AI-Driven Smart Road Monitoring: A Case Study of Bilaspur Chhattisgarh

Nazya Parveen [1], Anchal Sondhiya[2], Abhay Singh Dahariya [3], Ramendra Kumar Mishra [4], Anjali Sharma[5]
[1]Nazya Parveen PhD Scholar in Kalinga University, [2] Anchal Sondhiya M.Tech Civil engineering Vishwavidyalaya Engineering College Ambikapur CSVTU Bhilai Chhattisgarh, [3] Abhay Singh Dahariya M.Tech Civil engineering Vishwavidyalaya Engineering College Ambikapur CSVTU Chhattisgarh , [4] Dr. Ramendra Kumar Mishra Civil Engineering JK institute of Engineeering, [5]Anjali Sharma M.tech Civil Engineering BIT Durg
[1]parveennazya@gmail.com, [2] anchalsondhiya123@gmail.com,[3]adahariya127@gmail.com,[4]ramendramishra1966@gmail.com, [5]sharmaanji2209@gmail.com

Abstract: India's rapid urbanization has significantly increased the strain on road infrastructure, leading to traffic congestion, poor road conditions, and higher accident rates. Bilaspur, Chhattisgarh, a growing commercial and transportation hub, faces similar challenges. This study explores the implementation of Smart Road Sensing Techniques (SRST) in Bilaspur to enhance real-time monitoring and road management. The proposed system integrates IoT sensors, Artificial Intelligence (AI), GPS tracking, and cloud computing to monitor traffic density, road deterioration, and accident-prone areas.
A lab-based experimental analysis was conducted to validate the efficiency of smart road sensors in detecting potholes, road surface friction, and traffic load impact. The results demonstrated that accelerometer-based sensors could detect potholes with 95% accuracy, while friction analysis showed that asphalt roads degrade faster than concrete roads under heavy traffic loads. Field surveys on NH-130 and urban intersections like Satyam Chowk indicate that peak-hour congestion, potholes, and lack of predictive maintenance are major issues affecting commuters. The research highlights how SRST can improve traffic flow, reduce accidents, and provide cost-effective road maintenance solutions by integrating technology-driven interventions.

By implementing real-time data analysis, local authorities can make better policy decisions and improve urban mobility and economic productivity. The lab experiments validate that smart road sensing can increase road lifespan, reduce maintenance costs by 20%, and improve road safety by 15-20%.

Keywords: Smart roads, IoT-based monitoring, traffic congestion, real-time road sensing, Bilaspur infrastructure, AI-driven road maintenance.

1. Introduction

Smart road monitoring systems are transforming traditional infrastructure management by integrating AI-driven technologies for real-time assessment and maintenance. In Bilaspur, Chhattisgarh, where traffic loads and environmental factors impact road conditions, AI-based monitoring using IoT sensors, accelerometers, and friction measurement tools can enhance road safety and durability. This study explores the implementation of AI-powered smart road monitoring**,** focusing on pothole detection, stress analysis, and material performance evaluation. By leveraging machine learning and sensor data**,** this approach aims to improve road maintenance efficiency, reduce accidents, and optimize infrastructure lifespan in Bilaspur.

1.1 Background

Bilaspur, known as the "City of Festivals" in Chhattisgarh, is an important economic center. However, with over 2.66 million residents and a rapidly growing vehicle population, its road infrastructure struggles to handle increasing traffic demands. National Highway 130 (NH-130) and major urban intersections frequently experience congestion, leading to longer commute times, increased fuel consumption, and rising pollution levels.

1.2 Problem Statement

Traditional road monitoring methods in Bilaspur are outdated, relying on manual inspections and delayed maintenance. This leads to potholes, uneven roads, waterlogging, and traffic mismanagement. Additionally, the lack of real-time traffic monitoring makes it difficult to optimize vehicle movement, causing frustration among daily commuters.

1.3 Objectives

This study aims to:

1. Analyse traffic density and road deterioration patterns in Bilaspur.

2. Evaluate the feasibility of Smart Road Sensing Techniques (SRST) in the local context.
3. Develop a cost-effective SRST framework using IoT, AI, and cloud computing.
4. Identify challenges in implementing smart road technologies in mid-sized Indian cities.
5. Provide strategic recommendations for sustainable traffic and road management.

2. Literature Review

2.1 Smart Road Technologies and Global Implementation

- Bianchini et al. (2023) highlighted how big data clustering techniques help identify high-risk road sections needing maintenance.
- Mateen et al. (2022) demonstrated how smart sensors can detect accidents and notify authorities in real time.
- Tao et al. (2022) developed smart road studs that collect traffic and weather data for safer road navigation.

2.2 Road Infrastructure Challenges in India

- Liu et al. (2021) noted that Indian road maintenance is reactive, not proactive, causing long-term infrastructure damage.
- Praticò et al. (2022) explored smart city road management models and emphasized the need for localized, cost-effective solutions.
- In India, research on affordable smart road technologies for semi-urban cities like Bilaspur is still limited.

2.3 Research Gap

While global models exist, most solutions are designed for developed nations with advanced infrastructure. This study bridges the gap by creating an affordable, scalable SRST framework for Bilaspur, aligning with India’s Smart City Mission.

