "brake" suddenly to be able to make it around the curve. In doing so, the likelihood of head-on collisions, run-off-road crashes, and skidding increases.
- **Junctions that are hidden or concealed when the traffic is moving at higher speeds -** Junctions that are placed too close to curves, slopes or roadside vegetation create blind spots for the drivers. As per (IRC SP 088: Manual on Road Safety Audit, n.d.) Junctions on rural highways must have adequate approach sight distance and should not be placed at the immediate end of a curve or summit. As hidden junctions reduce the amount of time a driver has to react, they increase the frequency of side-impact crashes.
- **Insufficient sight distances -** As per IRC:73, one of the key requirements is that Stopping Sight Distance (SSD) and Overtaking Sight Distance (OSD) be maintained throughout the length of the roadway. Insufficient SSD can occur as a result of growth of vegetation, encroachment from objects, steep slopes and sharp curves, and will result in rear-end and overtaking crashes.
- **Inadequate or variable amount of super-**elevation (slope of the road) leads to sliding off of the road when travelling at high rates of speed. IRC:38 provides the maximum and minimum requirements of super-elevation to be applied; however, many roads become improperly constructed or deteriorated with time causing water to remain stagnant, a decrease in friction, and an increase in the tendency of heavy trucks to overturn when using these improperly constructed roads.

- **Poor horizontal and vertical alignment integration:-**The horizontal alignment of a highway may not be in harmony with the vertical alignment of the highway. As a result, crash prone locations are formed where vertical curves (grades and hill tops) do not match with horizontal curves. This sharp contrast between a steep hill and an abrupt horizontal curve contributes to severe off-road crashes due to the high speeds involved and lack of visibility.

1.4.2 Poor Road Infrastructure and Maintenance

Maintenance and infrastructure deficiencies significantly increase the risk of accidents by reducing road user awareness and compromising safe vehicle operation.

i. **Absence or lack of proper road markings and signs**- specifically referring to made under IRC Code 131-2022 (*IRC Code 131-2022*, n.d.) amounts to a public safety issue; according to IRC, retro-reflective sign(s), warning signs and road lane marking(s) are all mandatory safety items. Many black spots have faded or missing road lane markings and missing, incorrectly placed or overly close to the hazard signage. All of which will lead to a loss of driver anticipation—causing lane discipline problems, unsafe overtaking and late braking.

ii. **Absence of proper warning signs for dangerous areas**- as per IRC guidelines, high risk factors include sharp curves, merging traffic, pedestrian activity, and village approach points. Without adequate advance warning signs, particularly at nighttime, drivers have no ability to get ready and prepare for said hazards causing a high incidence of accidents at these conflict areas.

iii. **Poor road surface conditions-** both the distress of a road surface, e.g. (potholes), raveling, rutting, settling of a road surface; as noted in various crash investigation studies of vehicle skidding/loss of control conducted by MoRTH, contribute significantly to the increased number of wet weather accidents as slippery road surfaces (e.g. polished concrete, worn asphalt or mossy surface) inhibit friction thereby, causing increased accidents during wet weather.

iv. **Inadequate lighting, particularly for rural and peri-urban roads** - According to the Ministry of Road Transport and Highways' (MoRTH) Guidelines for Road Safety Audits issued in 2014, a night-time crash percentage of greater than 40% indicates that a road is under-lit. Poorly lit roads present increased difficulty for pedestrians to see or be seen, they will also obscure some roadway features (geometry, etc.) and are likely to result in increased numbers of animal-vehicle collisions on rural highways.

v. **Lack of pedestrian routing facilities -** There are high volume pedestrian locations that lack the proper allocation of infrastructure - i.e., marked crossings, footpaths, guards and elevated median strips. The IRC code (131-2022) states that all high volume pedestrian locations should have a marked crossing, but, due to lack of available funds, many rural and semi-rural areas are unable to install this type of infrastructure resulting in dangerous pedestrian traffic.

1.4.3 Environmental and Contextual Factors

Although not purely engineering-related, the surrounding environment often amplifies risk:

i. Roadside encroachment blocking sight lines
ii. Sharp transitions between urban and rural traffic conditions
iii. Rain-induced low visibility and hydroplaning
iv. Animals straying onto highways
v. Poor drainage leading to waterlogging and pavement failure
vi. MoRTH's "Black Spot Correction Guidelines" emphasize that environmental factors must be addressed through drainage improvements, roadside clearance, and speed-calming measures in built-up areas.

1.4.4 Behavioural and Operational Factors

According to National Crime Records Bureau (NCRB) data and MoRTH crash analyses:

i. Overspeeding on mismatched road geometry
ii. Dangerous overtaking due to inadequate sight distance

iii. Driver fatigue on monotonous highway stretches
iv. Overloaded or poorly maintained vehicles
v. Lack of enforcement at high-risk locations
vi. When these behaviours combine with poor design or maintenance, black spots intensify.

CHAPTER 2

LITERATURE REVIEW

The scientific approach to identifying accident black spots has evolved significantly over the past century, transitioning from simple reactive crash counts to sophisticated spatial-statistical and machine-learning models.[1] In the early phases of highway safety management, during the mid-twentieth century, transport departments relied almost exclusively on raw crash frequency to identify hazardous locations.[1] While simple to calculate, this approach fails to account for traffic exposure or random fluctuations in crash occurrences, often misidentifying low-risk, high-volume sites as black spots while neglecting high-risk, low-volume locations.[1]

To address these limitations, researchers introduced exposure-based metrics, such as the crash rate method, which normalizes crash counts against Annual Average Daily Traffic volumes.[1] However, even exposure-normalized models can suffer from regression-to-the-mean bias, where random spikes in crash data are mistaken for systemic safety failures.[1] This led to the development of the Empirical Bayes method and Safety Performance Functions, which predict expected crash frequencies by combining historical data with regional baseline rates.[1] More recently, the field has integrated GIS-based spatial tools, such as Kernel Density Estimation and spatial autocorrelation, allowing planners to analyze crash patterns as continuous spatial risk surfaces rather than isolated points.

After implementing remedial measures, the site is monitored for 1–3 years to evaluate effectiveness. Analysts compare before-and-after crash data, conduct follow-up audits, and observe new traffic behaviour. If crashes continue, additional measures are proposed. This step ensures accountability and continuous safety improvement.

The Table 4 below shows a comparative analysis of all the methods for black spot analysis.

Table 4: comparative analysis of all the methods for black spot analysis.

Method	Purpose	Data Required	Tools/Techniques Used	Strengths	Limitations
1. Accident Data Collection & Compilation	To gather accurate crash information for analysis	FIRs, iRAD, hospital data, GPS coordinates	Police records, transport dept., iRAD portals	Foundation for all analysis; multi-source verification increases reliability	Under-reporting is common; requires coordination with multiple agencies
2. Frequency Method	To identify spots with repeated accidents	Crash counts for 3+ years	Simple tabulation, charts	Easy, quick, widely used on highways	Does not consider severity; may miss low-frequency high fatality spots
3. Severity Index Method	To prioritize locations based on crash severity	Weighted crash data (fatal, serious, minor)	Severity scoring (3-2-1 system)	Balances both frequency & severity; more scientific	Requires accurate injury data; weighting may vary
4. Accident Rate Method	To normalize crash occurrence by traffic volume	Crash counts + AADT + road length	Formula-based rate calculation	Suitable for corridors with varying traffic loads	Needs reliable traffic volume; complex for rural roads
5. GIS & Spatial Mapping Method	To identify spatial crash clusters visually	Geo-coded crash locations	GIS tools: ArcGIS, QGIS, KDE	Very effective for large networks; clear mapping of clusters	Requires GIS skills; depends on accurate coordinates
6. Road Safety Audit (RSA)	To identify engineering safety defects	Field observations, geometry, signs, drainage	RSA checklists, speed studies, photos	Detects design flaws missed in data; engineering-focused	Requires trained auditors; time-consuming
7. Site Investigation & Field Surveys	To confirm causes of crashes on-ground	Pavement condition, sight distance, behaviour	GPS survey, speed gun, visual survey	Identifies real-time factors (encroachments, lighting)	Weather-dependent; subjective if not structured

Method	Purpose	Data Required	Tools/Techniques Used	Strengths	Limitations
8. Traffic Conflict Technique (TCT)	To identify near-misses as early warning signs	Video footage, observational conflicts	Video analytics, CCTV, manual coding	Proactive; does not wait for fatal crashes	Labor-intensive; requires trained observers
9. Crash Pattern Analysis	To detect recurring crash characteristics	Crash type, time, user type	Charts, cross-tabulation	Reveals hidden patterns (night crashes, pedestrian crashes)	Cannot detect root cause alone
10. Contributory Factor Analysis	To identify root cause of accidents	Engineering, behavioural, environmental data	Root cause matrix, checklists	Holistic; covers human, road, vehicle factors	Complex for multi-factor crashes
11. Prioritization & Ranking	To determine which spots, need intervention first	Severity score, rate, cost-benefit	Multi-criteria ranking	Helps allocate budgets efficiently	Requires strong justification and data
12. Engineering Remedial Measures Selection	To treat the black spot by introducing solutions	Causes identified + road design data	Immediate, medium, long-term countermeasures	Ensures targeted solutions; engineering-first approach	Requires funding & land acquisition
13. Post-Implementation Monitoring	To verify improvement effectiveness	Post-treatment crash data	Before-after analysis, audits	Ensures accountability; helps refine solutions	Long-term process; needs continuous monitoring

(Author)

2. 1 Discussion

Black spot identification has progressed from simple frequency-based counting to sophisticated statistical modelling, machine learning, surrogate-safety assessment, spatial statistics, and integrated audit systems. The collective body of literature reviewed demonstrates a multi-disciplinary evolution involving transportation engineering, GIScience, artificial intelligence, simulation modelling, and behavioural analytics. These approaches aim to address persistent gaps in traditional accident analysis such as under-

reporting, exposure variation, spatial clustering biases, and the inability to capture near-miss events.

Early foundational work emphasized statistical robustness and the importance of correcting for data irregularities. Classical approaches such as Poisson and Negative Binomial models remain widely referenced because they capture over-dispersion and structural variability in crash counts. For example, the study *A New Model for Determining the Traffic Accident Black Spots Using GIS-Aided Spatial Statistical Methods* (Dereli & Erdogan, 2017b) highlights how Empirical Bayes (EB) estimation provides more reliable rankings than raw crash frequencies, especially in corridors with heterogeneous traffic and geometric characteristics(Dereli & Erdogan, 2017b). Similarly, the report *Black Spot Analysis Methods Review* provides a comprehensive taxonomy of methods—from sliding-window screening to statistical modelling—and underscores the need for appropriate exposure control and multi-year data (Geurts & Wets, 2003).

A major limitation of fixed-length segmentation approaches is their tendency to artificially break continuous high-risk regions into separate units. Addressing this, the spacing-distribution method proposed in *Identifying Accident Black Spots Based on the Accident Spacing Distribution* introduces a theoretically grounded alternative by modelling inter-accident spacing as a negative-exponential distribution under Poisson assumptions (Cui et al., 2022). Unlike segmentation-based techniques, this continuous method detects hotspots through runs of abnormally short spacings, revealing contiguous dangerous stretches that conventional methods often obscure. This is particularly valuable for state and national highways where chainage data are available.

Beyond classical statistics, researchers have explored probabilistic reasoning models capable of capturing causal pathways. The study *Black Spots Identification Through a Bayesian Networks Quantification of Accident Risk Index* integrates Dynamic Traffic Assignment (DTA) with Bayesian Networks to calculate a scenario-adaptive Accident Risk Index (ARI) (Gregoriades & Mouskos, 2013). By merging simulated exposure with historical crash data, this model allows risk estimation across different time periods, traffic states, or demand scenarios—an advantage that static statistical models cannot provide. Such probabilistic frameworks also support sensitivity analysis, enabling

practitioners to assess the influence of driver behaviour, weather, or temporal demand shifts.

As data availability improved, machine learning gained prominence. The study *Research on Black Spot Identification of Safety in Urban Traffic Accidents Based on Machine Learning Method* demonstrates how Support Vector Machines (SVM) and Deep Neural Networks (DNNs) outperform traditional clustering-based methods by learning nonlinear patterns from multi-source datasets (e.g., road geometry, environment, traffic composition) (Fan et al., 2019). While these models provide strong predictive accuracy, interpretability remains a concern—especially in policy contexts where authorities require causal clarity to justify interventions. Complementing these advances, *Positive-Unlabeled Learning for Enhanced Black Spot Accident Identification* introduces a learning-from-scarce-labels approach, showing that positive–unlabeled pipelines are more effective when only partial crash labels exist.

An important parallel development involves deploying **surrogate safety measures** to supplement crash-based identification. The paper *A New Road Safety Indicator Based on Vehicle Trajectory Analysis* shows how trajectory-derived conflict indicators enable risk assessment even when crash data are sparse (Subirats et al., 2016). These indicators capture near-miss situations—events that traditional crash databases completely miss—yielding faster, proactive insights. Surrogate-based approaches are increasingly relevant in urban contexts where high-resolution video or LiDAR-based traffic sensing systems are now feasible.

Behavioural and text-analytic methods also emerged as powerful complements. The study *Behavioural Insights and Hotspot Identification Using NLP and ML* demonstrates how Natural Language Processing can classify cyclist crash narratives into meaningful behavioural themes and link them to spatial hotspots using Gi* analysis (Malaghan et al., 2025). This form of behavioural hotspot detection provides a richer understanding of underlying conflict mechanisms—for example, close-passing events, hazardous tram-rail interactions, or vehicle–cyclist turning conflicts—thereby enabling targeted interventions beyond geometric redesign.

Several studies in the literature also address operational and practitioner-centric gaps. *Developing a Road Safety Review Tool to Identify Design Standard and Safety Deficits*

presents ESReT, a cloud-integrated, video-based system for real-time field audits (Weekley et al., 2016). While not a black-spot identification method, such tools bridge the gap between analytical detection and on-ground engineering responses. By systematically comparing observed conditions with design standards, audit frameworks like ESReT enhance the consistency and accountability of field inspections.

Meta-analytical works further contextualize the state of the field. *Meta-Analysis of the Methodologies Practiced Worldwide for Identification of Road Accident Black Spots* synthesizes global approaches and identifies persistent problems such as under-reporting, lack of exposure data, and inconsistent definitions of "black spot" across jurisdictions (Aziz & Ram, 2022). Meanwhile, *A Comparative Analysis of Black Spot Identification Methods and Accident Segmentation Methods* shows segmentation choice critically affects outcomes and recommends pairing EB-based models with carefully selected segmentation rules (Ghadi & Török, 2019).

Local case studies—including *Identification and Analysis of Black Spots on Islampur–Ashta Highway*, *Black Spots on NH-4*, and the *Bhopal Black Spot Case Study*—provide practical evidence on the applicability of simpler tools like KDE, severity index, and manual field surveys in Indian contexts (Jadhav et al., n.d.). Despite methodological limitations (lack of exposure control, descriptive reliance), these studies remain valuable in regions with limited data availability.

Finally, national datasets such as *Road Accidents in India 2023* and the *Road Transport Year Book* serve as essential contextual references, offering macro-level accident trends, vehicle growth trajectories, and road network evolution (*Road Accidents in India, 2023; RTYB, 2020*). These inform the background rates against which local black spot findings are benchmarked.

