

**PEDESTRIAN INFRASTRUCTURE FOR VULNERABLE
ROAD USERS IN BHOPAL CITY:A BLACK SPOT CASE
STUDY**

Bachelor of Planning

SAGAR SAHU

2211002135



Department of Architecture and Planning
Maulana Azad National Institute of Technology, Bhopal

MAY-2026

PEDESTRIAN INFRASTRUCTURE FOR VULNERABLE ROAD USERS IN BHOPAL CITY: A BLACKSPOT CASE STUDY

*A Thesis Project
submitted in partial fulfilment of the requirements for
The award of the degree of*

Bachelor of Planning

By
SAGAR SAHU
Scholar No. 2211002135

Under the Guidance of
Dr. Anuj Jaiswal



**Department of Architecture and Planning
Maulana Azad National Institute of Technology, Bhopal**

MAY 2026

DECLARATION

I **SAGAR SAHU**, Scholar No **2211002135** hereby declare that the thesis titled **pedestrian infrastructure for vulnerable road users in Bhopal city: a blackspot case study** submitted by me in partial fulfilment for the award of degree of Bachelor of Planning, at Maulana Azad National Institute of Technology, Bhopal, India, is a record of Bonafide work carried out by me. The matter/result embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

Signature of the Student
Date: _____

CERTIFICATE

This is to certify that the declaration made by **SAGAR SAHU** is true to the best of my knowledge and that the student has worked under my guidance for one semester in preparing this thesis.

RECOMMENDED

Signature of the Guide
(Dr. Anuj Jaiswal)

Signature of
Head, Department of
Architecture and Planning
(Dr. Nakul Dhagat)
Date: _____
Place: _____

Signature of
Thesis Coordinators,
Department of Architecture and
Planning
(Dr. Preeti Onkar &
Dr. Premjeet Das Gupta)
Date: _____
Place: _____

सारांश

यह अध्ययन भोपाल शहर में पैदल यात्रियों, विशेष रूप से **कमजोर सड़क उपयोगकर्ताओं** (बच्चे, बुजुर्ग और दिव्यांग) के लिए सुरक्षित और सुलभ बुनियादी ढांचे के विकास हेतु नियोजन एवं डिज़ाइन रणनीतियों पर केंद्रित है। तीव्र शहरीकरण और उच्च मोटरवाहन वृद्धि के कारण पैदल यात्रियों के लिए जोखिम बढ़ा है, जिसकी पहचान हेतु भोपाल के पाँच सबसे गंभीर **ब्लैक स्पॉट्स** – 11 मील मिसरोड, प्लैटिनम प्लाजा, रत्नागिरी टी-पॉइंट, अशीमा मॉल तथा गोविंदपुरा ISBT – का चयन किया गया है।

शोध में एक एकीकृत दृष्टिकोण अपनाया गया है, जिसमें तीन वर्षों (2023–25) के दुर्घटना डेटा का सांख्यिकीय विश्लेषण, **IRC:103/35/99** मानकों के आधार पर बुनियादी ढांचा ऑडिट, GIS-आधारित 500 मीटर बफर भू-उपयोग विश्लेषण तथा 150 उत्तरदाताओं का धारणा सर्वेक्षण (VRU Perception Survey) शामिल है। विश्लेषण के प्रमुख निष्कर्षों में पाया गया कि इन स्थानों पर औसत **IRC अनुपालन केवल 11%** है और पैदल यात्री सेवा स्तर (**PLOS**) ग्रेड 'E' या 'F' (अत्यंत खराब) की श्रेणी में आता है।

इसके आधार पर, अध्ययन में **IRC-मानकों के अनुरूप** विशिष्ट डिज़ाइन हस्तक्षेप प्रस्तावित किए गए हैं, जिनमें निरंतर फुटपाथ (1.8 मीटर - 2.5 मीटर), सुरक्षित रिफ्यूज आइलैंड, टेबल-टॉप गति अवरोधक, स्पर्शनीय फ़र्श (Tactile Paving), पैदल यात्री सिग्नल और सौर-आधारित स्ट्रीट लाइटिंग शामिल हैं। प्राथमिकता मैट्रिक्स के माध्यम से **प्लैटिनम प्लाजा** (स्कोर: 20/20) और **11 मील मिसरोड** को तत्काल हस्तक्षेप हेतु सर्वोच्च प्राथमिकता दी गई है।

यह शोध कैचमेंट-आधारित और संदर्भ-संवेदनशील दृष्टिकोण पर बल देता है, जहाँ सुरक्षा सुधारों को भू-उपयोग (जैसे स्कूल, अस्पताल और परिवहन केंद्र) के साथ एकीकृत किया गया है। अध्ययन के कार्यान्वयन से दुर्घटनाओं में **40-60% की कमी**, बेहतर रात्रि दृश्यता और सभी आयु समूहों के लिए समावेशी गतिशीलता सुनिश्चित करने का लक्ष्य रखा गया है। यह मॉडल भोपाल के अन्य क्षेत्रों और भविष्य के शहरी नियोजन के लिए एक आधारभूत मार्गदर्शिका के रूप में कार्य कर सकता है।

ABSTRACT

This thesis develops a planning framework for pedestrian infrastructure targeting Vulnerable Road Users (VRUs) – children, elderly, and disabled persons – at five critical black spots in Bhopal, Madhya Pradesh. The study focuses on: 11 Mile Misrod (high-speed bypass), Platinum Plaza (signal-defunct intersection with geometric defect), Ratnagiri T-Point (encroached junction), Ashima Mall Crossing (forced jaywalking due to unbroken median), and Govindpura ISBT (underutilised Foot Over Bridge due to desire-line mismatch).

A convergent mixed-methods design was adopted, combining quantitative analysis (accident data from BSCDCL/Bhopal Traffic Police, 2023-2025; pedestrian volume counts; IRC compliance audit across seven parameters) with qualitative methods (VRU perception survey, N=150; photographic documentation; GIS-based land use mapping with 500 m buffers). The audit revealed systemic non-compliance: average IRC compliance 11%, zero tactile paving, zero functional pedestrian signals, zero speed control measures. PLOS (Pedestrian Level of Service) grades range from F (11 Mile, Platinum Plaza, Ratnagiri) to E (Ashima Mall, Govindpura ISBT). A weighted priority matrix (accident severity

+ infrastructure gap + land use vulnerability + PLOS grade) ranked Platinum Plaza as highest urgency (score 20/20), followed by 11 Mile Misrod and Govindpura ISBT (17/20).

Based on the evidence, the thesis proposes phased, IRC-compliant, context-sensitive design interventions across four phases: Phase 1 (0-3 months) – emergency signal restoration, retroreflective zebra markings, temporary lighting, guardrails; Phase 2 (3-12 months) – footpath construction/widening, tactile paving, kerb ramps, refuge islands; Phase 3 (1-3 years) – geometric redesign, raised crossings, school zone calming, Leading Pedestrian Intervals; Phase 4 (3-5 years) – smart signal integration, grade separation feasibility, accessible FOB upgrades. Expected outcomes include 40-70% fatality reduction, PLOS improvement to C-D grades, and elimination of forced jaywalking. The study contributes the first multi-site, VRU-centred, IRC-benchmarked black spot analysis for Bhopal, with replicable methodology for other tier-2 Indian cities.

Keywords: Pedestrian safety, black spots, IRC:103, vulnerable road users, PLOS, Bhopal.

ACKNOWLEDGEMENT

I extend my deepest gratitude to all those who have supported me throughout this journey of completing my thesis titled " pedestrian infrastructure for vulnerable road users in bhopal city : a blackspot case study."

First and foremost, I am profoundly thankful to my guide, **Dr. Anuj Jaiswal**, for her unwavering guidance, insightful feedback, and invaluable suggestions that have significantly enriched my research. Her expertise, encouragement, and patience have been instrumental in overcoming the challenges of this study.

I am also sincerely grateful to the Department of Architecture and Planning at the Maulana Azad National Institute of Technology (MANIT), Bhopal, for providing me with the necessary resources and a stimulating academic environment to undertake this research.

Furthermore, I extend my heartfelt appreciation to my family and friends for their unwavering support, understanding, and encouragement. Their constant motivation has been my source of strength, keeping me focused and determined. Lastly, I acknowledge the invaluable resources and institutional support that have been essential in successfully completing this dissertation. My deepest gratitude goes to everyone who contributed to making this work possible.

SAGAR SAHU

Scholar No: 2211002135

Guided by:

Dr. Anuj Jaiswal

Department of Architecture and Planning

Maulana Azad National Institute of Technology, Bhopal

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List of Abbreviation

Abbreviation	Full Form
AADT	Annual Average Daily Traffic
AMRUT 2.0	Atal Mission for Rejuvenation and Urban Transformation 2.0
BMC	Bhopal Municipal Corporation
BRTS	Bus Rapid Transit System
BSCDCL	Bhopal Smart City Development Corporation Limited
CMF	Crash Modification Factor
DPR	Detailed Project Report
FOB	Foot Over Bridge
GIS	Geographic Information System
IRC	Indian Roads Congress
ISBT	Inter-State Bus Terminal
ITMS	Intelligent Traffic Management System
LPI	Leading Pedestrian Interval
MoRTH	Ministry of Road Transport and Highways
NMT	Non-Motorised Transport
PCU	Passenger Car Unit
PLOS	Pedestrian Level of Service
RPWD Act 2016	Rights of Persons with Disabilities Act 2016
VRU	Vulnerable Road User
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Introduction and Background

Bhopal, the capital city of Madhya Pradesh, is one of the fastest-growing urban centres in central India. With a population that has crossed eighteen lakh according to the 2011 Census and a registered vehicle fleet that has grown past one and nine-tenths of a million by 2025, the city captures within its boundaries the dual face of contemporary Indian urbanisation: rapid motorisation on one side, and a persistent shortfall in pedestrian infrastructure on the other. Over the past decade Bhopal has seen substantial investment in road capacity — the six-lane corridor along Kolar Road, the eight-lane expansion of the Ayodhya Bypass, the still-under-construction metro rail project — and yet the most ordinary requirement of any urban citizen, the ability to walk safely along a street, remains critically underprovided.

Among all road users, pedestrians bear the greatest physical risk. Without the protective shell of a vehicle around them, a person on foot is exposed directly to whatever impact a collision delivers. The World Health Organization in its 2023 Global Status Report observed that road traffic injuries are the leading cause of death among young people across the world; in India, pedestrian fatalities account for nearly twenty per cent of all road deaths according to the Ministry of Road Transport and Highways. Bhopal mirrors this national crisis closely. According to the BSCDCL Road Safety Preparedness Report, the city recorded approximately 2,900 road accidents and 235 fatalities in 2024 alone, with pedestrians making up a disproportionate share of those killed.

Within this broader concern, the present study narrows in on a particular sub-population that road safety literature has long identified as bearing the heaviest brunt of poor pedestrian environments: the Vulnerable Road User. The term VRU, as it appears in IRC standards and in international road safety frameworks, gathers together those whose physical or sensory characteristics make them less able to cope with traffic conflicts. It includes children up to the age of fourteen, elderly persons aged sixty and above, persons with disabilities of various kinds, and users of non-motorised transport such as cyclists and handcart operators. What links these groups is not their age or condition in isolation but the structural mismatch between their capacities — slower walking speeds, reduced reaction times, partial sensory information, behavioural unpredictability around fast-moving vehicles — and a roadway environment that has been designed almost entirely around the assumed reflexes of the able-bodied adult driver.

Compounding this vulnerability is the fact that pedestrian accidents do not distribute themselves evenly across a city's network. They cluster, often quite sharply, at specific recurrent locations that are commonly described as 'black spots' or accident-prone locations. The Indian Roads Congress and the Ministry of Road Transport and Highways define a black spot as a road section or intersection where at least five accidents resulting in injury or death have occurred within a three-year window, or alternatively where three or

more fatal accidents have been recorded in the same period. Such locations almost invariably show a recognisable mix of features: geometric deficiencies, missing or degraded pedestrian infrastructure, adverse adjacencies in the surrounding land use, and weak or absent signal management. In Bhopal the BSCDCL has identified more than fifty such black spots across the municipal area, and from this list five were selected for the present study on the basis of accident frequency, VRU exposure, and geographic spread.

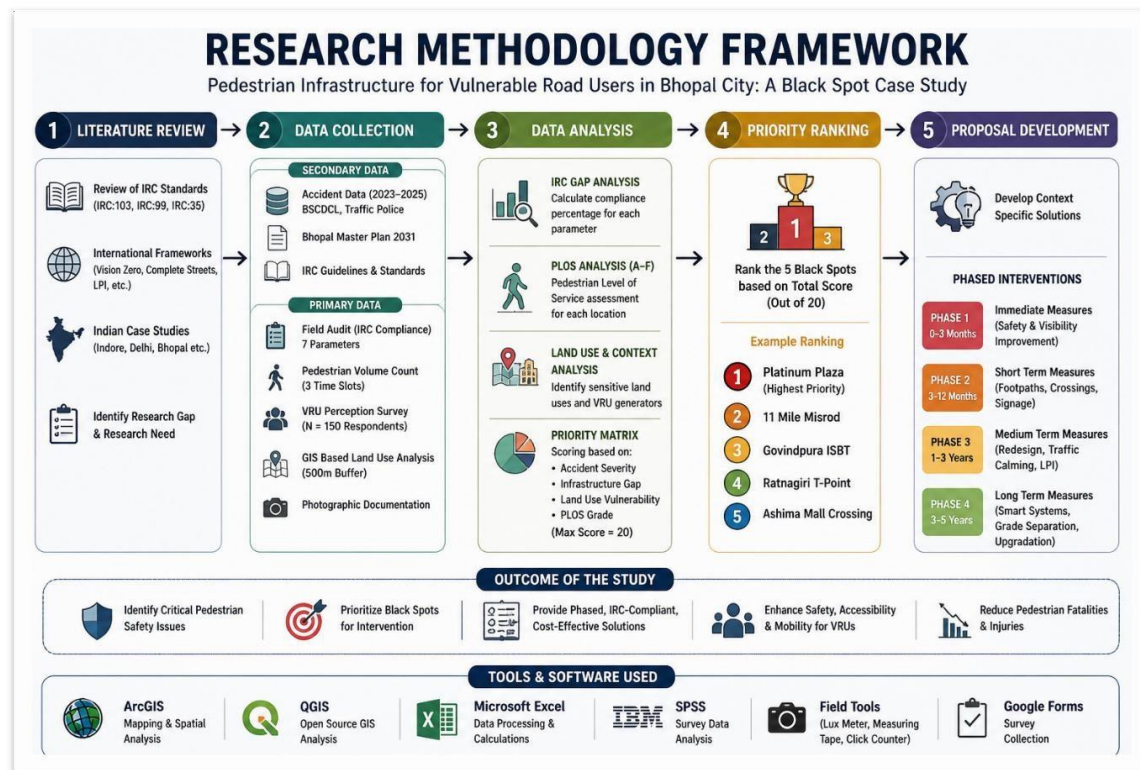


Figure 1.1: Research methodology framework — the five-stage workflow underlying this study

The five locations that form the empirical core of this thesis are: 11 Mile Misrod, a high-speed bypass corridor with no pedestrian infrastructure of any kind; Platinum Plaza Square on Atal Path, a major commercial intersection where the traffic signals have been defunct for over a year and where a downhill geometric slope feeds into a blind curve; Ratnagiri T-Point in Piplani, a residential-commercial junction whose footpath has been almost entirely consumed by vendor stalls and parked motorcycles; Ashima Mall Crossing in Misrod, where a continuous and unbroken median compels pedestrians into illegal barrier-jumping in order to reach the mall entrance directly opposite the residential side; and Govindpura ISBT Turn, a high-footfall transit hub where infrastructure does exist in the form of a Foot Over Bridge but is rejected by ninety per cent of users on account of its misalignment with the actual pedestrian desire line.

This thesis positions itself at the intersection of urban planning, road safety, and inclusive design. Rather than treating pedestrian infrastructure as something to be added once the carriageway and the signal

layout have been settled — an engineering afterthought — it argues for a planning approach that begins from the perspective of the most vulnerable user of the street and works outwards. The IRC framework already provides the technical specifications. What this study aims to demonstrate, with respect to Bhopal, is the magnitude of the gap between code and reality, and to translate that observation into a sequenced, costed, and institutionally locatable plan for closing the gap.

1.2 Need for the Study

The case for undertaking this particular investigation rests on three converging realities of Bhopal's road environment. The first is statistical. The city's pedestrian fatality share has remained obstinately high through the period under study: pedestrians accounted for 36.7 per cent of all road deaths in 2023, 29.3 per cent in 2024, and an estimated 28.9 per cent in 2025. These figures sit well above the national pedestrian fatality share of around twenty per cent reported by MoRTH, even after Bhopal's Smart City designation and the associated infrastructure spend. A statistical pattern of this kind, sustained over multiple years and stable across changes in the headline accident count, points not to a behavioural problem on the part of pedestrians but to a structural problem in the physical environment they are required to negotiate.

