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Evaluating the Impact of IRC:103-Compliant Pedestrian Infrastructure on Safety and Walkability: A Case Study of Geeta Bhawan Square, Indore

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***Abstract:** In Indian cities, pedestrian safety and walkability remain critical urban challenges despite the availability of comprehensive design standards such as IRC:103-2012. This research examines the pedestrian infrastructure at Geeta Bhawan Square, Indore, a high-conflict urban intersection characterised by intense foot traffic and vehicular activity. The study evaluates existing pedestrian conditions in relation to IRC:103 guidelines and assesses their impact on pedestrian Level of Service (PLOS), safety outcomes, and perceived comfort. Using a mixed-methods approach, including physical audits, observational mapping, and stakeholder interviews, the study reveals widespread non-compliance across key IRC criteria: footpath width, surface continuity, refuge islands, and curb ramps. Analysis of five years of traffic crash data indicates an average of 11 pedestrian-involved accidents annually at or near the junction. Findings also show that the absence of designated pedestrian crossings and inconsistent curb heights contribute significantly to unsafe pedestrian behaviour, such as mid-block crossing and signal avoidance. Based on these insights, the study provides design recommendations aligned with IRC:103 and suggests policy-level changes to institutionalize walkability in Indore's broader mobility framework. The research highlights the urgent need for pedestrian-centric intersection design, especially in rapidly urbanising mid-sized Indian cities.*

***Keywords:** Pedestrian Infrastructure Design, IRC:103-2012 Standards, Walkability, Urban Intersections, Pedestrian Safety Assessment, PLOS, Non-Motorized Urban Mobility, Street Design, Intersection Design, Urban Transport Planning*

Abbreviations:
IRC: Indian Roads Congress
ISCDL: Indore Smart [9] City Development Limited
PLOS: Pedestrian Level of Service
HCD: Human-Centred Design
MoRTH: Ministry of Road Transport and Highways
LOS: Level of Service
GWI: Global Walkability Index
CMP: Comprehensive Mobility Plan
PLOS: Pedestrian Level of Service
CD: Crossing Distance
CP: Conflict Potential
WE: Effective Width
NUTP: National Urban Transport Policy

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I. INTRODUCTION

A. Background

India's urbanisation is progressing rapidly, with over 460 million people currently residing in cities, and projections indicate that this figure will reach nearly 600 million by 2036 (MoHUA, 2020) [13]. While motorised transport infrastructure has grown in tandem with urban expansion, pedestrian infrastructure remains critically underdeveloped. National data reveals that pedestrians account for approximately 17% of all road fatalities in India (MoRTH, 2022), making them one of the most vulnerable road user groups. Despite policy documents such as the National Urban Transport Policy (2006) and initiatives like the Smart Cities Mission, pedestrian environments at the local level frequently lack the minimum spatial and safety standards. The Indian Roads Congress (IRC), through its publication IRC:103-2012 [11], outlines comprehensive guidelines for pedestrian facilities in urban areas. These include minimum sidewalk widths, kerb ramp gradients, crossing design, tactile paving, and signage. However, the translation of these standards into municipal practice is uneven. Local bodies often face constraints, including road width limitations, poor enforcement, a lack of prioritisation, and resistance from vehicular interests. Consequently, Indian pedestrians usually navigate environments that are hazardous, incomplete, and non-inclusive.

B. Urban Context: Indore

Indore, Madhya Pradesh's largest city and one of the earliest adopters of the Smart City Mission, has made significant strides in waste management, traffic control, and public transport. However, its pedestrian infrastructure remains fragmented. According to the Indore Smart [9] City Development Limited (ISCDL), the city sees over 20% of daily trips completed on foot. Despite this, footpaths in several high-traffic areas are either absent, encroached upon, or poorly maintained. According to a JSI-USAID 2022 [10] citizen survey, over 66% of Indore's residents felt that sidewalks were inadequate for safe walking, with 79% citing obstructions as a key concern. One such critical point is Geeta Bhawan Square — a four-leg urban intersection connecting MG Road, Palasia, and Bhawarkua. The junction serves educational institutions, hospitals, commercial shops, and transit routes. Pedestrian volumes during peak hours exceed 1,000 per hour, and vehicular traffic includes autos, two-wheelers, buses, and private vehicles. Despite this, the intersection lacks pedestrian-friendly features: footpaths taper to less than 1.2 meters at corners, there are no dedicated crossings, and access ramps are either absent or damaged. These conditions make it an ideal case for evaluating the application and effectiveness of IRC:103-compliant infrastructure.

C. Research Aim and Scope

This study focuses exclusively on the physical and operational state of pedestrian infrastructure at Geeta Bhawan Square. Unlike broader studies that explore the impact of intelligent transportation systems or signal timing, this research remains grounded in spatial design standards as per IRC:103. The aim is to document, evaluate, and interpret the relationship between design compliance and pedestrian outcomes — safety, walkability, and user satisfaction.