Inferences from Global and National Case Studies

Evaluating established road safety programs offers valuable operational lessons for emerging Tier-II cities.[1] Australia's National Black Spot Program serves as a global model for data-driven, cost-effective interventions.[1] The program uses a strict eligibility threshold of three casualty crashes within a five-year window, prioritizing projects based on Benefit-Cost Ratios calculated from projected crash-cost savings.[1] The program emphasizes low-cost, high-impact engineering

treatments, such as roundabouts, which have been shown to reduce intersection casualty crashes by up to 75%.[1]

In the Indian context, regional case studies highlight the distinct safety challenges that arise as cities grow.[1] The Amravati Case Study demonstrates how rapid commercial development and unregulated parking can turn major urban squares into high-frequency crash hotspots.[1] Key intersections like Rajkamal Square and Rajapeth Square, handling peak-hour volumes of over 33,000 vehicles, became dangerous due to poor lane discipline, commercial encroachments, and the absence of pedestrian refuge facilities.[1] This highlights the need for pedestrian-focused design in urban black spot mitigation, including raised crosswalks and channelized traffic flows.[1]

Similarly, the Kolhapur Case Study on the Sangli-Kolhapur Highway highlights how alignment errors and maintenance deficits can elevate crash risk in peri-urban areas.[1] The research identified seven critical black spots, such as the Hatkanangale Bus Stand and the Sangli Fata, where a lack of street lighting, unpaved shoulders, and unchannelized median openings contributed to a high concentration of severe nighttime accidents.[1] These national and global case studies demonstrate that black spot formation is rarely accidental, but is almost always caused by predictable and diagnosable structural issues

2. 2 Gap Findings

A review of the literature and legal guidelines reveals several persistent research gaps in the field of accident black-spot identification and planning.

i. Indian studies continue to rely heavily on police FIR-based crash datasets that suffer from under-reporting, missing geo-coordinates, and inconsistent severity classification. This limitation is openly acknowledged in case study papers such as *Identification and Analysis of Black Spots on Islampur–Ashta State Highway, Maharashtra, India* (Jadhav et al., n.d.) and *Identification of Accident Black Spots on National Highway 4* (Sorate et al., n.d.), both of which highlight incomplete or inaccurate crash data as a major barrier to precise hotspot detection. Broader methodological reviews such as *Black Spot Analysis Methods Review* (Geurts & Wets, n.d.) and *A Meta-Analysis of the Methodologies Practiced Worldwide for the Identification of Road Accident Black Spots* (Aziz & Ram, 2022) similarly emphasise the lack of standardized, high-quality crash databases in low- and middle-income countries.

ii. a significant methodological gap exists in segmentation practices. Comparative studies such as *Comparison of Different Black Spot Identification Methods* (Ghadi & Török, 2017) and advanced modelling papers like *Identifying Accident Black Spots Based on the Accident Spacing Distribution* (Cui et al., 2022) demonstrate that hotspot outputs vary substantially depending on whether fixed-length segments, sliding windows, clustering approaches, or continuous spacing models are used. Yet neither national nor state guidelines provide a rule-based framework for selecting segmentation according to road hierarchy, data availability, or analytical objective.

iii. Although international best practice identifies empirical-Bayes and SPF-based models as the most statistically reliable—demonstrated effectively in *A New Model for Determining the Traffic Accident Black Spots Using GIS-Aided Spatial Statistical Methods* (Dereli & Erdogan, 2017b) their uptake in India remains limited. This gap is largely due to scarce AADT data and the absence of region-specific SPFs for state and district roads, including those within Madhya Pradesh. The lack of standardised exposure data severely restricts the implementation of these advanced statistical approaches that are widely used in the United States and other developed contexts.

iv. modern data-driven techniques such as machine learning and PU-learning are rarely operationalised in Indian black-spot programmes. Papers such as *Research on Black Spot Identification of Safety in Urban Traffic Accidents Based on Machine Learning Method* (Fan et al., 2019) and (Sevetlidis et al., 2024) demonstrate the potential of ML-based approaches to detect nonlinear crash patterns and address label scarcity. However, these methods have not transitioned into government workflows due to data limitations, lack of standardised digital infrastructure, and minimal institutional technical capacity.

v. proactive and surrogate safety methods—such as trajectory- and conflict-based indicators described in *A New Road Safety Indicator Based on Vehicle Trajectory Analysis* (Subirats et al., 2016) remain underused in Indian settings. These methods allow for short-term assessment of safety and near-miss analysis where crash data are sparse or delayed, yet they are seldom adopted in national or state

black-spot programmes that continue to rely exclusively on historical crash records.

vi. behaviourally informed approaches are underrepresented in Indian research. Techniques demonstrated in *Behavioural Insights and Hotspot Identification Using NLP and ML* (Malaghan et al., 2025) reveal that analysing narrative accident descriptions can uncover behavioural triggers such as speeding, inattentiveness, or pedestrian conflicts. However, very few Indian studies integrate behavioural or narrative-based analysis into spatial hotspot identification, resulting in interventions that treat surface-level symptoms rather than deeper human factors.

vii. there is a pronounced institutional gap between statutory planning instruments and operational road-safety protocols. Master Plans, Development Plans, Comprehensive Mobility Plans, and Zonal Plans reference road safety in broad terms but do not define accident black spots or outline procedures for identification and remediation. Instead, operational detail appears only in technical guidelines such as the *MoRTH Protocol for Identification and Rectification of Black Spots* (MoRTH Black Spot Protocol) and *IRC:131-2022* (*IRC Code 131-2022*, n.d.). Even state-level documents like the *Madhya Pradesh Road Safety Action Plan* (MP Road Safety Action Plan) mention hotspot identification but fail to embed data standards, segmentation methodologies, or evaluation frameworks.

Collectively, these gaps highlight the need for integrated data systems, locally calibrated statistical tools, clear methodological decision rules, behavioural and proactive safety analytics, and stronger institutional alignment between urban planning documents and engineering-based black-spot workflows.

2. 3 Need of study

India is currently facing a severe and growing road safety crisis, an epidemic of public health that has led to over 172,890 fatalities in 2023 alone. Although National Highways comprise about two percent of the total road network, they account for over 36 percent of all road accident fatalities. Further examination makes it clear that this risk is hyper-concentrated at specific, identifiable locations, which are frequently referred to as

"accident black spots," brief segments of roadway characterized by a recurring history of fatal or grievously injury crashes. The Ministry of Road Transport and Highways (MoRTH) has identified and confirmed over 13,700 of these locations and adds that these types of fatalities and mostly injuries are more often due to flaws in road design engineering and less often due to driver error.

A nationwide Black Spot Rectification Program is in existence to address these locations, however there is a critical implementation gap. Progress to permanent, engineering-based options is lagging that of interim, short-term options. This report argues that a focused, accelerated, and engineering led approach to safely and permanently decommissioning these black spots is the best course of action and is the most urgent way to reduce road fatalities. Decommissioning these concentrated points of risk is also important for public safety, as an economic rationale to help mitigate the severe costs associated with this ongoing national crisis.

India faces one of the highest burdens of road traffic fatalities in the world, making systematic and evidence-based road safety interventions an urgent national priority. With over 168,000 deaths reported annually and millions more injured, road crashes in India account for a significant socio-economic loss, estimated at 3–5% of the national GDP. The *Road Accidents in India 2023* report indicates that fatal accidents continue to rise, despite multiple policy frameworks at national and state levels, underscoring that existing approaches have not yielded the desired reductions in crash severity or frequency. This alarming trend highlights an inherent structural problem in how safety issues are identified, prioritised, and addressed across Indian cities and highways. Among these issues, accident black spots—locations with abnormally high concentrations of fatal and grievous crashes—represent a disproportionately large share of national road fatalities. Addressing these hazardous locations through improved identification, analysis, and treatment has therefore become a core requirement for enhancing road safety performance across India.

Furthermore, while India has made strides through initiatives such as the *MoRTH Protocol for Identification and Rectification of Black Spots*, *IRC:131-2022*, and various state-level Road Safety Action Plans, challenges remain in the consistent application of these guidelines at ground level(*IRC Code 131-2022*, n.d.). Many cities and districts lack

reliable crash data, GIS capabilities, or adequately trained personnel to implement scientifically robust black-spot identification methods. Police-reported crash data—which form the backbone of most black-spot analyses—are often incomplete, under-reported, or spatially inaccurate, severely limiting the reliability of hotspot detection. This gap is especially critical in rapidly urbanising regions where changing traffic patterns, increased motorisation, and expanding road networks demand dynamic and data-driven identification of emerging hotspots. Without accurate hotspot mapping, safety interventions risk being misdirected, ineffective, or inefficient, leading to continued loss of life and public resources.

CHAPTER 3

RESEARCH DESIGN

3. 1 Aim

The aim of this research is to identify Accident Black Spot locations through data analysis and propose mitigation strategies. The study integrates traffic engineering principles, geometric improvements, and human factors to enhance road safety and reduce accidents at high-risk locations.

3. 2 Objectives

The objectives are divided into two phases

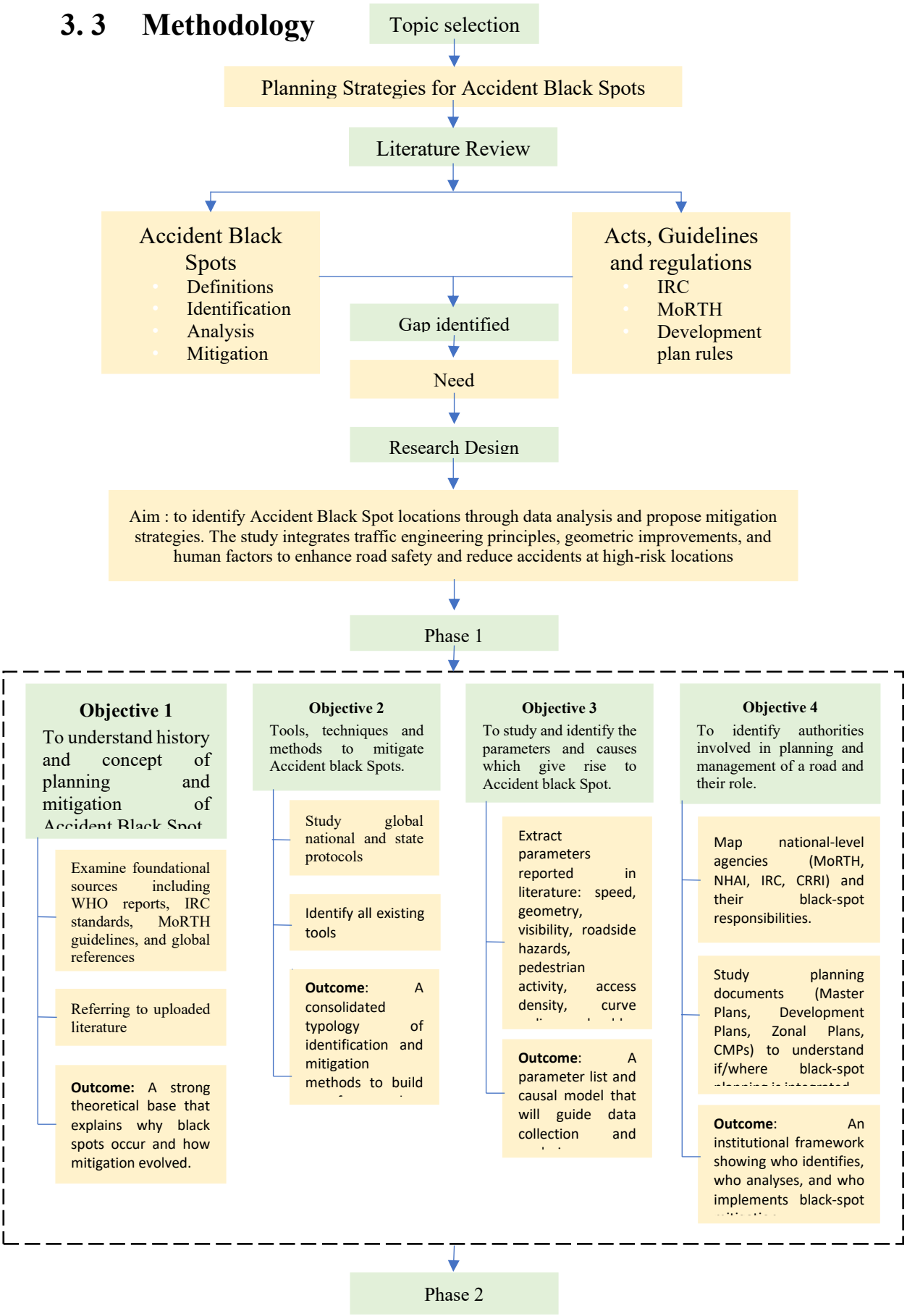
PHASE 1:-

1. To understand history and concept of planning and mitigation of Accident Black Spot.
2. To review existing literature, case studies, guidelines and standards and identify tools, techniques and methods to mitigate Accident black Spots.
3. To study and identify the parameters and causes which give rise to Accident black Spot.
4. To identify authorities involved in planning and management of a road and their role.

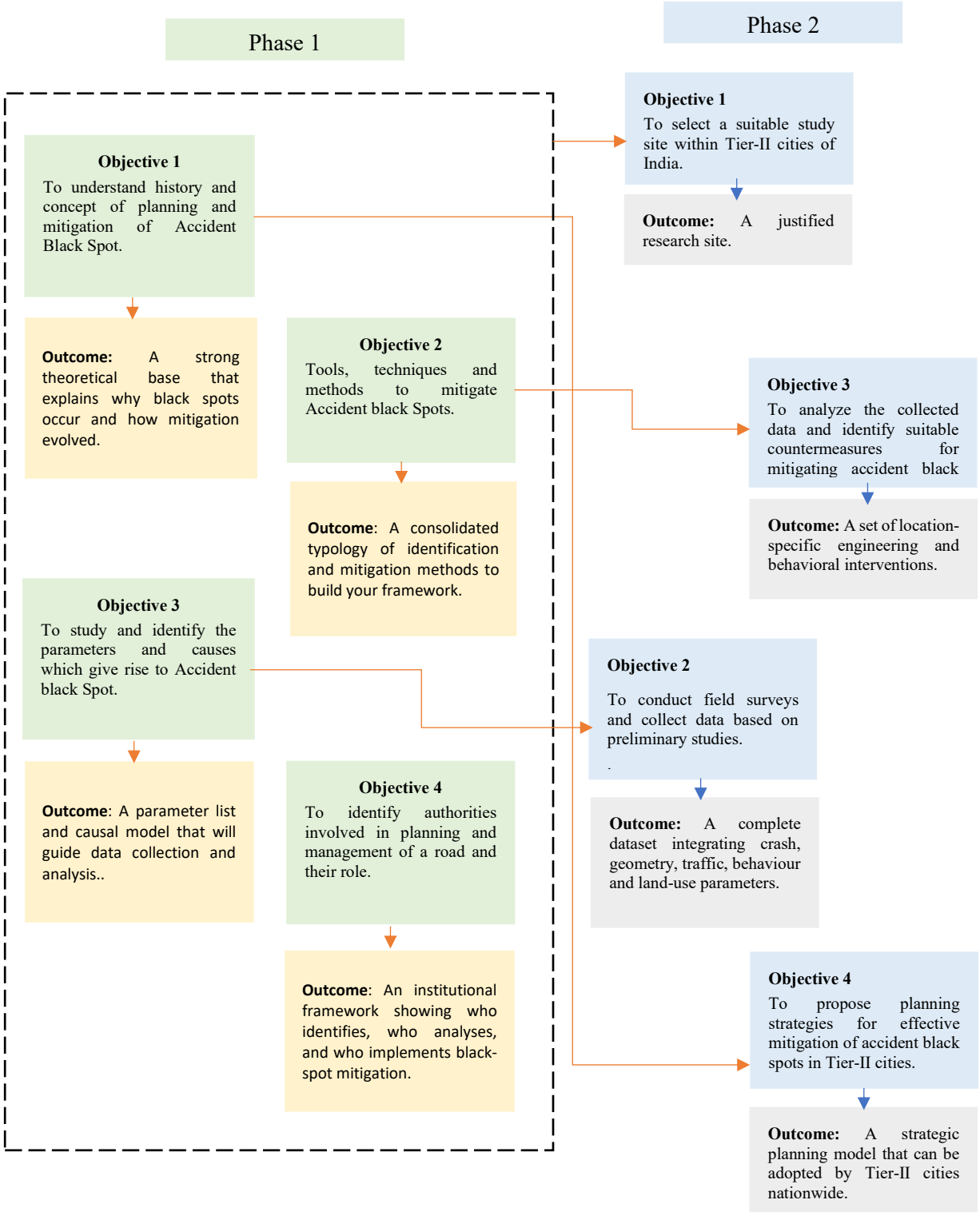
PHASE 2:-

1. To select a suitable study site within Tier-II cities of India.
2. To conduct field surveys and collect data based on preliminary studies.
3. To analyze the collected data and identify suitable countermeasures for mitigating accident black spots.
4. To propose planning strategies for effective mitigation of accident black spots in Tier-II cities.

3. 3 Methodology



3. 4 Correlation between Phase 1 and Phase 2 objectives



3. 5 Scope

The scope of this study is to assess and develop planning strategies for accident black spots within Bhopal city, Madhya Pradesh, with a focus on improving road safety through spatial analysis, road safety audits, and planning-based interventions. The study is undertaken as a live project and is based on accident black spots officially identified by concerned government authorities.

The research examines accident-prone locations across different categories of urban road networks, including arterial roads, sub-arterial roads, major intersections, commercial corridors, and institutional zones. By considering a variety of roadway environments, the study captures the diverse safety challenges present within a rapidly growing Tier-II city. Particular attention is given to issues such as high-speed traffic movement, geometric deficiencies, pedestrian conflicts, inadequate traffic control measures, poor visibility, roadside encroachments, and deficiencies in non-motorized transport infrastructure.

The study incorporates GIS-based spatial analysis, field investigations, road safety audits, and issue-based classification of black spots to understand the physical and operational factors contributing to unsafe conditions. Rather than focusing solely on accident frequency, the study adopts a risk-based assessment approach that evaluates traffic exposure, pedestrian activity, geometric characteristics, and observed safety deficiencies at each location.

Furthermore, the scope extends to the preparation of location-specific planning and engineering proposals aimed at reducing crash risk and improving overall mobility conditions. The study also explores broader planning implications by examining how accident black spot management can be integrated into urban planning instruments such as Comprehensive Mobility Plans, road safety action plans, and city-level transportation planning frameworks.

The proposed framework is intended to support local authorities and planning agencies in prioritizing interventions, enhancing road safety, and promoting safer and more sustainable urban mobility within Bhopal and other comparable Tier-II cities in India.

3. 6 Limitation

The study is based on accident black spots officially identified by concerned government authorities under a live project framework. Therefore, the research focuses on the assessment and rectification of identified locations rather than the independent identification of black spots through accident-frequency analysis.

i. Detailed location-specific accident records, crash severity data, and long-term accident databases were not available for all identified black spots during the study period. Consequently, the analysis relied primarily on field investigations, road safety audits, spatial analysis, and observed risk factors.

ii. Traffic observations and site assessments were conducted within a limited time frame and may not fully capture seasonal variations, special events, or long-term fluctuations in traffic conditions and road user behaviour.

iii. The study primarily examines physical, geometric, operational, and planning-related factors influencing road safety. Detailed behavioural analysis of drivers, enforcement effectiveness, and vehicle-related factors were beyond the scope of the research.

iv. Due to limitations in the availability of exposure-based data such as Annual Average Daily Traffic (AADT), advanced statistical methods including Empirical Bayes modelling, Safety Performance Functions, and crash prediction models could not be applied comprehensively.

v. The proposed interventions are conceptual planning and engineering recommendations developed on the basis of site conditions, road safety audit findings, and planning principles. Detailed engineering design, cost estimation, and implementation feasibility assessments were beyond the scope of this study.

vi. Since the proposed interventions have not yet been implemented, their effectiveness could not be evaluated through before-and-after accident analysis or post-implementation monitoring.

vii. The findings and recommendations are specific to the selected accident black spots in Bhopal; however, the proposed assessment framework may

be adapted for application in other Tier-II cities facing similar road safety challenges.