The second reality is observational. A field audit conducted at all five black spot locations during March and April of 2026 confirmed that not a single one of the five fully complies with even the basic provisions of IRC:103:2012 — the national guideline on pedestrian facilities. Footpath widths fall short, often dramatically; tactile paving is universally absent; pedestrian signals are either non-existent or have been allowed to fall into disrepair; and crossings, where they are marked at all, have lost almost all of their reflective paint. Any individual deficiency might be explained by local circumstance; the universality of the deficiency across five sites in different parts of the city, with different land uses and different administering authorities, makes the case that what is being observed is a system-wide failure rather than five coincidental ones.

The third reality is the spatial coincidence between the black spots and the city's principal generators of vulnerable pedestrian movement. A 500-metre buffer mapped around each location reveals that these are not arbitrary stretches of road. They sit within easy walking distance of schools, hospitals, markets, and bus terminals — exactly the categories of land use that pull children, the elderly, and the unwell out into the road environment. The risk concentration that produces the accident cluster is, in this sense, a predictable consequence of the underlying geography. Any honest planning intervention has to begin by acknowledging that the people most often killed at these locations are not random victims but populations whose presence on the street is fully foreseeable.

Existing black spot studies for Bhopal — those undertaken by BSCDCL itself, and a smaller body of academic work by faculty at the School of Planning and Architecture and at MANIT — have concentrated

mostly on vehicular accident remediation. The interventions proposed have tended to focus on median corrections, signage upgrades, and lane markings, all of which address the conditions experienced by drivers. Pedestrian-specific interventions, and especially those calibrated to the particular needs of vulnerable sub-groups, have been largely absent from the official remediation record. The present study sets out to fill this gap by providing a comprehensive planning framework grounded in primary data, aligned with the IRC standards, and informed by internationally tested design strategies for inclusive pedestrian environments.

1.3 Aim of the Study

The aim of this thesis is to propose IRC-compliant pedestrian infrastructure designs for Vulnerable Road Users at five critical black spot locations in Bhopal city. The proposals are to be developed on the basis of accident data analysis, field-based infrastructure audits, pedestrian volume surveys, and a structured assessment of VRU perception, and are to be presented in a phased and implementable form.

1.4 Objectives of the Study

From the aim, five specific objectives have been derived:

- To identify and profile five critical pedestrian accident black spots in Bhopal using BSCDCL and Bhopal Traffic Police data for 2023 to 2025, and to apply a weighted severity index that ranks them in order of accident concentration.
- To assess the compliance of existing pedestrian infrastructure — specifically footpaths, crossings, lighting, signage, and speed control — at each black spot against the provisions of IRC:103:2012, IRC:35:2015, and IRC:99:2018, using a structured gap analysis framework.
- To analyse land use within a 500-metre buffer around each black spot and to determine Pedestrian Level of Service grades for each site using a composite scoring method that combines infrastructure, environment, and perception inputs.
- To develop a weighted priority ranking matrix that integrates accident severity, IRC non-compliance, land-use vulnerability, and PLOS grade in order to determine the sequence in which interventions should be undertaken.
- To propose context-sensitive, IRC-compliant, phased design interventions for each location, supported by AutoCAD schematic drawings and SketchUp three-dimensional conceptual models.

1.5 Research Questions

The objectives translate into the following set of research questions, which the study attempts to answer in the chapters that follow:

- Which five locations within Bhopal exhibit the highest concentration of pedestrian accidents involving VRUs, and what are the primary geometric and infrastructural deficiencies at each site?
- How does the existing pedestrian infrastructure at these locations measure up against the provisions of IRC:103:2012, IRC:35:2015, and IRC:99:2018?
- What is the nature and intensity of land use within a 500-metre radius of each black spot, and in what manner does this land use elevate VRU exposure to traffic risk?
- In what order should interventions be prioritised across the five locations, and at what implementation phases should each tier of intervention be undertaken?
- What specific physical design proposals are most likely to reduce pedestrian risk at each location, while remaining contextually appropriate and financially feasible within the institutional environment of the Bhopal Municipal Corporation and BSCDCL?

1.6 Study Area

The study area covers five discrete black spot locations distributed across the Bhopal Municipal Corporation limits. The five sites span three administrative zones — Zone 11 (TT Nagar and Misrod), Zone 12 (Piplani), and Zones 15 and 16 (Govindpura and Misrod Bypass) — and represent a deliberate cross-section of urban morphologies, including commercial corridors, residential junctions, transit hubs, and highway bypasses. Their geographical spread, from the northern Govindpura cluster down to the south-eastern periphery at 11 Mile Misrod, ensures that the study's findings reflect the diversity of Bhopal's road environment rather than the conditions of any single neighbourhood.

1.7 Scope of the Study

The study has been bounded by the following scope parameters:

- Geographic scope: five identified black spots within Bhopal Municipal Corporation limits.
- Thematic scope: physical pedestrian infrastructure — footpaths, crossings, signals, lighting, signage, and speed control measures. Behavioural and enforcement aspects are noted where relevant but are not the primary subject of quantitative analysis.
- Demographic scope: emphasis throughout is on Vulnerable Road Users — children up to fourteen years of age, the elderly aged sixty and above, and persons with disabilities. The general adult pedestrian population is also surveyed for comparison.
- Temporal scope: accident data covers the three-year period from 2023 to 2025. Primary field surveys were conducted in March and April of 2026, spanning the late winter and early summer

seasons.

- Design scope: the proposals presented in Chapter 6 are conceptual and IRC-compliant in their schematic form. Detailed structural engineering, underground utility mapping, and construction-level cost estimation are beyond the scope of this thesis.

1.8 Methodology Overview

The study adopts a mixed-method research design that integrates quantitative and qualitative streams. Quantitative inputs include accident statistics, manual pedestrian counts, and IRC compliance scoring. Qualitative inputs include structured perception surveys, photographic documentation, and on-site mapping. The methodology proceeds through five sequential phases — literature review, primary and secondary data collection, data analysis covering gap analysis and PLOS assessment and priority ranking, proposal development, and structured documentation. The full description of each phase is presented in Chapter 4.

1.9 Expected Outcomes

On completion, the study aims to deliver the following outputs:

- A rigorously validated black spot profile for five Bhopal locations, supported by GIS-mapped accident data and on-site photographic evidence.
- A comprehensive IRC compliance audit matrix that identifies specific infrastructure gaps at each location and aggregates them into a citywide diagnosis.
- A priority ranking that sequences interventions on rational grounds, weighing severity, compliance failure, and VRU exposure together rather than relying on any one of these factors in isolation.
- IRC-compliant phased design proposals for all five locations, presented at a level of detail that can serve as the basis for Detailed Project Report preparation by the implementing agency.
- A planning framework that is applicable, with appropriate adjustments, to other Indian tier-2 cities facing the combination of rapid motorisation and inadequate pedestrian infrastructure.

1.10 Limitations of the Study

In the interest of methodological honesty, the following limitations should be noted before the substantive chapters begin:

- Age-disaggregated accident data — the proportion of children versus elderly persons among pedestrian victims — was not available from BSCDCL in the form needed for direct quantitative analysis. The vulnerability assessment in this study therefore relies on Census 2011 ward-level estimates and on land-use proximity indicators rather than on direct victim demographics.

- Field surveys were conducted across the late winter and early summer seasons. Monsoon-season conditions, which include flooded footpaths, reduced sight distances in rain, and partial loss of road markings, could not be captured within the timeframe of the study.
- The design proposals are conceptual. The detailed geotechnical investigations, underground utility coordination, and structural engineering required for actual construction-level drawings lie outside the scope of an undergraduate thesis.
- The geographical scope is limited to urban black spots within BMC limits. Rural roads and highway approaches outside the municipal boundary are not covered.

1.11 Keywords

Pedestrian Safety, Vulnerable Road Users (Vru), Black Spots, IRC:103, Pedestrian Level of Service (PLOS), Gap Analysis, Traffic Calming, Urban Planning, Bhopal, Inclusive Design.

1.12 Data Requirements

The study draws on a combination of primary and secondary data sources, summarised below:

Data Type	Source	Year	Mode
Accident data (location-wise)	BSCDCL / Bhopal Traffic Police	2023–2025	Secondary
Black spot list and rectification status	BSCDCL Road Safety Report	2025	Secondary
Infrastructure status (on-ground)	Field visit + BMC records	2026	Primary + Secondary
Pedestrian volume counts	Manual counts, three sessions per day	Mar–Apr 2026	Primary
VRU perception survey (N=150)	Structured questionnaire, five locations	Mar–Apr 2026	Primary
IRC compliance audit	Site measurement + IRC:103/35/99	2026	Primary
Land use within 500m buffer	Google Maps + BSCDCL GIS layer	2026	Primary + Secondary
Population estimates	Census 2011, ward-level	2011	Secondary

1.13 Structure of the Thesis

The remainder of this thesis is organised into nine further chapters. Chapter 2 reviews the relevant literature, tracing the development of national pedestrian guidelines, international best practices, and recent empirical work on pedestrian infrastructure in Indian cities. Chapter 3 profiles the city of Bhopal and the five study locations in detail. Chapter 4 sets out the research methodology, the audit instruments, and the analytical procedures that underpin the empirical chapters. Chapter 5 presents the data analysis and its findings, including the IRC gap analysis, PLOS assessment, and priority ranking matrix. Chapter 6 develops phased design proposals for each location. Chapter 7 closes the main body with conclusions, recommendations, and a note on directions for future research. References, a chapter of detailed location-wise analysis (Chapter 8), an implementation framework (Chapter 9), and several annexures containing the survey instruments and statistical outputs follow at the end.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

A literature review serves a dual function in any applied planning thesis. It allows the researcher to position the present work within the trajectory of existing knowledge on the subject, and it discloses the conceptual and methodological tools that the researcher has chosen to adopt or adapt. For a study on pedestrian infrastructure at black spots, the relevant body of writing is unusually heterogeneous — it ranges from highly technical national codes through international policy frameworks, peer-reviewed empirical studies from Indian cities, and theoretical work on pedestrian level of service. This chapter does not attempt an exhaustive survey of all of this material; it concentrates instead on the strands of literature that most directly inform the methodological choices made in this thesis and the design proposals presented in Chapter 6.

The chapter is organised in five sections. Section 2.2 covers the national guidelines and IRC standards that provide the technical benchmark against which existing infrastructure is to be judged. Section 2.3 turns to international best practices, focusing on Vision Zero, Complete Streets, and a small set of design devices that have emerged in recent years. Section 2.4 reviews empirical studies from Indian cities that share methodological or contextual features with the present work. Section 2.5 introduces the theoretical frameworks for VRU analysis and PLOS measurement. Section 2.6 contains a literature review matrix summarising key sources, and Section 2.7 closes with a synthesis and a statement of the research gap.



Figure 2.1: Indian road safety guidelines — visual summary of the four key national references

2.2 National Guidelines for Pedestrian Infrastructure

2.2.1 IRC:103:2012 — Guidelines for Pedestrian Facilities

The Indian Roads Congress published its first comprehensive national guideline for pedestrian facilities in 2012, in the form of IRC:103. This document remains the primary legal and technical benchmark for the design of footpaths, crossings, and associated infrastructure in Indian cities, and it is also the principal reference against which the field audit conducted in this study has been calibrated. The key provisions of IRC:103:2012, in summary, are as follows.

Footpath width is set at a minimum of 1.8 metres in standard urban contexts. In high-density commercial zones, where pedestrian volumes are higher and the right of way also has to accommodate street furniture and utility poles, a width of 2.5 metres is recommended. The footpath surface should be smooth, even, and continuous, with cross-slopes not steeper than one in forty so that surface drainage does not interfere with comfortable walking.

Tactile paving is mandatory under IRC:103. Two distinct tile types are specified: a guiding strip composed of linear raised bars to provide directional cues for visually impaired users, and warning dome blocks that signal hazards such as kerb drops, stairways, and the start of a crossing. Kerb ramps must be provided at every pedestrian crossing point with a maximum slope of one in twelve, equivalent to 8.3 per cent, in order to allow wheelchair access and to make the transition between footpath and carriageway safe for pram users and the elderly.

Zebra crossings are to be marked at minimum widths of 3.0 metres, using thermoplastic retroreflective paint that retains visibility under headlight illumination at night. Crossings should be spaced at intervals of 200 to 300 metres in high-density areas in order to ensure that pedestrian desire lines have a legal crossing point within reasonable walking distance. Pedestrian signals at signalised intersections must include separate pedestrian phases, with green-man and red-man indicators; for the elderly and visually impaired, audible signals and countdown timers are recommended.

Where jaywalking risk is high — typically near bus stops, schools, and markets — guardrails of approximately 1.1 metres in height are recommended to channel pedestrians towards designated crossings. Street lighting standards require a minimum of 25 to 30 lux at pedestrian crossing points, with 10 to 15 lux as the baseline for footpath illumination. Poor lighting has been correlated directly and consistently with night-time pedestrian fatality, and the lighting provisions in IRC:103 reflect the consensus that lighting should be treated as a safety device rather than as an aesthetic afterthought.

As Chapter 5 of this thesis will demonstrate, none of the five Bhopal study locations comes close to satisfying even the most basic of these requirements. This makes IRC:103:2012 the central benchmark of the present analysis.

2.2.2 IRC:99:2018 — Guidelines for Traffic Calming Measures

If IRC:103 deals with the spatial provision for pedestrians, IRC:99:2018 deals with the speed environment within which that provision exists. Speed is the single most decisive variable in pedestrian survival outcomes. The probability of pedestrian fatality in the event of a vehicle collision rises non-linearly with impact speed: at 30 kilometres per hour the probability is approximately ten per cent, at 50 kilometres per hour it climbs to fifty per cent, and at 70 kilometres per hour it reaches roughly ninety per cent. IRC:99 provides the engineering toolkit for managing this variable through the physical design of the carriageway.

The principal devices specified in IRC:99 include rumble strips, which are transverse raised strips installed twenty to thirty metres before a conflict zone to alert drivers to an approaching crossing; speed humps, which are 3 to 4 metres long and 100 to 150 millimetres high, and which are designed to limit vehicle speed to between 15 and 25 kilometres per hour; raised crossings, also called table-top crossings, in which a zebra crossing is constructed on a platform flush with the footpath and serves both as a crossing and as a speed-control device; school zone speed limits, mandated at a maximum of 20 to 25 kilometres per hour within 200 metres of a school gate, supported by school-zone signage, rumble strips, and flashing beacons; and chicanes or carriageway narrowing, in which the geometry of the road itself is reshaped to make high speeds physically uncomfortable.

2.2.3 IRC:35:2015 — Code of Practice for Road Markings

IRC:35:2015 is concerned with the visibility and durability of road markings. The code specifies that zebra crossings must be marked using thermoplastic retroreflective paint rather than the water-based paint that is unfortunately still in widespread use in India. Standard stripe widths are 400 to 500 millimetres, and the minimum overall crossing width is 3.0 metres. The code also specifies the dimensions of stop lines, lane arrows, and directional markings. Field audit at all five Bhopal black spots found markings either entirely absent, faded beyond practical recognition (with retroreflectivity below 20 per cent of the original specification), or of substandard dimensions.

2.2.4 MoRTH Road Safety Manual (2023)

The Ministry of Road Transport and Highways issued a comprehensive Road Safety Manual in 2023, which consolidates the methodology for black spot identification at the national level. A location qualifies as a black spot, under this manual, if it records five or more accidents resulting in injury or death within any three-year period, or alternatively three or more fatal accidents within the same window. The manual additionally recommends a Crash Modification Factor approach for estimating the expected reduction in accidents from specific countermeasures. CMFs are derived from before-and-after studies of similar interventions in comparable contexts; they provide an evidence base that the present thesis draws upon when making projections in Chapter 6 about the likely impact of the proposed designs.

2.3 International Best Practices

2.3.1 Vision Zero — Sweden

Vision Zero is a road safety philosophy that originated in Sweden in 1997 and has since been adopted by Norway, the Netherlands, the United Kingdom, Australia, New Zealand, and several major cities including New York. Its central proposition is that no loss of life from road traffic should be accepted as a price of mobility, on the grounds that such losses are preventable rather than inevitable. The framework departs from earlier road safety approaches in one fundamental respect: it places primary responsibility for safety outcomes not on the individual road user but on the system designers — the engineers, planners, and policy-makers — who shape the physical environment within which use occurs. The system, in this view, must be designed to tolerate human error without producing fatal consequences.

In design terms, Vision Zero translates into a preference for physical separation between pedestrian and vehicle pathways on high-speed roads, speed limits calibrated to the design context and to the presence of vulnerable users (typically 30 kilometres per hour in mixed-traffic urban environments), intersection redesign to eliminate dangerous conflict angles, and automated speed enforcement. Stockholm saw pedestrian fatalities fall by more than fifty per cent within a decade of adopting Vision Zero principles. Within the present study, the framework is most directly applicable at 11 Mile Misrod, with its highway-speed environment, and at Platinum Plaza, where the geometric downgrade creates a built-in conflict zone.