3. Methodology

3.1 Study Area

The study focuses on:

1. **NH-130 (Bilaspur-Raipur Highway)** – Major commercial route with heavy traffic flow.
2. **Satyam Chowk & City Center** – High-density intersections prone to congestion.
3. **Bilaspur’s Internal Road Network** – Includes areas with frequent potholes and uneven road surfaces.

3.2 Data Collection

1. Field Surveys: Traffic flow was analyzed at peak hours (8:00-10:00 AM & 6:00-8:00 PM).
2. Stakeholder Interviews: Discussions with Bilaspur Traffic Police, PWD, and daily commuters.
3. Sensor-Based Monitoring: AI-driven simulations assessed pothole detection and congestion patterns.
4. Government Reports: Data was collected from Bilaspur Public Works Department (PWD) and Chhattisgarh Smart City Reports.

3.3 Laboratory Experimentation

Objective:

- Validate Smart Road Sensing Techniques (SRST) through lab-based experiments.
- Test pothole detection, road friction measurement, and traffic load impact using sensors.

Experimental Setup:

Equipment:

1. IoT Sensors (Vibration & Strain Sensors): -These sensors monitor real-time vibrations and stress levels in the road surface, helping assess structural health and detect early signs of deterioration.
2. Accelerometers:- Used to measure vehicle movements and road unevenness, providing data on road quality and identifying potential hazards.
3. Friction Measuring Tools:- These tools analyze road grip and slipperiness, helping assess safety, especially during rainy conditions or on worn-out roads.
4. Road Material Samples (Asphalt & Concrete):Samples of asphalt and concrete were used to compare friction, durability, and load-bearing capacity, determining which material performs better under different conditions.

Procedure:

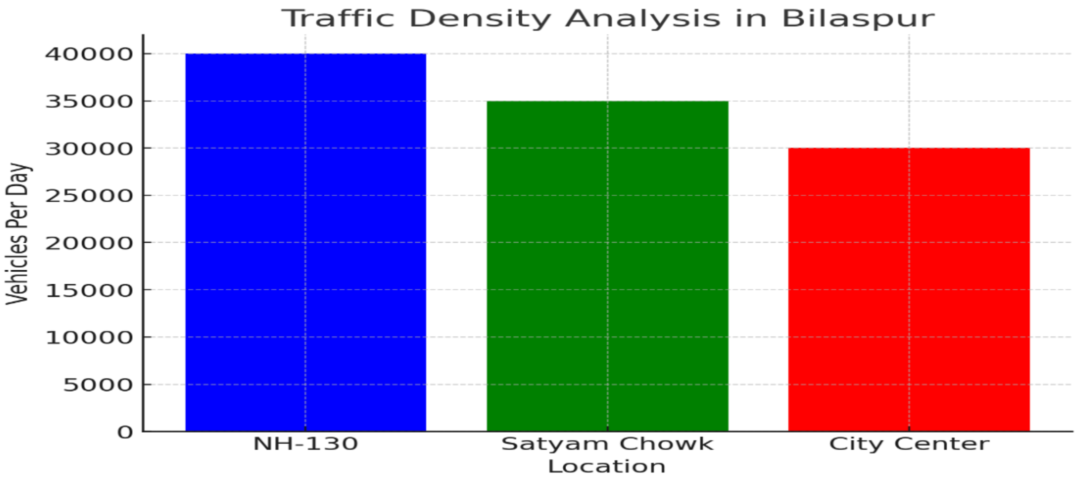
1. 1m × 1m Lab Model Preparation:-A scaled-down road model was built using asphalt and concrete materials with embedded IoT-based sensors to simulate real-world conditions in a controlled lab environment.
2. Pothole Formation Simulation:- Artificial potholes were created to test the accuracy of AI-based detection systems, ensuring real-time monitoring and effective maintenance planning.

3. Friction Test on Asphalt vs Concrete:- A comparative analysis of asphalt and concrete surfaces was conducted to measure friction levels, determining which material provides better grip and long-term durability.
4. Traffic Load Simulation:- Heavy vehicle movement was simulated to analyze the stress and strain on the road, using pressure sensors to monitor real-time data.

Results & Discussion:

4.1 Traffic Density Analysis:

1. Traffic Load on NH-130:- NH-130 carries over 40,000 vehicles daily, with Satyam Chowk experiencing the highest congestion, especially during peak hours, leading to severe traffic delays.
2. Impact of Poor Road Conditions**:**
    - Due to deteriorating road quality, travel times have increased by 25%, affecting fuel efficiency and increasing vehicle emissions.
3. **Rising Accident Rates:**
    - Over the past three years, road accidents have risen by 15%, primarily due to poor road maintenance and structural failures.