CHAPTER 4

DATA AND DATA ANALYSIS (PRIMARY DATA AND SITE SELECTION)

4. 1 Selection of the Study Area: Bhopal as a Tier-II Urban Model

The capital city of Bhopal located in the state of Madhya Pradesh was chosen as the location for Phase II since the characteristics of this city are reflective of rapidly growing Tier-II Indian cities.5 Situated near 23.2599° N and 77.4126° E, Bhopal has a very distinctive topography with areas that consist of hills, natural lakes, and plains.21 This unique geography has caused urbanization to develop along distinct high-speed corridors.6 The city's transportation network consists of a variety of vehicles, including freight trucks, passenger vehicles, intermediate transport buses, two wheelers, and pedestrian traffic.1

Bhopal currently has several ongoing projects in the realm of infrastructure development; one of them being the metro railway development project of the Orange and Blue lines.5 While the development of this project is expected to benefit the city greatly in terms of mobility, the current construction work poses various challenges to road users.14 The project causes congestion on roads and results in the narrowing of active lanes and creating dangerous conflict zones near stations.

4. 2 Data Considerations.

The present study was undertaken as a live project focusing on the assessment and planning-based improvement of accident black spots within Bhopal city. The locations selected for detailed investigation were officially identified as accident black spots by the concerned government authorities responsible for road safety management and transportation infrastructure. As these locations had already been recognized as accident-prone through official processes, the primary objective of the study was not to independently identify black spots using accident-frequency analysis but to understand

the underlying causes contributing to unsafe conditions and develop suitable planning and engineering interventions.

Although accident data forms an important component of black spot identification, the availability of detailed location-specific accident records remains a significant challenge in many Indian cities. Comprehensive datasets containing precise accident locations, severity classifications, vehicle involvement details, temporal distribution, and long-term crash histories were not uniformly available for all identified locations during the study period. Furthermore, accident records are often maintained by multiple agencies, including traffic police departments, transport authorities, health departments, and road-owning agencies, resulting in issues related to data accessibility, standardization, and completeness.

Considering these constraints, the study adopted a risk-based and diagnostic approach that focused on assessing the physical, operational, and environmental characteristics of identified black spots. This approach is consistent with the principles of Road Safety Audit (RSA) and proactive road safety assessment methodologies recommended by the Indian Roads Congress (IRC:131-2022) and international road safety practices. Rather than relying solely on historical crash frequencies, the study evaluated factors known to contribute to accident occurrence and severity, including roadway geometry, traffic movement patterns, pedestrian exposure, visibility conditions, traffic control measures, roadside conditions, and land-use characteristics.

To support this assessment, GIS-based spatial analysis was employed to examine the distribution and characteristics of accident black spots within the urban road network. Detailed field investigations and site visits were conducted to document existing conditions, identify safety deficiencies, and understand the interaction between road users and the built environment. Traffic observations, photographic documentation, geometric assessments, and issue-based classification techniques were used to systematically evaluate the risk profile of each location.

The study further adopted a prioritization framework based on observed risk factors, including traffic exposure, pedestrian activity, geometric deficiencies, speed-related risks, and strategic importance within the city road network. This enabled the identification of locations requiring immediate intervention even in situations where

detailed accident statistics were unavailable. Such an approach aligns with contemporary road safety planning practices that emphasize proactive risk management rather than relying exclusively on historical crash records.

The resulting methodology allowed the study to move beyond the identification of accident-prone locations and focus on understanding why these locations remain unsafe and how they can be improved through context-specific planning and engineering measures. Consequently, the research contributes to the development of practical and implementable solutions for improving road safety in Bhopal while also providing a framework that may be adapted for use in other Tier-II Indian cities facing similar data and institutional constraints.

4. 3 Identification of Accident Black Spots

The following summary provides a structured overview of accident black spot identification within Bhopal's complex road network. By integrating spatial characteristics—such as the city's radial-ring pattern and rapid urban expansion—with standardized MoRTH safety criteria, the study isolates 61 high-risk hotspots. These areas are categorized into four distinct traffic zones, ranging from congested commercial cores to high-speed peripheral corridors, serving as a critical framework for developing targeted planning interventions and road safety strategies.

4.3.1 Road Network Characteristics of Bhopal

Bhopal is described as having a **hierarchical road network**, which is a structured system where roads are categorized by their function and capacity:

- **National Highways:** High-speed, long-distance routes like **NH-46** and **NH-146**.
- **State Highways:** Connectivity between cities and regions.
- **Arterial and Sub-arterial Roads:** Major inner-city roads that carry high volumes of local traffic.
- **Local Streets:** Neighborhood-level access roads.

The city follows a **radial and ring road pattern**, which often leads to complex intersections. The text notes that Bhopal is experiencing **rapid peri-urban expansion**

(growth on the city outskirts) and contains **mixed land-use corridors**, where commercial and residential activities overlap, increasing the risk of vehicle-pedestrian conflict.

4.3.2 Identification of Black Spots

The study uses the official **MoRTH (Ministry of Road Transport and Highways) criteria** to define a "black spot." To qualify, a road stretch of **300–500 meters** must meet one of the following conditions over a **3-year period**:

"five or more crashes involving fatalities or grievous injuries occur within a three-year period, or *ten or more fatalities occur within the same period"*

Based on this, **61 black spots** were identified using data sourced from police accident records and road-owning agencies like the **PWD (Public Works Department)** and **Nagar Nigam (Municipal Corporation)**.

4.3.3 Zonal Analysis of Traffic Hotspots

The identified spots are categorized into four distinct **Traffic Zones**, each with a unique risk profile:

Table 2 Zonal Analysis of Traffic Hotspots

Zone	Characteristics	Primary Risk Factor
Zone 01	Commercial Areas	High congestion leading to a mix of frequent minor and fatal accidents.
Zone 02	Mixed Residential + Arterial	Medium traffic volume but plagued by poor infrastructure design.
Zone 03	Expanding Urban Corridors	Rapid urbanization resulting in unsafe or incomplete infrastructure.
Zone 04	Peripheral + Highway Zones	Characterized by high speeds, leading primarily to fatal accidents.

The map shows Figure 1 the spatial distribution of accident black spots in Bhopal city. Most black spots are concentrated in the central urban area along major arterial roads and important intersections such as MP Nagar, Polytechnical Square, Bharatmata Square, and

Board Office Square. These locations experience high traffic volume, congestion, mixed traffic movement, and heavy pedestrian activity.

Several black spots are also located along major corridors like Hoshangabad Road, Raisen Road, and highway entry points such as Karond Chauraha and 11 Mile Tiraha, indicating risks due to high-speed traffic and merging movements.

The overall pattern suggests that accident occurrence in Bhopal is strongly associated with busy intersections, commercial activity zones, inadequate traffic management, and increasing vehicular pressure on major transport corridors.

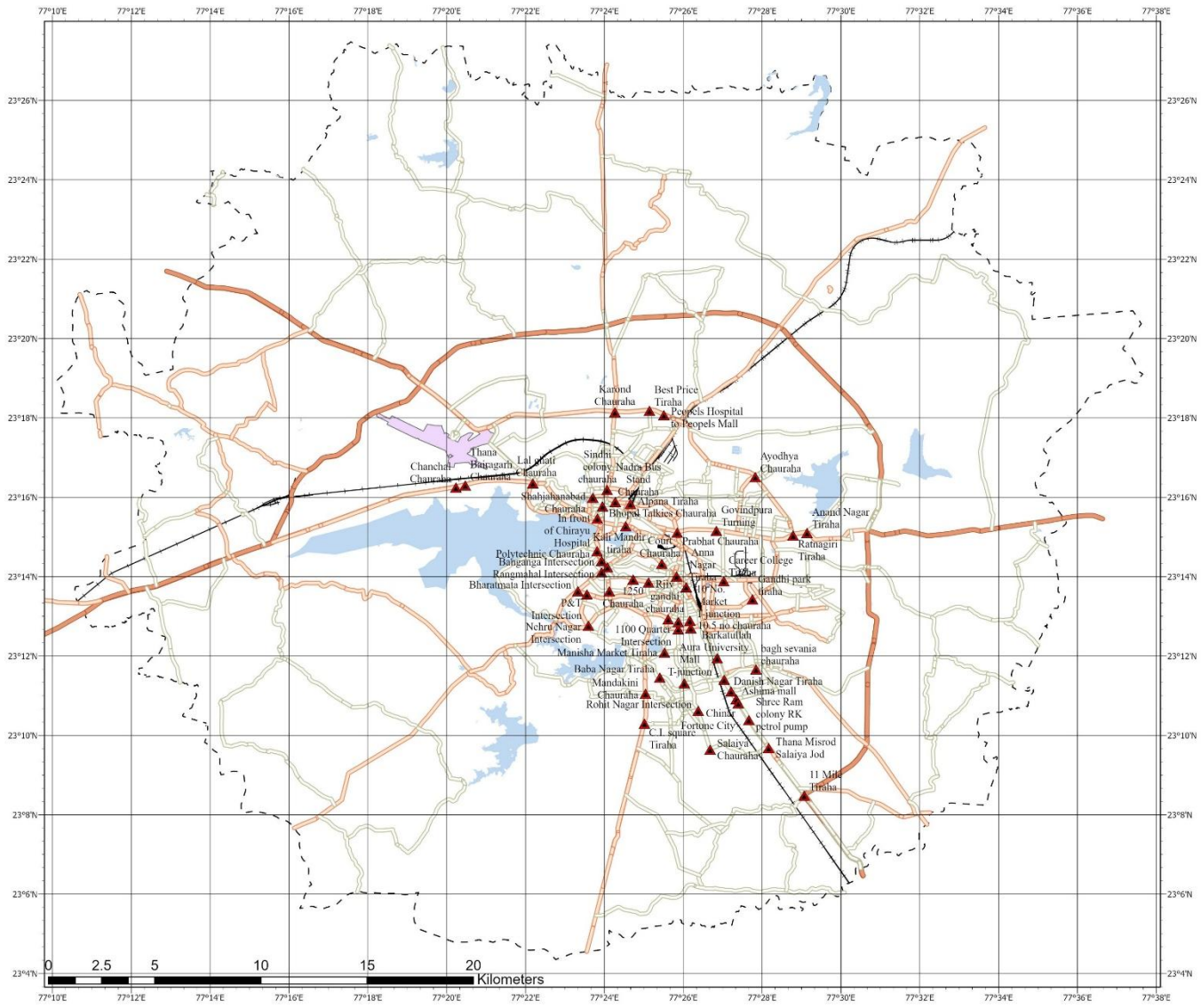


Figure 1Issues wise classification of accident Black Spots (Author)

Below is the list of various black spots in Bhopal identified by traffic Police Department, Bhopal.

Traffic Zone 1

Table 3 Traffic Zone 1 Location Of ABS

S. No.	Location Name	Road Owning Agency
1	Bairagarh Chauraha	Nagar Nigam Bhopal
2	Bharat Talkies Chauraha	Nagar Nigam Bhopal
3	Nehru Nagar Chauraha	Nagar Nigam Bhopal
4	Rajiv Gandhi Chauraha	Nagar Nigam Bhopal
5	1100 Quarters Chauraha	Nagar Nigam Bhopal
6	Rohit Nagar Chauraha	Nagar Nigam Bhopal
7	Ayodhya Nagar Chauraha	Nagar Nigam Bhopal
8	10 No. Market Tiraha	Nagar Nigam Bhopal
9	Sadiq Nagar Chauraha	Nagar Nigam Bhopal
10	Alpana Tiraha	Nagar Nigam Bhopal
11	Board Office Square	Nagar Nigam Bhopal
12	DB Mall Chauraha	Nagar Nigam Bhopal
13	TT Nagar Chauraha	Nagar Nigam Bhopal

(Traffic Police Department, Bhopal)

Traffic Zone 2

Table 4: Traffic Zone 2(ABS)

14	Bansal Hospital Chauraha	PWD
15	Misrod Tiraha	PWD
16	Danish Nagar Tiraha	Nagar Nigam Bhopal

17	Bagsewania Tiraha	Nagar Nigam Bhopal
18	Near Habibganj Bridge	Nagar Nigam Bhopal
19	Ayodhya Nagar Tiraha	PWD
20	Anand Nagar Tiraha	PWD
21	Asharam College (Raisen Road)	Nagar Nigam Bhopal
22	Career College Tiraha	Nagar Nigam Bhopal

(Traffic Police Department, Bhopal)

Traffic Zone 3

Table 5Traffic Zone 3(ABS)

23	Ashoka Garden Chauraha	PWD
24	Peoples Mall Chauraha	PWD
25	Kali Mandir Chauraha	PWD
26	Polytechnic Chauraha	PWD
27	Bhopal Talkies Chauraha	PWD
28	Shahjahanabad Chauraha	PWD
29	Alpana Tiraha	PWD
30	Nadra Bus Stand Chauraha	PWD
31	Lalghati Chauraha	NHAI

(Traffic Police Department, Bhopal)

Traffic Zone 4

Table 6Traffic Zone 4

32	Sehore Naka Chauraha	PWD
33	Kali Mandir Tiraha	PWD

34	Bairagarh (Hospital Area)	PWD
35	Karond Chauraha	PWD
36	Mandideep Chauraha	PWD
37	Bairasia Road Chauraha	PWD
38	Berasia Tiraha	PWD
39	Police Hospital to Lalghati Stretch	PWD
40	Bhadbhada Bridge Tiraha	PWD
41	Bawadia Kalan Tiraha	Nagar Nigam
42	Manisha Market Tiraha	Nagar Nigam
43	MP Nagar Zone-II	Nagar Nigam
44	Near AIIMS Bhopal	PWD

(Traffic Police Department, Bhopal)

List of Priority Black Spots

Table 7 List of Priority Black Spots

S. No.	Location	Type	Key Issues Identified
1.	Platinum Plaza	Intersection	High traffic + commercial activity
2.	Govindpura Turning	Intersection	Sharp turning radius
3.	Aashima Mall	Commercial Intersection	High pedestrian + parking conflict
4.	Bagsewania Chauraha	Intersection	Mixed traffic, congestion
5.	Rangmahal Chauraha	Intersection	Poor visibility
6.	Saliya Chauraha	Intersection	Unregulated turning

7.	Prabhat Chauraha	Intersection	Traffic conflict
8.	Court Chauraha	Institutional	Pedestrian movement
9.	DB Mall Tiraha	Commercial	High footfall
10.	1250 Chauraha	Intersection	Congestion
11.	1100 Quarters Chauraha	Intersection	Traffic load
12.	Tarun Pushkar Tiraha	Intersection	Poor signage
13.	Ratnagiri Tiraha	Intersection	Visibility issues
14.	11 Mile Tiraha	Highway Junction	Poor lighting at night leads to frequent accidents.
15.	Best Price Tiraha	Highway/Commercial	Heavy vehicle movement
16.	Banganga Chouraha	Intersection	High speed accidents (steeper slope)

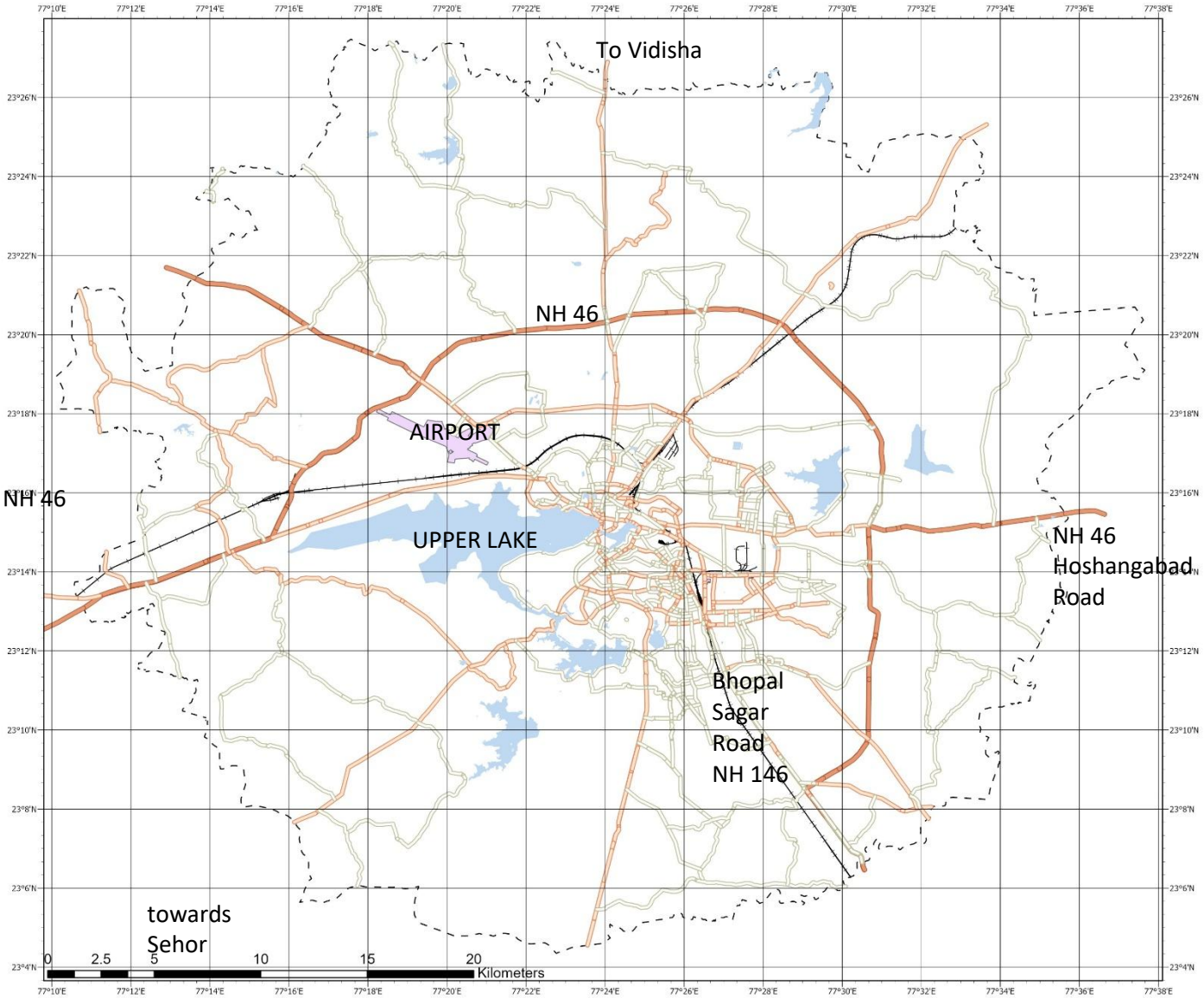


Figure 2spatial distribution of accident black spots in Bhopal city (Author)

(Traffic Police Department, Bhopal)

The map shows Figure 2 the spatial distribution of accident black spots in Bhopal city. Most accident-prone locations are concentrated in the central urban area along major roads and important intersections. These black spots are mainly associated with heavy traffic flow, congestion, mixed traffic movement, and intense commercial activities. Some black spots are also located along highway corridors and city entry points, indicating risks due to high-speed traffic and uncontrolled turning movements.