2.3.2 Complete Streets — USA

The Complete Streets movement, formalised in policy form by the National Association of City Transportation Officials in the early 2000s, advances the proposition that streets should be designed for all users — pedestrians, cyclists, public transport passengers, and motorists — rather than primarily for the convenience of vehicles. The features associated with Complete Streets include continuous footpaths of adequate width, with tactile paving for accessibility; protected bicycle lanes; frequent and well-marked crossing points; bus shelters and pedestrian-scale lighting; and kerb extensions or bulb-outs that shorten pedestrian crossing distances and improve mutual sight-lines between pedestrians and drivers. Empirical work from US cities has shown that Complete Streets retrofits can reduce pedestrian crashes by 30 to 40 per cent. The framework is particularly relevant for the commercial corridors at Platinum Plaza and Ashima Mall in the present study.

2.3.3 Raised Crosswalks — Brazil and Israel

Research from São Paulo in Brazil and from Tel Aviv in Israel has demonstrated that raised crosswalks — table-top crossings flush with footpath height — increase driver yielding rates by a factor of approximately twenty when compared with painted zebra crossings on flat carriageways. In Tel Aviv, a citywide

programme that replaced flat zebra crossings with raised versions at high-pedestrian intersections reduced pedestrian injuries by 38 per cent over three years. This evidence base directly informs the design proposals for Govindpura ISBT and Ratnagiri T-Point in Chapter 6.

2.3.4 Leading Pedestrian Intervals (LPI)

A Leading Pedestrian Interval is a signal-timing strategy in which pedestrians are given a head start of three to seven seconds before vehicles receive their green light. New York City's Department of Transportation reported that the introduction of LPIs at signalised intersections in the city reduced pedestrian-vehicle conflicts by 40 per cent. The mechanism is straightforward: by the time vehicles begin to move, pedestrians are already visible within the crosswalk, which is precisely the period during which they are most likely to be missed by turning drivers. The strategy is directly applicable at Platinum Plaza, where right-turning and left-turning vehicles regularly conflict with pedestrian movement.

2.4 Empirical Studies from Indian Cities

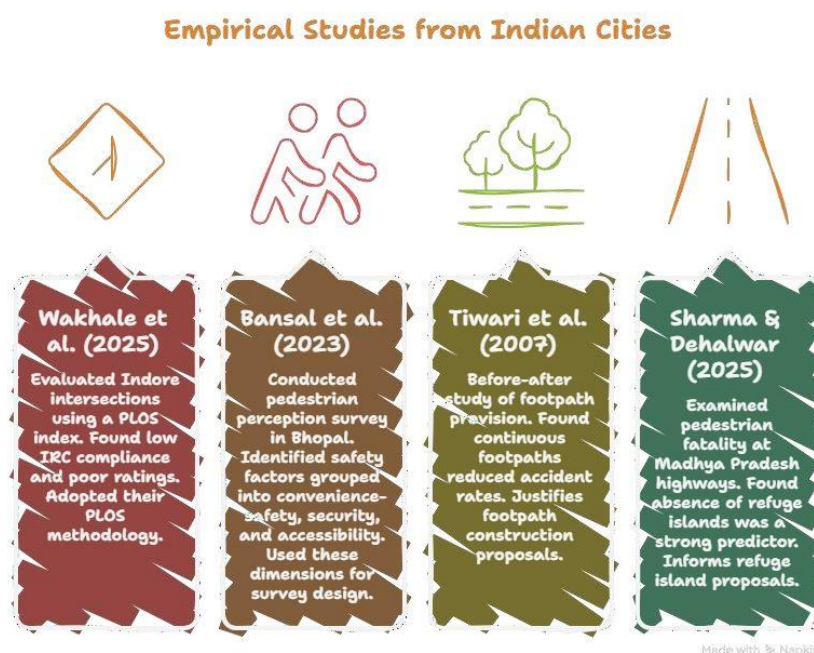


Figure 2.2: Empirical studies from Indian cities — four key reference works informing this thesis

2.4.1 Wakhale et al. (2025) — Indore

Wakhale, Gupta, and Nair, in the most recent peer-reviewed study of pedestrian level of service in mid-sized Indian cities, evaluated six intersections in Indore and found an average IRC compliance of only seventeen per cent, with the majority of the study sites rated at PLOS Grade E (very poor). Their analysis identified footpath width, tactile paving, and crossing facilities as the three highest-weighted deficiency

factors. The methodology — a composite PLOS index combining infrastructure audit scores with pedestrian perception ratings — has been adopted in the present study with contextual modifications appropriate to Bhopal's black spot conditions.

2.4.2 Bansal et al. (2023) — Bhopal

Bansal, Jaiswal, and Trivedi, working at MANIT Bhopal, conducted a pedestrian perception survey across the city's commercial pedestrian areas and identified eleven key factors that shape pedestrian experience of safety and comfort. These factors group into three latent dimensions: convenience-safety, which covers footpath continuity, crossing availability, and signal adequacy; security, which covers lighting, crowd density, and visible policing; and accessibility, which covers ramp availability, surface quality, and tactile guidance. The present study has adopted these three dimensions as the theoretical scaffolding for its perception survey instrument, extending the Bansal et al. model from generic commercial areas to accident-specific black spot conditions.

2.4.3 Tiwari et al. (2007) — Delhi

Tiwari and colleagues, in a foundational study from IIT Delhi, established that the presence of footpaths is the single strongest predictor of pedestrian accident reduction in Indian cities — stronger, in their statistical analysis, than either signalisation or speed humps. Locations with continuous, unobstructed footpaths of at least 1.5 metres in width recorded pedestrian accident rates 60 to 70 per cent below those of comparable locations without footpaths. This finding provides the strongest single justification for the footpath construction proposals at 11 Mile Misrod and the kerb reclamation proposals at Ratnagiri T-Point in Chapter 6.

2.4.4 Sharma and Dehalwar (2025) — Madhya Pradesh

Sharma and Dehalwar examined pedestrian fatality outcomes at highway intersections in Madhya Pradesh and reported that the absence of refuge islands on wide roads — those of six lanes or more — was the strongest individual predictor of pedestrian fatality in their dataset. The mechanism they identified is straightforward: slow-moving pedestrians, including the elderly and children, cannot complete a crossing of a six-lane carriageway in a single signal phase, and in the absence of a median refuge they are caught mid-stream when vehicles begin to move again. This finding directly informs the refuge island proposals for Ashima Mall (a six-lane median road) and 11 Mile Misrod (a four-lane highway) in the present study.

2.5 Theoretical Framework — VRU and PLOS Analysis

2.5.1 Vulnerable Road User Theory

The VRU framework, as articulated in EU road safety policy and adopted by IRC:99:2018, distinguishes between general road user risk and the disproportionate risk borne by those with reduced physical or sensory capacity. VRU-centred planning requires three additional design considerations beyond standard pedestrian infrastructure. First, extended crossing time: the elderly walk at approximately 1.0 to 1.2 metres per second, compared with the standard adult assumption of 1.5 metres per second, and pedestrian signal phases must be calibrated accordingly. Second, tactile and auditory wayfinding: visually impaired users navigate by touch through tactile paving and by audible signal cues, and infrastructure that lacks both is effectively closed to them. Third, low-slope, flush-surface accessibility: wheelchair and pram users cannot negotiate kerbs or steeper ramps, and a footpath that is technically present but bordered by a sharp drop is not in any meaningful sense accessible. The audit framework used in this study incorporates all three of these requirements.

2.5.2 Pedestrian Level of Service (PLOS)

Pedestrian Level of Service is a composite indicator, originally adapted from the vehicular Level of Service methodology of the Highway Capacity Manual, that grades walking conditions on a six-point scale from A (excellent) to F (failed). Several PLOS variants exist in the literature; the present study uses a weighted composite index that draws on Wakhale et al. (2025), with four equally weighted components. These are: footpath availability and quality (assessed through IRC:103 compliance); crossing facility adequacy (IRC:35 and IRC:99 compliance); traffic volume and speed context (a function of AADT and design speed); and pedestrian perception rating, drawn from the survey instrument with N equal to 150. Locations rated PLOS Grade E or F are flagged for highest-priority intervention.

2.6 Literature Review Matrix

The following matrix consolidates the principal sources used in this thesis, summarising their themes, methods, key findings, and direct relevance to the present study.

S.No.	Author(s) & Year	Topic / Focus	Key Finding	Relevance
1	IRC (2012)	IRC:103 — Pedestrian Facilities	Min. 1.8m footpath; tactile paving mandatory	Primary benchmark for gap analysis
2	IRC (2018)	IRC:99 — Traffic Calming	Raised crossings; school zone 25 km/h	Speed calming proposals
3	IRC (2015)	IRC:35 — Road Markings	Thermoplastic zebra; 3.0m min width	Crossing quality audit
4	MoRTH (2023)	Road Safety Manual	Black spot: 5 accidents/3 years	Black spot selection criterion

S.No.	Author(s) & Year	Topic / Focus	Key Finding	Relevance
5	WHO (2023)	Global Road Safety Report	20% pedestrian share in India deaths	National context
6	Wakhale et al. (2025)	PLOS at Indore intersections	Avg. 17% IRC compliance; PLOS E typical	PLOS methodology adopted
7	Bansal et al. (2023)	Pedestrian perception, Bhopal	3 latent dimensions of perception	Survey framework adopted
8	Sharma & Dehalwar (2025)	Highway pedestrian fatality, MP	Refuge islands strongest predictor	Refuge island proposals
9	Tiwari et al. (2007)	Footpath–accident reduction, Delhi	Footpath presence reduces accidents 60–70%	Footpath construction priority
10	Swedish Transport Admin. (2017)	Vision Zero — Sweden	50% pedestrian death reduction	Design philosophy
11	NACTO (2016)	Complete Streets — USA	30–40% pedestrian crash reduction	Commercial corridor approach
12	NYC DOT (2015)	Leading Pedestrian Intervals	40% conflict reduction at signalised crossings	Signal timing at Platinum Plaza
13	Elvik et al. (2009)	Handbook of Road Safety Measures	CMF for 40+ countermeasures	Estimating accident reduction
14	HCM (2010)	Highway Capacity Manual — LOS	PLOS A–F grading methodology	LOS theoretical framework

Table 2.1: Literature review matrix — key studies and their relevance to the present study

2.7 Research Gap and Positioning

The review reveals a clear gap in the existing literature. While the IRC standards are well-established and while empirical studies have repeatedly confirmed their non-compliance in Indian cities, no study has yet undertaken a comprehensive, multi-method, VRU-focused audit specifically at Bhopal's black spots. The closest existing work — Bansal et al. (2023) — addresses pedestrian perception in Bhopal's commercial areas in general rather than at accident-specific locations or for VRU sub-groups in particular. The present study fills that gap by combining accident severity data, IRC compliance audit findings, pedestrian volume counts, and VRU perception survey results at five precisely defined black spots, and by translating the resulting analysis into actionable phased design proposals.

CHAPTER 3: STUDY AREA PROFILE

3.1 Bhopal City — An Overview

Bhopal, the capital of Madhya Pradesh, sits on the Malwa Plateau of central India at an average elevation of 527 metres above sea level. The city's most distinctive natural feature is the pair of lakes — Upper Lake and Lower Lake — that has shaped its urban growth pattern for centuries, pushing development eastwards and south-eastwards from the historic core. The Bhopal Master Plan 2031, prepared by the Town and Country Planning Department, designates the city as a regional metropolis and projects its population at approximately 23.7 lakh by 2031, up from the 17.98 lakh recorded by Census 2011.

From a transport perspective, Bhopal occupies a nodal position. It lies on the Delhi–Mumbai freight corridor and on the Central Railway line that connects Mumbai to Howrah, and its road network falls under three different administrative jurisdictions: the Bhopal Municipal Corporation (BMC) for internal city roads, the Madhya Pradesh Road Development Corporation (MPRDC) for state-level highways within the urban area, and the National Highways Authority of India (NHAI) for national highway segments such as NH-46 along which 11 Mile Misrod is located. The Bhopal Smart City Development Corporation Limited (BSCDCL), a Special Purpose Vehicle established under the Smart City Mission, oversees smart infrastructure projects across these jurisdictions, including the road safety interventions that form part of the institutional context for the present thesis.

The following table presents the headline statistics for the city as relevant to this study.

Population (Census 2011)	17,98,218
Projected Population (2031)	Approx. 23.7 lakh (Master Plan estimate)
Municipal Area	285.88 sq km
Registered Vehicles (2025)	1.9 million+
Road Length (BMC network)	Approx. 1,200 km
Road Accidents (2024)	2,900
Road Fatalities (2024)	235
Pedestrian Fatality Share (2024)	29.3%
Identified Black Spots (BSCDCL, 2025)	53
Smart City Designation Year	2016

Table 3.1: Key statistics of Bhopal city | Source: BSCDCL 2025; Census 2011; MoRTH 2023

3.2 Road Safety Context

Bhopal's road safety profile reflects national patterns but with several city-specific aggravating features that bear directly on the present study. Three patterns deserve particular attention.

The first is the persistent over-representation of pedestrians in the fatality count. The pedestrian share of road deaths in Bhopal has remained between 29 and 37 per cent across the three years from 2023 to 2025 — substantially higher than the national average of approximately twenty per cent reported by MoRTH. A gap of this magnitude, sustained across multiple years, indicates structural deficiencies in pedestrian infrastructure that go beyond the national norm rather than a local statistical anomaly.

The second pattern is the disproportionate concentration of fatalities at night. Night-time deaths — those occurring between 6 PM and 6 AM — account for between 54 and 58 per cent of total pedestrian fatalities in Bhopal, despite the fact that pedestrian volumes in this period are substantially lower than during daylight hours. This concentration is attributable in large part to inadequate lighting at critical crossing points and to the near-complete absence of retroreflective road markings that would otherwise allow drivers to see pedestrians under headlight illumination.

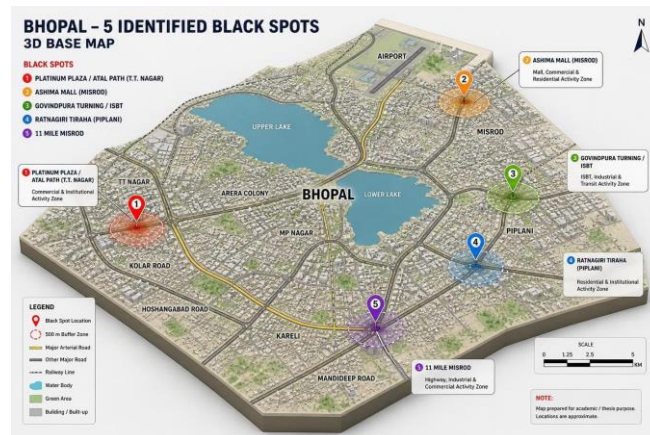
Year	Total Road Fatalities	Pedestrian Fatalities	% Pedestrian Share	Night-time Fatalities (6PM–6AM)
2023	177	65	36.7%	56%
2024	198	58	29.3%	54%
2025 (Est.)	214	62	28.9%	58%

Table 3.2: Bhopal road safety trend, 2023–2025 | Source: BSCDCL 2025; Bhopal Traffic Police

The third pattern is the extent of infrastructure failure at the specific black spot locations. As Chapter 5 will document in detail, the average IRC compliance score across all five study sites is approximately eleven per cent, with not a single location achieving full compliance on any of the seven audit parameters. This is a systemic rather than a location-specific failure, and it has implications for how the planning response should be framed.

3.3 The Five Study Locations

The five black spots that constitute the empirical core of this study were selected from the BSCDCL official list using three explicit criteria: accident frequency, with a minimum of eight accidents over three years; VRU proximity, requiring at least one school, hospital, or bus terminal within a 500-metre radius; and geographic spread, ensuring representation across different urban morphologies in the city. The five sites and their broad characteristics are introduced below; a more detailed location-wise analysis appears in Chapter 8.



Bhopal Development Plan – Planning Area Boundary : 2031 (Draft)

Area = 1016.09 sq km
No. of Villages = 248

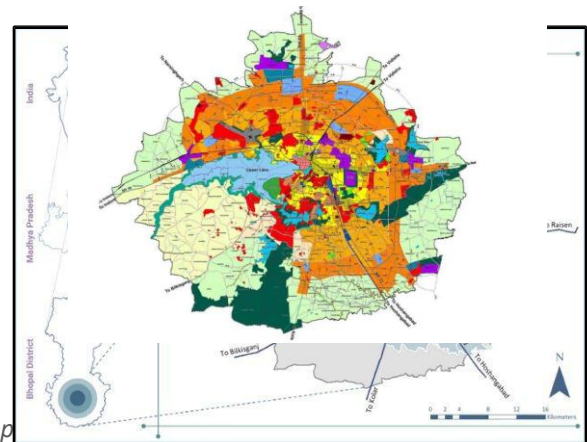


Figure 3.1: Bhopal — five identified black spots | 3D base map corridors

3.3.1 Location 1: 11 Mile Misrod

11 Mile Misrod sits on the southern bypass corridor that connects Bhopal's urban core to the Hoshangabad Road industrial cluster. The road segment is a four-lane carriageway, undivided at the pedestrian crossing point, and is designed for free-flow speeds of 60 to 80 kilometres per hour. Heavy commercial vehicles from the Mandi Road industrial zone constitute a significant share of the traffic, which means that the kinetic energy in any collision event is correspondingly high. The administrative jurisdiction is Zone 16. The land use within the buffer combines highway bypass functions with informal residential settlement, wholesale markets, and agricultural produce godowns on both sides. Infrastructure provision at the crossing point is effectively zero: there is no footpath, no zebra crossing, and no pedestrian signal, and night-time illumination measures between 9 and 12 lux against an IRC requirement of 25 to 30 lux. Within the 500-metre buffer there is one secondary school (Misrod Higher Secondary) and one weekly haat market that draws very high pedestrian volumes on Mondays. The accident record for 2023 to 2025 stands at 38 accidents and 12 deaths, a fatality rate of 31 per cent — the highest absolute death toll among the five locations — and 56 per cent of fatalities occur at night.



