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Traffic Control System: Case Study of Balewadi High Street Signal

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Abstract

The increasing demand for efficient traffic management in urban areas is crucial for enhancing safety, reducing congestion, and improving overall mobility. This study focuses on the design and implementation of an intelligent traffic control system at two critical intersections in Pune: Balewadi High Street Bridge and Lt. Baburao Habaji Saykar Chowk. The study identifies key traffic flow issues, including congestion, delay, and poor intersection geometry, and proposes the use of advanced traffic control measures, such as traffic signals, road markings, and intelligent systems, to manage peak traffic loads. The study identifies key traffic flow issues, including congestion, significant delays, poor intersection geometry, and inefficient signal timing, which hinder smooth vehicular movement. In response to these challenges, the research proposes the deployment of advanced traffic control measures, including optimized traffic signals, road markings, sensor-based monitoring systems, and adaptive traffic management technologies to ensure real-time responses to changing traffic conditions. The intelligent system is designed to prioritize traffic flow efficiency while enhancing pedestrian safety and reducing vehicle idle time, which contributes to lower fuel consumption and decreased carbon emissions. Through field observations, traffic data collection, and simulation modeling, the study evaluates current traffic patterns and proposes tailored interventions suited to the specific conditions at each intersection. The implementation of such intelligent systems aims not only to manage peak traffic loads but also to provide scalable solutions that can be applied to other urban intersections across Pune and similar metropolitan areas. Ultimately, this research contributes to the development of sustainable urban transportation networks by offering practical solutions that balance mobility needs with safety and environmental concerns.

Keywords: Traffic control system, traffic congestion, urban traffic management, intelligent transportation systems, traffic signal optimization, intersection design

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INTRODUCTION

Urban traffic management has become a critical challenge for cities experiencing rapid growth and increased vehicle ownership. Traffic congestion, delays, and safety concerns are prevalent issues in densely populated regions, where the demand for road infrastructure often exceeds its capacity. As cities expand, the need for efficient traffic control systems becomes essential to ensure the smooth movement of people and goods.

In recent years, intelligent transportation systems (ITS) have emerged as a viable solution to manage urban traffic flow, improve safety, and reduce travel times. These systems leverage advanced technologies to monitor and control traffic conditions in real time, offering dynamic solutions that adapt to fluctuating traffic patterns. Key components of traffic control systems include traffic signals, road markings, and sensors, which together optimize vehicular movement and minimize congestion, especially at intersections [1–4].

This paper presents a case study of traffic signal design and optimization at two critical intersections in Pune, India: Balewadi High Street Bridge and Lt. Baburao Habaji Saykar Chowk. Both locations face significant traffic congestion during peak hours, resulting in delays and safety concerns. The aim of this study is to design an efficient traffic control system that reduces congestion, improves traffic flow, and enhances road safety [5].

The methodology involves collecting real-time traffic volume data, conducting peak-hour traffic surveys, and analyzing vehicular movements. Using the data, optimized signal timings are proposed, considering factors such as saturation flow, phase design, and green-time allocation. The results demonstrate that introducing well-designed traffic signals at these intersections significantly improves traffic efficiency and reduces waiting times, offering a cost-effective alternative to infrastructure expansion projects such as flyovers [6].

This work highlights the importance of using intelligent traffic control measures to address the growing traffic challenges in urban areas and contributes to the broader vision of developing smart cities.

LITERATURE REVIEW

The research studies on Pune’s traffic congestion highlight critical issues, but several gaps remain unaddressed. Chetan Shivatare et al. discuss traffic problems and control measures but lack quantitative data and feasibility analysis for advanced technologies. Dr. Dhananjay Mandlik’s study identifies key causes of congestion but does not assess policy [7].

Interventions or AI-based traffic solutions. Dr. Surekha Gaikwad’s research highlights urbanization and inadequate infrastructure but does not provide empirical evidence or behavioral insights on rule violations. Devkate R. A. et al. focus on three congested intersections without a city-wide perspective or traffic simulation validation. Sumit Mallik proposes Intelligent Transportation Systems (ITS) but lacks feasibility and cost-benefit analysis for Pune. Ninad Lanke and Sheetal Koul suggest RFID-based traffic control but do not address implementation challenges, security concerns, or pilot testing. Shobha Rekh et al. propose smart traffic systems using sensors and cloud computing but do not analyze scalability or maintenance issues [8].

Abhijeet Choudhary et al. introduce an AI-based traffic management system but fail to test it in real-world conditions or assess weather impacts on video processing. Khodakaram Salimifard and Mehdi Ansari model traffic signals using Arena simulation, but their study is based in Iran, making applicability to Pune uncertain. Pravin J. Pawar et al. identify causes of congestion but provide broad solutions without prioritization or predictive analytics. Pratik S. Gawade focuses on expanding public transport without considering vehicle ownership reduction policies. Koustubh Patil et al. analyze congestion on specific roads but do not explore behavioral patterns or real-world testing of solutions. Gouri S. Patil et al. suggest smart parking and public transport improvements but do not examine technological implementation or behavioral impacts [9].

