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Pedestrian Underpass Safety at BRT Corridors

Challenges and Solutions - A Case Study of Kalewadi Phata, Pune

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Abstract - Pedestrian safety at Bus Rapid Transit (BRT) underpass crossings represents a critical challenge in rapidly growing urban areas. This research paper investigates the pedestrian safety conditions at the Kalewadi Phata BRT corridor in Pune, Maharashtra, focusing on the underpass crossings that expose pedestrians to significant risks from high-speed bus movements. The study identifies the major causes of accidents and near-miss incidents, including poor visibility, absence of effective warning systems, inadequate signage, and lack of pedestrian-awareness infrastructure.

Through two rounds of structured field surveys involving direct observation and one-to-one interaction with pedestrians, the research documents the frequency of unsafe crossings, the demographic profile of affected users, and the deficiencies in the existing system. Based on these findings, the paper proposes a multi-pronged solution incorporating an Arduino UNO-based IR sensor warning system, installation of retroreflective sign boards, concave road mirrors, rumble strips, and improved road markings. A working prototype of the Arduino-based alert model was fabricated and tested. The proposed solutions are low-cost, technically feasible, and operationally maintainable, making them suitable for implementation across BRT corridors in Indian cities.

Keywords: Pedestrian Safety, BRT Underpass, Arduino Warning System, IR Sensor, Kalewadi Phata, Traffic Safety, Rumble Strips, Road Signage.

INTRODUCTION

Urban mobility in Indian cities has undergone significant transformation with the introduction of Bus Rapid Transit (BRT) systems designed to provide efficient, dedicated bus lanes that reduce traffic congestion. However, the physical infrastructure created for BRT corridors — particularly underpasses used for pedestrian crossings — has introduced new safety hazards. In cities like Pune, BRT corridors run along the center of wide arterial roads, with high-frequency bus services operating at speeds that are unsafe for pedestrians attempting to cross.

An underpass crossway in a BRT corridor serves as the designated route for pedestrians to cross from one side of the road to the other without disrupting bus movement. While this design theoretically improves safety by separating pedestrian and vehicular movement, in practice, pedestrians are often unaware of an approaching bus when they emerge from the underpass onto the BRT lane. The resulting scenario — a pedestrian walking onto a bus lane without knowledge of a fast-approaching vehicle — is a leading cause of accidents at these locations.

The Kalewadi Phata to Jagtap Dairy stretch in Pune covers a 2.4 km BRT corridor with four lanes, three underpasses, two intersections, and two diverging/merging points. This corridor was selected as the study area due to its high pedestrian footfall, frequent bus movement, and documented near-miss incidents. The research aims to provide a scientific basis for

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designing and implementing low-cost safety improvements that can be replicated across similar BRT infrastructure in India.

The paper is organized as follows: Section 3 presents the case study description; Section 4 outlines the methodology and survey procedures; Section 5 presents key observations and data; Section 6 discusses practical applications of the proposed solutions; Section 7 draws conclusions.

CASE STUDY: KALEWADI PHATA BRT UNDERPASS, PUNE

Study Area Description

The study area is the Kalewadi Phata to Jagtap Dairy BRT corridor, spanning 2.4 km along a major arterial route in Pune, Maharashtra. The corridor comprises four lanes — two central lanes for general traffic and two flanking BRT lanes for exclusive bus operation. The corridor includes three underpass crossings, two signalized intersections, and two diverging and merging points.

The Kalewadi Phata underpass is the primary site of concern. It is used extensively by commuters, students, daily wage workers, and elderly pedestrians to cross the BRT corridor. The underpass structure provides a tunnel below road level, with openings at either end that emerge directly onto the BRT bus lane. This layout places pedestrians at direct risk of collision with approaching buses, especially during peak hours.

Problem Identification

The core problem identified at this site is that pedestrians exiting the underpass have no reliable means of knowing whether a bus is approaching on the BRT lane. The following specific deficiencies were noted during initial observation:

- Absence of any active warning system (auditory or visual) at underpass exits
- No working pedestrian crossing signals synchronized with BRT bus movements
- Insufficient or absent retroreflective signage indicating bus lane hazard
- Poor lighting inside and at exits of the underpass during early morning and evening hours
- No physical barrier or holding area at underpass exits to allow pedestrians to pause and verify bus approach
- High vehicle speeds on BRT lane due to limited enforcement measures
- Absence of rumble strips near the underpass mouth to slow approaching buses

These deficiencies collectively create a dangerous environment, particularly for children, elderly pedestrians, and people with disabilities who may have reduced ability to visually scan for approaching vehicles.

Stakeholder Profile

A wide range of pedestrian profiles was observed using the Kalewadi Phata underpass, including office commuters, school children, market visitors, and senior citizens. Interactions with these stakeholders revealed that the majority were aware of the danger but perceived it as an unavoidable part of using the corridor. Many reported incidents of near-misses, and several had witnessed accidents. Despite awareness of the risk, most continued using the underpass due to the absence of a viable alternative crossing point.