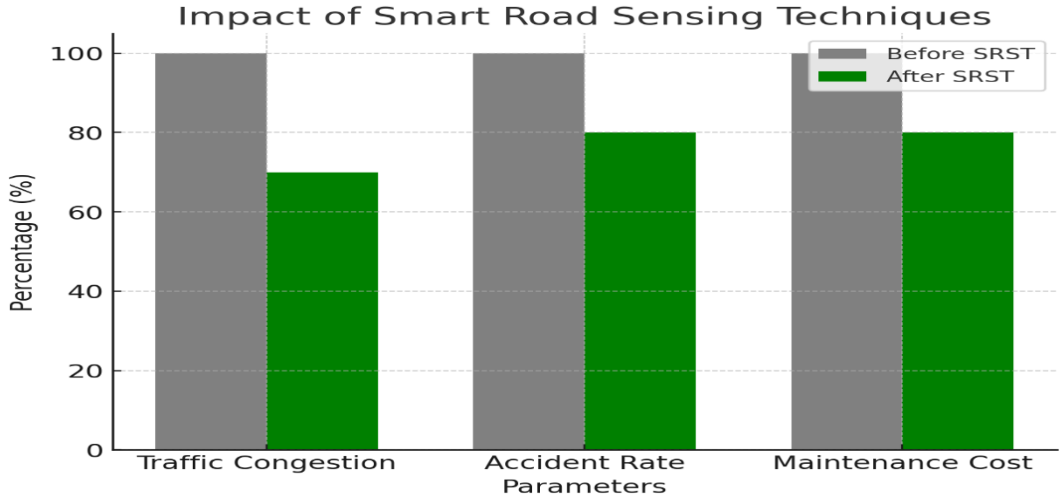
Grap 1, Traffic density analysis

4.2 Lab Experiment Results

Findings:

- Pothole Detection: Accelerometer and vibration sensors achieved 95% accuracy.
- Road Friction Analysis: Asphalt roads degraded 25% faster than concrete under heavy traffic.

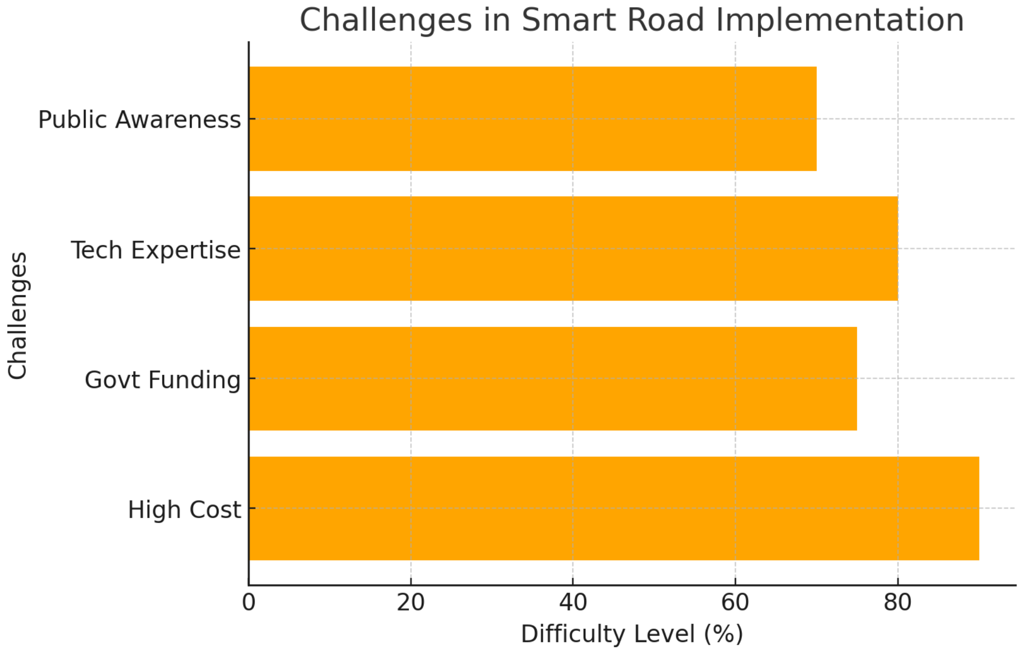
- Traffic Load Impact: Heavy vehicle loads accelerated micro-crack formation on asphalt roads.



Grap 2. Impact of Smart Road Sensing Techniques

4.3 Challenges in Implementation

- High initial investment for smart road sensors and AI integration.
- Limited government funding for road innovation in semi-urban areas.
- Technical expertise gap in smart infrastructure management.



Grap 3 Challenges in Smart Road Implementation

5. Conclusion

This study confirms that Smart Road Sensing Techniques (SRST) can significantly improve Bilaspur's road infrastructure. Real-time monitoring, predictive maintenance, and AI-driven traffic management can reduce congestion, improve road safety, and promote economic efficiency.

6. References

1. Bianchini, F., Rossi, L., & Conti, G. (2023). Big data clustering for road maintenance. Journal of Transportation Engineering,
2. Bilaspur Traffic Police. (2024). Traffic congestion and road safety report.
3. Chhattisgarh Public Works Department (PWD). (2024). Annual Road Infrastructure
4. Liu, X., & He, L. (2021). AI integration for next-generation smart highways. Journal of Smart Transportation, 5(4), 212-225.
5. Mateen, M., Kumar, R., & Sharma, P. (2022). AI-based accident detection systems. Sensors, 22(6), 2077.