4. 4 Analysis of Primary Data

The maps and the data collected collectively provide a comprehensive spatial analysis of accident black spots within Bhopal city, illustrating their distribution, concentration, and area of influence in relation to the urban road network. The analysis reveals a significant clustering of accident-prone locations within the central urban core and along major arterial corridors, indicating a strong relationship between traffic intensity, land-use concentration, and accident occurrence.

The first mapFigure 1 presents the spatial distribution and categorization of identified black spots across the city. The concentration of accident-prone locations within the central business and institutional areas highlights the impact of high traffic volume, mixed land use, and increased vehicular-pedestrian interaction on road safety. Major intersections such as MP Nagar, Polytechnical Square, Bharatmata Intersection, and Prabhat Chauraha emerge as critical nodes experiencing continuous traffic pressure and operational conflicts.

The second map Figure 2 further refines the analysis by identifying the exact geographic locations of accident black spots. The spatial pattern demonstrates that a majority of black spots are located at major intersections, junctions, and traffic corridors characterized by complex turning movements, inadequate traffic control, congestion, and heterogeneous traffic conditions. Additionally, several black spots are distributed along highway-connected corridors and peripheral growth areas such as Karond Chauraha, Ayodhya Chauraha, and 11 Mile Tiraha, indicating the influence of urban expansion and high-speed vehicular movement on accident vulnerability.

The third map Figure 3 illustrates the influence zones of the identified black spots through spatial buffering techniques. The overlapping buffer zones in the central and southern sectors of the city indicate a high-density accident corridor, reflecting the cumulative effect of closely spaced intersections and continuous traffic interaction. The spatial overlap suggests that accident occurrence is not isolated to individual junctions but is concentrated along interconnected transport corridors with high mobility demand.

The overall spatial analysis indicates that accident black spots in Bhopal are strongly associated with:

- Major arterial and sub-arterial road networks,

- High traffic density and congestion,
- Mixed traffic composition,
- Commercial and institutional land-use concentration,
- Inadequate intersection geometry and traffic management,
- And increasing urbanization along peripheral corridors.

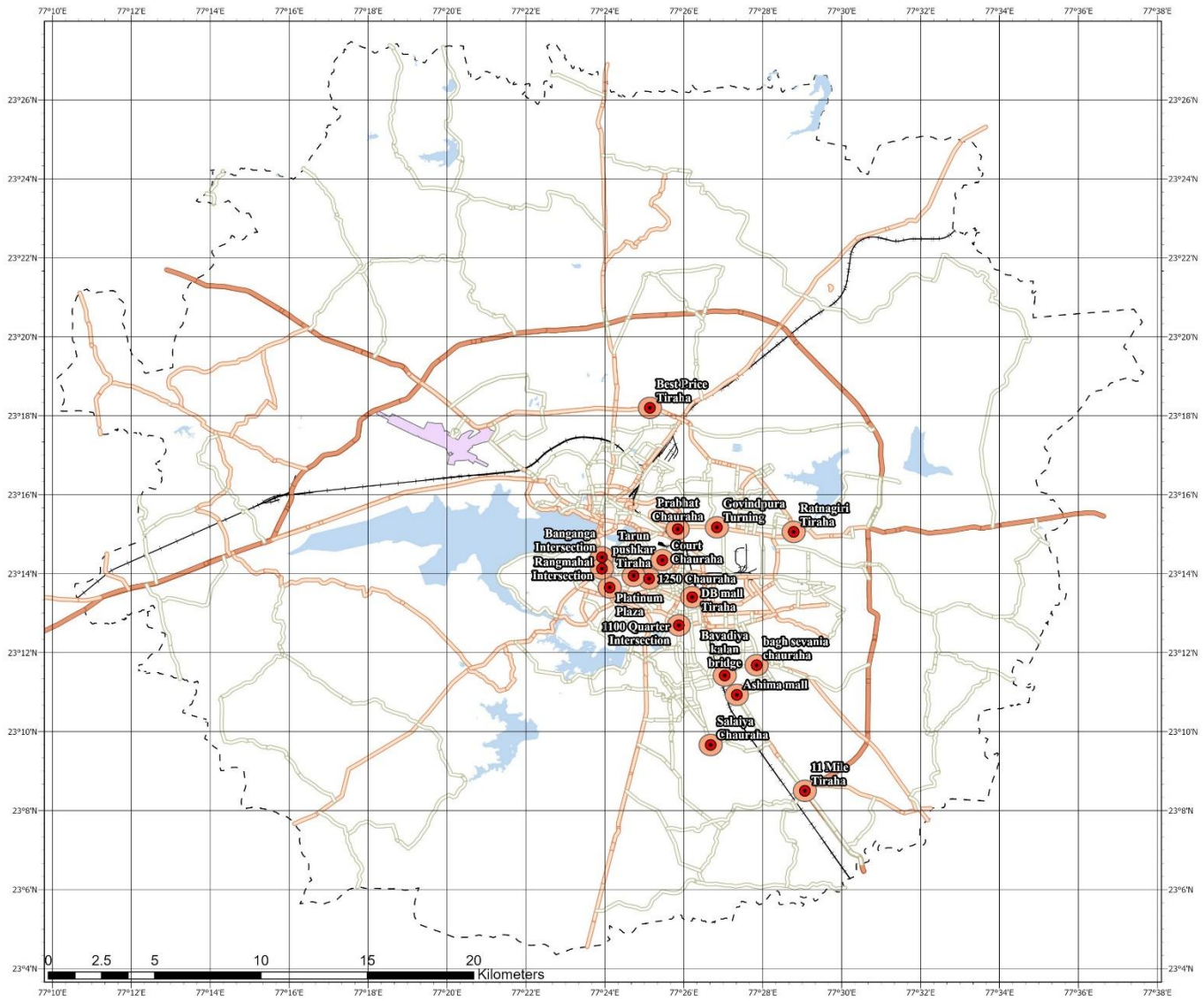


Figure 3 the influence zones of the identified black spots through spatial buffering techniques(Author)

The findings emphasize the need for integrated corridor-level road safety interventions, including intersection redesign, traffic calming measures, signal optimization, pedestrian infrastructure improvement, and enhanced traffic management strategies in the identified high-risk zones.

4. 5 Risk-Based Prioritization of Identified Accident Black Spots

4.5.1. Need for Prioritization

The identification of accident black spots alone is insufficient for effective road safety management. Due to limitations in financial resources, administrative capacity, and implementation timelines, it is often not feasible to address all accident-prone locations simultaneously. Therefore, prioritization is required to identify locations that demand immediate attention and intervention.

In conventional black spot studies, prioritization is primarily based on accident frequency and severity data. However, detailed location-specific accident records were not available for all identified black spots during the study period. Therefore, this study adopts a risk-based prioritization framework based on road safety audit findings, field observations, traffic exposure, pedestrian activity, geometric deficiencies, speed-related risks, and the strategic importance of each location within the urban road network.

The adopted approach enables proactive identification of locations with the highest potential safety risks and supports the efficient allocation of resources for future intervention planning.

4.5.2. Prioritization Framework

Five parameters were considered for evaluating the relative risk level of each identified black spot.

Table 8 Prioritization framework for Accident Black spot

Parameter	Description	Score Range
Traffic Exposure	Relative traffic volume and traffic intensity	1–5
Pedestrian Exposure	Level of pedestrian movement and pedestrian conflict	1–5
Geometric Deficiency	Presence of visibility issues, sharp curves, poor turning radii, conflict points, etc.	1–5
Speed Risk	Potential for overspeeding and high-speed collisions	1–5
Strategic Importance	Importance of the location within the city road hierarchy	1–5

(Author)

The cumulative score was calculated using:

Priority Score = Traffic Exposure + Pedestrian Exposure + Geometric Deficiency + Speed Risk + Strategic Importance

The maximum possible score was 25.

4.5.3 Risk-Based Prioritization of Accident Black Spots

Table 9 Risk-Based Prioritization of Accident Black Spots

Location	Traffic	Pedestrian	Geometry	Speed	Importance	Total Score	Priority Level
Banganga Chouraha	5	3	5	5	5	23	Very High
Bawadiya Kalan Bridge Corridor	5	2	4	4	5	20	Very High
11 Mile Tiraha	4	2	4	5	5	20	Very High
Ashima Mall	5	5	3	2	5	20	Very High
DB Mall Tiraha	5	5	2	2	5	19	High
Best Price Tiraha	4	2	3	4	5	18	High
Platinum Plaza	5	3	3	2	5	18	High
Bagsewania Chauraha	4	3	3	3	4	17	High
Court Chauraha	3	5	2	2	4	16	Medium
Govindpura Turning	3	2	5	3	3	16	Medium
1250 Chauraha	4	2	2	2	4	14	Medium
1100 Quarters Chauraha	4	2	2	2	4	14	Medium
Rangmahal Chauraha	3	2	4	2	3	14	Medium
Saliya Chauraha	3	2	4	2	3	14	Medium

Prabhat Chauraha	3	2	3	2	3	13	Medium
Ratnagiri Tiraha	3	2	3	2	3	13	Medium
Tarun Pushkar Tiraha	2	2	3	2	3	12	Low

4.5.4 Priority Categories

Based on the total risk scores, the identified black spots were grouped into four priority levels.

Priority I – Immediate Intervention (Score ≥ 19)

- Banganga Chouraha
- Bawadiya Kalan Bridge Corridor
- 11 Mile Tiraha
- Ashima Mall
- DB Mall Tiraha

These locations exhibit a combination of high traffic volumes, geometric deficiencies, speed-related risks, and significant pedestrian exposure. Immediate engineering and planning interventions are recommended.

Priority II – Short-Term Intervention (Score 17–18)

- Best Price Tiraha
- Platinum Plaza
- Bagsewania Chauraha

These locations experience considerable operational conflicts and traffic pressure but present relatively lower overall risk compared to Priority I locations.

Priority III – Medium-Term Intervention (Score 13–16)

- Court Chauraha
- Govindpura Turning
- 1250 Chauraha
- 1100 Quarters Chauraha
- Rangmahal Chauraha
- Saliya Chauraha
- Prabhat Chauraha
- Ratnagiri Tiraha

These locations require targeted improvements focusing on visibility, turning movements, pedestrian facilities, and traffic management measures.

Priority IV – Routine Monitoring (Score ≤ 12)

- Tarun Pushkar Tiraha

Although safety concerns exist, the observed risk level is comparatively lower than the other identified locations. Continuous monitoring and low-cost safety improvements are recommended.

4.5.5 Key Findings

The prioritization exercise reveals that the highest-risk locations are predominantly situated along major arterial corridors and highway-influenced intersections where high vehicle speeds combine with geometric deficiencies and complex traffic movements. Locations such as Banganga Chouraha, Bawadiya Kalan Bridge Corridor, and 11 Mile Tiraha demonstrate elevated risk due to high-speed approaches and roadway design constraints. Commercial centres such as Ashima Mall and DB Mall Tiraha exhibit significant pedestrian-vehicle conflicts arising from intense commercial activity and high footfall.

The results indicate that accident black spots within Bhopal are not solely associated with traffic volume but are strongly influenced by roadway geometry, pedestrian exposure, and operational deficiencies. Therefore, future intervention strategies should adopt a location-specific approach combining engineering improvements, pedestrian safety measures, traffic management strategies, and planning-based interventions.

CHAPTER 5

ROAD SAFETY AUDIT AND DIAGNOSTIC ASSESSMENT OF IDENTIFIED ACCIDENT BLACK SPOTS

The identification and prioritization of accident black spots provide only a preliminary understanding of road safety concerns. To develop effective mitigation strategies, it is essential to investigate the physical, operational, and environmental factors contributing to unsafe conditions at these locations. Therefore, a detailed road safety audit and diagnostic assessment were undertaken for the identified accident black spots in Bhopal.

The assessment focused on evaluating roadway geometry, traffic movement characteristics, pedestrian activity, visibility conditions, traffic control measures, roadside environment, and operational deficiencies. The purpose of this chapter is to identify the root causes of safety risks and establish the basis for the planning and engineering interventions proposed in subsequent chapters.

5. 1 Road Safety Audit Framework

The road safety audit was conducted through field visits, site observations, photographic documentation, and spatial analysis. The assessment considered five key parameters:

5.1.1 Geometric Assessment

The geometric assessment evaluated the physical characteristics of the roadway and intersections. The following aspects were examined:

i. Road alignment
ii. Turning radius
iii. Junction geometry
iv. Sight distance
v. Road width
vi. Median configuration

vii. Gradient and slope conditions

Deficiencies in roadway geometry often contribute to increased vehicle conflicts and reduced driver reaction time.

5.1.2 Traffic Assessment

Traffic-related factors influencing road safety were assessed through field observations. The assessment included:

i. Traffic volume
ii. Vehicle composition
iii. Turning movements
iv. Traffic conflicts
v. Congestion levels
vi. Speed characteristics

Locations experiencing high traffic demand and complex traffic movements were identified as having elevated safety risks.

5.1.3 Pedestrian Safety Assessment

Pedestrian facilities and movement patterns were evaluated because vulnerable road users constitute a significant proportion of road accident victims.

The assessment included:

i. Footpath availability
ii. Pedestrian crossings
iii. Refuge islands
iv. Accessibility conditions
v. Pedestrian-vehicle conflict points

5.1.4 Traffic Control and Visibility Assessment

The effectiveness of traffic control measures was evaluated based on:

i. Traffic signage
ii. Road markings
iii. Signalization
iv. Street lighting
v. Visibility conditions

Poor visibility and inadequate traffic control significantly increase accident risk.

5.1.5 Environmental Assessment

Environmental factors influencing road safety included:

i. Roadside encroachments
ii. Parking activities
iii. Commercial activities
iv. Land use interactions
v. Roadside obstructions

These factors often create operational conflicts and increase accident potential.

5. 2 Issue-Based Classification of Identified Accident Black Spots

Based on the road safety audit findings, the identified accident black spots were classified into four categories according to their dominant safety concerns.

Category A: High-Speed Conflict Zones

These locations experience elevated accident risks due to high vehicle speeds, highway influences, and inadequate speed management measures.

Locations:

i. Banganga Chouraha
ii. Bawadiya Kalan Bridge Corridor
iii. 11 Mile Tiraha
iv. Best Price Tiraha

Major Issues:

i. High approach speeds
ii. Severe collision potential
iii. Highway-related conflicts
iv. Limited speed calming measures

5. 3 Pedestrian Conflict Zones

These locations exhibit significant pedestrian movement and frequent pedestrian-vehicle interactions.

Locations:

i. Ashima Mall
ii. DB Mall Tiraha
iii. Court Chauraha

Major Issues:

i. High pedestrian footfall
ii. Inadequate pedestrian crossings
iii. Commercial activity
iv. Parking conflicts

5. 4 Geometric Deficiency Zones

These locations are characterized by deficiencies in roadway geometry and visibility.

Locations:

i. Govindpura Turning
ii. Rangmahal Chauraha
iii. Saliya Chauraha
iv. Ratnagiri Tiraha

Major Issues:

i. Sharp turning radii
ii. Poor visibility
iii. Unregulated turning movements
iv. Inadequate channelization

5. 5 Congestion and Mixed-Traffic Conflict Zones

These locations experience operational conflicts arising from mixed traffic conditions and congestion.

Locations:

i. Platinum Plaza

ii. Bagsewania Chauraha
iii. Prabhat Chauraha
iv. 1250 Chauraha
v. 1100 Quarters Chauraha
vi. Tarun Pushkar Tiraha

Major Issues:

i. Traffic congestion
ii. Mixed traffic movement
iii. Insufficient lane discipline
iv. Operational conflict

CHAPTER 6

INFERENCES

6. 1 Inference Chapter Summary

From the reviews of literature and documents from various cities, as well as case studies, there are common patterns for the emergence of accident black spots, their detection, and solutions. From both the developed and the developing world, black spots are created from a blend of geometric problems, operational problems, behavioral issues, and the demands made by surrounding land uses. Spatial analysis tools like Kernel Density Estimation, severity scoring, distance between crashes, and field safety analysis constantly show that areas of high risk arise when the design, behaviors, and surroundings combine in reinforcing ways. This point is also supported by various Indian case studies such as Bhopal, Amravati, Kolhapur, NH-4, and Islampur-Ashta.

A significant aspect noted based on the review of literature is the wide range of methodologies utilized in hot spot detection. Each analysis methodology produces varying hot spots depending on the type of tool used. In global literature, empirical Bayes and SPF analysis methods are regarded as statistical techniques; however, Indian researchers prefer using frequency and severity methods owing to data availability issues. Lack of access to credible crash data, traffic exposure data, and geometric information poses a great challenge to improving methodologies. Machine learning methodology can be quite effective but requires data unavailable in India.