METHODOLOGY AND PROCEDURE

Research Design

This study follows a mixed-method research design combining quantitative field observation with qualitative one-to-one interaction. The research was conducted in two phases corresponding to two structured surveys, each conducted at the Kalewadi Phata underpass during peak pedestrian hours (8:00 AM – 10:00 AM and 5:00 PM – 7:00 PM).

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Survey Procedure

The following systematic procedure was adopted for data collection:

1. Site reconnaissance and identification of three key observation points: underpass entry, underpass exit (BRT side), and midpoint tunnel area.
2. Development of a structured observation checklist capturing pedestrian count, bus frequency, near-miss events, signal awareness, and demographic profile.
3. Deployment of two team members at the underpass exit for continuous observation during survey hours.
4. One-to-one structured interaction with pedestrians immediately after crossing, using a 10-question verbal questionnaire covering awareness, perception of risk, and preference for proposed solutions.
5. Manual count of buses on the BRT lane using a stopwatch and tally method.
6. Photography and video documentation of site conditions and pedestrian behaviour.
7. Comparison of Survey 1 and Survey 2 data to identify trends, changes in behaviour, and the effect of increased awareness.

Prototype Development

Parallel to field surveys, a working prototype of the Arduino-based pedestrian warning system was designed and fabricated. The prototype employs the following design logic:

- An IR sensor is placed at the BRT lane approach to the underpass exit, oriented to detect vehicles (buses) moving toward the crossing zone.
- When the IR sensor detects an approaching bus, it sends a HIGH signal to the Arduino UNO microcontroller.
- The Arduino triggers a buzzer (auditory alert) and an LED indicator (visual alert) at the underpass exit, warning pedestrians before they step onto the lane.
- The alert remains active until the bus has passed the detection zone, after which the system resets automatically.

The prototype was tested at a simulated scale model representing the underpass exit geometry, using a remote-controlled vehicle to simulate BRT bus movement. System response time and sensitivity of the IR sensor were calibrated to provide a minimum 4–6 second warning window prior to vehicle arrival at the crossing zone.

OBSERVATIONS

Survey Data Summary

The following table presents key observations collected during both survey rounds at the Kalewadi Phata BRT underpass. Data was compiled over four survey sessions (two sessions per survey round) with a total observation duration of approximately 16 hours.

Sr. No.	Parameter Observed	Survey 1 Count	Survey 2 Count	Remarks
1	Pedestrians using underpass per hour	142	158	Increasing trend
2	Buses passing through BRT corridor/hr	38	41	High frequency

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3	Near-miss incidents observed	7	5	Reduced post-awareness
4	Pedestrians aware of BRT signal	23%	31%	Low awareness
5	Respondents preferring warning system	76%	82%	Strong demand
6	Respondents using alternative crossing	45%	38%	Risk-taking behaviour
7	Children and elderly pedestrians (%)	28%	31%	Vulnerable group

Table 1: Comparative Survey Observations — Kalewadi Phata BRT Underpass

Key Findings from Observations

Analysis of the survey data reveals the following significant patterns:

- Pedestrian volume increased between Survey 1 and Survey 2 (142 to 158 per hour), reflecting growing usage of the corridor.
- Bus frequency on the BRT lane remained consistently high at approximately 38–41 buses per hour, implying an average gap of only 88–95 seconds between consecutive buses.
- Near-miss incidents declined from 7 to 5 between Survey 1 and Survey 2, possibly reflecting increased cautionary behaviour following awareness interactions.
- Only 23–31% of pedestrians were aware of BRT bus signals, indicating a critical gap in user awareness.
- 76–82% of respondents expressed a strong preference for a reliable pedestrian warning system.
- 45% of pedestrians were observed attempting to cross the BRT lane at non-designated points, indicating that the existing underpass does not fully channelize crossing behaviour.
- Children and elderly pedestrians constituted 28–31% of underpass users, representing a vulnerable group with heightened risk exposure.

One-to-One Interaction Findings

During structured interactions, the majority of respondents rated pedestrian safety at the underpass as 'Poor' or 'Very Poor.' Key responses included widespread demand for a warning buzzer at the exit, requests for better lighting, and suggestions for a waiting zone or hold line at the underpass mouth. Several respondents cited witnessing accidents or near-miss events on multiple occasions.