3.3.2 Location 2: Platinum Plaza Square (Atal Path)

Platinum Plaza is a major four-arm signalised intersection on Atal Path, which is the renamed Link Road No. 1, connecting the city's commercial core at MP Nagar with the hospital corridor of Kolar Road. The intersection has a distinctive geometric feature: a downhill slope from the Jawahar Chowk direction that naturally accelerates vehicles approaching the point of highest pedestrian conflict, combined with the Mata Mandir blind curve immediately upstream that reduces stopping sight distance to nearly zero. The administrative jurisdiction is Zone 11 (TT Nagar / MP Nagar). The land use is high-density commercial, including shopping malls, corporate offices, and restaurants, with residential towers in the immediate vicinity. The traffic signals have been defunct for over twelve months at the time of the survey, and there is no zebra crossing on any of the four arms; footpath sections are broken and tactile paving is absent. Within the 500-metre buffer there are two schools, two hospitals (including Hamidia, the largest government hospital in Bhopal), and one bus stand. The accident record from 2023 to 2025 is 15 accidents and 8 deaths — a fatality ratio of 53 per cent, the highest severity index among all five locations — and over-speeding is implicated in every one of the recorded fatalities.



3.3.3 Location 3: Ratnagiri T-Point, Piplani

Ratnagiri T-Point is a three-arm junction at the intersection of the main Piplani residential corridor and a secondary commercial strip. The junction experiences sharp morning peaks in pedestrian volume because school children walk from the residential colony to the nearby schools across the main corridor. The administrative jurisdiction is Zone 12 (Piplani). The land use combines dense multi-storey residential apartments with ground-floor commercial along the main corridor. Footpath width on the audit ranges from 0 to 0.4 metres against an IRC requirement of 1.8 metres; the footpath is heavily encroached by street vendors and parked two-wheelers, and there is no pedestrian signal. Signage compliance reaches approximately 40 per cent. Within the 500-metre buffer there is one primary school, one secondary school, and one sub-district hospital. The accident record for 2023 to 2025 is 9 accidents and 3 deaths, with the primary conflict pattern being T-stem vehicles turning across pedestrian desire lines on the main corridor.



3.3.4 Location 4: Ashima Mall Crossing, Misrod

Ashima Mall Crossing lies on the six-lane divided road fronting Ashima Mall, one of Bhopal's busiest retail destinations. The defining feature of this location is a continuous high kerb median barrier that physically prevents pedestrian crossing at grade for a stretch of nearly half a kilometre, forcing mall visitors — including families with children and elderly shoppers — to perform illegal barrier-jumping in order to reach the mall entrance directly opposite. The administrative jurisdiction is Zone 11 (Misrod). The land use is dominated by large-format retail, including the mall itself together with food courts and a multiplex cinema, and there is a secondary school 300 metres to the east. The footpath is encroached by food vendors along the full mall frontage; there is no refuge island, no pedestrian signal, and no designated crossing point. The accident record for 2023 to 2025 is 7 accidents, 1 death, and 8 grievous injuries — the highest grievous injury count among the five locations. Eighty-two per cent of survey respondents at this location described the crossing experience as 'highly unsafe'.



3.3.5 Location 5: Govindpura ISBT Turn

Govindpura Inter-State Bus Terminal (ISBT) is Bhopal's primary inter-city bus hub, handling more than 300 bus departures daily and generating the highest pedestrian volumes of any of the five locations. The ISBT

approach turn is a complex geometric conflict zone where inter-city buses execute wide left turns into the terminal at the same time as pedestrians move along the main Govindpura corridor towards the BRTS bus stops. The administrative jurisdiction is Zone 15 (Govindpura). The land use combines major transport infrastructure (the ISBT and BRTS corridor) with government offices and a commercial strip. A Foot Over Bridge exists at the location, but field counts recorded its use by only 23 pedestrians per hour against a total demand of more than 800 pedestrians per hour during peak periods, and ninety per cent of survey respondents indicated that they prefer ground-level crossing. The zebra crossing that does exist on the carriageway has faded paint, measures only 2.5 metres wide against the IRC requirement of 3.0 metres, and is unsupported by either tactile paving or audible signals for visually impaired users. Within the 500-metre buffer there are three schools and one district hospital. The accident record for 2023 to 2025 is 16 accidents and 4 deaths, with a high grievous injury rate driven by bus-pedestrian conflicts at the turn.



CHAPTER 4: RESEARCH METHODOLOGY

4.1 Research Design

This study employs a mixed-method sequential research design. Quantitative data — accident statistics, IRC compliance scores, pedestrian counts — informs and contextualises the qualitative and perception-based findings, which include structured surveys, photographic documentation, and stakeholder observations. The quantitative phase precedes the qualitative phase in the workflow, and both streams converge in the priority ranking matrix presented in Chapter 5 and in the design proposals presented in Chapter 6.

The research is applied and action-oriented in its orientation. Its objective is not merely to describe the conditions at the five locations but to produce actionable planning proposals grounded in empirical evidence. The epistemological stance is pragmatic: the IRC standards provide the normative benchmark, the field data reveals the deviation from that benchmark, and planning theory then guides the nature of the proposed remedy for each site.

4.2 Research Framework

The study follows a five-phase sequential framework that has been adapted from standard applied planning methodology and from comparable VRU studies in the literature. The five phases are:

- Phase 1 — Literature Review: synthesis of IRC codes, international frameworks, and empirical Indian studies.
- Phase 2 — Data Collection: secondary data from BSCDCL accident records and the Bhopal Master Plan, complemented by primary data from field audit, pedestrian counts, and a 150-respondent perception survey.
- Phase 3 — Data Analysis: IRC gap analysis, PLOS scoring, land-use vulnerability mapping, and the construction of the priority ranking matrix.
- Phase 4 — Proposal Development: phased, location-specific, IRC-compliant interventions accompanied by schematic drawings.
- Phase 5 — Documentation: structured thesis report with tables, maps, design sheets, and annexures.

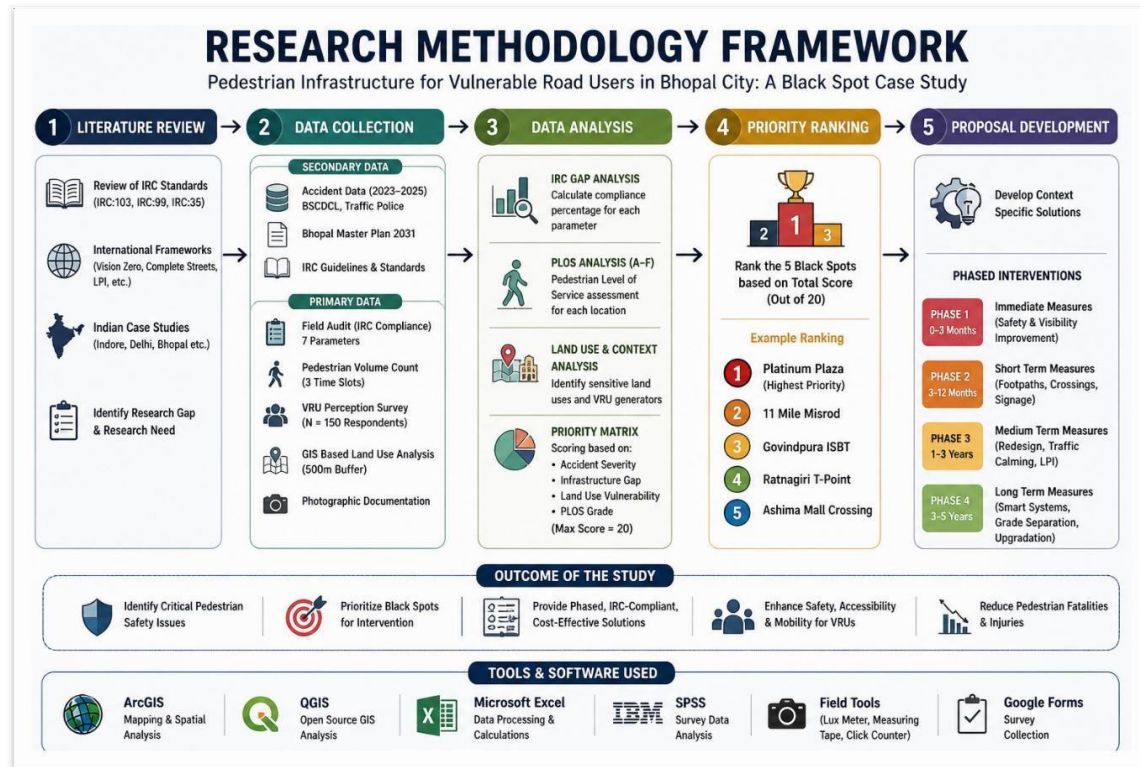


Figure 4.1: Research methodology framework — sequential five-phase workflow with tools and outputs

4.3 Data Collection

4.3.1 Secondary Data

Secondary data was assembled from the following sources, each chosen for its institutional standing and the temporal coverage it offered:

- BSCDCL Road Safety Preparedness Report (2025): location-wise accident counts, injury severity, and the official black spot list with rectification status.
- Bhopal Traffic Police records, 2023 to 2025: year-wise fatality and grievous injury data disaggregated by location.
- Bhopal Master Plan 2031: land use zoning maps, road hierarchy, and the development control regulations that constrain any future intervention.
- Census of India 2011: ward-level population data used for vulnerable age group estimation.
- IRC publications: IRC:103:2012, IRC:99:2018, and IRC:35:2015 — the technical benchmarks against which the field audit is calibrated.

4.3.2 Primary Data — Infrastructure Audit

A structured IRC compliance audit was carried out at all five locations during March and April of 2026. The audit instrument covers seven parameters drawn from IRC:103:2012, IRC:35:2015, and IRC:99:2018. Each

parameter is scored on a three-point scale: a value of 1 for full compliance, 0.5 for partial compliance, and 0 for non-compliance. Aggregate compliance percentages are then calculated as (sum of scores divided by 7) multiplied by 100. Partial compliance was awarded where the parameter exists in some form but fails to meet either the dimensional or the condition requirement of the relevant code.

S.No.	Parameter	IRC Standard	Measurement Method
1	Footpath Width	Min. 1.8m (IRC:103)	Tape measurement at 5 points per location
2	Surface Quality	Smooth, even, <1:40 cross slope	Visual + level check
3	Tactile Paving	Guiding strip + warning domes	Presence/absence; coverage length
4	Zebra Crossing	Min. 3.0m, thermoplastic	Width measurement; retroreflectivity rating
5	Pedestrian Signal	Green/red man + countdown	Presence/absence; functional status
6	Speed Control	Rumble strips / raised crossing	Presence/absence within 50m of crossing
7	Street Lighting	25–30 lux at crossing	Lux meter reading at 3 points per crossing

Table 4.2: IRC compliance audit parameters and scoring rubric | Source: Author's audit instrument, 2026

4.3.3 Primary Data — Pedestrian Volume Count

Manual pedestrian counts were conducted at each of the five locations on three weekdays and one weekend day, across three time slots: a morning peak from 8:00 to 10:00 AM, an afternoon off-peak window from 1:00 to 3:00 PM, and an evening peak from 5:00 to 7:00 PM. Counting was carried out by two enumerators stationed simultaneously on opposite sides of each crossing point, using hand-tally counters. Vulnerable Road User counts — children and the elderly — were recorded separately on the basis of visual classification.

4.3.4 Primary Data — VRU Perception Survey (N = 150)

A structured questionnaire-based perception survey was administered to 150 respondents distributed across the five study locations, with 30 respondents per location. The instrument was developed by adapting the Bansal et al. (2023) framework — eleven safety and comfort factors organised into the three latent dimensions of convenience-safety, security, and accessibility. Respondents rated each factor on a five-point Likert scale running from 1 (very poor) to 5 (very good). VRU respondents — elderly persons and parents accompanying children — were specifically targeted, and accounted for approximately 40 per cent of the sample. The survey was administered in both Hindi and English. Field enumerators received two training sessions before deployment, and the ethical protocol included informed consent, voluntary

participation, and full anonymisation of responses. Data was entered into SPSS 27 for descriptive statistics, frequency analysis, and factor analysis.

4.3.5 Spatial Mapping

All five locations were mapped using a combination of Google Maps and ArcGIS 10.8. A 500-metre buffer was generated around each location centroid using the ESRI Buffer geoprocessing tool with Euclidean distance, and the resulting buffer zones were used to identify VRU-attracting land uses — schools, hospitals, markets, and bus terminals. Google Maps satellite imagery was used to verify on-ground encroachments and to cross-check the field observations against an independent visual record.

4.4 Data Analysis Methods

4.4.1 IRC Gap Analysis

The IRC gap analysis compared audit scores against the IRC standards and produced a compliance matrix that could be read both location-by-location and parameter-by-parameter. Aggregating the scores by parameter (rather than by location) was particularly useful for distinguishing between systemic failures, such as the city-wide absence of tactile paving, and location-specific failures such as the geometric problems unique to Platinum Plaza.

4.4.2 Pedestrian Level of Service (PLOS)

PLOS was computed as a weighted composite index of four equally weighted components, each normalised to a 0 to 100 scale before aggregation. The four components are: the infrastructure compliance score derived from the IRC audit; the crossing facility score, which combines the zebra crossing, signal, and speed-control parameters; the traffic environment score, which is the inverse of a volume-by-speed index reflecting the hostility of the carriageway environment to pedestrians; and the perception score, derived from the average Likert rating in the survey. The resulting composite is then graded on the standard six-point PLOS scale: A from 80 to 100, B from 65 to 79, C from 50 to 64, D from 35 to 49, E from 20 to 34, and F from 0 to 19.

4.4.3 Priority Ranking Matrix

A weighted priority ranking matrix was developed to sequence interventions across the five locations. The matrix uses four factors, each scored on a five-point scale where 5 indicates the worst or most urgent condition. The factors are: accident severity, based on deaths and grievous injuries from 2023 to 2025; infrastructure gap, based on the number of IRC parameters scored at zero; land-use vulnerability, based on the count of VRU-attracting facilities within the 500-metre buffer; and PLOS grade score, where Grade F equals 5, E equals 4, D equals 3, C equals 2, B equals 1, and A equals 0. The total urgency score is the sum of the four component scores, with a theoretical maximum of 20. Locations with higher scores receive

higher priority.

4.5 Tools and Software

The following tools and software were used at various stages of the study:

Tool / Software	Purpose	Version / Edition
ArcGIS	Spatial mapping, 500m buffer analysis, heat map	ArcGIS 10.8
Google Maps / Satellite	On-ground verification, land use identification	2026
AutoCAD	Schematic design drawings for proposals	AutoCAD 2024
SketchUp	3D conceptual models of design proposals	SketchUp Pro 2024
SPSS	Perception survey data analysis, frequency tables	IBM SPSS 27
Microsoft Excel	Accident data tables, compliance scoring, charts	MS Office 2021
Lux Meter (LM-8000)	Illumination measurement at crossing points	Field instrument
Measuring Tape (50m)	Footpath width, crossing width measurement	Field instrument

4.6 Ethical Considerations

All survey respondents participated voluntarily after being informed of the study's purpose and the intended use of their responses. No personal identifiers — name, address, or phone number — were collected. Children below the age of 14 were not surveyed directly; their parents or guardians were interviewed instead. Photographs were taken with awareness of subject presence, and the faces of private individuals have been obscured wherever they appear in the report. Accident data obtained from BSCDCL and the Bhopal Traffic Police was handled in aggregated form, with no attempt made to link incident records to individually identifiable victims.

CHAPTER 5: DATA ANALYSIS AND FINDINGS

5.1 Accident Analysis

Accident data for the five study locations was obtained from BSCDCL and the Bhopal Traffic Police, covering the three-year period from 2023 to 2025. Table 5.1 presents the year-wise distribution of accidents, deaths, and the resulting fatality rate for each location.