The institutional review highlights that while engineering departments follow structured processes for black-spot identification and mitigation, statutory planning documents such as Master Plans, Development Plans, Zonal Plans and Municipal Corporation Plans do not incorporate any operational procedures for identifying or managing black spots. They articulate broad mobility aspirations—safer roads, reduced conflicts, improved intersections—but fail to include actionable, data-driven steps. This disconnect leaves black-spot management outside the planning system, relying solely on MoRTH and IRC procedures without integration into land-use planning, transportation corridors, redevelopment strategies or budgeting processes. The study identifies this as a critical

institutional gap and proposes ways in which black-spot assessment can be embedded into spatial planning, thereby aligning long-term planning with immediate safety needs.

finally, the inferences indicate that the research outcomes have wide applicability. Developed cities can use the methods to refine mature networks; developing cities can apply the techniques to manage rapid, mixed-traffic growth; and new towns can incorporate safety considerations at the design stage to prevent future high-risk sites. The chapter, therefore, concludes that the analytical processes and insights derived from the reviewed documents are both universally relevant and locally actionable, offering significant value to engineering, planning, and governance domains.

6. 2 Implications for Planning Practice

The findings of this study carry substantial implications for contemporary planning practice in India and globally. First, they highlight the need for transport safety to be treated as a core planning responsibility rather than an external engineering concern. Currently, Master Plans, Development Plans and Zonal Plans articulate safety only in conceptual terms, rarely offering practical tools for identifying hazardous locations. The study demonstrates that incorporating analytical techniques—such as crash mapping, conflict analysis, severity scoring and location-based diagnostics—into statutory planning documents would allow planners to intervene proactively rather than reactively.

Second, the analysis underscores the importance of integrating land-use decisions with safety outcomes. Many black spots emerge at locations where commercial frontage, street vending, schools, transit stops, or mixed traffic activities create unregulated conflict points. Planning authorities must therefore adopt more safety-sensitive zoning, access control, and corridor planning strategies. This requires closer collaboration between municipal engineers, police, transport departments and planning bodies—something currently lacking in most Indian cities.

Third, the study illustrates the necessity of institutionalising data-driven practices within planning systems. By embedding periodic crash-data review, monitoring of hazardous corridors, and safety audits into the planning cycle, local bodies can create an adaptive approach to mobility planning that evolves with emerging safety trends. The outcome is a more resilient, evidence-based planning process that can guide infrastructure

investment, phasing decisions, and design revisions with greater precision and accountability.

Finally, these insights push planning agencies toward a more interdisciplinary role. Instead of focusing solely on land allocation and urban form, planners must expand their capacity to interpret traffic data, collaborate with engineering teams, and participate in safety-led decision-making. The study provides the analytical tools and reasoning to support such a shift.

6. 3 How the Findings Apply to Tier-II Cities

Tier-II cities exhibit unique challenges characterized by rapid growth, mixed traffic, limited enforcement capacity, informal land-use practices, and constrained data availability. The findings of this study speak directly to these conditions. The analysis shows that simpler yet effective identification methods—such as crash-frequency mapping, severity-weighted scoring, Kernel Density Estimation, field audits, and visual diagnostics—are well suited to Tier-II contexts where empirical-Bayes and machine-learning models may not be feasible due to data gaps. These methods offer a realistic, implementable approach for authorities operating in resource-limited settings.

In addition, Tier-II cities often experience unplanned access patterns, roadside commercial activity, and pedestrian-heavy corridors, all of which contribute to black-spot formation. The study's insights into geometric improvement, access management, junction redesign, speed management, and pedestrian safety interventions can be adopted with modest financial and institutional requirements. Examples from the Islampur–Ashta and Kolhapur case studies demonstrate that even small-scale treatments can yield meaningful safety benefits.

Another key application lies in the integration of safety into local development processes. Tier-II cities are actively preparing Master Plans, Development Plans, and Mobility Plans as they grow. The study offers actionable methodologies that can be embedded into these documents to identify and manage high-risk locations, allowing cities to address safety proactively rather than after crashes accumulate.

Finally, Tier-II cities are at a pivotal stage: they are transitioning from small towns to growing urban economies. The findings empower them to adopt practices that prevent the long-term safety deficits seen in metropolitan cities. By applying the methods and

insights from this study, Tier-II cities can ensure safer network expansion, more controlled growth along corridors, and safer environments for vulnerable road users, thereby building more resilient mobility systems for the future.

6. 4 Integrated Framework for Accident Black Spot Management in Tier-II Cities

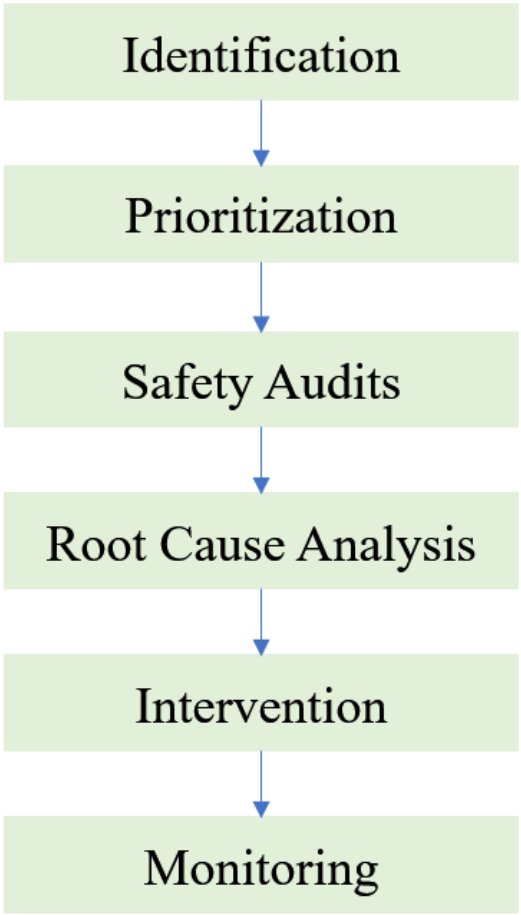


Figure 4 Integrated Framework for Accident Black Spot Management

The framework illustrates the systematic process adopted in the study for managing accident black spots. The process begins with the identification and mapping of accident-prone locations, followed by risk-based prioritization and detailed diagnostic assessment through road safety audits. Based on the identified deficiencies, planning and engineering interventions are proposed and integrated into broader urban planning frameworks.

Continuous monitoring and evaluation ensure long-term effectiveness and support the development of safer and more sustainable urban mobility systems.

Institutional and Stakeholder Analysis

Table 10 Institutional and Stakeholder Analysis

Stakeholder	Responsibility
Traffic Police	Enforcement and crash records
BMC	Footpaths and local roads
PWD	Road geometry improvements
Smart City	Funding and project implementation
Urban Planning Authorities	Policy integration
Transport Department	Road safety coordination

Effective black spot management requires coordination among multiple agencies. The absence of institutional coordination often delays implementation and monitoring of road safety interventions

CHAPTER 7

PROPOSED PLANNING STRATEGIES FOR IDENTIFIED ACCIDENT BLACK SPOTS

Road accident black spots are critical locations within the urban road network where a high concentration of crashes occurs due to deficiencies in roadway geometry, traffic management, pedestrian facilities, visibility, and uncontrolled vehicular movements. The identified black spots in Bhopal exhibit issues such as traffic congestion, unsafe turning movements, pedestrian conflicts, inadequate road markings, improper intersection geometry, lack of channelization, and poor visibility conditions.

Based on the field observations, traffic movement analysis, and spatial assessment of accident-prone locations, site-specific planning proposals have been prepared for selected black spots. The proposals focus on improving traffic safety, enhancing pedestrian accessibility, regulating vehicular movement, and increasing the operational efficiency of intersections and corridors.

- The proposed interventions mainly include:
- Junction channelization
- Raised pedestrian crossings
- Zebra crossings
- Road markings and lane segregation
- Traffic calming measures
- Footpath development
- Green belt development
- Removal of roadside obstructions
- Improved turning radii
- Access management strategies
- Geometric improvements

The chapter presents detailed planning proposals for major identified black spots in Bhopal city.

7. 1 Proposal for Banganga Junction

Banganga Junction is one of the major accident-prone intersections identified during the study. The junction experiences heavy vehicular movement, uncontrolled turning patterns, pedestrian conflicts, and congestion during peak hours. The absence of proper channelization and organized pedestrian infrastructure increases the probability of collisions.

The proposed redesign focuses on converting the existing uncontrolled intersection into a safer and more organized traffic junction through geometric and traffic engineering improvements.(Annexure)

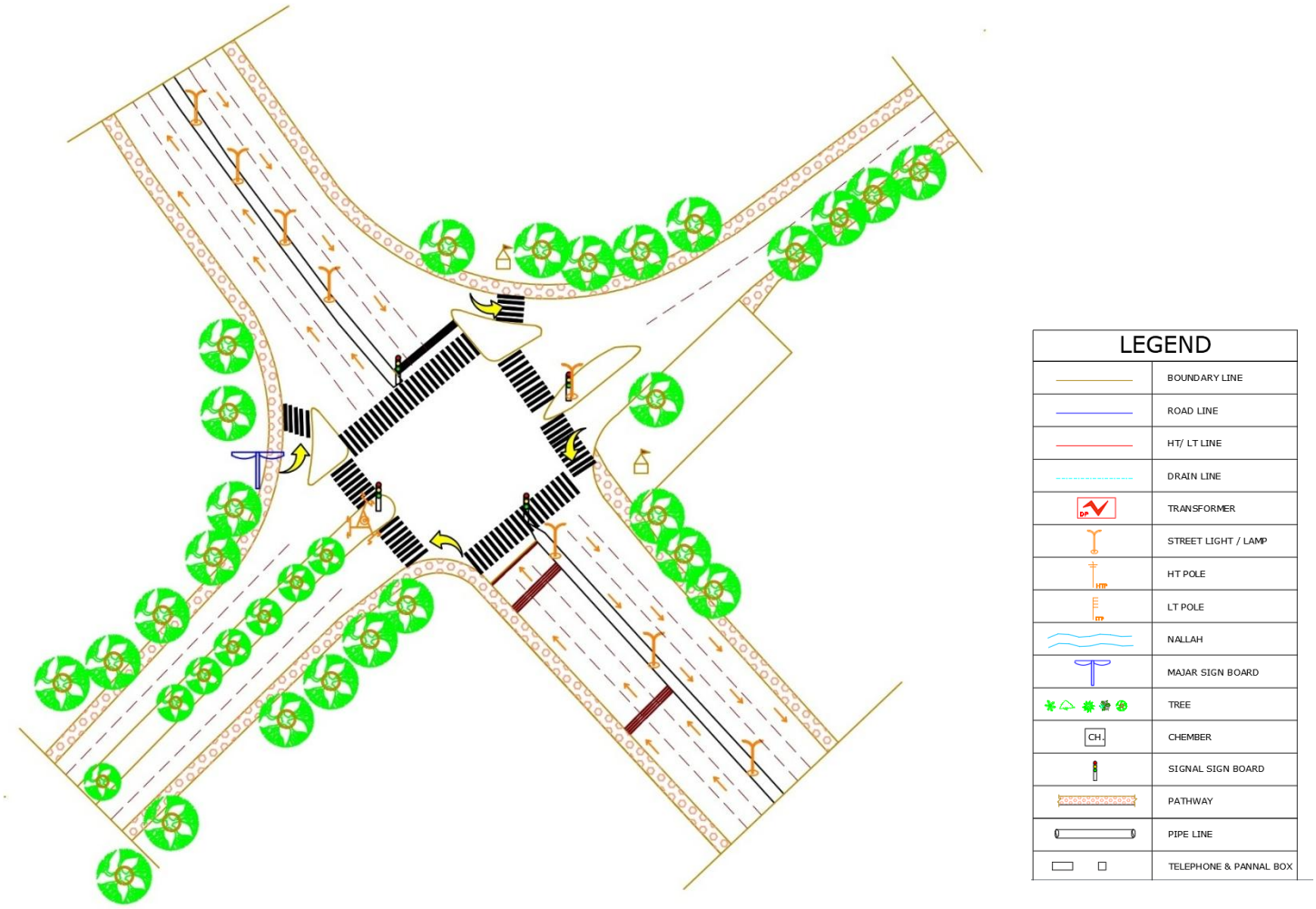


Figure 5 existing plan of Banganga Junction

(Author)

Proposed Interventions

- Introduction of a raised central intersection island for movement regulation.
- Proper carriageway markings and lane channelization.
- Development of zebra crossings on all junction approaches.
- Provision of raised pedestrian crossings to reduce vehicular speed.
- Improvement of turning radii for smoother vehicle movement.
- Removal of obstructing roadside structures to improve visibility.
- Development of roadside green belts for environmental enhancement.
- Installation of organized pedestrian pathways and traffic guidance elements.

Expected Outcomes

- Reduction in vehicle conflict points.
- Improved pedestrian safety.
- Better lane discipline and traffic regulation.
- Reduction in congestion and random turning movements.
- Enhanced intersection visibility and operational efficiency.

7. 2 Proposal for Ashima Mall Corridor

The Ashima Mall corridor is characterized by high traffic volume, commercial activity, roadside parking pressure, and pedestrian movement associated with shopping and commercial establishments. The existing road section lacks adequate pedestrian infrastructure and organized access management.

The proposal aims to improve corridor safety and traffic flow through roadway improvements and pedestrian-oriented planning measures. (Annexure)

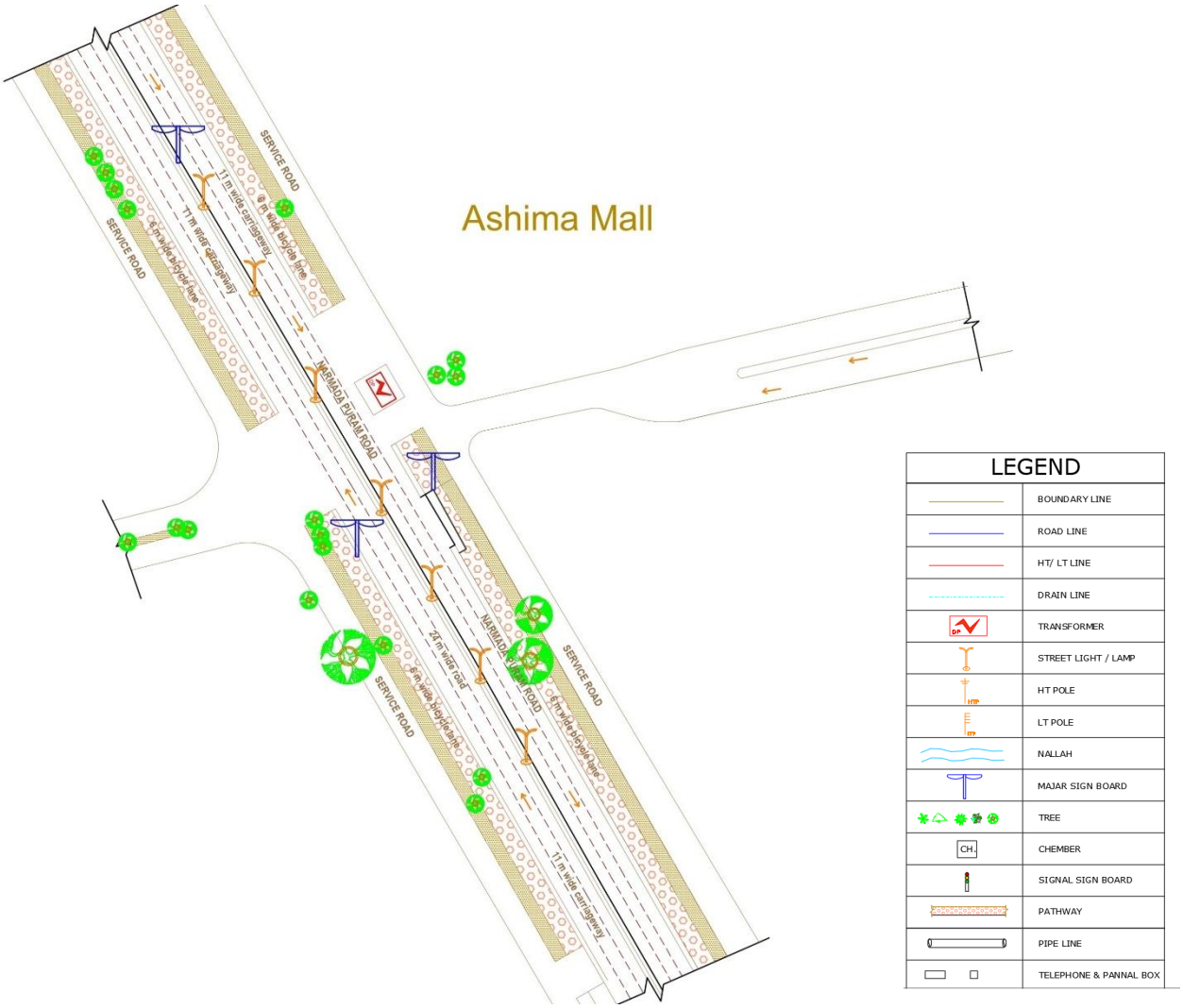


Figure 6 Existing Plan of Ashima Mall Junction

Proposed Interventions

- Development of continuous footpaths along the corridor.
- Provision of raised pedestrian crossings near activity zones.
- Improved carriageway markings and lane organization.
- Channelization of vehicular movement near entry and exit points.
- Green belt development along road edges.
- Removal of roadside encroachments and obstructing structures.
- Enhancement of street lighting and signage systems.

Expected Outcomes

- Improved pedestrian mobility and safety.
- Reduced roadside conflicts and congestion.
- Better access management near commercial areas.
- Enhanced traffic flow efficiency.
- Improved urban streetscape quality.