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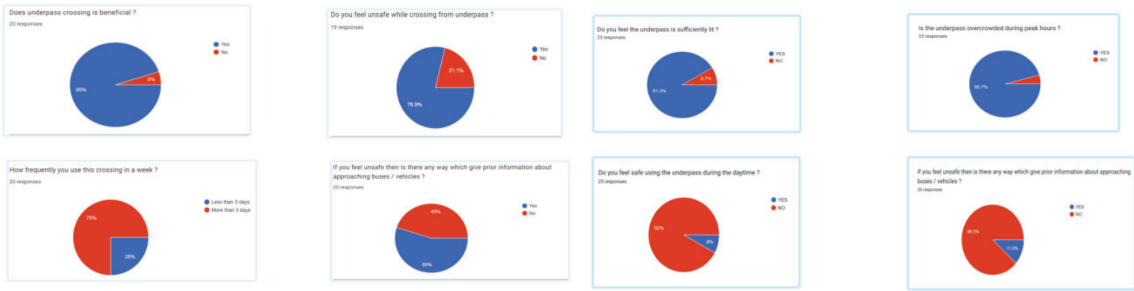

Practical Applications of Proposed Solutions

Arduino-Based IR Sensor Warning System

The Arduino UNO-based warning system is the primary proposed intervention. It consists of an IR sensor module placed at a strategic distance upstream of the underpass exit on the BRT lane, connected to an Arduino UNO microcontroller that triggers a buzzer and LED indicator at the pedestrian exit point. The system operates continuously and requires no active human intervention after installation.

For full-scale implementation, the IR sensor would be replaced or supplemented with an ultrasonic sensor or inductive loop detector embedded in the road surface, providing greater reliability under varying lighting and weather conditions. The warning panel at the underpass exit would include a large LED display reading 'BUS APPROACHING — WAIT' in Marathi, Hindi, and English, along with the auditory buzzer. Power would be supplied through the existing road lighting infrastructure or a solar panel with battery backup.

PEDESTRIAN CROSSING SIGN BOARDS

Retroreflective sign boards compliant with Indian Roads Congress (IRC) standards would be installed at the following locations: the underpass approach paths on both sides, the underpass exit mouth, and at 50m intervals along the BRT lane adjacent to the crossing zone. The sign boards would include mandatory warning messages ('PEDESTRIAN CROSSING AHEAD'), cautionary messages ('BUS LANE — HIGH SPEED VEHICLES'), and instructional messages ('WAIT FOR GREEN SIGNAL BEFORE CROSSING').

RUMBLE STRIPS

Rumble strips — raised thermoplastic strips placed perpendicular to the direction of travel — would be installed on the BRT lane at 30m and 15m ahead of the underpass crossing zone. These strips cause a tactile and auditory sensation inside a bus cabin when driven over at high speed, serving as a physical reminder to the bus driver to reduce speed in the crossing zone. Rumble strips are a low-cost, passive safety intervention that requires minimal maintenance.

Road Markings and Storage Lane

Improved road markings including a clearly delineated pedestrian crossing zone, warning chevrons, and a storage lane (a pavement area immediately outside the underpass exit) would allow pedestrians to wait in a protected zone before stepping

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onto the BRT lane. The storage lane would be demarcated with coloured thermoplastic paint and physical bollards. These markings reinforce proper crossing behaviour and improve visibility for bus drivers approaching the zone.

Concave Road Mirrors

Convex road mirrors (600mm diameter, retro-reflective) would be installed at the underpass exit corners and at the BRT lane edge at the crossing zone. These mirrors allow pedestrians to see around the underpass structure and observe approaching buses before stepping onto the lane. This passive solution is immediately effective, requires no power supply, and is highly durable.

Integrated Implementation Strategy

For maximum effectiveness, all five solutions should be implemented as an integrated system rather than individually. The Arduino-based warning system provides active, real-time alerts; sign boards and road markings deliver passive informational cues; rumble strips enforce speed reduction; and concave mirrors extend pedestrian visibility. Together, these interventions address the safety problem from multiple angles, creating redundancy so that if one system fails, others continue to provide protection.

CONCLUSION

This study investigated the pedestrian safety conditions at the Kalewadi Phata BRT underpass corridor in Pune and demonstrated through structured field surveys and stakeholder interaction that the existing infrastructure is critically inadequate in protecting pedestrians — particularly children, elderly users, and those with limited mobility — from the risk of collision with BRT buses.

The findings confirm that the absence of active warning systems, poor signage, inadequate lighting, and the absence of a pedestrian holding zone are the primary contributing factors to near-miss incidents and accidents at this location. Survey data showed that less than one-third of pedestrians were aware of BRT signals, while more than three-quarters expressed strong demand for a dependable warning system.

The proposed Arduino-based IR sensor warning system, validated through prototype fabrication and testing, offers a technically feasible, low-cost, and easily maintainable solution that can be implemented at existing BRT underpasses without major civil works. When integrated with retroreflective sign boards, concave road mirrors, rumble strips, and improved road markings, this system creates a comprehensive safety infrastructure that addresses both the pedestrian awareness and vehicle speed aspects of the problem.

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