Ms. Priya Hirave and Dr. Vidula Sohoni emphasize urbanization-driven congestion but lack empirical data on vehicle usage and congestion pricing models. Vinayak Rajendra Kshirsagar and Dr. Surekha Gaikwad propose BRTS, metro, and strict lane discipline but do not consider economic feasibility or emerging mobility trends. Gayatri S. Choudekar and Rohit R. Salgude analyze traffic at two intersections but do not integrate smart traffic lights or study social impacts. Suyash Kamble et al. suggest an Inclusive Motorcycle Lane (IMCL) but do not explore feasibility in dense urban settings or conflicts with other transport modes. Amit Jadhav et al. recommend flyovers and underpasses while eliminating BRTS but fail to present a study on its consequences or integration with non-motorized transport. Lastly, Prajakta Mondkar et al. propose AI-based adaptive traffic signals but do not address legal, administrative, or emergency response concerns [10].

While these studies provide valuable insights into Pune's traffic crisis, gaps in technological feasibility, empirical validation, policy assessment, and behavioral analysis indicate the need for further research to develop holistic, implementable solutions [11].

METHODOLOGY

This study adopts a mixed-methods approach, combining quantitative analysis (traffic volume, congestion patterns, and accident data) and qualitative insights (surveys, expert interviews, and policy evaluations). The research is exploratory and analytical, aiming to assess traffic conditions, identify causes of congestion, and propose viable solutions (Figure 1) [12].

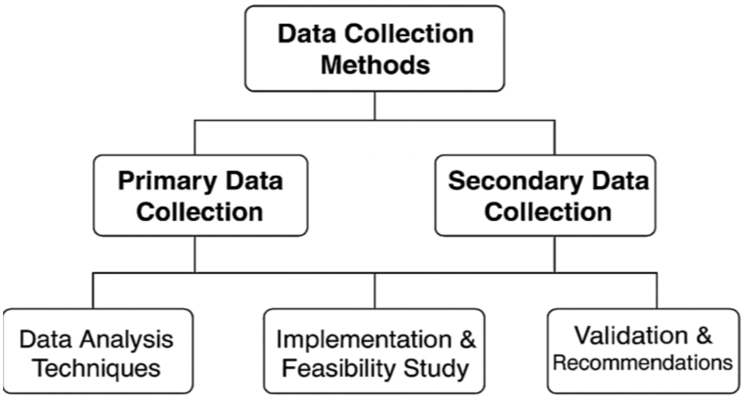

Figure 1. Methodology graph.

DATA COLLECTION METHODS

Primary Data Collection

- *Traffic Surveys & Field Observations:* Conduct real-time traffic volume counts, congestion mapping, and signal wait time studies at major intersections at Radha Chowk to Balewadi high street.
- *Vehicular Movement Study:* Use GPS tracking, drone surveillance, and image processing to analyze vehicular density and movement patterns.
- *Public Perception Surveys:* Gather responses from daily commuters, drivers, traffic police, and city planners about congestion challenges and potential solutions.
- *Expert Interviews:* Traffic police department (Figure 2 and Tables 1–4) [13–15].

Secondary Data Collection

- *Government Reports & Traffic Data:* Analyze Pune Municipal Corporation (PMC), Regional Transport Office (RTO), and Pune Traffic Police reports on vehicle registration trends, accident statistics, and road network expansion.
- *Smart Traffic System Studies:* Review case studies of successful smart traffic management implementations in other cities.
- *Satellite Imagery & GIS Analysis:* Use remote sensing and GIS tools to study road congestion, land use patterns, and urban expansion affecting traffic flow [16–18].

Table 1. Vehicular movement in Veh/hr from East.

From	To	Two-Wheeler	Auto Rickshaw	Bus	Truck	Car	Cycle	Pedestrian	Total
E	Straight(W)	1551	57	39	98	608	–	78	2431
	Left (S)	53	20	3	3	15	–	68	162
	Total	1604	77	42	101	623	–	146	2593

Figure 2. Field visit at Radha Chowk on 19/10/24.
Note: Field study (Vehicular movement in Veh/hr).

Table 2. Vehicular movement in Veh/hr from West.

From	To	Two-Wheeler	Auto Rickshaw	Bus	Truck	Car	Cycle	Pedestrian	Total
W	Straight (E)	200	20	5	11	70	0	45	351
	Right (S)	112	9	3	5	15	0	39	183
	Left (N)	330	21	3	8	105	0	46	513
	Total	642	50	11	24	190	0	130	1047

Table 3. Vehicular movement in Veh/hr from North.

