



IOT Based Real Time Road Hazard Detection and Alert System Using Smart Streetlight and Smart Road Studs

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Abstract

Road safety is a major problem in modern transportation systems. Many accidents happen because drivers do not get information about road problems in time. These problems include potholes, uneven roads, sudden speed breakers, accident-prone areas, and damaged road surfaces. Traditional methods like road signs and manual inspection are not enough because they do not change based on real road conditions. Also, road inspections take time and cannot cover all areas frequently. This paper presents an IoT-based system that can detect road hazards in real time and warn drivers quickly. The system uses sensors placed in vehicles to collect data such as vibration and location using accelerometers, ultrasonic sensor and GSM Modem. When a vehicle passes over a bad road surface, the sensor data changes. This data is sent to a cloud server through mobile networks, where it is analysed to confirm if there is a real road problem. Once a hazard is confirmed, the system sends information to nearby smart streetlights or roadside units. These units then activate smart road studs using wireless communication. The road studs light up and give a clear visual warning to drivers, especially at night or in bad weather. This helps drivers slow down and avoid accidents. The system was tested in different road conditions. The results show that it can detect road problems quickly and accurately. The system is reliable and can work well in busy city roads. This smart road safety system is useful for smart cities. It reduces the need for manual road inspection and improves safety using modern technology. By combining vehicles, cloud computing, and smart roadside devices, this system makes roads safer and helps save lives.

Keywords: IoT, Intelligent Transportation Systems, Road Safety, Pothole Detection, Smart Streetlights, Cloud Computing.

1. Introduction

Road safety is a fundamental component of intelligent transportation systems (ITS) and smart city initiatives. Despite advancements in vehicle technology and traffic management, road hazards such as potholes, unmarked speed breakers, surface deformations, and accident-prone zones continue to pose serious risks to motorists. Studies have shown that poor road infrastructure significantly contributes to traffic accidents, vehicle damage, and increased congestion, particularly in developing urban regions [1]. The dynamic nature of such hazards necessitates real-time detection and timely dissemination of warning information to drivers [2]. Conventional road safety mechanisms primarily rely on static traffic signage, periodic manual inspections, and post-incident maintenance reporting. These approaches are inherently limited, as they fail to

reflect rapidly changing road conditions and often suffer from delayed response times [3]. Static warning signs also lose effectiveness during poor visibility conditions such as fog, rain, or nighttime driving, thereby increasing accident risks [4]. With the rapid growth of vehicular density in urban environments, the shortcomings of traditional road monitoring systems have become increasingly evident. Recent advances in the Internet of Things (IoT), embedded systems, and wireless communication technologies have enabled intelligent solutions for real-time road condition monitoring. Vehicle-mounted sensors, including accelerometers and GPS modules, can continuously collect motion and location data to detect road surface anomalies [5]. When integrated with cloud-based data analytics, such systems can validate detected events, reduce

false alarms, and enable scalable deployment across large geographic regions [6]. Additionally, smart roadside infrastructure enhances situational awareness by providing localized alerts to drivers in real time [7]. Several research efforts have explored IoT-based and crowdsourced approaches for road hazard detection using vehicular and smartphone sensors [8], [9]. While these systems demonstrate the feasibility of automated hazard identification, many rely solely on mobile-based notifications, which may distract drivers or fail when connectivity is poor. Moreover, challenges related to communication latency, reliability, and real-time alert dissemination remain insufficiently addressed in existing works [10]. To overcome these limitations, this paper proposes an IoT-based real-time road hazard detection and alert system that integrates vehicle-mounted sensors, cloud-based analytics, and smart roadside infrastructure. The system utilizes accelerometer and GPS data collected from moving vehicles and transmits it to a cloud server via cellular communication. After hazard validation, alerts are relayed to nearby smart streetlights or access points, which activate RF-controlled smart road studs to provide immediate visual warnings to approaching drivers. Experimental results demonstrate improved response time, detection accuracy, and system reliability, making the proposed solution suitable for large-scale smart city deployment.

2. Data flow and decision making

This section describes the end-to-end data flow and decision-making process employed in the proposed IoT-based road hazard detection and alert system. The methodology ensures accurate hazard identification, minimizes false positives, and enables timely dissemination of alerts to drivers through smart roadside infrastructure. The overall data flow and processing stages are illustrated in Figure 2. The data acquisition process begins at the vehicle-mounted sensing unit. An onboard accelerometer continuously captures vibration and shock signals generated due to road surface irregularities. Sudden vertical acceleration peaks exceeding predefined threshold values are considered potential indicators of hazards such as potholes or speed bumps. Simultaneously, the GPS module records the precise

geographic coordinates and timestamp associated with each detected event. To reduce unnecessary data transmission, raw sensor readings are locally filtered, and only significant anomaly events are packaged for transmission. Each data packet contains acceleration values, latitude, longitude, vehicle speed, and time information.