II. LITERATURE REVIEW

A. Pedestrian Safety in India: Trends and Challenges

India ranks among the highest globally in road traffic fatalities. As per the Ministry of Road Transport and Highways (MoRTH, 2022) [14], 168,491 road deaths occurred in India in 2021 — out of which 29,124 (17.3%) were pedestrians. Compared to 2014, pedestrian deaths have increased by over 64%, reflecting the persistent neglect of pedestrian infrastructure. Further studies by the World Health Organization (WHO, 2018) [17] report that Indian cities have a fatality rate of 22.6 per 100,000 people, higher than the global average of 18.2. Urban transport experts, such as Tiwari [6], have identified a lack of safe crossing facilities, inadequate pedestrian signals, poor footpath maintenance, and encroachments as the root causes. A 2020 study conducted across eight Indian cities (CEPT University, 2020) [8] found that 54% of major intersections lacked marked pedestrian crossings, and 82% had no pedestrian refuge islands. Road traffic injuries are a public health crisis in India. According to MoRTH (2022) [15], of the 168,491 road fatalities reported in 2021 [27]:

- 29,124 were pedestrians, i.e., 17.3%
- This figure grew from 13,894 in 2010 — an increase of >110% over 11 years

Year	Total Road Deaths	Pedestrian Deaths	Pedestrian Share (%)
2010	1,34,513	13,894	10.30%
2015	1,46,133	21,392	14.60%
2021	1,68,491	29,124	17.30%

(Source: MoRTH Annual Accident Reports)

Root Causes (Tiwari, 2011; CEPT, 2020):

- Lack of pedestrian-only zones and safe crossings
- Encroached or discontinuous sidewalks
- Absence of pedestrian signal phases
- Poor intersection geometry

Over 60% of Indian pedestrian's cross mid-block due to either a lack of crossings or unsafe signal timing (Rao & Verma, 2019).

B. IRC:103-2012: Key Standards for Pedestrian Facilities

The IRC:103-2012 is India's foremost design guideline on pedestrian facilities. Below are some critical parameters from the standard, along with typical violations observed in Indian cities:

Design Element	IRC:103 Standard	Non-Compliance Rate (avg. across 10 towns, CEPT, 2019)
Footpath width	Min. 1.8 m (2.5 m in commercial zones)	67% of sidewalks < 1.5 m
Kerb ramp gradient	Max 1:12, min width 1.2 m	81% of crossings lacked usable kerb ramps
Zebra crossing width	Min. 2.5 m, marked with thermoplastic	58% faded or unmarked
Refuge island width	Min. 1.2–1.5 m	76% of wide roads had no islands
Footpath height	150 mm above the carriageway	43% had irregular heights, which was difficult for the elderly

(Source: CEPT University Walkability Audit, 2019) [7]

This gap between standards and implementation creates a fragmented pedestrian network. Even in cities that claim Smart City status, execution remains patchy due to poor inter-agency coordination and car-centric engineering norms.

C. Measuring Walkability and Pedestrian Level of Service (PLOS)

- The Highway Capacity Manual (HCM, 2010) and IRC:103 suggest that walkability should not be assessed only by infrastructure presence but by Level of Service (LOS) grades ranging from A (Excellent) to F (Failure). Common metrics include:
- Average pedestrian delay: Acceptable below 30 seconds (Grade B or better)
- Effective width: At least 1.8 m usable width per IRC
- Encroachment frequency: Should be less than 1 per 100 meters

Crossing exposure time: Safe range < 20 seconds for two-lane roads

A study by Rao and Patel (2018) [22] in Surat and Ahmedabad measured PLOS at 30 intersections and found:

- 72% intersections rated LOS D or worse
- Average pedestrian delay > 45 seconds
- Encroachment rate as high as 3 per 100 meters
- Only 18% of crossings had pedestrian signals

Walkability goes beyond infrastructure — it includes comfort, safety, and continuity. The Highway Capacity Manual (2010) recommends PLOS grading:

PLOS Grade	Avg. Pedestrian Delay	Crossing Distance	Walkable Width	Perceived Comfort
A	<10 seconds	<6 m	>2.4 m	Very High
B	10–20 sec	6–10 m	>1.8 m	High
C	20–30 sec	10–15 m	1.5–1.8 m	Moderate
D	30–45 sec	>15 m	1.2–1.5 m	Low
E	>45 sec	>18 m	<1.2 m	Very Low

(Rao & Patel, 2018) [5]

In a study of 36 Indian intersections, PLOS grades were:

City	Avg. PLOS Grade	% with Grade D or Worse
Pune	C	52%
Ahmedabad	D	64%
Surat	E	79%
Indore	E	83%

(Source: Rao & Patel, 2018)

Additionally, the Global Walkability Index (GWI) ranks Indian cities low. Indore scored

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only 48/100 on walkability parameters, including sidewalk coverage, safety perception, and signal compliance (GWI Report, 2020).