7. 3 Proposal for Govindpura Turning

Govindpura Turning is a critical turning location where high-speed vehicular movement, improper turning geometry, and insufficient pedestrian facilities contribute to accident occurrence. The turning movement currently lacks proper channelization and safe pedestrian crossing infrastructure. (Annexure)

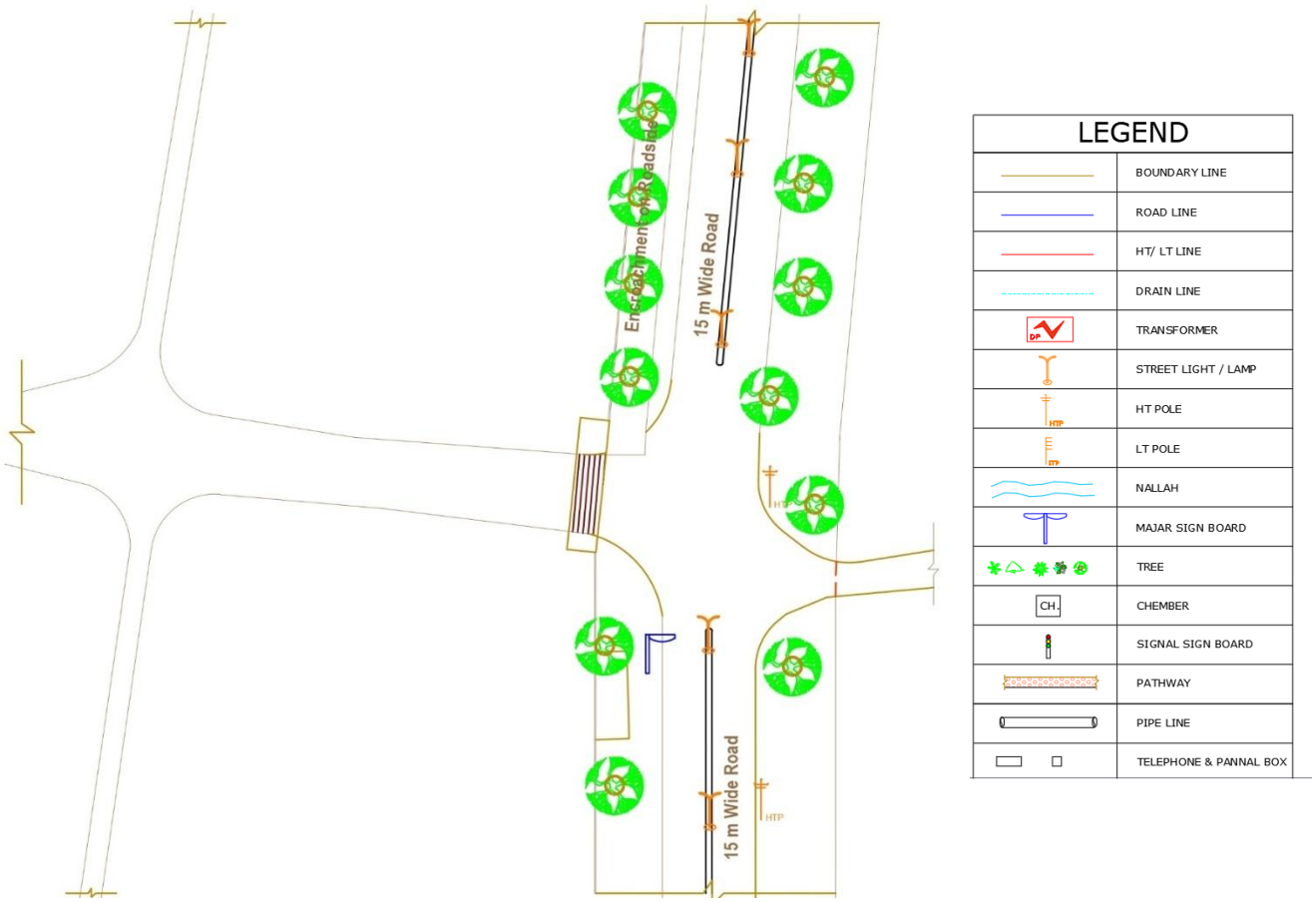


Figure 7Existing Plan of Govind Pura Turning

The proposal emphasizes geometric correction and pedestrian safety enhancement.

Proposed Interventions

- Geometric redesign of the turning radius.
- Provision of dedicated pedestrian crossings.
- Construction of organized footpaths along the road edge.
- Installation of traffic calming elements near turning zones.
- Improved lane markings and directional guidance.
- Green buffer development along the corridor.

Expected Outcomes

- Safer turning movements.
- Reduced risk of side-impact collisions.
- Improved pedestrian accessibility.
- Better traffic organization and reduced speed conflicts.

7. 4 Proposal for Bawadiya Kalan Bridge Corridor

The Bawadiya Kalan Bridge corridor experiences high-speed traffic movement and unsafe merging conditions near connecting roads. Lack of pedestrian facilities and inadequate channelization further increase accident risks.

The proposed plan aims to improve corridor safety through geometric and traffic engineering interventions. (Annexure)

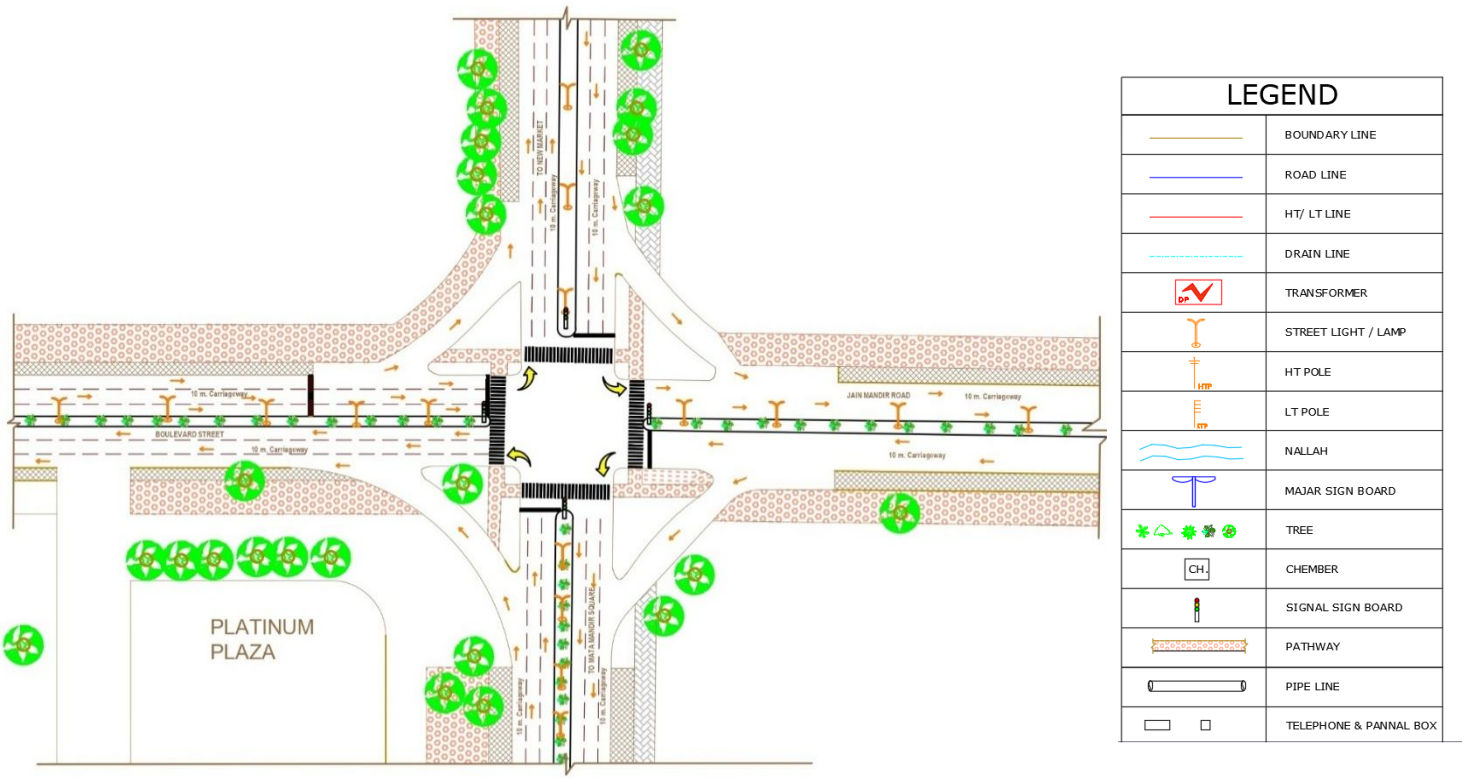


Figure 8 existing plan of Bawadiya Kalan Bridge Corridor

Proposed Interventions

- Channelization of merging traffic movements.
- Development of pedestrian pathways and crossing facilities.
- Introduction of green buffer zones.
- Improvement of road markings and lane segregation.
- Enhancement of visibility through obstruction removal.
- Provision of safer entry and exit geometry near the bridge corridor.

Expected Outcomes

- Reduction in merging conflicts.
- Improved driver visibility and movement guidance.
- Enhanced pedestrian safety.
- Better traffic organization along the corridor.
- Better roadway organization and visibility.

7. 5 Proposal for Platinum Plaza Square

Platinum Plaza Square is an important urban intersection characterized by mixed traffic movement and significant pedestrian activity. The existing junction lacks organized pedestrian crossing facilities and proper traffic calming infrastructure, increasing the probability of accidents.

The proposed intervention aims to create a safer and more organized intersection environment.

Existing Issues

- Unsafe pedestrian crossing conditions.
- Unregulated vehicular turning movements.
- High traffic speed through the intersection.
- Lack of lane discipline and proper road markings.
- Limited pedestrian infrastructure.

Proposed Interventions

- Development of a raised intersection platform for speed control.
- Provision of zebra crossings on all approaches.
- Introduction of channelized turning lanes.
- Footpath and pedestrian pathway improvement.
- Green belt enhancement along the road edges.
- Improvement in lane markings and traffic guidance systems.
- Installation of traffic calming measures near crossing areas.

Expected Outcomes

- Reduced vehicular speed at the intersection.
- Improved pedestrian accessibility and safety.
- Better traffic discipline and movement organization.
- Reduction in conflict points and accident probability.
- Enhanced streetscape and urban environment quality.

7. 6 Proposal for Bawadiya Kalan Bridge Corridor

The Bawadiya Kalan Bridge corridor experiences high-speed vehicular movement and unsafe merging conditions due to improper geometric design and insufficient traffic segregation. The absence of organized pedestrian infrastructure further contributes to unsafe movement conditions.

The proposal focuses on corridor improvement through geometric correction and traffic engineering measures.

Existing Issues

- Unsafe merging and diverging traffic movements.
- High-speed vehicle movement.
- Inadequate pedestrian facilities.
- Poor lane organization and channelization.
- Lack of green buffer and roadside safety elements.

Proposed Interventions

- Geometric redesign of merging areas.
- Channelization of traffic movement through lane segregation.
- Provision of footpaths and pedestrian pathways.
- Development of roadside green buffer zones.
- Improved carriageway markings and directional guidance.
- Removal of roadside obstructions affecting visibility.
- Enhancement of entry and exit geometry near the bridge corridor.

Expected Outcomes

- Safer traffic merging operations.
- Improved traffic flow efficiency.
- Better visibility and movement guidance.
- Enhanced pedestrian safety.
- Reduction in side-swipe and merging collisions.

7. 7 Comparative Assessment of Existing and Proposed Conditions

The comparative assessment of existing and proposed conditions highlights the overall improvement in roadway safety, traffic efficiency, pedestrian accessibility, and intersection management after the implementation of the proposed planning strategies. The assessment has been carried out on the basis of field observations, identified traffic issues, roadway characteristics, and the expected impact of the proposed interventions at major accident black spots in Bhopal.

Under the existing condition, most intersections and corridors were found to have unorganized traffic movement, inadequate pedestrian infrastructure, improper turning geometry, lack of traffic channelization, and insufficient road safety measures. These deficiencies resulted in traffic congestion, unsafe pedestrian crossings, visibility problems, and frequent vehicular conflicts. High-speed movement, mixed traffic conditions, roadside encroachments, and random turning behavior further increased the probability of accidents at these locations.

The proposed condition introduces a more organized and safer transportation environment through the application of traffic engineering and urban planning strategies. Channelized intersections, improved carriageway markings, raised pedestrian crossings, zebra crossings, footpath development, and geometric redesign are expected to regulate vehicular movement and reduce conflict points. The inclusion of traffic calming measures and controlled turning radii will help in reducing vehicle speeds and improving operational efficiency at intersections.

Pedestrian safety is one of the major improvements observed in the proposed condition. Dedicated crossing facilities, raised crossings, and improved footpaths create a safer environment for pedestrians and reduce pedestrian-vehicular conflicts. Similarly, green belt development and streetscape enhancement improve the visual quality of the corridor while also acting as buffer zones between vehicular traffic and pedestrian movement.

The comparative analysis also indicates that the proposed interventions improve visibility conditions and roadway organization by removing roadside obstructions and

introducing proper lane segregation. As a result, traffic discipline and movement efficiency are expected to improve significantly.

Overall, the proposed planning strategies demonstrate a substantial improvement over the existing condition by creating safer, more efficient, pedestrian-friendly, and environmentally responsive urban road corridors. These interventions are expected to reduce accident occurrence, improve traffic operations, and enhance the overall urban mobility system in Bhopal city.

Table 11 Comparative Assessment of Existing and Proposed Conditions

Parameter	Existing Condition	Proposed Condition
Traffic Flow	Congested and unorganized	Regulated and channelized
Pedestrian Infrastructure	Inadequate	Safe and accessible
Turning Movements	Random and conflict-prone	Controlled and organized
Road Safety	High accident risk	Improved safety conditions
Visibility	Obstructed at several locations	Improved sight distance
Streetscape Quality	Poor urban environment	Enhanced through landscaping
Traffic Discipline	Weak lane organization	Proper lane segregation

(Author)

7. 8 Implementation Framework

Immediate Interventions (0–1 Year)

i. Road markings
ii. Signage
iii. Lighting
iv. Speed calming

Short-Term Interventions (1–3 Years)

i. Pedestrian crossings
ii. Refuge islands
iii. Channelization

Long-Term Interventions (3–5 Years)

i. Junction redesign
ii. Grade separation
iii. Corridor improvement

Table 12 Implimentation Framework

Time Frame	Intervention Type
Immediate	Low-cost measures
Short-term	Moderate-cost improvements
Long-term	Major infrastructure

(Author)

7. 9 Conclusion

The proposed planning strategies for the identified accident black spots aim to improve roadway safety, traffic efficiency, and pedestrian mobility within Bhopal city. The interventions focus on geometric improvements, traffic engineering solutions, pedestrian-oriented planning, and environmental enhancement.

Implementation of these proposals can significantly reduce accident risk and improve the operational performance of urban intersections and corridors. The proposed measures also support the development of a safer, more sustainable, and user-friendly urban transportation network in Bhopal.

CHAPTER 8

CONCLUSION AND RECOMMENDATIONS

Road safety has emerged as one of the most critical urban and transportation planning concerns in rapidly urbanizing Indian cities. Increasing motorization, mixed traffic conditions, inadequate roadway infrastructure, and unplanned urban expansion have significantly contributed to the rise of accident-prone locations across urban road networks. Accident black spots represent concentrated zones of severe traffic conflicts where deficiencies in roadway geometry, traffic management, pedestrian infrastructure, and operational control lead to repeated crashes and fatalities.

8.1 Summary of the Study

The study was conducted in two major phases. Phase I focused on understanding the conceptual background, global practices, national guidelines, and existing methodologies related to accident black spot identification and mitigation. A detailed review of literature, IRC standards, MoRTH protocols, international case studies, and planning frameworks was undertaken to understand the evolution of road safety assessment methods and identify research gaps. The study highlighted the transition from traditional frequency-based accident analysis methods toward advanced GIS-based, statistical, and machine-learning approaches.

Phase II focused on the practical application of these concepts in the context of Bhopal city. Multi-source crash data were collected and analyzed using spatial and severity-based approaches to identify accident black spots. The analysis revealed that accident concentration in Bhopal is strongly associated with major intersections, high-speed corridors, commercial activity zones, mixed traffic conditions, and inadequate pedestrian infrastructure. Locations such as Banganga Junction, DB Mall Junction, Platinum Plaza Square, Govindpura Turning, Ashima Mall Corridor, and Bawadiya Kalan Bridge Corridor were identified as critical black spots requiring immediate intervention.

The study further developed location-specific planning proposals involving geometric redesign, traffic channelization, pedestrian infrastructure enhancement, raised crossings, traffic calming measures, footpath development, access management, and green belt

integration. These proposals aimed to create safer and more organized roadway environments while improving overall traffic efficiency.

8.2 Major Findings of the Study

The study identified several important findings related to accident black spots and urban road safety conditions in Tier-II Indian cities:

- Accident black spots are primarily concentrated along major arterial roads, busy intersections, commercial corridors, and highway transition zones.
- Poor roadway geometry, lack of channelization, inadequate pedestrian infrastructure, and mixed traffic movement are major contributors to accident occurrence.
- High-speed vehicular movement combined with unregulated turning behavior significantly increases crash severity.
- Existing planning documents and urban development frameworks inadequately address operational black spot identification and mitigation strategies.
- Most black spot mitigation practices in India continue to rely on reactive approaches rather than proactive safety planning.
- GIS-based spatial analysis and severity indexing are highly effective tools for identifying and prioritizing accident-prone locations.
- Pedestrian safety infrastructure remains insufficient in most identified black spots despite high pedestrian activity levels.
- Traffic engineering interventions such as raised crossings, improved markings, channelization, and traffic calming can substantially improve roadway safety conditions.

8.3 Planning Implications

The findings of the study indicate that accident black spot management should not remain limited only to transportation engineering departments but must become an integral component of urban planning and mobility planning processes. Presently, most statutory planning documents, including Master Plans and Comprehensive Mobility Plans, provide broad mobility goals but lack specific operational frameworks for black spot identification and treatment.

The study demonstrates the need for:

i. Integration of road safety assessment into urban planning frameworks.
ii. Preparation of GIS-based citywide accident databases.
iii. Inclusion of black spot mitigation strategies within mobility plans and road development projects.
iv. Institutional coordination among planning agencies, traffic police, road-owning agencies, and urban local bodies.

Adoption of pedestrian-oriented and safety-sensitive urban street design principles.