From	To	Two-Wheeler	Auto Rickshaw	Bus	Truck	Car	Cycle	Pedestrian	Total
N	Straight (S)	265	38	1	1	35	0	69	409
	Right (W)	236	18	3	3	31	0	45	336
	Left (E)	118	7	4	4	9	0	40	182
	Total	619	63	8	8	75	0	154	927

Table 4. Vehicular movement in Veh/hr from South.

From	To	Two-Wheeler	Auto Rickshaw	Bus	Truck	Car	Cycle	Pedestrian	Total
S	Straight (N)	385	22	3	8	77	0	45	540
	Right (E)	376	43	6	9	36	0	33	503
	Left (W)	70	5	0	0	13	0	26	114
	Total	831	70	9	17	126	0	104	1157

Data Analysis Techniques

- *Traffic Volume Analysis:* Determine the average number of vehicles passing through during peak and non-peak hours.
- Traffic volume analysis is conducted using both manual counts and Automatic Traffic Counters (ATCs) at major intersections, helping authorities understand peak-hour congestion patterns. Geographic Information Systems (GIS) and remote sensing have been utilized to map hotspots, analyze road networks, and plan new infrastructure projects.
- To optimize traffic signals, Pune has adopted Adaptive Signal Control Technology (ASCT) and Green Wave Systems, which dynamically adjust signal timings based on real-time vehicle flow, reducing waiting times and fuel wastage [19].
- The combined use of AI, IoT, GIS, and simulation-based predictive modeling has enabled Pune to adopt a data-driven approach to traffic management, improving urban mobility and road safety.

Implementation & Feasibility Study

- The most cost-effective solutions are Intelligent Traffic Management Systems (ITMS), which include adaptive traffic signals, CCTV-based monitoring, and Automatic Number Plate Recognition (ANPR) for enforcing traffic rules.
- The estimated implementation cost for this phase is ₹50–70 crore, which is significantly lower than large-scale infrastructure projects but offers immediate impact.

Validation & Recommendations

- Implement Adaptive Traffic Signal Control (ATSC) at Radha Chowk to Balewadi high street road.
- Use CCTV-based AI traffic monitoring to analyze congestion patterns before and after the intervention.
- Compare pre- and post-implementation traffic conditions using GPS tracking, AI-driven CCTV surveillance, and vehicle density metrics.
- Retrofit existing signals with AI-based sensors and IoT-enabled surveillance rather than installing new hardware.
- Automate fine collection using ANPR and AI-driven traffic monitoring, ensuring better compliance with traffic laws.

RESULT AND DISCUSSION

- The adoption of AI-driven adaptive traffic signals in Pune holds significant potential for long-term traffic decongestion, improved road safety, and sustainable urban mobility. As these systems are progressively deployed across the city, future goals should focus on achieving seamless traffic flow, real-time traffic optimization, and enhanced public transport integration. With continuous AI learning and data collection, signal timings will be dynamically adjusted based on live traffic density, reducing wait times and vehicle idling by an estimated 40–50%. This will lead to lower fuel consumption, decreased emissions, and improved air quality, making Pune's transportation system more eco-friendly.
- Overall, if implemented effectively, AI-driven adaptive traffic signals can transform Pune into a smart, well-managed urban hub, ensuring smoother, safer, and more sustainable transportation. However, continuous monitoring, system upgrades, and public engagement will be key to adapting these solutions to the city's evolving mobility challenges.

CONCLUSIONS

The successful transformation of Pune's traffic management requires a holistic, data-driven, and technology-integrated approach that balances cost-effectiveness, sustainability, and scalability. While the initial investment in AI-driven adaptive traffic signals, smart monitoring systems, and optimized public transport may be substantial, long-term benefits – reduced congestion, improved road safety, lower emissions, and enhanced commuter efficiency – far outweigh the costs. A phased implementation strategy, backed by government policies, stakeholder collaboration, and public participation, will ensure sustainable urban mobility while minimizing financial and infrastructural burdens. The integration of real-time traffic analytics, intelligent transport systems (ITS), and AI-driven enforcement mechanisms will enable dynamic traffic optimization, automated rule enforcement, and emergency response prioritization, further enhancing urban mobility. Looking forward, the city must adopt continuous validation processes, adaptive policy frameworks, and smart urban planning to future-proof Pune's traffic infrastructure**,** ensuring resilience against rapid urbanization and evolving mobility needs. By embracing innovation, collaboration, and sustainable transport solutions, Pune can set a benchmark for efficient, intelligent, and eco-friendly traffic management, ultimately enhancing the quality of life and economic productivity of the city.

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