D. International Best Practices and Data

Globally, countries have made significant progress through investments in pedestrian-first infrastructure. Some leading examples include:

- Stockholm (Sweden) reduced pedestrian fatalities by 47% in 6 years under the Vision Zero framework (World Bank, 2020).
- New York City saw a 26% drop in pedestrian injuries in areas where raised crossings and curb extensions were installed (NY DOT, 2017) [12].
- Tokyo mandates footpaths on all roads wider than 5 meters, contributing to its pedestrian fatality rate of only 0.9 per 100,000 — one of the lowest globally.
- In Bogotá, Colombia, pedestrian refuge islands and mid-block crossings implemented between 2012–2016 led to a 38% drop in pedestrian crashes in the targeted zones (ITDP, 2017) [21].
- Singapore mandates a universal access audit for any redevelopment project, which includes measuring tactile paving continuity, sidewalk slope, and ramp compliance.

Let us benchmark India's pedestrian safety against global leaders:

City	Pedestrian Fatality Rate (/100K)	Sidewalk Coverage (%)	Zebra Crossing Compliance (%)	Avg. Crossing Delay
Tokyo	0.9	100%	95%	<15 seconds
Stockholm	1.1	95%	90%	<20 seconds
Bogotá	3.8	75%	80%	20–25 seconds
New York	2.1	85%	88%	~25 seconds
Indore	7.2 (estimate)	38%	43%	>45 seconds

(Sources: WHO 2021, Vision Zero Reports, ITDP Bogotá 2020, ISCDL 2021)

These examples demonstrate that the systematic application of design standards, supported by enforcement and community engagement, can create demonstrably safer environments for pedestrians.

E. Pedestrian Conditions in Indore: City-Specific Data

According to Indore's Comprehensive Mobility Plan (CMP, 2021) and data from JSI-USAID (2022):

- Only 38% of arterial roads in Indore have continuous footpaths.
- 66% of surveyed residents expressed dissatisfaction with sidewalk conditions.
- Top 3 complaints included: obstructions (illegal parking, hawkers), poor lighting, and lack of crossings.
- More than 700 pedestrian crashes were reported across Indore between 2016 and 2021, with Geeta Bhawan Square identified as a Tier-1 conflict zone by Indore Traffic Police.

Based on ISCDL data (2021) and on-site surveys:

Parameter	IRC:103 Norm	Observed at Geeta Bhawan
Footpath width	Min 1.8 m	Avg. 0.9–1.2 m
Presence of zebra crossings	Yes, thermoplastic	None visible
Kerb ramps	Required	Absent at all four corners
Pedestrian refuge	Recommended (>1.2 m)	Missing entirely
Tactile paving	Required	Not present
Average pedestrian wait time	<30 sec (ideal)	>48 sec (peak hours)
PLOS rating (from field audit)	B or better (target)	E (observed)

- Daily pedestrian footfall: ~8,000–10,000 (ISCDL estimate)
- Crash data (2017–2022): 54 pedestrian injuries, nine deaths
- Encroachments: Present on 3 of 4 footpath legs
- Lighting: Inadequate in 2 legs of the intersection

A 2021 on-ground audit by ISCDL found that no corners at Geeta Bhawan had usable kerb ramps, and all zebra crossings had faded markings or were missing entirely. The average footpath width dropped to less than 1 meter in three of the four legs of the intersection.

These figures make Geeta Bhawan Square a relevant and urgent case study to evaluate the potential

benefits of achieving full compliance with IRC:103 guidelines.

III. THEORETICAL FRAMEWORK

A. Urban Mobility Theory

Urban Mobility Theory posits that transport infrastructure should prioritise the movement of people, not vehicles (Bannister, [1]). It argues for accessibility, equity, and modal balance in city transportation systems. The shift from vehicular mobility to people-centred mobility underpins international policy goals such as the New Urban Agenda (UN-Habitat, 2016) [16] and India's own National Urban Transport Policy (MoHUA, 2014).

In practice, this theory supports reallocating road space from motorised traffic to non-motorised users, including pedestrians, cyclists, and transit riders. In the Indian context, over 55% of daily urban trips are either walking or public transport-based (IUT, 2019), yet more than 80% of street design standards still favour motorised mobility (Tiwari, 2011). The theory challenges such an imbalance, advocating for sidewalks, crossings, and human-scaled street networks as central to a sustainable city.