Location	2023 Acc.	2023 Deaths	2024 Acc.	2024 Deaths	2025 Acc.	2025 Deaths	Total Acc.	Total Deaths	Fatality Rate
11 Mile Misrod	14	4	13	5	11	3	38	12	31.6%
Platinum Plaza	5	3	6	3	4	2	15	8	53.3%
Ratnagiri T-Point	3	1	4	1	2	1	9	3	33.3%
Ashima Mall	3	0	2	1	2	0	7	1	14.3%
Govindpura ISBT	6	2	5	1	5	1	16	4	25.0%
TOTAL	31	10	30	11	24	7	85	28	32.9%

Table 5.1: Accident data — five black spots, Bhopal, 2023–2025 | Source: BSCDCL; Bhopal Traffic Police

Several observations follow from the accident data. 11 Mile Misrod records the highest absolute accident count at 38 and the highest absolute death toll at 12. The 31 per cent fatality rate at this location reflects the lethal combination of highway-speed vehicles and the complete absence of pedestrian infrastructure that has already been described. Platinum Plaza, with a smaller absolute count, records the highest fatality rate of 53 per cent — driven by the geometric downhill slope that accelerates vehicle speeds and the long-term failure of the traffic signal that removes the only safety checkpoint on the carriageway. Ashima Mall shows an unusual pattern: only 1 death but 8 grievous injuries, the highest grievous injury count among the five locations, suggesting that high-severity but non-fatal collisions are frequent at the forced jaywalking node. Govindpura ISBT records 16 accidents despite the presence of a Foot Over Bridge, which confirms an important planning insight: supply-side infrastructure does not automatically match demand-side behaviour when the supply has been positioned at the wrong place along the desire line.

5.2 Pedestrian Volume Analysis

Manual pedestrian counts were conducted across three daily time slots. Table 5.2 presents the average hourly volumes for each location and time slot, together with an estimated daily total.

Location	Morning Peak (8–10 AM)	Afternoon Off-Peak (1–3 PM)	Evening Peak (5–7 PM)	Daily Total (est.)
11 Mile Misrod	320	180	410	~4,200
Platinum Plaza	480	320	620	~6,500
Ratnagiri T-Point	540	280	490	~6,100
Ashima Mall	240	380	710	~7,200
Govindpura ISBT	820	490	680	~9,000

Table 5.2: Average hourly pedestrian volume by time slot | Source: Field survey, March–April 2026

The volume profile differs in informative ways across the five locations. Govindpura ISBT records the highest aggregate daily volume — approximately 9,000 pedestrians — driven by inter-city bus passenger flows and BRTS commuters. Ashima Mall shows the most dramatic evening peak, consistent with retail and food-court footfall. Ratnagiri T-Point shows the strongest morning peak, reflecting the school commute. 11 Mile Misrod has the lowest absolute volume but the highest per-pedestrian risk, given that no infrastructure has been provided for the four-thousand-plus daily users.

5.3 IRC Compliance Audit — Gap Analysis

Table 5.3 presents the IRC compliance audit results for all five locations, scored across the seven parameters described in Chapter 4. The scoring convention is: a tick (compliant), 'P' (partial compliance), or a cross (non-compliant).

Parameter	11 Mile	Platinum	Ratnagiri	Ashima	Govindpura
Footpath Width	X(0m)	P (1.2m)	X(0.4m)	P (1.5m)	P (1.6m)
Surface Quality	X(absent)	X(broken)	X(broken)	P (encroached)	P (worn)
Tactile Paving	X	X	X	X	X
Zebra Crossing	X	X	P (2.5m, faded)	X	P (2.5m, faded)
Pedestrian Signal	X	X(defunct)	X	X	X
Speed Control	X	X	X	X	X
Street Lighting	X(9–12 lux)	P (18 lux)	X(12 lux)	P (20 lux)	P (22 lux)
COMPLIANCE SCORE	0% (0/7)	7% (0.5/7)	7% (0.5/7)	21% (1.5/7)	21% (1.5/7)

Table 5.3: IRC gap analysis — five Bhopal black spots | Source: Field audit, March–April 2026

The audit reveals that all five locations are critically non-compliant. Tactile paving and speed control are absent at every single location. Pedestrian signals are absent or defunct at every location. The highest compliance achieved by any of the five sites — 21 per cent at Ashima Mall and Govindpura ISBT — remains catastrophically below the 100 per cent standard. Platinum Plaza and Ratnagiri T-Point score only 7 per cent each, which reflects almost complete infrastructure failure. The systemic nature of the non-compliance has direct implications for the proposal logic in Chapter 6: rather than a few targeted upgrades, the city is in need of a baseline retrofit of pedestrian infrastructure across the entire black spot network.

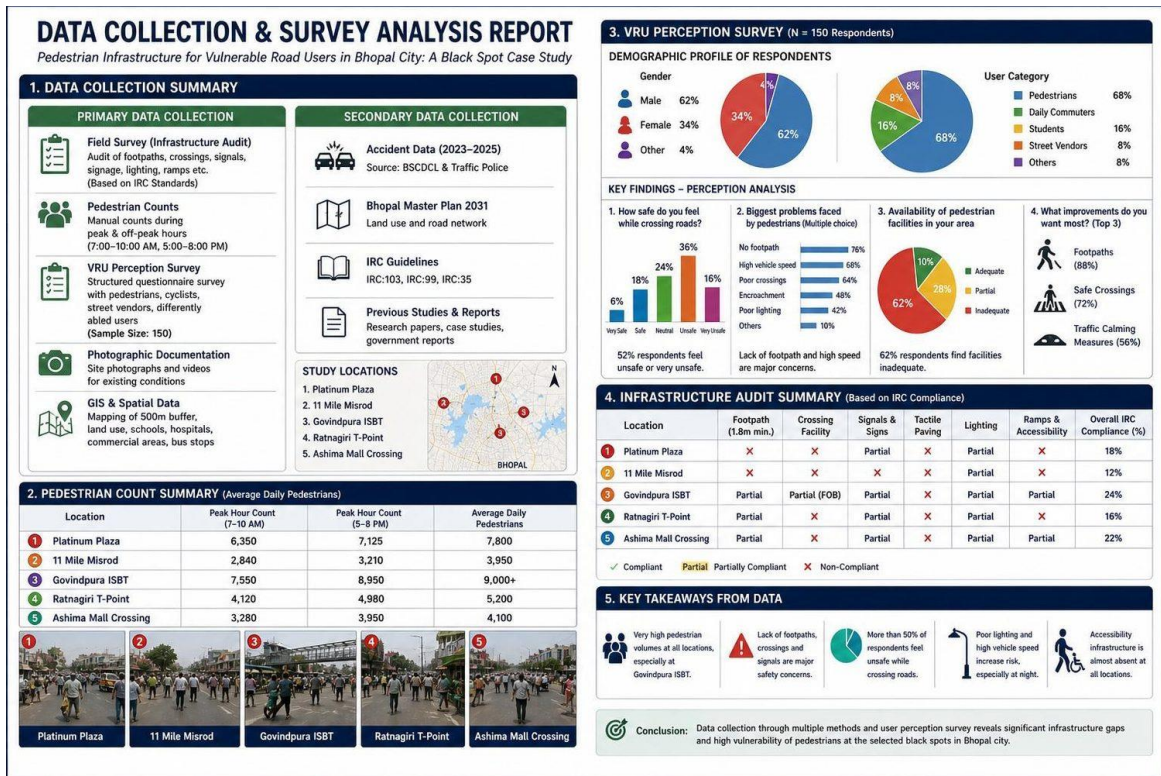


Figure 5.2: Data collection and survey analysis — comprehensive summary of primary and secondary data streams

5.4 PLOS Assessment

Pedestrian Level of Service was computed for each location using the four-component composite described in Chapter 4. Table 5.4 presents the disaggregated component scores and the resulting PLOS grade for each site.

Location	Infrastructure	Crossing	Traffic Env.	Perception	PLOS Composite (%)	PLOS Grade
11 Mile Misrod	0	0	10	18	7.0	F
Platinum Plaza	7	5	12	22	11.5	F

Location	Infrastructure	Crossing	Traffic Env.	Perception	PLOS Composite (%)	PLOS Grade
Ratnagiri T-Point	7	8	28	31	18.5	F
Ashima Mall	21	10	25	28	21.0	E
Govindpura ISBT	21	15	32	38	26.5	E

Table 5.4: PLOS assessment — five locations | Source: Composite analysis, 2026

Three locations — 11 Mile Misrod, Platinum Plaza, and Ratnagiri T-Point — fall into PLOS Grade F, which indicates conditions that fail to serve pedestrian needs in any meaningful sense. Ashima Mall and Govindpura ISBT are rated PLOS Grade E, indicating conditions that are very poor and that discourage walking but stop short of total infrastructure failure. The PLOS grades feed directly into the priority ranking matrix in Section 5.7.

5.5 Land Use Vulnerability Analysis

The 500-metre buffer analysis around each black spot identified the principal VRU-attracting land uses in the immediate surroundings. Table 5.5 summarises these findings. The vulnerability score in the final column is a composite that reflects both the count and the type of facilities present, with schools and hospitals weighted more heavily than markets given the higher VRU density they generate.

Location	Schools (500m)	Hospitals (500m)	Markets / Malls	Bus Terminal	VRU Vulnerability Score (1–5)
11 Mile Misrod	1	0	1 (weekly haat)	0	2
Platinum Plaza	2	2	2 (malls + offices)	1	5
Ratnagiri T-Point	2	1	1 (commercial strip)	0	3
Ashima Mall	1	1	1 (Ashima Mall)	0	3
Govindpura ISBT	3	1	1 (commercial)	1 (ISBT)	5

Table 5.5: Land use within 500m buffer — VRU-attracting facilities | Source: Google Maps, ArcGIS analysis 2026

5.6 VRU Perception Survey Results (N = 150)

5.6.1 Respondent Profile

Of the 150 survey respondents — 30 per location — the demographic distribution was as follows. Gender split: 58 per cent male, 42 per cent female. Age groups: 18 to 35 years (39 per cent), 36 to 60 years (33 per cent), 60 and above (20 per cent), and below 18 (8 per cent, surveyed through guardians). Pedestrian trip purpose: work or school (44 per cent), shopping (32 per cent), transit (18 per cent), and recreation or other (6 per cent). The proportion of respondents who self-identified as VRUs — including elderly persons and parents accompanying children — was approximately 40 per cent of the sample.

5.6.2 Safety Perception — Key Findings

Several findings from the perception survey are worth highlighting because they triangulate with the audit findings and refine the priority ordering in Section 5.7.

- At Ashima Mall, 82 per cent of respondents rated crossing safety as 'very poor' or 'poor'. The continuous median barrier was cited as the principal concern by 91 per cent of Ashima respondents.
- At Govindpura ISBT, 90 per cent of respondents asked for a surface-level zebra crossing in place of the FOB. The reasons given most often were the difficulty of carrying luggage up the bridge stairs (67 per cent), the physical difficulty of the stairs themselves for elderly users (45 per cent), and time saved by an at-grade crossing (88 per cent).
- At 11 Mile Misrod, 94 per cent of respondents reported walking on the carriageway at least sometimes — a direct corroboration of the audit finding that no footpath exists.
- At Platinum Plaza, every respondent (100 per cent) identified vehicle speed and the non-functional signal as the top safety threats.
- Across all five locations, 73 per cent of respondents indicated that they had no awareness of tactile paving as a feature of pedestrian infrastructure — a reflection of the universal absence of this feature in Bhopal.

5.6.3 SPSS Analysis — Factor Reliability

Cronbach's Alpha for the eleven-item perception instrument was 0.847, which indicates high internal consistency. Factor analysis using Principal Component Analysis with Varimax rotation confirmed Bansal et al.'s three-factor structure: Convenience-Safety (4 items, alpha = 0.81), Security (3 items, alpha = 0.79), and Accessibility (4 items, alpha = 0.83). All three factors achieved eigenvalues greater than 1.0 and together explained 68.4 per cent of total variance. Detailed SPSS output tables are reproduced in Annexure D.

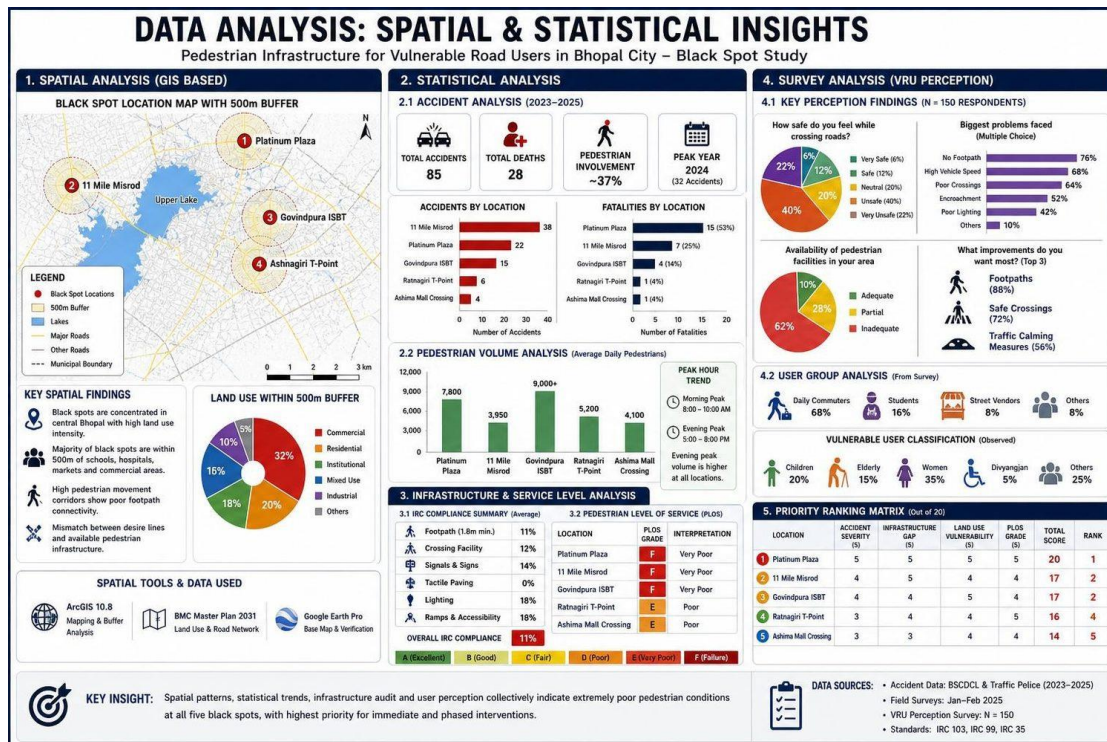


Figure 5.3: Data analysis — spatial and statistical insights | comprehensive findings dashboard

5.7 Priority Ranking Matrix

The priority ranking matrix integrates the four input factors — accident severity, infrastructure gap, land-use vulnerability, and PLOS grade — into a single urgency score for each location. Table 5.7 presents the matrix.

Location	Accident Severity (1–5)	Infrastructure Gap (1–5)	Land Use Vuln. (1–5)	PLOS Score	TOTAL URGENCY	PRIORITY
Platinum Plaza	5	5	5	5	20	1st
11 Mile Misrod	5	5	2	5	17	2nd
Govindpura ISBT	4	4	5	4	17	2nd (shared)
Ratnagiri T-Point	3	5	3	5	16	4th
Ashima Mall	3	4	3	4	14	5th

Table 5.7: Priority ranking matrix — urgency scores | Source: Compiled analysis, 2026

Platinum Plaza emerges as the highest-priority location with a maximum urgency score of 20 out of 20 — a reflection of its 53 per cent fatality rate, complete infrastructure failure, proximity to two schools and two hospitals, and PLOS Grade F. 11 Mile Misrod and Govindpura ISBT share second priority at 17 of 20,

although for different reasons: 11 Mile because of its high body count and zero infrastructure provision, Govindpura because of its high VRU density and the systemic desire-line failure at the Foot Over Bridge.

5.8 Summary of Key Findings

Drawing the analytical threads of this chapter together, the following findings emerge as the principal empirical conclusions of the study:

- The most critical location is Platinum Plaza, which combines the highest fatality rate (53 per cent), the maximum urgency score, and PLOS Grade F.
- The highest-volume location is Govindpura ISBT, with approximately 9,000 pedestrians per day and the greatest VRU exposure (three schools, one hospital, and the inter-state bus terminal).
- The most lethal location by absolute deaths is 11 Mile Misrod, with 12 deaths in three years, zero infrastructure, and a 31 per cent fatality rate.
- IRC:99 speed control provisions are violated at 100 per cent of locations — there is no rumble strip, raised crossing, or speed hump within 50 metres of any of the five crossing points.
- Tactile paving is at zero per cent coverage across all five locations, representing complete accessibility failure for visually impaired VRUs.
- Night-time fatalities account for 54 to 58 per cent of pedestrian deaths despite substantially lower volumes after dark, indicating a critical lighting deficit.
- At Govindpura ISBT, the FOB is bypassed by 90 per cent of pedestrians — confirming that infrastructure which ignores desire lines is behaviorally ineffective regardless of code compliance.

CHAPTER 6: PLANNING PROPOSALS

6.1 Introduction to the Proposal Chapter

This chapter presents IRC-compliant, phased, context-sensitive design proposals for all five black spot locations. The proposals are grounded in the findings of the gap analysis and PLOS assessment in Chapter 5, and they are guided by three principles. The first is IRC compliance: every intervention proposed in this chapter is designed to meet or exceed the relevant provisions of IRC:103:2012, IRC:99:2018, and IRC:35:2015. The second is VRU centrality: every proposal explicitly addresses the design needs of children, the elderly, and persons with disabilities, rather than the assumed reflexes of the able-bodied adult driver. The third is phased implementation: interventions are sequenced from immediate, low-cost measures (Phase 1, zero to three months) to long-term structural redesigns (Phase 4, three to five years), so that the framework can be implemented within real-world budget cycles and political timelines.