The research also highlights the importance of adopting context-sensitive planning approaches for Tier-II cities where rapid urban growth, mixed land use, and increasing vehicular ownership create unique roadway safety challenges.

8.4 Recommendations

Based on the findings and analysis, the following recommendations are proposed:

Engineering Recommendations

- Improvement of intersection geometry and traffic channelization.
- Development of dedicated pedestrian crossings and raised crosswalks.
- Installation of traffic calming measures at high-risk zones.
- Provision of continuous footpaths and pedestrian pathways.
- Enhancement of road signage, lane markings, and street lighting.
- Removal of visual obstructions and roadside encroachments.
- Improvement of merging and turning movements through geometric correction.

Planning Recommendations

- Integration of black spot management within Master Plans and CMPs.
- Preparation of GIS-enabled urban road safety databases.
- Prioritization of pedestrian safety in urban road design.
- Development of standard black spot assessment frameworks for urban local bodies.
- Incorporation of safety audits within transportation infrastructure projects.

Institutional Recommendations

- Strengthening coordination between traffic police, PWD, municipal authorities, and planning agencies.
- Capacity building for GIS-based road safety analysis.
- Improvement of crash data collection systems and geo-referenced accident databases.
- Adoption of evidence-based decision-making for roadway safety interventions.

8.5 Contribution of the Study

The study contributes toward the development of an integrated planning-oriented framework for accident black spot identification and mitigation in Tier-II Indian cities. Unlike conventional approaches that focus primarily on engineering corrections, this research combines urban planning, GIS analysis, traffic engineering, and pedestrian-oriented design strategies.

The proposed framework can assist planners, municipal authorities, transportation agencies, and policymakers in:

Identifying high-risk urban corridors,

- Prioritizing accident-prone locations,
- Developing location-specific mitigation measures,
- Improving pedestrian safety,
- Enhancing urban mobility and traffic efficiency.

The study also helps bridge the gap between urban planning policy and practical roadway safety implementation.

8.6 Scope for Future Research

Although the present study provides a comprehensive planning framework for accident black spot mitigation, several areas require further research:

Integration of machine learning and AI-based crash prediction models.

- Real-time traffic conflict analysis using CCTV and trajectory-based systems.
- Economic evaluation and cost-benefit analysis of black spot treatments.
- Long-term post-implementation monitoring of proposed interventions.

- Development of exposure-based and predictive safety models for Indian urban roads.
- Integration of smart-city technologies with urban road safety systems.

Future research can also focus on comparative analysis across multiple Tier-II cities to develop region-specific planning guidelines for urban road safety improvement.

8.7 Final Conclusion

The study concludes that accident black spots are not isolated traffic engineering problems but are deeply connected with urban growth patterns, transportation planning deficiencies, roadway design limitations, and inadequate pedestrian infrastructure. The increasing complexity of urban mobility in Indian Tier-II cities demands integrated, data-driven, and planning-oriented approaches for improving roadway safety.

The proposed planning strategies demonstrate that significant improvements in traffic safety and operational efficiency can be achieved through relatively practical and location-specific interventions such as channelization, pedestrian prioritization, geometric correction, traffic calming, and streetscape enhancement. The study further establishes that integrating road safety within mainstream urban planning processes is essential for creating safer, more sustainable, and people-oriented urban transportation systems.

Overall, this research provides a comprehensive framework for accident black spot identification, analysis, and mitigation that can support policymakers, planners, and transportation agencies in reducing accident risk and improving safe urban mobility in rapidly developing Indian cities.

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ANNEXURE

Methodology

Proposal Drawings.

Methodology

Topic selection

Planning Strategies for Accident Black Spots

Literature Review

Accident Black Spots
- Definitions
- Identification
- Analysis
- Mitigation

Acts, Guidelines and regulations
- IRC
- MoRTH
- Development plan rules

Gap identified

Need

Research Design

Aim : to identify Accident Black Spot locations through data analysis and propose mitigation strategies. The study integrates traffic engineering principles, geometric improvements, and human factors to enhance road safety and reduce accidents at high-risk locations

Phase 1

Phase 1

Objective 1
To understand history and concept of planning and mitigation of Accident Black Spot.

Outcome: A strong theoretical base that explains why black spots occur and how mitigation evolved.

Objective 2
Tools, techniques and methods to mitigate Accident black Spots.

Outcome: A consolidated typology of identification and mitigation methods to build your framework.

Objective 3
To study and identify the parameters and causes which give rise to Accident black Spot.

Outcome: A parameter list and causal model that will guide data collection and analysis..

Objective 4
To identify authorities involved in planning and management of a road and their role.

Outcome: An institutional framework showing who identifies, who analyses, and who implements black-spot mitigation.

Phase 2

Objective 1
To select a suitable study site within Tier-II cities of India.
Outcome: A justified research site.

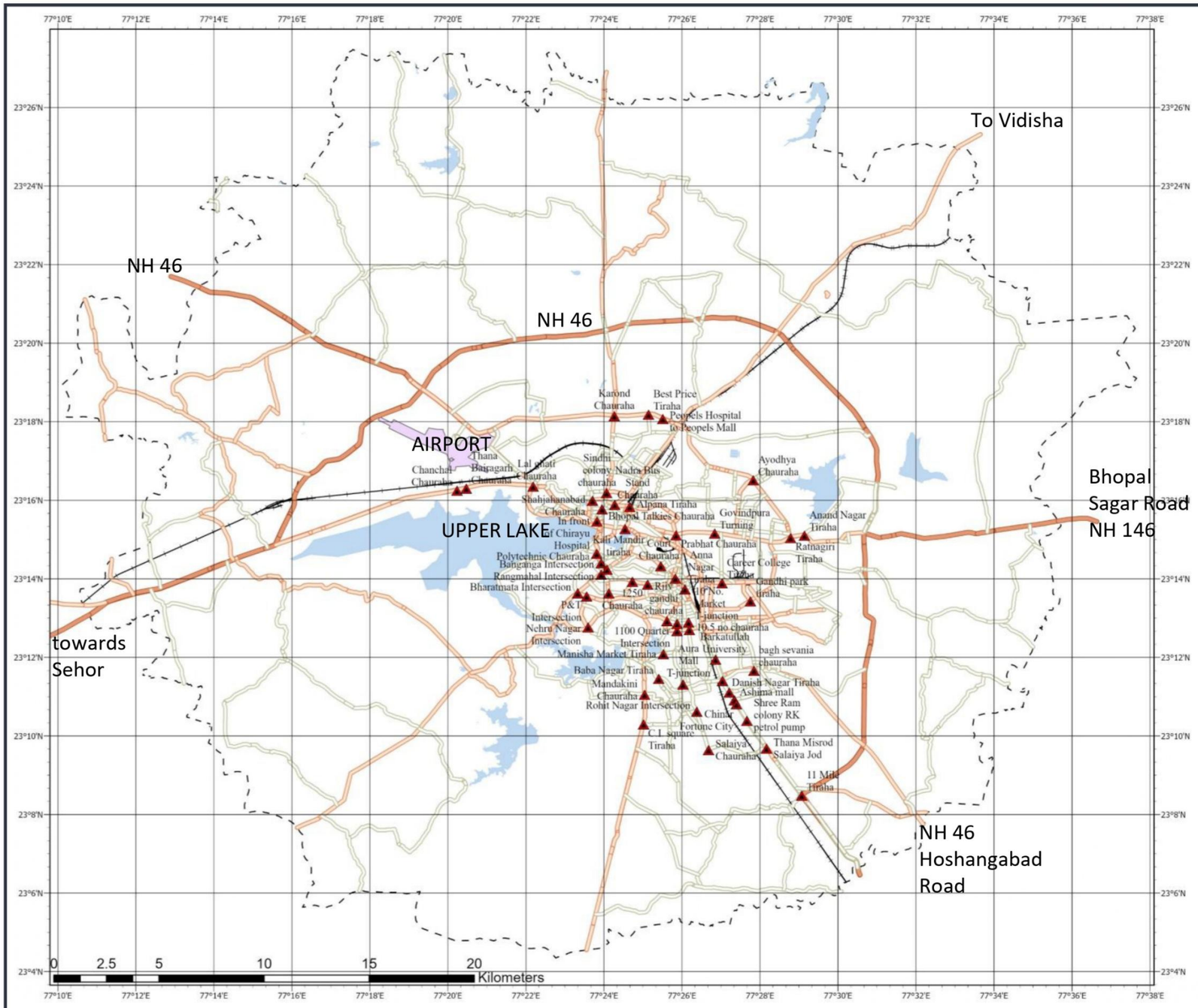
Objective 3
To analyze the collected data and identify suitable countermeasures for mitigating accident black spots.
Outcome: A set of location-specific engineering and behavioral interventions

Objective 2
To conduct field surveys and collect data based on preliminary studies.
Outcome: A complete dataset integrating crash, geometry, traffic, behaviour and land-use parameters.

Objective 4
to develop an institutional and planning framework for the implementation, coordination, and monitoring of accident black spot mitigation measures.
Outcome: An integrated planning framework identifying stakeholder roles, implementation responsibilities, and monitoring mechanisms for effective black spot management.

Locations of Accident Black Spot

These are the officially identified black spots provided by the concerned authorities



Legends

- Highway
- Major Roads
- Minor Roads
- Location of ABS
- Railway track
- Airport
- Water Body
- City Boundary

N

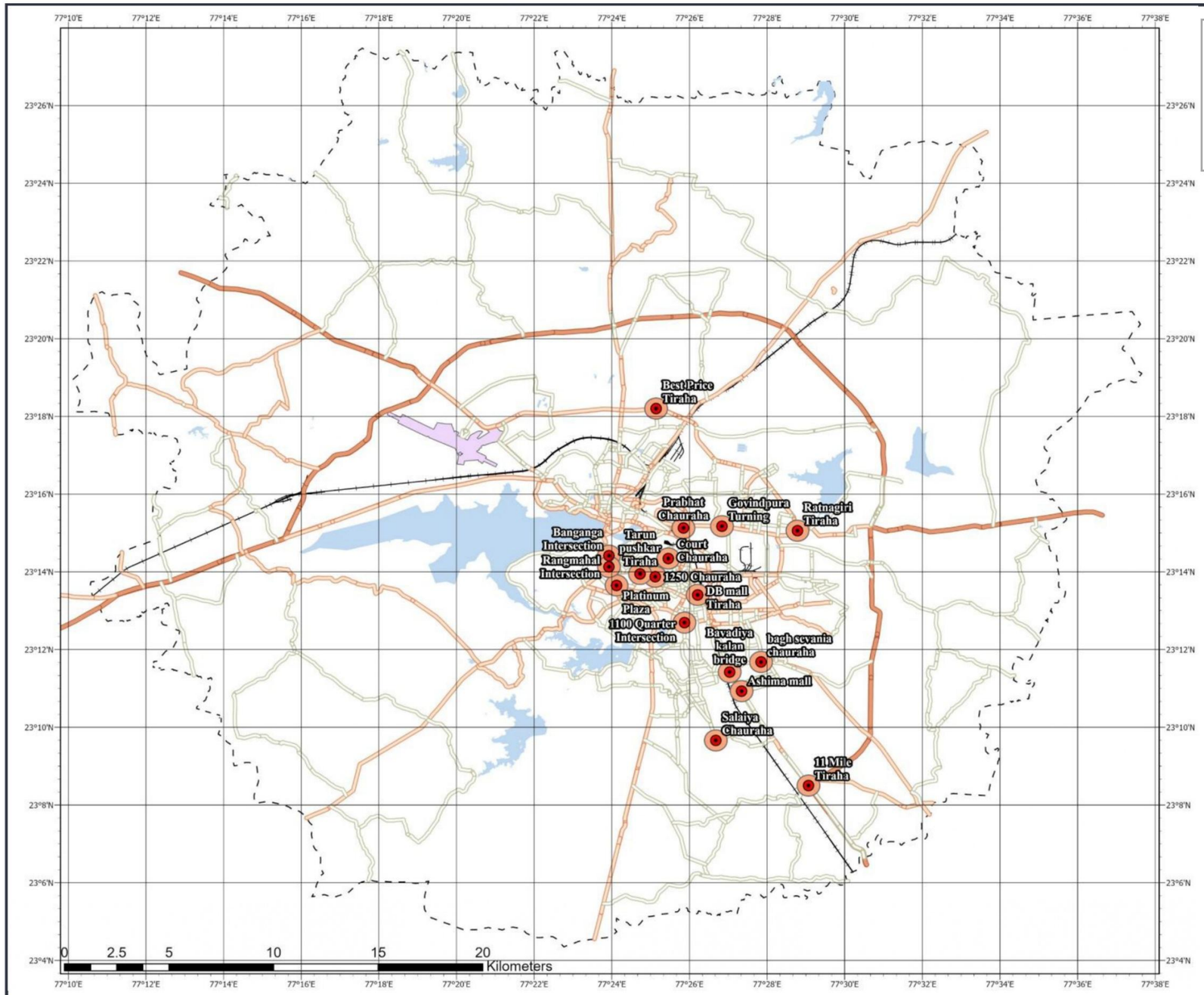
Source :- Author

2

Priority Spots with Impact Area

Buffer - 500m

This map represents the buffer analysis of identified accident black spots across Bhopal city. Each junction is surrounded by a defined buffer zone, which helps in understanding its area of influence and impact on surrounding road networks.



Legends

- Highway
- Major Roads
- Minor Roads
- Priority Spots
- Railway track
- Impact area
- Airport
- Water Body
- City Boundary

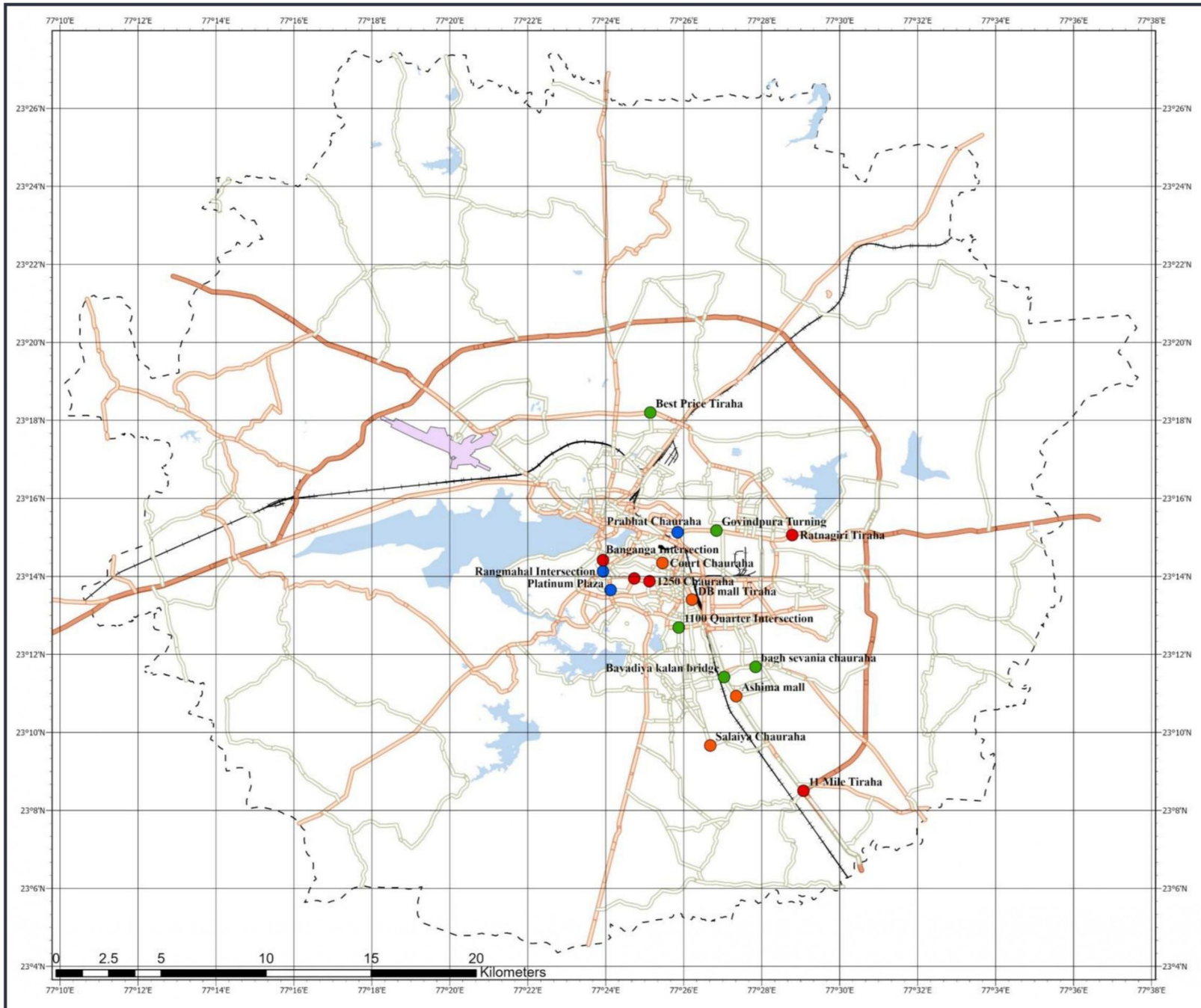
Source :- Author

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3

Identified Key issued

Different areas show different dominant issues, requiring location-specific solutions