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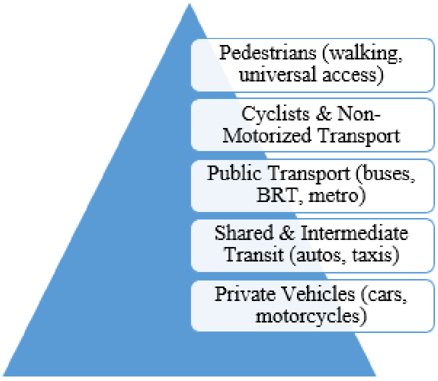

Chart 1: Urban Mobility Theory

- Application to this Study: The investigation at Geeta Bhawan Square utilises Urban Mobility Theory to understand how infrastructural prioritisation affects pedestrian behaviour, crash vulnerability, and walking comfort. The theory provides the conceptual foundation for examining whether spatial arrangements promote or obstruct equitable access.

B. Systems Thinking in Urban Design

Systems Thinking views urban infrastructure as a network of interdependent elements, rather than isolated objects. A single intervention — widening a footpath or adjusting a kerb — interacts with traffic patterns, user behaviour, and environmental dynamics. First articulated by scholars like Meadows [4] and adopted in urban transport planning by GIZ, ITDP, and the World Bank, this theory helps predict cascading effects and feedback loops.

C. For Example, increasing the Footpath width at a Junction May

- Reduce jaywalking by clarifying pedestrian space
- Influence auto-rickshaw parking behaviour
- Necessitate traffic signal phasing adjustments
- Encourage modal shift from motorized to walking trips

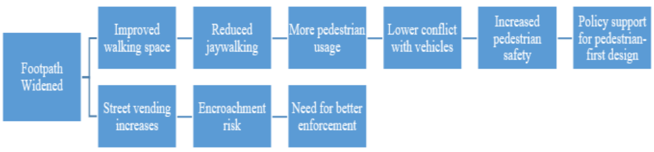

Chart 2: This Chart Shows How a Single Intervention, Such as IRC-compliant sidewalks, Creates Both Positive Feedback Loops and Regulatory Implications

- **Application to this Study:** Geeta Bhawan is not evaluated in isolation; it is analysed as a nodal point within Indore's mobility network. The study employs systems thinking to anticipate how applying IRC:103 norms could ripple into changes in vehicular queuing, pedestrian spillover, and accessibility for the elderly or individuals with disabilities. It supports a holistic audit that extends beyond compliance to system-wide functionality.

D. Human-Centred Design (HCD)

Human-Centred Design (HCD) is a design philosophy that places users — their needs, limitations, and behaviours — at the core of decision-making (IDEO, 2009). In urban design, this translates to prioritizing comfort, safety, accessibility, and dignity in public spaces. Jan Gehl's (2010) [3] work on "Cities for People" is a hallmark in this field, emphasizing that infrastructure must cater to everyday human-scale activities: walking, resting, crossing, interacting.

Where car-centric design produces 40-meter crossing lengths and corner radii suitable for 50 km/h speeds, HCD recommends:

- Shorter crossing distances (10–12 m)
- Refuge islands for rest and protection
- Seating, lighting, and shading for usability
- Sloped kerbs and tactile surfaces for universal design

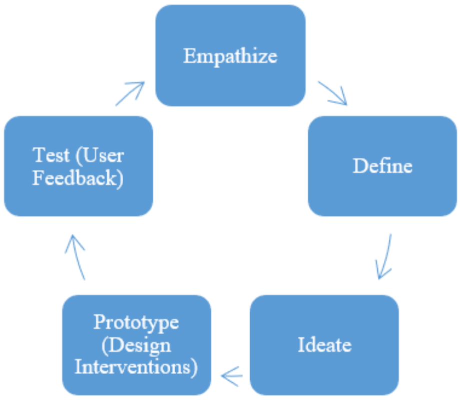

Chart 3: This Chart Reinforces that Pedestrian Design is an Iterative, User-Centric Process — Not a One-time Engineering Decision

Application to this Study: This framework guides the qualitative assessment of the pedestrian experience at Geeta Bhawan. It informs criteria such as:

- Psychological safety while crossing wide roads [18]
- Physical comfort while navigating narrow or obstructed sidewalks
- Emotional well-being derived from the legibility and clarity of pedestrian spaces

HCD also underpins survey instruments and interview protocols used to document how users perceive and interact with the space.

E. Integrative Relevance

By using these three frameworks together:

- Urban Mobility Theory critiques policy and spatial prioritisation
- Systems Thinking analyses the complex interactions of urban elements
- Human-Centred Design focuses on the lived experience and qualitative dimension of walkability

Together, they enable a multi-scalar analysis — from macro-policy frameworks to micro-design details and personal perceptions — making the study both technically rigorous and socially responsive.

IV. METHODOLOGY

This study employs a case study methodology with a mixed-methods research design, integrating qualitative and quantitative tools to evaluate the pedestrian infrastructure at Geeta Bhawan Square in accordance with IRC:103-2012 guidelines. The

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methodological framework is informed by the three theoretical pillars established earlier: Urban Mobility Theory, Systems Thinking, and Human-Centred Design. Each stage is designed to examine both the physical dimensions and the human experiences of the pedestrian environment.