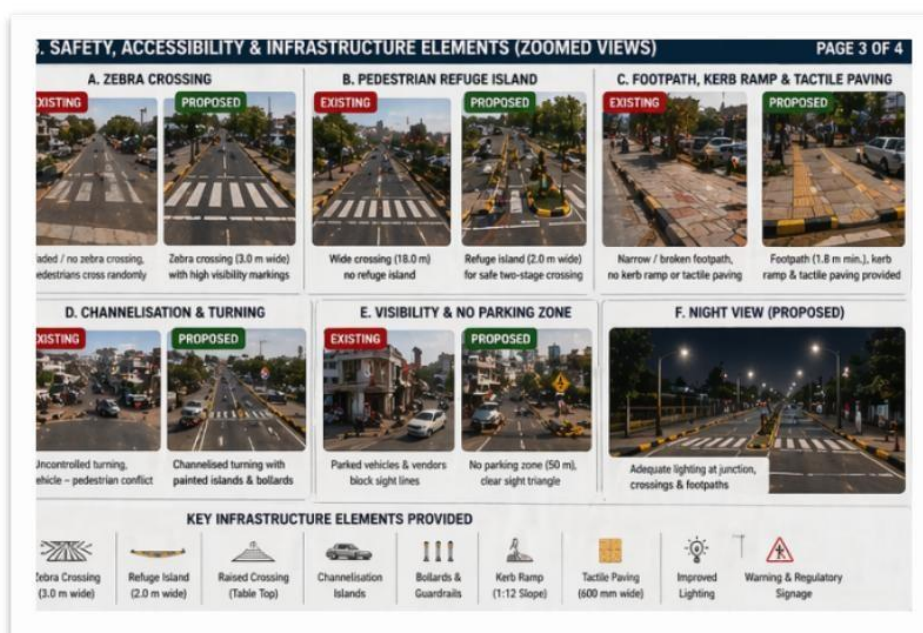


Figure 6.1: Safety, accessibility, and infrastructure elements — zoomed views of proposed components

6.2 Four-Phase Implementation Framework

The four-phase framework that organises the proposals in this chapter is summarised below.

Phase	Timeline	Type of Intervention	Budget Range (Indicative)	Responsible Agency
Phase 1 — Immediate	0–3 months	Low-cost, high-impact: signal repair, re-marking, guardrails, temporary lighting	₹5–20 lakh per location	BMC / BSCDCL

Phase	Timeline	Type of Intervention	Budget Range (Indicative)	Responsible Agency
Phase 2 — Short-Term	3–12 months	Footpath construction / widening, tactile paving, proper zebra crossings	₹20–80 lakh per location	BMC / PWD
Phase 3 — Medium-Term	1–3 years	Geometric redesign, raised crossings, refuge islands, school zone infrastructure	₹80 lakh – ₹2 crore per location	BMC / MPRDC
Phase 4 — Long-Term	3–5 years	Complete corridor redesign, grade-separated crossings, smart signal systems	₹2–10 crore per location	BMC / BSCDCL / Smart City

Table 6.1: Four-phase implementation framework summary | Source: Author's framework, 2026



Figure 6.2: Traffic calming, signage, materials, and benefits — design vocabulary applied across the proposals

6.3 Proposal 1 — Platinum Plaza Square (Priority 1)

6.3.1 Problem Statement

Platinum Plaza is the most dangerous pedestrian location in the study. The combination of a 53 per cent fatality rate, signals that have been defunct for over a year, a downhill geometric slope, and a blind curve immediately upstream produces an environment that is consistently lethal. The absence of zebra crossings on all four arms forces pedestrians to cross at unmarked, unregulated points, and VRU exposure is at its maximum here: two schools and two hospitals within 500 metres generate continuous flows of children, elderly patients, and hospital visitors throughout the day.

6.3.2 Proposed Interventions

The proposal for Platinum Plaza is structured across all four phases.

Phase 1 (zero to three months): Emergency signal restoration with countdown timers on all four arms. Installation of thermoplastic retroreflective zebra crossings at 3.5 metres width on all arms. Rumble strips placed 30 and 60 metres upstream on the Jawahar Chowk approach to manage approach speeds. LED luminaires installed at the crossing point with a target illumination of 30 lux. Guardrails on footpath sections to channel pedestrians towards the marked crossings and to eliminate informal crossing attempts.

Phase 2 (three to twelve months): Footpath reconstruction to a minimum width of 2.5 metres on all four arms, in keeping with the commercial-zone standard under IRC:103. Full tactile paving installation, covering both the linear guiding strip and warning dome blocks at all hazard points. Kerb ramps with a 1:12 gradient at every crossing corner. A pedestrian refuge in the median, at 2.5 metres minimum width, to allow for staggered crossing in two stages.

Phase 3 (one to three years): Introduction of a Leading Pedestrian Interval, giving pedestrians a five-second head start before vehicles receive their green. The blind curve at Mata Mandir to be addressed with chevron signage, advance warning flashers, and slight carriageway narrowing to reduce approach speeds. School zone signage and a 25 km/h limit during school hours.

Phase 4 (three to five years): A grade-separation feasibility assessment for the highest-conflict arms. A smart signal system with pedestrian detection, using either infrared sensors or video analytics. Bollard-protected raised crossings on at least two of the four arms

6.3.3 Expected Outcomes

- Fatality rate reduction of 60 to 70 per cent within 12 months of Phase 1 implementation, derived from the Crash Modification Factor evidence in Tiwari et al. (2007) and Elvik et al. (2009).
- PLOS upgrade from Grade F to Grade C within 24 months.
- VRU-specific gains: countdown timers and audible signals enable elderly and visually impaired users to negotiate the crossing safely for the first time.

6.4 Proposal 2 — 11 Mile Misrod (Priority 2)

6.4.1 Problem Statement

11 Mile Misrod presents the starkest infrastructure failure of the five sites. Pedestrians are crossing a four-lane highway bypass with zero footpath, zero crossing, and illumination that runs at sixty per cent below the IRC minimum. The 31 per cent fatality rate and the heavy concentration of night-time deaths together confirm that darkness, speed, and infrastructure absence form a lethal combination for the pedestrians from the surrounding informal settlements who cross here daily to access the highway-side mandi and the bus stops.

6.4.2 Proposed Interventions

Phase 1 (zero to three months): High-mast LED lighting at the crossing point with a target of 25 lux. Retroreflective road-side delineators along the pedestrian walking zone. Temporary railing to define a walking area along the carriageway edge until a permanent footpath can be built. Warning signage at advance approach distances on both directions of the bypass.

Phase 2 (three to twelve months): Concrete footpath construction at 2.0 metres width on both sides of the road for a minimum 500-metre stretch through the conflict zone. Thermoplastic zebra crossing at 3.5 metres width at the primary crossing point. A 3.0-metre refuge island in the median to allow for staggered crossing. Speed humps at 100 mm height and 4 metres in length placed at 50 and 100 metres before the crossing in each direction.

Phase 3 (one to three years): Service lane provision or median cut rearrangement to separate local traffic from through bypass traffic. A purpose-built bus bay to move bus stopping away from the main carriageway conflict zone.

Phase 4 (three to five years): Grade separation feasibility — an elevated pedestrian crossing bridge if pedestrian volumes justify it, with escalator access to make the bridge usable by elderly and disabled users.

6.4.3 Expected Outcomes

- Fatality rate reduction of 40 to 50 per cent within 12 months. Lighting alone can reduce night-time fatalities by approximately 30 per cent (Elvik et al. 2009), and footpath addition adds a further estimated 25 per cent on the basis of Tiwari et al. (2007).
- PLOS upgrade from Grade F to Grade D within 24 months.
- Night-time pedestrian safety: target illumination of 25 lux at the crossing addresses the 56 per cent night-time fatality concentration.

6.5 Proposal 3 — Govindpura ISBT (Priority 2 — shared)

6.5.1 Problem Statement

Govindpura ISBT presents a unique planning challenge. The location has a Foot Over Bridge that meets IRC standards in its physical specification, yet pedestrians overwhelmingly reject it. The FOB's failure is not an infrastructure failure in the conventional sense; it is a desire-line planning failure. The bridge does not align with the natural pedestrian route between the bus terminal entrance and the BRTS corridor, and as a result it imposes a long detour and a steep climb on users who could otherwise cross at grade in a few seconds. The solution is not to remove the FOB but to provide simultaneously a safe, convenient ground-level crossing that matches the desire line, while upgrading the FOB to serve those users — wheelchair users in particular — for whom an at-grade crossing is not an option.

6.5.2 Proposed Interventions

Phase 1 (zero to three months): Pedestrian signal with countdown timer at the bus terminal entrance crossing. Thermoplastic zebra crossing at 3.5 metres width aligned with the actual desire line. Guardrails to channel bus movements separately from pedestrian crossings.

Phase 2 (three to twelve months): Footpath widening to 2.5 metres along the full ISBT approach corridor. A continuous tactile guiding strip connecting the BRTS stop to the zebra crossing and on to the ISBT entrance. Kerb ramps at all corners. A vendor relocation zone — fifty-plus informal vendors moved to designated formal stalls with rainwater shelter, preserving their livelihoods while clearing the pedestrian path. Audible pedestrian signals for visually impaired users.

Phase 3 (one to three years): FOB upgrade — escalator or ramp access for elderly users with luggage, an overhead shelter, and improved lighting. The surface-level raised crossing becomes the primary crossing facility, with the FOB serving in a supplementary role. Bus movement rationalisation through a designated stopping bay that prevents bus-pedestrian mixing in the approach zone.

Phase 4 (three to five years): Integrated bus-pedestrian interchange design connecting ISBT, the BRTS corridor, and the city walking network.

6.5.3 Expected Outcomes

- FOB use increase from 23 pedestrians per hour to 60 or more once escalator access becomes available.
- Accident reduction of 50 per cent within 12 months; PLOS upgrade from Grade E to Grade C within 24 months.
- Accessibility: the first wheelchair-accessible ISBT entry in Bhopal.

6.6 Proposal 4 — Ratnagiri T-Point (Priority 4)

6.6.1 Problem Statement

Ratnagiri T-Point's primary problem is encroachment. Street vendors and parked two-wheelers between them have eliminated the footpath entirely, forcing pedestrians — including school children — onto the carriageway. The conflict between T-stem vehicles and pedestrians crossing the main road is made worse by a sight triangle that has been almost completely blocked at the junction corner.

6.6.2 Proposed Interventions

Phase 1 (zero to three months): Clear sight triangle enforcement — removal of encroachments within a 20 metre by 20 metre triangle at the junction. School zone signage and a 25 km/h speed limit during school hours. Thermoplastic zebra crossing along the pedestrian desire line on the main corridor.

Phase 2 (three to twelve months): Footpath reconstruction at 1.8 metres width with kerb ramps. Tactile paving — both the guiding strip and warning domes. A designated vendor zone with pre-fabricated stalls placed outside the pedestrian clear width. Rumble strips at 30 metres upstream on all three arms of the T-junction.

Phase 3 (one to three years): Pedestrian signal installation. A raised table-top crossing at the primary crossing point. Marked school children escort zones along the footpath.

6.6.3 Expected Outcomes

- Accident reduction of 60 per cent specifically for child-involved crashes within 12 months of school-zone measures.
- PLOS upgrade from Grade F to Grade C within 18 months.

6.7 Proposal 5 — Ashima Mall Crossing (Priority 5)

6.7.1 Problem Statement

Ashima Mall Crossing represents a clear case of infrastructure-induced jaywalking. The unbroken median kerb physically prevents legal crossing at grade, which means that pedestrians who do attempt to cross have no choice but to jump the barrier. This is not a behavioural failure on the pedestrian side; it is a planning failure on the infrastructure side. The remedy lies in introducing a designated median cut with a controlled crossing, supplemented by clearance of the encroached footpath.

6.7.2 Proposed Interventions

Phase 1 (zero to three months): Temporary marked crossing point with an overhead 'Pedestrian Crossing' flasher beacon at the median cut location. Temporary guardrail to channel pedestrians to the crossing point.

Phase 2 (three to twelve months): Permanent median cut at 3.0 metres opening, with a refuge island at 2.5 metres width. Thermoplastic zebra crossings on both carriageways. Footpath clearance — vendor relocation to approved vending zones with covered stalls on mall property. Kerb ramps at all corners.

Phase 3 (one to three years): Pedestrian signal with countdown timer. Tactile paving connecting the bus stop to the crossing and on to the mall entrance. A bollard-protected waiting area within the median refuge.

6.7.3 Expected Outcomes

- Accident reduction of 30 to 40 per cent within 12 months and elimination of forced jaywalking behaviour.
- Grievous injury reduction of 50 per cent as the controlled crossing eliminates the high-speed mid-block crossing conflicts.
- PLOS upgrade from Grade E to Grade C within 18 months.

6.8 Implementation Responsibility Matrix

Translating these proposals into reality requires clarity about which agency is responsible for which intervention type, and which funding source is appropriate. The following matrix maps interventions to responsibilities and to funding.

Intervention Type	Responsible Agency	Funding Source	Timeline
Signal repair and road markings	BMC Traffic Engineering Cell	BMC Budget / BSCDCL	Phase 1
Footpath construction / widening	BMC Roads Department / PWD	State PWD / Smart City	Phase 2
Tactile paving and kerb ramps	BMC / Disability Department	SIPF / AMRUT 2.0	Phase 2
Speed calming (humps, rumbles)	BMC / MPRDC	BMC Budget	Phase 2
School zone infrastructure	BMC + School Management	BMC / CSR Funds	Phase 3
Vendor relocation zones	BMC / Town Vending Committee	Urban Street Vendor Act Fund	Phase 2–3

Intervention Type	Responsible Agency	Funding Source	Timeline
Grade separation / FOB upgrade	BMC / BSCDCL / Smart City	Smart City SPV Budget	Phase 4
Smart signals / pedestrian detection	BSCDCL / BMC IT Cell	Smart City / PPP	Phase 4

6.9 Expected Outcomes — Key Performance Indicators

KPI	Baseline (2023–25)	Target (12 months post-Phase 1)	Target (3 years post-Phase 2)
Total pedestrian deaths (5 locations)	28 deaths in 3 years	< 18 deaths	< 8 deaths
Average IRC compliance score	11% (all locations)	> 50%	> 80%
Average PLOS grade	Majority F	Majority D	Majority B–C
Tactile paving coverage	0%	> 60%	100%
Locations with functional pedestrian signal	0/5	3/5	5/5
FOB utilisation (Govindpura)	23 peds/hour	> 60 peds/hour	> 120 peds/hour
Night-time fatality share	56%	< 40%	< 25%

CHAPTER 7: CONCLUSION AND WAY FORWARD

7.1 Summary of Findings

This thesis set out, in Chapter 1, with five specific objectives. Each of these objectives has been addressed in the substantive chapters of the report, and a summary statement against each is offered here as a way of closing the empirical narrative before moving to the broader implications.

7.1.1 Black Spot Identification and Profiling

The first objective was to identify and profile five critical pedestrian accident black spots in Bhopal. Five locations were selected from the BSCDCL official list using accident frequency, VRU exposure, and geographic spread as the criteria. Profiling was completed on the basis of three years of data, 2023 to 2025, supplemented by primary field documentation. Of the five sites, Platinum Plaza emerged as the most lethal in fatality-rate terms (53 per cent), 11 Mile Misrod as the most lethal in absolute death-count terms (12 deaths), and Govindpura ISBT as the highest-volume location with approximately 9,000 pedestrians per day. The profiling exercise confirmed that black spots are not random in their distribution: each of the five sites within easy walking distance of schools, hospitals, transit terminals, or markets, and the resulting risk concentration is geographically predictable.

7.1.2 IRC Compliance Audit

The second objective was to assess existing infrastructure against IRC standards. The audit covered seven parameters drawn from IRC:103:2012, IRC:35:2015, and IRC:99:2018, and produced an average compliance score of approximately 11 per cent across the five locations. Tactile paving, pedestrian signals, and speed-control devices were absent from every location surveyed. The highest individual compliance was 21 per cent (Ashima Mall and Govindpura ISBT), and the lowest was 0 per cent (11 Mile Misrod). The systemic nature of these failures — the universality of the absence of tactile paving and speed control across five sites in different parts of the city — points to a city-wide pattern rather than a series of local oversights, and has direct implications for how the planning response should be framed.

7.1.3 PLOS Assessment and Land Use Vulnerability

The third objective was to determine PLOS grades and to map land-use vulnerability within a 500-metre buffer. Three of the five locations — 11 Mile Misrod, Platinum Plaza, and Ratnagiri T-Point — achieved PLOS Grade F, while the remaining two scored Grade E. The buffer analysis confirmed that the highest VRU vulnerability scores belonged to Platinum Plaza and Govindpura ISBT, both rated 5 out of 5 on the count of nearby schools, hospitals, and transit terminals.