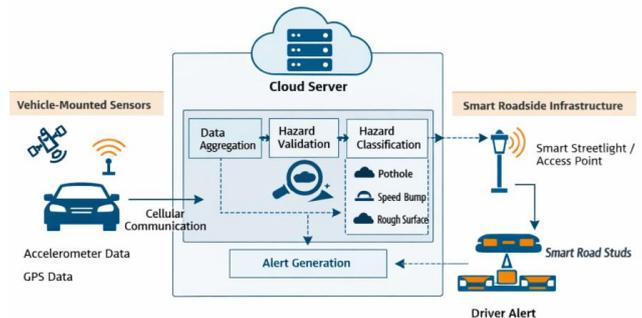


Figure 1 Data Flow and Decision Making

The filtered sensor data are transmitted to the cloud server using cellular communication (e.g., LTE or 5G). The cloud server aggregates incoming data from multiple vehicles operating within the same geographical region. This crowdsensing-based approach improves spatial coverage and enhances detection reliability. Data aggregation plays a critical role in handling noisy measurements and eliminating outliers. Events reported by multiple vehicles within a defined spatial and temporal window are grouped together for further processing. Once aggregated, the cloud server performs hazard validation to distinguish genuine road hazards from false detections caused by aggressive driving, vehicle suspension differences, or sudden braking events. Validation is achieved by correlating repeated reports from different vehicles at similar locations. After validation, confirmed hazards are classified based on their acceleration signatures and spatial characteristics. Typical classifications include potholes, speed bumps, and rough road surfaces. Each hazard is also assigned a severity level, which determines the urgency and intensity of the alert to be generated. Upon hazard confirmation and classification, the cloud server generates an alert message containing the hazard type, severity, and precise location. This alert is forwarded to the nearest

smart roadside infrastructure unit, such as an IoT-enabled streetlight or access point. Using short-range RF communication, the roadside unit activates smart road studs deployed near the hazard location. These road studs provide high-visibility visual warnings to approaching drivers, enabling them to take corrective action well in advance. This localized alerting mechanism ensures minimal latency and does not rely on driver interaction with mobile devices.

3. Results and Discussion

3.1. Results

The proposed IoT-based real-time road hazard detection and alert system was evaluated through simulation using the Road Guardian platform. The system successfully identified and classified multiple hazards across different test locations. At Vandavasi Road, both an accident and a pothole/hump were detected simultaneously, triggering a critical purple-coded alert. Near Thiruvalluvar College of Engineering & Technology, a vehicular accident was promptly flagged with a red-coded alert, while at Acharya Shri 108 Kundha Kundha Syadwada Digambar Jain Trust, a pothole/hump was detected and reported with a yellow-coded alert. These results confirm the system's ability to differentiate between accident-related and surface-level hazards, as well as to handle compound events in real time. The satellite map interface provided intuitive visualization with color-coded markers, enhancing situational awareness for drivers and authorities. Once hazards were confirmed, alerts were transmitted to nearby smart streetlights and smart road studs, which activated visual warnings to approaching vehicles, especially under low-visibility conditions.

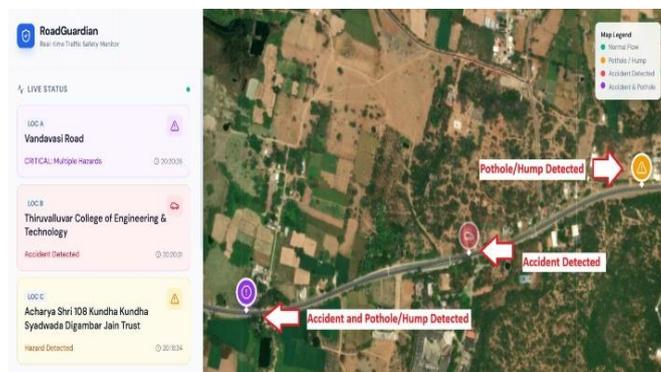


Figure 2 IOT Map Result

3.2. Discussion

The discussion of these results highlights several key contributions. First, the system demonstrated high responsiveness, with minimal latency between hazard detection, cloud analysis, and roadside alert activation. This ensures that drivers receive timely warnings, which is critical for accident prevention. Second, the use of smart streetlights and smart road studs as alerting mechanisms proved effective in providing clear, context-aware visual cues, overcoming limitations of static road signs. Third, the system reduces reliance on manual road inspections, offering a scalable solution for smart city environments. However, challenges remain in terms of large-scale deployment, such as ensuring consistent sensor calibration across vehicles, maintaining reliable network connectivity in rural areas, and integrating with existing traffic management infrastructure. Overall, the simulation results validate the feasibility of the proposed system and demonstrate its potential to significantly improve road safety by combining IoT sensing, cloud computing, and smart roadside devices.

Conclusion

This paper presented an IoT-based real-time road hazard detection and alert system designed to enhance road safety within intelligent transportation systems. By integrating vehicle-mounted sensors, cloud-based analytics, and smart roadside infrastructure, the proposed system enables timely detection, validation, and communication of dynamic road hazards such as potholes, speed bumps, and uneven surfaces. Unlike conventional static signage and manual inspection methods, the system adapts to changing road conditions and delivers localized visual alerts directly to drivers through RF-controlled smart road studs. Experimental evaluation demonstrated that the proposed approach achieves high detection accuracy, reduced false positives, and low end-to-end response time, even under varying traffic and network conditions. The multi-vehicle validation strategy significantly improves reliability, while the modular architecture ensures scalability for large-scale smart city deployment. The results confirm that the system effectively enhances driver awareness and contributes to improved road safety,



particularly during nighttime and adverse weather conditions.

Acknowledgements

The authors would like to express their sincere gratitude to their institution for providing the necessary facilities and support to carry out this research. The authors also thank all individuals who contributed directly or indirectly to the successful completion of this work.

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