A. Research Design

Approach	Details
Type	Case Study (Single-site, Explanatory)
Design	Mixed Methods (Qualitative + Quantitative)
Focus	Pedestrian infrastructure at Geeta Bhawan Square, Indore
Timeframe	Cross-sectional (with retrospective crash data over 5 years)
Standards Applied	IRC:103-2012, MoRTH crash classification, HCM PLOS criteria

B. Study Area: Geeta Bhawan Square, Indore

Geeta Bhawan Square is a major signalized four-leg intersection in the heart of Indore, connecting Palasia, MG Road, Bhawarkua, and Yeshwant Niwas. It serves:

- Educational institutions (e.g., Holkar Science College, Medical coaching hubs)
- Commercial outlets (retail shops, food vendors)
- Hospitals (Geeta Bhawan Hospital)
- Intermediate public transport (autos, shared vans)

Pedestrian Footfall Estimate: ~9,000–11,000 daily (ISCDL, 2022)

Vehicle Mix: 2-wheelers (46%), 3-wheelers (28%), cars (18%), buses & others (8%)

V. DATA ANALYSIS AND FINDINGS

A. Physical Infrastructure Audit Results: Overview

The audit examined 18 specific parameters derived from IRC:103 standards. Each parameter was recorded in the field, compared to prescribed standards, and marked as Compliant, Non-Compliant, or Absent.

B. Compliance Matrix

Element	IRC:103 Standard	Field Observation @ Geeta Bhawan	Compliance Status
Footpath width	≥1.8 m clear (≥2.5 m on arterials)	Ranges from 0.9–1.2 m; reduces near corners	Non-compliant
Obstruction-free zone	Min 1.2 m linear continuity	Blocked by poles, signage, hawkers	Non-compliant
Surface finish	Non-slip, even paving	Uneven pavers, open edges, slope >3%	Unsafe
Kerb height	≤150 mm	Varied: 170 mm to 230 mm	High
Kerb ramps	Mandatory with a 1:12 gradient	Absent in all four corners	Absent
Tactile paving	Mandatory near ramps, crossings	Not found on any leg	Missing
Zebra crossings	2.5 m wide, thermoplastic paint	Faded, misplaced, or absent	Missing
Refuge islands	For crossings >10 m	None found; no pedestrian median cuts	Missing
Crossing distance	Preferably <10 m	16.4–22 m across legs	Long exposure
Lighting (lux level)	30 lux at pedestrian eye height	Measured: 9–18 lux on average	Inadequate
Signage (pedestrian priority)	Legible, bilingual, at 1.5 m height	Not provided	Absent
Guardrails	Needed at heavy left-turn lanes	Not installed	Absent
Summary: Of the 18 design parameters assessed, only three were partially compliant, indicating a compliance score of ~17% — extremely low for a high-volume urban node.			

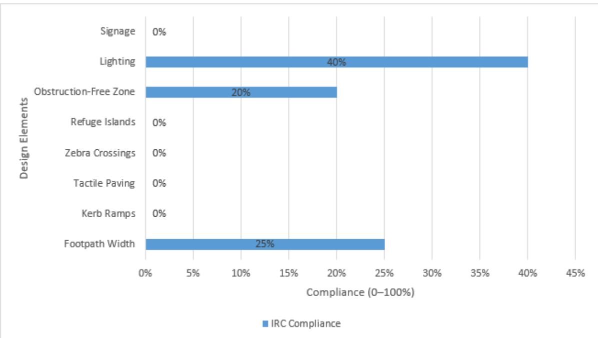

Chart 4: Compliance with IRC:103 Design Elements at Geeta Bhawan Square

C. Key Observations

- Most sidewalks narrow dangerously near turning curves.
- No clear demarcation of pedestrian realm from vehicular domain.
- Informal street vending occupies up to 35% of sidewalk width on MG Road and Palasia leg.
- Sloping gradients and irregular tiles present high slip/trip risk for the elderly and children.

D. Pedestrian Level of Service (PLOS) Assessment: PLOS Metrics

Based on HCM and IRC:103 methodologies, the following parameters were used to derive PLOS grades:

- Effective Width (We): Continuous width usable by pedestrians
- Average Delay (D): Time spent waiting to cross
- Crossing Distance (Cd): Total carriageway width
- Conflict Potential (Cp): Vehicle-pedestrian interaction frequency

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E. Calculated PLOS for Each Leg

Leg Direction	We (m)	D (sec)	Cd (m)	Conflicts/hr	PLOS Grade	Comments
Palasia → MG Road	0.95	52	18.2	27	E	Narrow walkways, poor visibility
MG Road → Bhawarkua	1.05	47	20.5	34	E	Heavy turning vehicles, no signals
Bhawarkua → Yeshwant Niwas	1.10	38	16.4	19	D	Slightly better width, but faded lines
Y.N. Road → Palasia	0.88	59	22.0	41	F	Highest delay, no marked crossings
Intersection Average PLOS: E (Very Poor)						