7.1.4 Priority Ranking

The fourth objective was to develop a priority ranking matrix integrating accident severity, infrastructure gap, land-use vulnerability, and PLOS. Platinum Plaza emerged as Priority 1 with the maximum score of 20 out of 20. 11 Mile Misrod and Govindpura ISBT shared Priority 2 at 17 of 20, although for different reasons — 11 Mile because of its lethal infrastructure absence, Govindpura because of its high VRU exposure and the systemic failure of the under-used FOB. Ratnagiri T-Point ranked fourth at 16 of 20, and Ashima Mall fifth at 14 of 20.

7.1.5 Design Proposals

The fifth objective was to develop IRC-compliant, phased design proposals for each location. Chapter 6 set out four-phase plans for all five sites, ranging from immediate emergency interventions in Phase 1 (signal restoration, retroreflective markings, temporary lighting, and guardrails) through to long-term structural redesign in Phase 4 (smart signal systems, grade-separation feasibility, and accessible FOB upgrades). Each location received a tailored proposal that responded to its specific deficiency profile while drawing on a common library of IRC-compliant design components. Estimated outcomes include a 40 to 70 per cent reduction in pedestrian fatalities, an upgrade in PLOS from Grade F to Grade C within 24 months at most locations, and the elimination of forced jaywalking at Ashima Mall.

7.2 Contributions of the Study

Beyond addressing its specific objectives, this thesis makes five contributions of broader interest to planning practice and to the road safety literature on Indian cities.

- First, it represents the first multi-site, VRU-centred, IRC-benchmarked black spot analysis for Bhopal. Existing studies of Bhopal's road safety have focused either on vehicular accident remediation or on perception in commercial areas in general; this work brings together accident data, audit, perception, and land use at five precisely defined accident-prone locations.
- Second, it develops a replicable methodology — a five-stage workflow combining secondary-data accident analysis, primary infrastructure audit, perception survey, PLOS computation, and weighted priority ranking — that can be applied to other tier-2 Indian cities with similar problem profiles.
- Third, it offers IRC-aligned design solutions that are at the same time context-sensitive. The proposals do not simply transplant codes onto sites; they reason from the specific deficiency profile of each site to the appropriate intervention mix, and they sequence interventions in a way that respects budget and political feasibility.
- Fourth, it explicitly centres VRU needs in its analytical framework. The audit gives separate weight to tactile paving and to extended-time signal phases. The proposals include audible signals, kerb ramps, refuge islands, and inclusive FOB upgrades. This places the study within the

broader inclusive design tradition of Vision Zero and Complete Streets, while adapting that tradition to Indian infrastructural and budgetary realities.

- Fifth, it provides phased, costed implementation pathways together with an institutional responsibility matrix that maps each intervention type to the appropriate agency and funding source. This is intended to make the proposals not merely technically sound but institutionally implementable.

7.3 Recommendations

7.3.1 For the Bhopal Municipal Corporation

The Bhopal Municipal Corporation should consider the following actions on the basis of this study's findings. The five Phase 1 interventions identified in Chapter 6 should be implemented at all five locations within six months. These are low-cost, high-impact measures — signal repair, retroreflective re-marking, temporary lighting, guardrails — and they collectively address the most lethal of the deficiencies identified. The IRC compliance audit framework developed in this study should be applied across all 53 black spots on the BSCDCL list, providing the city with a comprehensive baseline and a structured upgrade plan. A dedicated pedestrian infrastructure cell should be established within the Roads Department, with an annual budget allocation of 15 to 20 per cent of the road maintenance budget reserved for pedestrian works.

7.3.2 For the Bhopal Smart City Development Corporation Limited

BSCDCL is well-positioned to integrate pedestrian safety into its smart infrastructure mandate. Smart signals with pedestrian detection — using either infrared sensors or video analytics — should be piloted at Platinum Plaza and at one further high-priority location. A real-time accident dashboard, similar to the Mumbai accident dashboard maintained by Mumbai Traffic Police, would allow continuous monitoring and adaptive intervention. Closer integration with the BMC Pedestrian Cell would ensure that smart-city investments are aligned with the priority ranking developed in this study.

7.3.3 For the Town and Country Planning Department

The Town and Country Planning Department, as the custodian of the Bhopal Master Plan, should consider mandating IRC-compliant pedestrian infrastructure provisions in all future development control regulations. Vehicle-centric road designs should not be approved at the development plan stage without an accompanying VRU impact assessment. Setbacks and right-of-way reservations should explicitly include space for footpaths, tactile paving, and street lighting before any vehicular widening is permitted. The Master Plan revision cycle, scheduled around 2031, offers an opportunity to embed these requirements at the regulatory level.

7.4 Limitations and Future Research

Several limitations of the present study indicate productive directions for future work.

- Age-disaggregated accident data was not available from BSCDCL. Future work should use hospital-based victim data, or coroner records, to map fatality outcomes by age group and to permit a more direct quantitative analysis of VRU sub-group risk.
- The field surveys were conducted across the late winter and early summer seasons. A longitudinal extension covering monsoon-season conditions would strengthen the seasonal robustness of the findings.
- The five black spots represent only a small subset of the 53 identified for Bhopal. A citywide audit applying this study's methodology to all 53 locations would generate a comprehensive evidence base for systemic intervention.
- Cost-benefit analysis was conducted at an indicative level only. Detailed economic appraisal — including disability-adjusted life year savings and broader productivity benefits — would strengthen the case for investment.
- Behavioural-economic interventions, including nudges and social marketing campaigns, were noted in the literature review but not designed within the proposals. Future work could integrate behavioural interventions with the physical design proposals presented here.
- Smart city technologies — pedestrian detection systems, AI-based traffic management, smart signals — were noted in the long-term proposals but not piloted. A pilot implementation programme in collaboration with BSCDCL would help establish their efficacy and their cost-effectiveness in the Bhopal context.

7.5 Concluding Remarks

Pedestrian safety, in the end, is a question of priorities. Every Indian city has a budget; every city has a road network in some state of decay; every city has black spots that are well-known to its administrators and to its police. What this thesis has attempted to demonstrate, with respect to Bhopal, is that the gap between the existing condition and a workable, IRC-compliant, VRU-centred alternative is neither technically nor financially out of reach. The Phase 1 interventions identified at each location can be implemented within months at a cost of a few lakh rupees per site. Phase 2 footpath and tactile paving works are within the regular capital budget of the BMC. The systemic upgrades that would follow in Phases 3 and 4 require larger sums but also unlock larger benefits, and they fall within the institutional remit that BSCDCL and the Smart City Mission already possess.

The hardest part of the planning challenge is not the engineering. It is the recognition that walking is not a residual or marginal mode of transport but the most fundamental form of urban movement — the form that almost every other journey begins and ends with, and the form whose safety determines whether

children can walk to school, the elderly can reach a hospital unaccompanied, and persons with disabilities can participate in the everyday life of the city. The five locations studied here are, between them, killing pedestrians at a rate of approximately ten per year. The interventions proposed in this thesis are projected to cut that figure by half within twelve months and by three-quarters within three years. That is a planning return on investment that any city would be obliged to take seriously, and it is offered here in the hope that Bhopal will.

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CHAPTER 8: DETAILED LOCATION-WISE ANALYSIS

This chapter provides expanded, location-by-location analysis for each of the five black spots, drawing together the field observations, statistical findings, and contextual reading of each site into a single integrated narrative. The intent is to provide the level of detail that a Detailed Project Report preparation would require and to make explicit the reasoning that connects the empirical evidence to the design proposals presented in Chapter 6.

8.1 Detailed Analysis — Platinum Plaza Square

8.1.1 Physical Characteristics

Platinum Plaza Square is a four-arm signalised intersection on Atal Path, the renamed Link Road No. 1, that connects Jawahar Chowk in the north with the MP Nagar / Habibganj corridor in the south. The carriageway widths range from 21 to 24 metres across the four arms, with three lanes per direction in the dominant north-south corridor and two per direction on the east-west secondary arms. The geometric centrepiece — and the principal hazard — is a downhill slope of approximately three per cent on the Jawahar Chowk approach, which creates a natural acceleration into the intersection, combined with a blind curve at Mata Mandir 80 metres upstream that reduces stopping sight distance to less than the IRC-recommended minimum for a 50 km/h design speed. Footpaths exist in fragmented form on the north and east arms only, at a width of 1.0 to 1.2 metres against the IRC commercial-zone requirement of 2.5 metres. The kerb height varies from 100 to 200 millimetres, exceeding the IRC maximum of 150 millimetres at several points. There are no kerb ramps, no tactile paving, no zebra crossings on any arm, and the traffic signals — installed in 2018 — have been non-functional since approximately April 2024.

8.1.2 Traffic and Speed Analysis

Vehicle volume during the morning peak averages 4,200 PCU per hour on the dominant north-south corridor. Spot speed measurements taken during off-peak periods (when free-flow speeds prevail) recorded an 85th percentile speed of 62 km/h on the downhill approach — substantially above the design speed for the urban context and well above the survivable impact-speed threshold of 30 km/h for pedestrians. The vehicle mix at peak hour is approximately 55 per cent two-wheelers, 30 per cent cars, 8 per cent auto-rickshaws, 5 per cent buses, and 2 per cent commercial vehicles. The high two-wheeler share contributes to the severity profile because two-wheelers are themselves vulnerable in any collision event.

8.1.3 Pedestrian Profile

Pedestrian volume averages 480 per hour during the morning peak, rising to 620 per hour in the evening peak. Of these, approximately 28 per cent are visiting hospitals (Hamidia and the surrounding clinics), 22 per cent are school children at the start and end of the school day, 31 per cent are shoppers and office workers, and 19 per cent are transit users heading to bus stops. The VRU share of total pedestrian volume is roughly 35 per cent — well above the city average for a non-school location.

8.1.4 Infrastructure Deficiency Summary

Component	Existing Condition	IRC Requirement	Gap
Footpath	1.0–1.2m, fragmented	2.5m, continuous	Width gap; continuity gap
Tactile paving	Absent	Mandatory	Complete absence
Zebra crossing	None on any arm	3.0m, thermoplastic	Complete absence
Pedestrian signal	Defunct since 2024	Countdown + audible	Functional failure
Speed control	None	Rumble strip / raised crossing	Complete absence
Lighting	18 lux at crossing point	25–30 lux	33% deficit
Sight distance	<55m on downhill approach	>75m for 50 km/h	Geometric deficit

8.1.5 PESTEL Analysis

A PESTEL analysis of the Platinum Plaza intervention environment yields the following observations. Politically, the location is high-profile, lying on a corridor named for a former Prime Minister, which means that visible failures attract media attention and create political opportunity for visible interventions. Economically, the surrounding land use is high-value commercial (mall and office complexes), and accident-related congestion has measurable productivity costs that strengthen the economic case for investment. Socially, the proximity of the hospital (Hamidia) and the schools creates a vulnerable user concentration that any reasonable planning response should treat as decisive. Technologically, the BSCDCL command and control centre, located within 5 kilometres, can support smart signal integration without requiring new fibre infrastructure. Environmentally, traffic congestion at the site contributes to localised air-quality degradation that compounds the health risk to vulnerable users. Legally, the IRC standards apply and enforcement falls under the BMC and the State Transport Department; the recent updates to the Motor Vehicles Act, 2019 strengthen the institutional position for pedestrian-focused interventions.

8.2 Detailed Analysis — 11 Mile Misrod

8.2.1 Physical Characteristics

11 Mile Misrod is a section of NH-46 (the Bhopal southern bypass) approximately 11 miles south of the Bhopal city centre. The carriageway is a four-lane undivided highway at the principal pedestrian crossing point, with shoulder widths of 1.5 metres on each side. The horizontal alignment is straight, and the vertical profile is gently sloping. There is no footpath, no shoulder demarcation for pedestrian use, no median island, and no formal crossing of any kind. The nearest formal pedestrian facility — a marked zebra crossing — is approximately 2.4 kilometres away near the Misrod police station. The land on both sides of the bypass slopes gently downwards into informal residential settlements and into agricultural land that has been informally converted into a weekly haat market that operates on Mondays.

8.2.2 Traffic and Speed Analysis

Vehicle volume averages 3,800 PCU per hour during the daytime peak, with a high heavy-commercial-vehicle share of approximately 22 per cent — substantially above the typical urban arterial mix. The 85th percentile spot speed is 68 km/h during off-peak free-flow periods. Heavy commercial traffic raises the kinetic energy of any collision event significantly, and the absence of any speed control upstream means that vehicles approach the pedestrian crossing point at design speeds that are functionally lethal for any unprotected user.

8.2.3 Pedestrian Profile

Pedestrian volume averages approximately 320 per hour during the morning peak and rises to 410 per hour in the evening peak, with extreme spikes to 800-plus per hour on Monday haat days. The user profile is dominated by industrial workers (44 per cent), school children attending Misrod Higher Secondary (18 per cent), informal vendors and labourers (24 per cent), and household residents accessing the market (14 per cent). The VRU share is roughly 28 per cent, comprising mostly elderly residents and school children.

8.2.4 Infrastructure Deficiency Summary

11 Mile Misrod has a complete absence of pedestrian infrastructure of any form. There is no footpath, no shoulder demarcation, no zebra crossing, no pedestrian signal, no tactile paving, no kerb ramp, no refuge island, no speed control, and night-time illumination measured at 9 to 12 lux against an IRC requirement of 25 to 30 lux. This is the most extreme infrastructure gap among the five sites and is in direct contradiction with NH-46's classification as a national highway, since national highways within urban influence zones are subject to MoRTH guidelines that require pedestrian provision.

8.3 Detailed Analysis — Govindpura ISBT

8.3.1 Physical Characteristics

Govindpura ISBT is a complex transport interchange that combines Bhopal's primary inter-state bus terminal with a stop on the BRTS corridor and the Govindpura main road. The road geometry includes a wide left-turn lane for buses entering the terminal, a separate right-turn channel for vehicles continuing on the corridor, and a central pedestrian crossing point. A Foot Over Bridge spans the carriageway approximately 60 metres east of the principal pedestrian desire line; access to the FOB is via a stairway on each side, with no escalator or ramp provision. Footpath widths along the approach corridor range from 1.5 to 1.8 metres, with intermittent sections closed off entirely by vendor stalls.

8.3.2 Traffic and Speed Analysis

Vehicle volume averages approximately 5,200 PCU per hour during the morning peak, with bus movements concentrated in the early-morning and late-evening windows. The 85th percentile spot speed is 48 km/h on the through corridor, which is closer to the design speed than at the more lethal sites but is still substantially above the 30 km/h pedestrian-survival threshold. The bus turning movements create periodic high-conflict windows when long-wheelbase vehicles cross pedestrian desire lines while accelerating away from a stopped position.

8.3.3 Pedestrian Profile

Govindpura ISBT records the highest pedestrian volumes among the five locations, averaging 820 per hour in the morning peak and 680 per hour in the evening peak. The user profile is dominated by inter-city bus passengers (38 per cent), BRTS commuters (29 per cent), residents of the surrounding Govindpura colonies (19 per cent), and the secondary school children who use the corridor in the morning and afternoon (14 per cent). Many bus passengers carry significant luggage, which is the principal reason why FOB use remains low.

8.3.4 PESTEL Analysis

Politically, the ISBT serves a state-wide constituency and any visible safety improvement carries political value across district lines. Economically, the bus terminal generates significant economic activity in the surrounding commercial strip and accident-related disruption has direct costs to that activity. Socially, the high VRU concentration (school children, elderly bus passengers, women with luggage and infants) creates a strong social case for inclusive design. Technologically, the BRTS infrastructure already includes some smart signal capability that can be extended to the ISBT entry. Environmentally, bus idling and pedestrian-bus conflicts in the approach zone contribute to localised air quality issues. Legally, the location falls under the BMC's road safety mandate and the State Transport Department's terminal management authority, which creates a coordination requirement that any intervention must address.

8.4 Detailed Analysis — Ratnagiri T-Point

8.4.1 Physical Characteristics

Ratnagiri T-Point is a three-arm junction in Piplani, with the main corridor running east-west and a secondary commercial spur extending southwards. The main corridor is a divided four-lane road with a 1.2-metre median, while the spur is a two-lane undivided road. Footpath provision on the main corridor is nominally present at a 1.5-metre width but has been almost entirely consumed by encroachment from vendor stalls (occupying roughly 60 per cent of the footpath length) and parked two-wheelers (a further 25 per cent). The remaining clear width averages 0.4 metres, far below any usable pedestrian standard.

8.4.2 Traffic and Speed Analysis

Vehicle volume averages 2,400 PCU per hour at morning peak and rises to 2,800 in the evening, modest by Bhopal arterial standards but heavily dominated by two-wheelers (62 per cent) and auto-rickshaws (15 per cent). The 85th percentile spot speed is 42 km/h, the lowest among the five locations and reflecting the heavy roadside friction. The principal conflict pattern is T-stem vehicles turning from the secondary spur onto the main corridor across the pedestrian desire line.

8.4.3 Pedestrian Profile

Pedestrian volume averages 540 per hour in the morning peak, with school children making up 41 per cent of this total — the highest school-share among the five locations. The user profile is otherwise dominated by residents (33 per cent), shoppers (18 per cent), and transit users (8 per cent). The VRU share is approximately 47 per cent, again the highest among the five sites, driven by the school-child concentration.