Legends

Issues

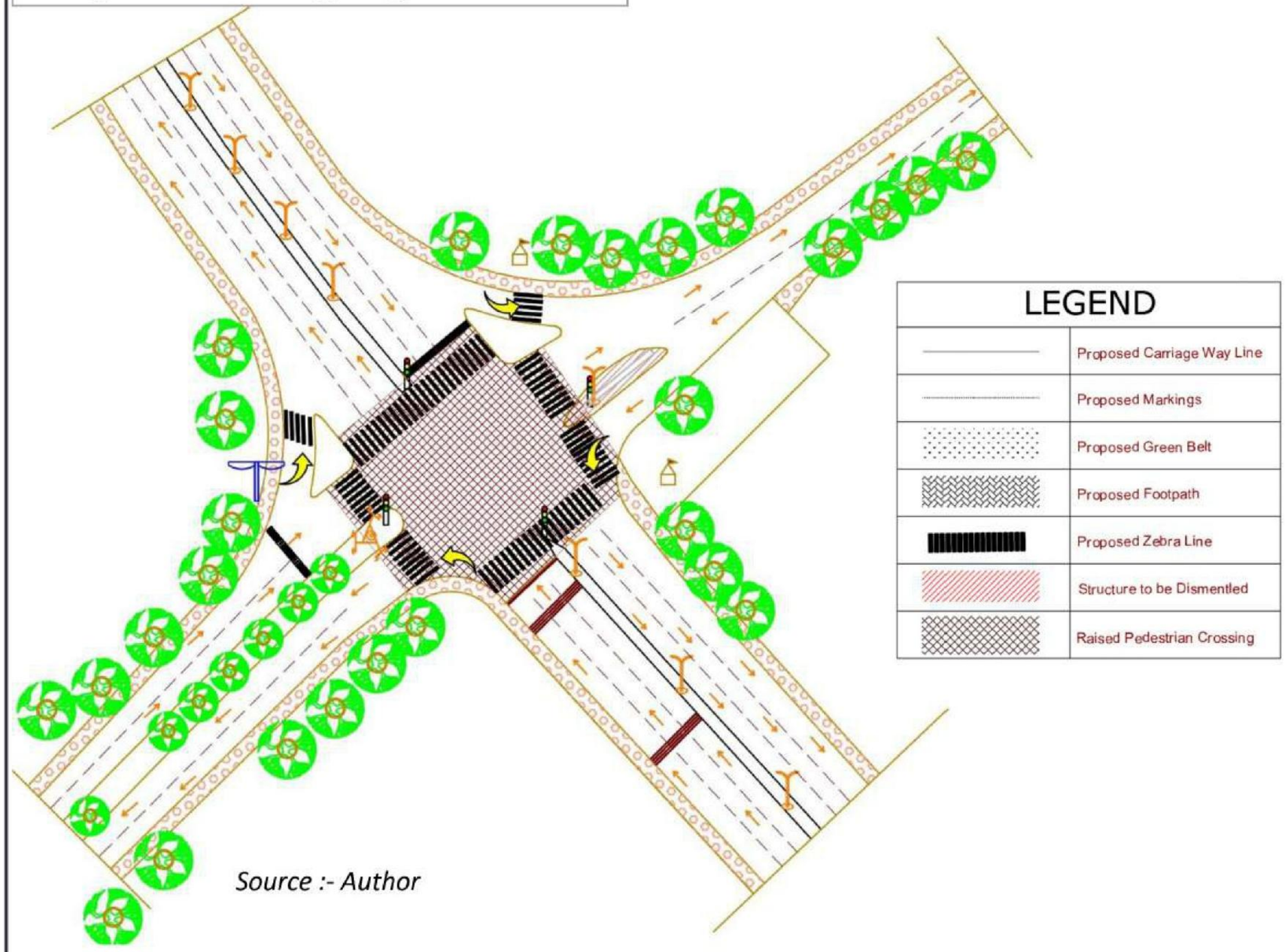
- Geometric Improvement
- Pedestrian Improvement
- Traffic Management
- Speed Management
- Highway
- Major Roads
- Minor Roads
- Railway track
- Water Body
- Airport
- City Boundary

N

Source :- Author

4

Proposal:- Banganga Junction



Proposed Interventions

- Introduction of a raised central intersection island for movement regulation.
- Provision of raised pedestrian crossings to reduce vehicular speed.
- Improvement of turning radii for smoother vehicle movement.
- Removal of obstructing roadside structures to improve visibility.

Expected Outcomes

- Reduction in vehicle conflict points.
- Improved pedestrian safety.
- Better lane discipline and traffic regulation.
- Reduction in congestion and random turning movements.
- Enhanced intersection visibility and operational efficiency.

N

5

Proposal:- Govindpura Turning



Source :- Author

Proposed Interventions

- Geometric redesign of the turning radius.
- Provision of dedicated pedestrian crossings.
- Provision for traffic signals.
- Construction of organized footpaths along the road edge.
- Improved lane markings and directional guidance.
- Green buffer development along the corridor.

Expected Outcomes

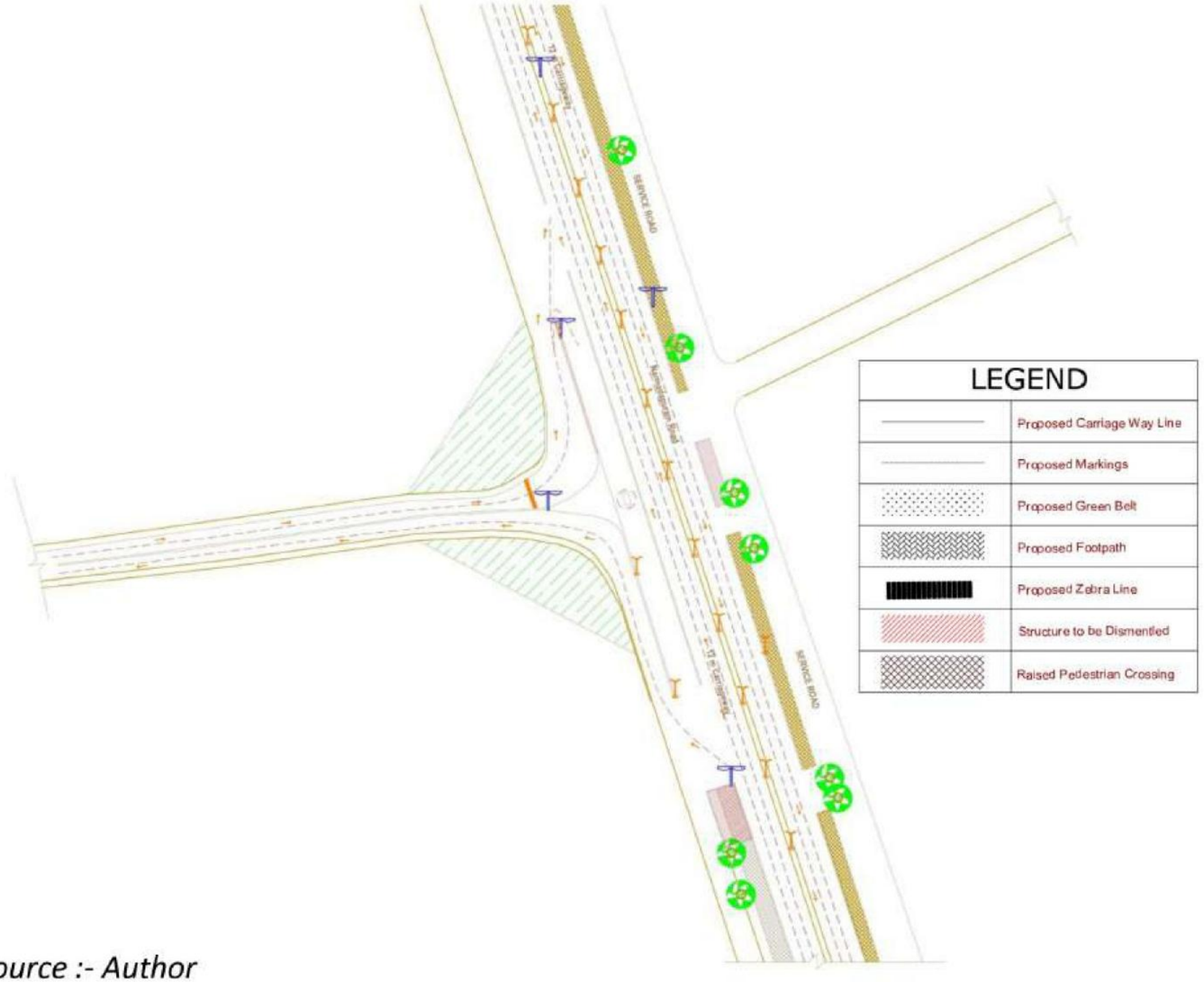
- Safer turning movements.
- Reduced risk of side-impact collisions.
- Improved pedestrian accessibility.
- Better traffic organization and reduced speed conflicts.

LEGEND	
	Proposed Carriage Way Line
	Proposed Markings
	Proposed Green Belt
	Proposed Footpath
	Proposed Zebra Line
	Structure to be Dismentled
	Raised Pedestrian Crossing

N

6

Proposal Bawadiya Kalan Bridge



Source :- Author

Proposed Interventions.

- Channelization of vehicular movement using medians and separators.
- Provision of organized zebra crossings.
- Improvement in carriageway markings and lane segregation.
- Pedestrian-friendly pathways and crossing facilities.
- Controlled turning geometry to minimize conflict points.
- Access management near adjoining roads and activity zones

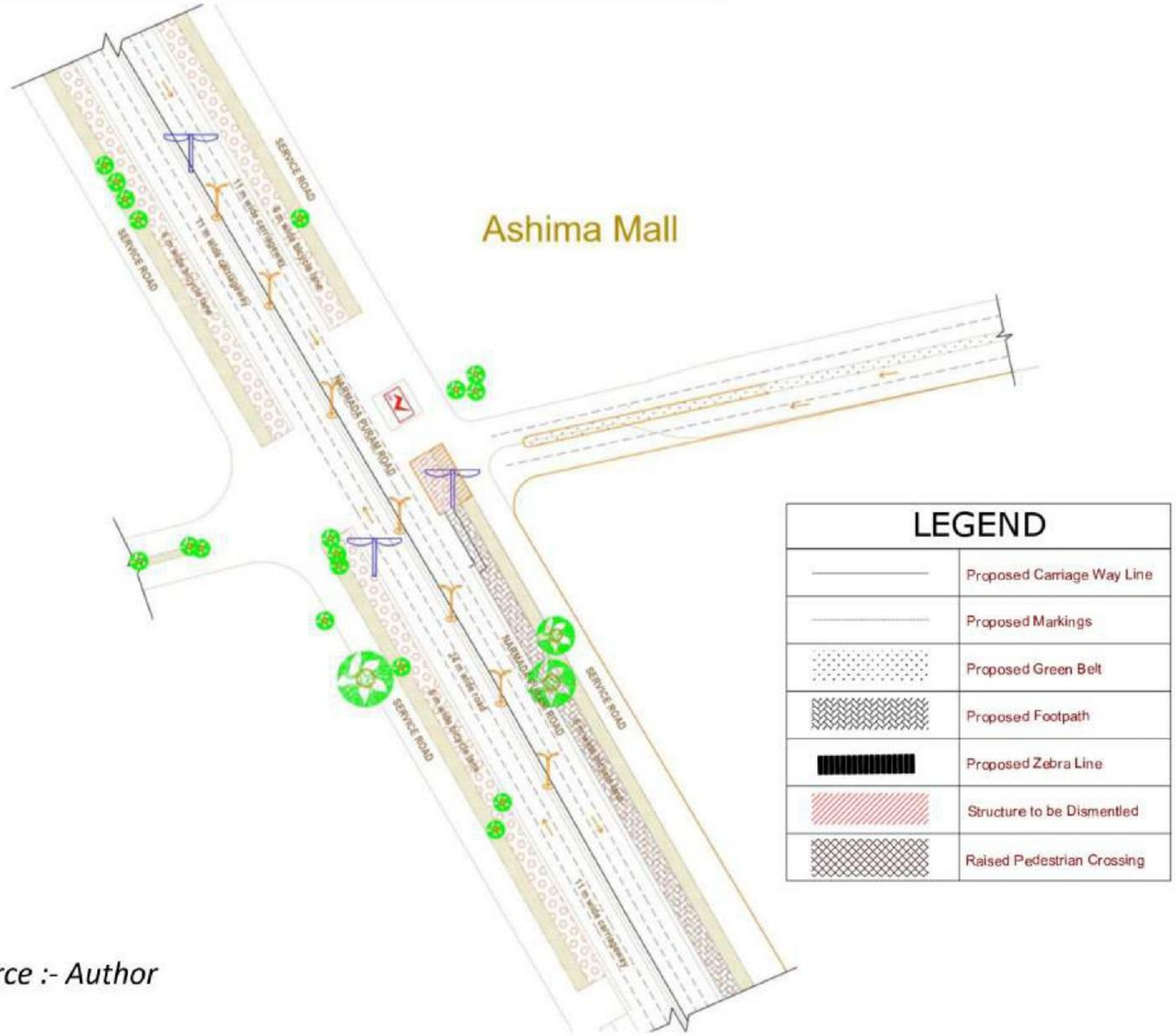
Expected Outcomes

- Reduction in traffic congestion and intersection delay.
- Improved traffic circulation and movement efficiency.
- Enhanced pedestrian safety.
- Reduction in random vehicular turning conflicts.
- Better roadway organization and visibility.

N

7

Proposal:- Ashima Mall Junction



LEGEND	
	Proposed Carriage Way Line
	Proposed Markings
	Proposed Green Belt
	Proposed Footpath
	Proposed Zebra Line
	Structure to be Dismentled
	Raised Pedestrian Crossing

Source :- Author

Proposed Interventions

- Development of continuous footpaths along the corridor.
- Improved carriageway markings and lane organization.
- Channelization of vehicular movement near entry and exit points.
- Green belt development along road edges.
- Removal of roadside encroachments and obstructing structures.
- Enhancement of street lighting and signage systems.

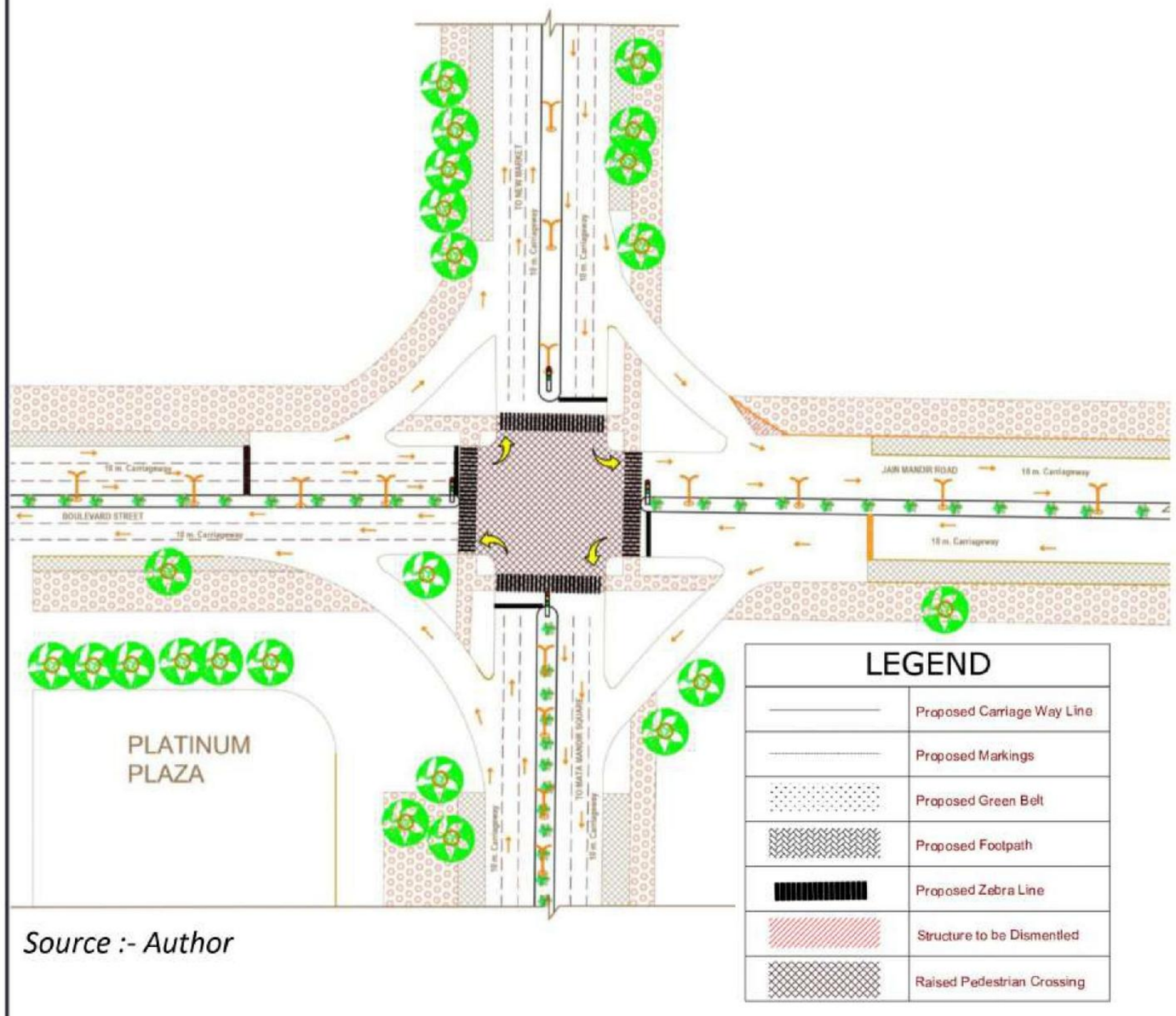
Expected Outcomes

- Improved pedestrian mobility and safety.
- Reduced roadside conflicts and congestion.
- Better access management near commercial areas.
- Enhanced traffic flow efficiency.
- Improved urban streetscape quality.

N

8

Proposal: Platinum Plaza square



Source :- Author

Proposed Interventions

- Development of a raised intersection platform for speed control.
- Provision of zebra crossings on all approaches.
- Footpath and pedestrian pathway improvement.
- Improvement in lane markings and traffic guidance systems.
- Installation of traffic calming measures near crossing areas.

Expected Outcomes

- Safer turning movements.
- Reduced risk of side-impact collisions.
- Improved pedestrian accessibility.
- Better traffic organization and reduced speed conflicts.

N

9