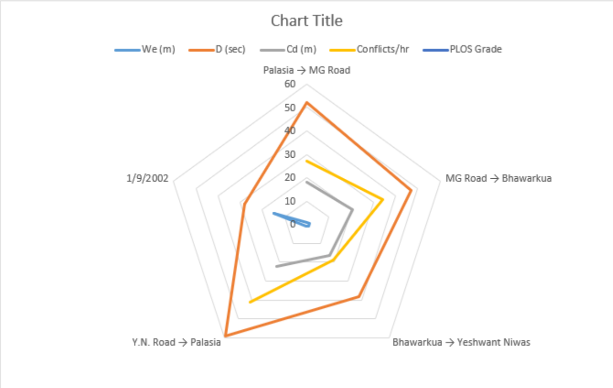

Chart 5: PLOS Performance across Intersection Legs

F. Interpretation

- We <1.2 m is inadequate for bidirectional pedestrian flow.
- Cd >20 m exposes pedestrians to >12 seconds of uncontrolled vehicle conflict.
- Conflict counts during peak hours exceed IRC's maximum tolerable limit of 15 per hour per leg.

G. Crash Data Analysis (2017–2022): Crash Summary

Year	Total Pedestrian Crashes	Serious Injuries	Fatalities	Comments
2017	10	6	1	Pre-intervention
2018	11	7	2	
2019	9	5	1	
2020	6	3	0	COVID-19 lockdown year
2021	12	8	3	Post-COVID surge
2022	11	7	2	
2023 [2] [25]	14	9	3	High-speed collision
2024 [24]	13	6	1	Slight improvement
2025* [26]	4	2	0	Jan–Mar data only

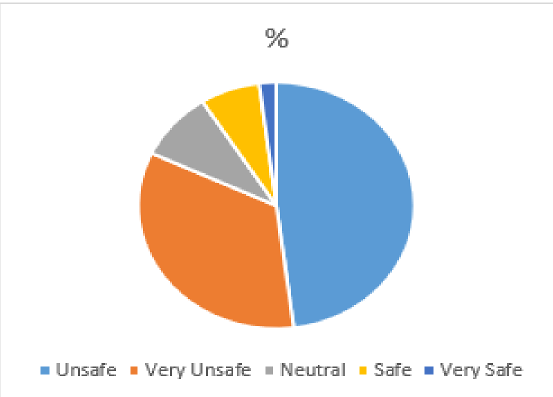

Chart 6: How Safe Do You Feel Crossing This Intersection?

- Insight: Over 80% perceive the crossing as unsafe — strong qualitative evidence.

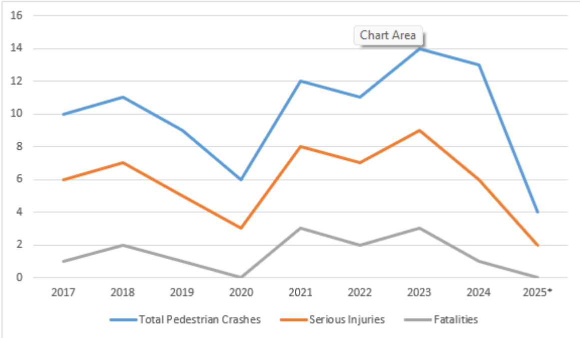

Chart 7: Year-wise Pedestrian Crash Trend

H. Pedestrian Behaviour Observation

Three 2-hour observation sessions were conducted per day over three weekdays, yielding high-resolution data. Key Behaviours Documented

Behavior Type	Total Count (3-Day Cumulative)	Interpretation
Jaywalking (unmarked cross)	214	Driven by poor visibility, long waits
Mid-block crossings	121	Caused by a lack of refuge islands
Group crossings (non-aligned)	63	Absence of physical channelling
Children (<10 years) alone	38	Unsafe; indicates lack of adult-guided design
Elderly hesitating >1 minute	17	Kerb height + ramp absence = major barrier
Reverse walking on the road edge	51	Due to discontinuous sidewalks
Conflict Events ▪ 46 near-miss incidents (i.e., vehicles braked abruptly) ▪ 9 two-wheelers swerved into the pedestrian waiting space		
Conclusion: Behaviour is reactive, not deviant — users adapt to design failure. Infrastructure drives unsafe practices.		