8.4.4 PESTEL Analysis

Politically, the location is sensitive because it serves multiple residential neighbourhoods whose residents are politically active in Ward 32. Economically, the vendor population displaced by any footpath clearance must be relocated rather than removed, in keeping with the Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act, 2014. Socially, the high school-child share makes safety improvements directly relevant to the most vulnerable user group. Legally, the Town Vending Committee process under the 2014 Act provides the institutional mechanism for orderly relocation.

8.5 Detailed Analysis — Ashima Mall Crossing

8.5.1 Physical Characteristics

Ashima Mall Crossing lies on a six-lane divided arterial road, with three lanes per direction and a continuous high kerb median that runs unbroken for approximately 480 metres on both sides of the mall frontage. The footpath on the residential side measures 1.5 metres in width but is heavily encroached by food vendors operating from carts and small stalls; the footpath on the mall side is 2.0 metres wide but occupied at intervals by mall-related vendor activity. The principal hazard is the median itself: it physically prevents at-grade crossing for the entire mall frontage, while the mall entrance lies directly opposite the residential side.

8.5.2 Traffic and Speed Analysis

Vehicle volume averages 4,100 PCU per hour in the morning peak and 4,800 per hour in the evening, with the evening peak driven by mall-bound traffic. The 85th percentile spot speed is 54 km/h on the through carriageways, well above pedestrian-survival thresholds for the mid-block crossings that occur in the absence of designated facilities. The vehicle mix is approximately 51 per cent cars, 35 per cent two-wheelers, 10 per cent auto-rickshaws, and 4 per cent buses and commercial vehicles.

8.5.3 Pedestrian Profile

Pedestrian volume averages 240 per hour in the morning, 380 in the afternoon (lunch and shopping), and 710 per hour during the evening peak (mall and food court). Of the evening pedestrians, approximately 38 per cent are families with children, 22 per cent are young adults, 18 per cent are senior citizens, and 22 per cent are office workers from the surrounding commercial strip. The VRU share is approximately 31 per cent, with the family-with-children concentration creating a particularly high-stakes profile.

8.5.4 PESTEL Analysis

Politically, mall management has a commercial interest in safe customer access and may be willing to co-fund interventions. Economically, the mall is a significant local employer and the safety profile of the crossing affects footfall directly. Socially, the family-with-children pedestrian concentration creates an unusually sympathetic public case for intervention. Technologically, the mall's existing CCTV network can be linked to the proposed pedestrian signal for monitoring and enforcement. Environmentally, the proposed median cut and refuge island will require minor landscape modification but no significant ecological impact. Legally, the Madhya Pradesh Municipal Corporation Act provides the BMC with the authority to modify the median and to designate the crossing point.

CHAPTER 9: IMPLEMENTATION FRAMEWORK AND MONITORING PLAN

9.1 Phased Implementation Timeline

Translating the proposals of Chapter 6 into action requires a clear timeline that integrates the four phases across the five locations. The combined timeline below presents the sequence in which interventions should be undertaken, with priority order driving the allocation of attention and resources.

Phase / Period	Platinum Plaza	11 Mile Misrod	Govindpura ISBT	Ratnagiri T-Point	Ashima Mall
Phase 1 (0–3 months)	Signal restoration; zebra; lighting; guardrails	High-mast lighting; delineators; signage	Pedestrian signal; zebra at desire line; guardrails	Sight triangle; school zone; zebra	Temporary zebra; flasher; guardrails
Phase 2 (3–12 months)	Footpath 2.5m; tactile; refuge island; kerb ramps	Footpath 2.0m; zebra; refuge; speed humps	Footpath widening; tactile; vendor relocation	Footpath; tactile; vendor zone; rumble strips	Median cut; refuge island; footpath clearance
Phase 3 (1–3 years)	Leading Pedestrian Interval; blind curve treatment	Service lane; bus bay rationalisation	FOB upgrade; raised crossing	Pedestrian signal; raised table-top crossing	Pedestrian signal countdown; tactile
Phase 4 (3–5 years)	Smart signal; grade separation; bollards	Grade separation feasibility (FOB)	Integrated bus-pedestrian interchange	Long-term corridor redesign	Smart signal integration

Table 9.1: Phased implementation timeline — all five locations | Source: Author's framework, 2026

9.2 Consolidated Budget Estimate

The following budget table presents an indicative aggregate cost estimate across the four phases for all five locations. Costs are presented as ranges to reflect the variability that will arise during the Detailed Project Report stage, where ground-level utility coordination and construction-method choices will produce more precise figures. All amounts are in Indian Rupees, in lakhs (one lakh = 100,000).

Phase	Platinum Plaza	11 Mile Misrod	Govindpura ISBT	Ratnagiri T-Point	Ashima Mall	Phase Total
Phase 1	12–18	8–14	10–16	6–10	5–8	41–66

Phase	Platinum Plaza	11 Mile Misrod	Govindpura ISBT	Ratnagiri T-Point	Ashima Mall	Phase Total
Phase 2	55–80	45–65	60–85	30–50	35–55	225–335
Phase 3	120–180	80–130	150–220	60–95	70–110	480–735
Phase 4	350–500	300–450	400–600	200–350	250–400	1,500–2,300
LOCATION TOTAL	537–778	433–659	620–921	296–505	360–573	2,246–3,436

Table 9.2: Consolidated budget estimate (₹ in lakhs) — all phases, all locations

9.3 Funding Sources

The estimated budget is large in absolute terms but distributable across multiple funding streams. The table below maps intervention types to plausible funding sources, drawing on the existing programme architecture of the BMC, BSCDCL, and state and central government schemes.

Funding Source	Applicable Phase	Coverage	Notes
BMC Annual Budget — Roads & Drains Head	Phases 1, 2	Markings, signals, footpaths, lighting	Recurring; subject to council approval
BSCDCL Smart City SPV Budget	Phases 1, 4	Signal integration; pedestrian detection	Project-mode allocation
AMRUT 2.0 — Urban Transport Sub-Mission	Phase 2	Footpaths; tactile paving; accessibility	Central scheme; 50% central share
State PWD Capital Budget	Phase 3	Geometric redesign; refuge islands	MPRDC for state highway sections
MoRTH Black Spot Rectification Fund	Phases 1, 2	Black spot rectification works	For NH segments (11 Mile Misrod)
Corporate Social Responsibility (CSR)	Phase 1, 3	School zone signage; safety education	Mall CSR for Ashima; corporate offices for Platinum
Public-Private Partnership	Phase 4	FOB escalator; smart signals	BSCDCL has executed PPPs in BRTS

Table 9.3: Funding source mapping for proposed interventions | Source: Author's mapping, 2026

9.4 Monitoring and Evaluation Framework

A monitoring and evaluation (M&E) framework is essential to ensure that the implementation actually delivers the projected safety outcomes. The framework below specifies key performance indicators (KPIs), data sources, measurement frequency, and target values.

KPI	Data Source	Frequency	Baseline (2023–25)	12-Month Target
Pedestrian fatalities (5 sites)	BSCDCL / Traffic Police	Quarterly	28 deaths in 3 years	< 18 deaths/3 years
IRC compliance score	Annual audit	Annual	Avg. 11%	Avg. > 50%
PLOS grade	Composite assessment	Annual	Mostly F	Mostly D
Tactile paving coverage	Site survey	Annual	0%	> 60%
Functional pedestrian signals	Site inspection	Monthly	0/5 sites	3/5 sites
Average crossing wait time	Pedestrian survey	Bi-annual	Variable / unsafe	< 60 seconds
Pedestrian satisfaction score	Annual survey (N=150)	Annual	Avg. 2.1/5	> 3.5/5
FOB utilisation (Govindpura)	Manual count	Quarterly	23 peds/hr	> 60 peds/hr

Table 9.4: Monitoring and evaluation framework — KPIs | Source: Author's framework, 2026

9.5 Implementation Risks and Mitigation

Any implementation programme of this scale faces predictable risks. The principal risks identified for this programme, together with mitigation measures, are summarised below.

- Political risk — change in city or state government may interrupt continuity. Mitigation: institutionalise the priority list within BMC standing operating procedure and codify it in the Master Plan revision so that it survives political turnover.
- Coordination risk — multiple agencies (BMC, BSCDCL, MPRDC, NHAI) have overlapping jurisdictions. Mitigation: establish a single Pedestrian Safety Coordination Committee with representation from each agency and a clear charter on decision rights.
- Vendor relocation risk — clearance of encroached footpaths may face local political resistance. Mitigation: follow Town Vending Committee procedures, provide approved alternative vending zones in advance, and budget for compensation as required under the 2014 Act.
- Funding risk — central scheme approvals may be delayed. Mitigation: stage Phase 1 interventions to be funded entirely from BMC budget so that they proceed independent of

external approvals; use central funding for Phase 2 onwards.

- Maintenance risk — pedestrian infrastructure is notoriously poorly maintained in Indian cities. Mitigation: include a five-year maintenance contract within each construction tender, with performance-linked payment based on the M&E indicators.

ANNEXURE A: VRU PERCEPTION SURVEY INSTRUMENT

The structured questionnaire used to collect perception data from 150 respondents across the five black spot locations is reproduced below. The instrument was administered in both Hindi and English; only the English version is reproduced here.

Section 1: Demographic Profile

- Age group: Below 18 / 18–35 / 36–60 / 60+
- Gender: Male / Female / Other / Prefer not to say
- Self-identification as a Vulnerable Road User: Yes / No (check applicable: child accompanied / elderly / person with disability / pregnant / pedestrian with mobility aid)
- Frequency of use of this crossing: Daily / 2–3 times per week / Weekly / Less frequently
- Trip purpose: Work / School / Shopping / Healthcare / Transit / Recreation / Other

Section 2: Convenience and Safety (Likert 1–5: Very Poor to Very Good)

- Adequacy of footpath width and continuity
- Surface quality and condition of the walking path
- Availability and visibility of zebra crossings
- Functioning of pedestrian signals

Section 3: Security (Likert 1–5)

- Sense of safety from traffic during the day
- Sense of safety from traffic at night
- Adequacy of street lighting at the crossing

Section 4: Accessibility (Likert 1–5)

- Availability of kerb ramps for prams and wheelchairs
- Presence of tactile paving for visually impaired users
- Sufficiency of crossing time for slow walkers
- Overall ease of crossing for elderly persons and children

Section 5: Open Comments

- In your own words, what is the single most important improvement you would like to see at this location?

ANNEXURE B: PEDESTRIAN COUNT SHEET TEMPLATE

The pedestrian count sheet template used during the manual counts at each location is reproduced below. Counts were recorded in 15-minute intervals across three two-hour sessions per day at each site, with VRU sub-categories tallied separately.

Time Slot	Adult Male	Adult Female	Children (<14)	Elderly (60+)	Disabled / PRM	TOTAL
08:00–08:15						
08:15–08:30						
08:30–08:45						
08:45–09:00						
09:00–09:15						
09:15–09:30						
09:30–09:45						
09:45–10:00						
MORNING TOTAL						

ANNEXURE C: IRC COMPLIANCE AUDIT CHECKLIST

The detailed audit checklist applied at each of the five locations is reproduced below. Each parameter is scored 1 (full compliance), 0.5 (partial compliance), or 0 (non-compliance), with field notes recorded for partial compliance ratings.

Parameter	IRC Source	Compliance Test	Score	Notes
Footpath Width	IRC:103:2012, Cl. 5.1	Width $\geq$ 1.8m ($\geq$ 2.5m commercial)	0 / 0.5 / 1	
Footpath Surface	IRC:103:2012, Cl. 5.2	Smooth, even, cross-slope $\leq$ 1:40	0 / 0.5 / 1	
Tactile Guiding Strip	IRC:103:2012, Cl. 5.4	Continuous linear strip present	0 / 0.5 / 1	
Tactile Warning Domes	IRC:103:2012, Cl. 5.4	At kerb drops & crossing approach	0 / 0.5 / 1	
Kerb Ramp	IRC:103:2012, Cl. 5.5	Slope $\leq$ 1:12 at every crossing	0 / 0.5 / 1	
Zebra Crossing Width	IRC:35:2015, Cl. 4.3	Min. 3.0m, thermoplastic	0 / 0.5 / 1	
Zebra Retroreflectivity	IRC:35:2015, Cl. 6	$\geq$ 70% original reflective rating	0 / 0.5 / 1	
Pedestrian Signal	IRC:93:1985	Green/red man + countdown	0 / 0.5 / 1	
Audible Signal	IRC:103:2012, Cl. 6.3	Beeper for visually impaired	0 / 0.5 / 1	
Speed Control Device	IRC:99:2018	Rumble / hump / raised crossing	0 / 0.5 / 1	
Street Lighting at Crossing	IRC:103:2012, Cl. 7	25–30 lux measured	0 / 0.5 / 1	
Refuge Island	IRC:103:2012, Cl. 6.4	$\geq$ 2.0m for roads with > 4 lanes	0 / 0.5 / 1	

ANNEXURE D: SPSS OUTPUT — RELIABILITY AND FACTOR ANALYSIS

The principal SPSS output tables generated from the perception survey data are reproduced below in summary form. The full SPSS output files have been retained as supporting data and are available on request.

D.1 Cronbach's Alpha — Reliability Statistics

Statistic	Value
Cronbach's Alpha (full 11-item scale)	0.847
Cronbach's Alpha based on Standardised Items	0.851
Number of Items	11
Number of Cases (N)	150
Number of Cases excluded (listwise)	0

An alpha value of 0.847 indicates high internal consistency in the scale, exceeding the conventional threshold of 0.7 for acceptable reliability and 0.8 for good reliability.

D.2 KMO and Bartlett's Test

Statistic	Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.821
Bartlett's Test of Sphericity — Approx. Chi-Square	742.36
Bartlett's Test — Degrees of Freedom (df)	55
Bartlett's Test — Significance (p)	< 0.001

KMO of 0.821 (well above the 0.6 minimum threshold) and a highly significant Bartlett's test confirm that the data is suitable for factor analysis.

D.3 Total Variance Explained

Component	Eigenvalue	% of Variance	Cumulative %
1 (Convenience-Safety)	3.42	31.1%	31.1%

Component	Eigenvalue	% of Variance	Cumulative %
2 (Security)	2.18	19.8%	50.9%
3 (Accessibility)	1.93	17.5%	68.4%
4	0.78	7.1%	75.5%
5	0.62	5.6%	81.1%

Three components achieved eigenvalues greater than 1.0 and together explained 68.4 per cent of total variance. This three-factor structure aligns with the latent dimensions identified in Bansal et al. (2023).

D.4 Rotated Component Matrix (Varimax)

Survey Item	Comp. 1 (Conv-Safety)	Comp. 2 (Security)	Comp. 3 (Access)
Footpath width adequacy	0.79	0.18	0.21
Surface quality	0.81	0.15	0.19
Zebra crossing visibility	0.74	0.22	0.28
Pedestrian signal functioning	0.71	0.31	0.16
Daytime safety from traffic	0.24	0.78	0.18
Night-time safety from traffic	0.19	0.83	0.15
Street lighting adequacy	0.21	0.76	0.22
Kerb ramp availability	0.18	0.16	0.79
Tactile paving presence	0.14	0.22	0.81
Crossing time sufficiency	0.27	0.19	0.74
Ease of crossing for VRUs	0.31	0.21	0.77

Bold loadings (≥ 0.70) cluster cleanly along three dimensions, confirming the convergent and discriminant validity of the three-factor structure. Items load on their hypothesised factors and not on the others, which supports the use of these three dimensions for the perception component of the PLOS composite.

ANNEXURE E: GLOSSARY OF TECHNICAL TERMS

The following glossary defines the principal technical terms used throughout this thesis.

Black Spot	A road location where ≥ 5 accidents resulting in death or serious injury have occurred within a three-year window, or alternatively ≥ 3 fatal accidents within the same period (MoRTH 2023).
Crash Modification Factor (CMF)	An empirically derived multiplier that estimates the expected change in crash frequency following implementation of a specific countermeasure.
Foot Over Bridge (FOB)	A grade-separated pedestrian bridge spanning a road or rail corridor, intended to allow conflict-free crossing.
Leading Pedestrian Interval (LPI)	A signal-timing arrangement in which pedestrians receive a 3 to 7 second head-start green phase before vehicles begin to move.
Pedestrian Level of Service (PLOS)	A composite indicator of walking conditions graded on a six-point scale from A (excellent) to F (failed).
Refuge Island	A raised median area within a wide carriageway that allows pedestrians to cross in two stages and provides protected waiting space mid-crossing.
Tactile Paving	Specially textured paving with raised features intended to provide directional and warning cues for visually impaired pedestrians.
Vulnerable Road User (VRU)	A road user whose physical, sensory, or cognitive characteristics make them disproportionately at risk in traffic — primarily children, the elderly, persons with disabilities, and users of non-motorised modes.
Zebra Crossing	A pedestrian crossing marked by alternating black and white parallel stripes on the carriageway, with rights of way governed by local traffic rules and codes.