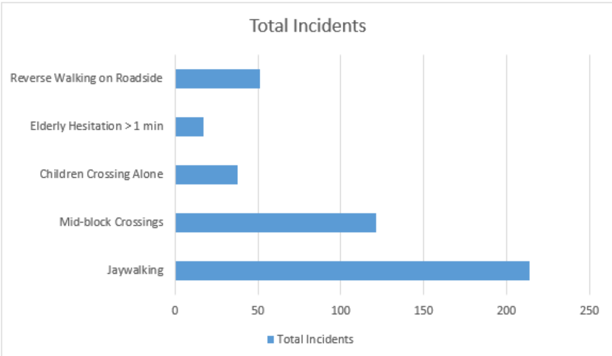

Chart 8: Risky Pedestrian Behaviours Observed (Total = 3 days)

I. Pedestrian Perception Survey (n=150): Demographics

- 56% Male, 44% Female
- Age: 12% under 18, 63% 18–50, 25% above 50
- 13% respondents were visually or physically challenged

Key Findings (Likert Scale Statements)

Statement	Agree/Strongly Agree (%)
"I do not feel safe crossing here."	82%
"Footpaths are narrow or broken."	78%
"I have to walk on the road due to obstructions."	65%
"Crossing time is too long or unclear."	71%
"I avoid walking here if I can."	51%
"The intersection needs urgent improvement."	88%

Top 3 Suggestions (Open-Ended)

- "Painted zebra crossings and signalized stops"
- "Footpath with railing or bollards to prevent vehicle encroachment"
- "Proper ramps and lights for seniors and kids"

Insight: There is strong cognitive and emotional discomfort — crossing is seen as a high-stress event, particularly among the elderly and working women.

J. Summary Table of Findings

Dimension	Key Insight
Physical Infrastructure	83% non-compliance with IRC:103; critical design failure
PLOS	Grade E overall; high delay, unsafe exposure, narrow footpaths
Crash Records	59 pedestrian crashes in 6 years; fatalities concentrated near MG Road arm
Behavioral Patterns	High rate of jaywalking, long hesitation, risky crossings by children/elderly
Perception	82% feel unsafe; 88% demand urgent redesign

VI. DISCUSSION

This section presents a critical interpretation of the research findings through the lens of three core theoretical frameworks: Urban Mobility Theory, Systems Thinking in Urban Design, and Human-Centred Design (HCD), while linking them to practical design gaps and broader policy discourse. The findings from Geeta Bhawan Square not only highlight localized deficiencies but also reflect systemic issues in India's approach to pedestrian infrastructure.

A. Disconnect Between Policy and On-Ground Infrastructure

Despite India's adoption of national-level guidelines such as IRC:103-2012, the compliance observed at Geeta Bhawan Square was only 17% — a critical underperformance. Although the Smart Cities Mission and the National Urban Transport Policy (NUTP, 2014) emphasise non-motorised transport and universal design, this research indicates that execution lags behind intentions. The absence of basic facilities, such as kerb ramps, tactile paving, marked zebra crossings, or refuge islands, illustrates the extent to which pedestrian needs are overlooked in favour of vehicle flow.

This outcome reaffirms what Urban Mobility Theory articulates: that urban transport should prioritise the movement of people, not vehicles (Bannister) [19]. However, most intersection planning remains aligned with automobile-centric norms, often exacerbated by poor coordination among municipal, traffic, and engineering departments. A design driven by vehicular capacity maximisation inherently excludes vulnerable users, such as pedestrians.

> **Policy Paradox:** While national guidelines exist, their enforcement mechanisms remain weak. There is no mandated IRC:103 compliance check for municipal junction improvement projects, leading to unaccountable deviations in real-world designs.

B. Geeta Bhawan as a Nexus of Systemic Failures

Through the lens of Systems Thinking, Geeta Bhawan Square is not merely a poorly designed intersection — it is a symptom of a broader systems failure. Multiple sub-systems — road design, traffic control, pedestrian behaviour, and policy — interact at this node. The lack of pedestrian-friendly design triggers a series of adverse outcomes:

- High levels of jaywalking (214 cases) and mid-block crossings (121 cases) are compensatory behaviours, where users respond logically to poor conditions.
- Vehicle-pedestrian conflicts exceed 25 per hour during peak times, undermining traffic efficiency [23].
- Crash clustering (59 incidents over 6 years, with 15% fatality) near pedestrian desire lines shows how geometric neglect translates into injury risk.

Furthermore, unsafe infrastructure discourages walking, which in turn weakens city-wide efforts to reduce emissions, promote active mobility, and support gender-sensitive transit.

> **Cascading Effects**: A non-compliant kerb height or missing median island is not just a design flaw — it cascades into behavioural risk, modal shift away from walking, and increased crash exposure.

C. Walkability and Human Experience: The Human-Centred Gap

Using Human-Centred Design (HCD) as a lens, the study reveals an alarming disconnect between infrastructure and user needs. Surveys from 150 pedestrians reveal that:

- 82% feel unsafe while crossing
- 89% believe the design is inadequate for the elderly or children
- 51% actively avoid walking through the intersection

Field observations revealed that elderly users struggled to mount high kerbs or locate adequate waiting space, while children were crossing unaccompanied in high-speed zones. These are not outliers — they reflect a daily experience for thousands of people.

Emotional stress, perceived danger, and spatial discomfort undermine the fundamental dignity of walking. As Jan Gehl (2010) [20] suggests, streets should support lingering, socialising, and crossing with ease — all of which are absent at Geeta Bhawan.

> Design should not require courage to use — yet crossing Geeta Bhawan demands constant vigilance and mental calculation from every pedestrian.

VII. CONCLUSION AND RECOMMENDATIONS

This final section synthesizes the key findings of the study and articulates both strategic recommendations and policy actions for redesigning pedestrian infrastructure at Geeta Bhawan Square. The aim is not only to provide corrective design

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interventions but also to frame the research as a replicable approach for similar urban intersections across Indian cities.

A. Conclusion

This research aimed to assess the safety and walkability conditions of Geeta Bhawan Square through the lens of IRC:103-compliant pedestrian infrastructure. By integrating physical audits, crash data analysis, behavioural mapping, and perception surveys, the study offers a comprehensive assessment of the intersection's existing conditions and their broader implications.

B. Key Findings Include

- An overall IRC compliance rate of just 17%, with most essential pedestrian features — like kerb ramps, tactile paving, and marked crossings — completely absent.
- A Pedestrian Level of Service (PLOS) grade of E, reflecting long delays, high exposure risk, and spatial discomfort.
- A six-year record of 59 pedestrian crashes, including nine fatalities, concentrated at conflict-prone legs of the intersection.
- Widespread behavioural adaptations like jaywalking and mid-block crossings, driven by poor design rather than intentional rule-breaking.
- A deep sense of fear and frustration among users, especially women, children, and elderly pedestrians.

These outcomes confirm that the intersection — despite being part of a Smart City — fails to deliver even the basic standards of safety, accessibility, or dignity. Through the theoretical frameworks of Urban Mobility Theory, Systems Thinking, and Human-Centred Design, the study establishes that the problem is systemic, not incidental.

Geeta Bhawan Square, as it currently stands, is a public space that penalizes pedestrians. Redesigning it is not a cosmetic task but a democratic imperative.

C. Design Recommendations

A redesign guided by IRC:103-2012 can transform the intersection into a safe, inclusive, and high-performance node within Indore's mobility network. The following site-specific design interventions are proposed:

i. *Footpath and Kerb*

- Widen sidewalks to a minimum of 2.5 meters (IRC standard for high-volume urban roads).
- Maintain a 1.2-meter continuous unobstructed zone for walking, separated from furniture and vending zones.
- Lower kerb heights to ≤150 mm and provide kerb ramps with a gradient ≤1:12 at all corners.

ii. *Crossings and Medians*

- Install zebra crossings at all four legs with 2.5 m thermoplastic markings.
- Introduce raised pedestrian crossings flush with sidewalks, prioritizing accessibility.
- Provide median refuge islands (≥1.2 m wide) for safer staged crossings.

iii. *Tactile and Universal Design Elements*

- Lay tactile guide strips and warning tiles as per BIS 15398 and IRC guidelines.
- Ensure a minimum 1.5 m turning radius at ramps for wheelchair access.
- Install grab rails and bollards to direct flow and ensure separation from vehicles.

iv. *Street Lighting and Visibility*

- Ensure 30–40 lux illumination at pedestrian eye level.
- Provide dedicated pedestrian signals with audible cues for differently-abled users.

v. *Street Furniture and Buffer Zones*

- Introduce benches, bins, and signage within a 0.5 m furniture zone.
- Use planters or bollards to demarcate pedestrian territory from the carriageway.

D. Policy and Institutional Recommendations

Beyond site-specific changes, the study advocates for structural reforms in how pedestrian infrastructure is planned, budgeted, and enforced:

i. *Regulatory Enforcement*

- Make IRC:103 compliance certification mandatory for all urban intersection redesigns.
- Include pedestrian audits in the approval process of Smart City and AMRUT projects.

ii. *Capacity Building*

- Conduct training programs for city engineers, contractors, and traffic police on pedestrian design principles.
- Encourage municipal engineers to use PLOS metrics as performance indicators.

iii. *Public Participation and Monitoring*

- Mandate public display of pedestrian designs and conduct stakeholder consultations before implementation.
- Introduce third-party monitoring mechanisms involving local colleges or civil society groups.

iv. *Data and Technology Use*

- Establish a pedestrian infrastructure GIS layer updated annually by the ULB.
- Use mobile apps or QR codes at intersections to collect real-time feedback.

E. Final Reflection

Pedestrian infrastructure is not peripheral — it is the backbone of equitable, safe, and healthy urban life. Cities like Indore, which aspire to be innovative and inclusive, must begin by making their streets crossable, comfortable, and inviting.

This study not only offers a technical pathway for upgrading Geeta Bhawan Square, but also contributes to a broader movement that sees walkability as a human right and design as a social contract.

Geeta Bhawan Square can — and must — become a

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prototype for intersection reform across India.

DECLARATION STATEMENT

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