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Real-Time Smart Road Accident Detection System Using IoT and Sensors for Faster Emergency Response

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ABSTRACT

This literature review examines studies related to real-time smart road accident detection systems using IoT, sensors, communication technologies, and intelligent emergency response methods. The reviewed studies show that accident detection systems commonly use accelerometers, gyroscopes, GPS, GSM/GPRS, microcontrollers, cloud platforms, dashboards, and real-time alerting mechanisms to reduce delays in emergency notification. Some studies focus on low-cost vehicle-mounted systems, while others explore broader emergency response platforms, V2V/V2I communication, smart traffic lights, driver monitoring, and AI-based accident or incident detection. The reviewed studies also show that machine learning, deep learning, computer vision, YOLO-based models, and multi-agent systems can support accident recognition and traffic monitoring. However, several limitations remain, including limited real-world testing, false alarms, threshold sensitivity, weak emergency coordination, connectivity problems, limited sensor fusion, and security or privacy concerns. Overall, the reviewed studies support the need for a practical hybrid system that combines IoT-based sensing, location tracking, reliable communication, emergency alerting, and, where suitable, AI-based validation for faster and more reliable road accident response.

Keywords: *Road Accident Detection, IoT, Sensors, Emergency Response, GPS, GSM, Smart Road, LoRa Communication.*

INTRODUCTION

At the present, detecting and responding to road accidents have become an important research areas in IoT-based safety systems. The reviewed studies show that many existing systems try to reduce delays in accident reporting by using sensors, microcontrollers, GPS, GSM/GPRS, cloud platforms, dashboards, and real-time alerting methods. Instead of depending only on manual reporting, these systems aim to detect accidents or emergency situations automatically and send useful information, especially location and event details, to responders or responsible authorities. For example, IoT-based emergency systems have been designed to support rapid detection, classification, alert dissemination, and emergency notification through connected sensors, edge devices, cloud platforms, and communication modules (Zhang, Zhang, & Sun, 2025; Mohsin & Muyeed, 2024). The reviewed studies can be grouped into several connected areas. Some papers focus directly on vehicle accident detection using low-cost hardware such as accelerometers, gyroscopes, GPS modules, GSM modules, Arduino-based boards, and other IoT devices. These systems are useful because they are simple, affordable, and suitable for real-time alerting. Kumar (2025), for instance, proposed a low-cost crash monitoring system using MPU6050, GPS, SIM800A, SD card storage, and Arduino-based control for real-time SMS alerts and accident reconstruction support. Similarly, Vamshi et al. (2025) developed an automatic accident detection system using an accelerometer, GPS, GSM, and Arduino Nano to detect accidents and send location-based alerts. Even so, the previous study also shows that these sensor-based systems may face limitations such as false alarms, threshold sensitivity, unstable sensor behavior, limited quantitative evaluation, and dependence on network availability. Other studies focus more on communication and smart-road infrastructure. V2V, V2I, and IoV-related works show the significant role of connecting vehicles, road infrastructure, drivers, and emergency services. Naeem, Chaudhary, and Meng (2024) reviewed V2V communication architectures and showed how connected vehicles can exchange real-time safety and traffic information.

Oliva et al. (2025) focused on V2I communication for emergency vehicle priority and pedestrian safety at intelligent intersections, while Visconti et al. (2025) reviewed driver monitoring, vehicle condition monitoring, and smart-road systems within the Internet of Vehicles paradigm. These studies are useful for understanding how accident detection can be linked with emergency vehicle priority, traffic-light control, driver alerts, and authority dashboards.

The literature also includes AI and computer-vision-based approaches. These approaches can improve incident recognition, scene understanding, and post-accident analysis, but they may require cameras, datasets, and stronger computing resources. Ramazhan, Bustamam, and Buyung (2025) used an enhanced YOLOv9 model for car damage detection and damage severity assessment, although the study focused more on post-accident damage assessment than immediate emergency alerting.

Ayesha et al. (2025) proposed a multi-agent machine learning framework using YOLOv11 and VideoLLaMA3 for accident detection, scene description, localization, and coordinated emergency response. Alzamzami et al. (2025) also presented an intelligent traffic light system that combines incident detection, adaptive signal control, driver alerting, and authority reporting. These studies suggest that AI can strengthen accident response systems, but their integration with low-cost physical IoT crash sensors is still an important gap. Some related studies are not directly focused on vehicle crash detection but still provide useful support for the research direction. Ahmed et al. (2023) examined MEMS accelerometers for vehicle vibration monitoring, which is useful because reliable acceleration and vibration sensing can support future accident detection logic. Pour et al. (2022) studied machine learning-based accident detection using multimodal in-car sensors and found that CNN-based feature extraction with an SVM classifier showed good performance, although the exact metric values are not clearly mentioned in the table. Tseng, Huang, and Kau (2025) proposed a wearable fall detection system with real-time localization and notification, which is not a vehicle accident detection system, but its low-complexity detection and location-alerting idea is relevant to emergency notification design. Pandey, Chaudhary, and Tóth (2025) also discussed IoT-enabled sensor networks for real-time process monitoring, although their study is general and not specifically focused on road accident detection. In general, the literature suggests that a strong real-time smart road accident detection system should combine sensing, decision-making, and communication. The main direction shown in the study is a hybrid system that uses vehicle-mounted sensors for immediate crash detection, GPS and GSM/4G/5G for emergency alerting, and optional AI or computer vision for validation, severity estimation, and scene understanding. At the same time, the reviewed studies show key limitations, including limited real-world testing, false alarms, weak sensor fusion, connectivity problems, and incomplete coordination with hospitals, police, ambulances, and traffic systems. Therefore, the primary aim of this review is to examine how the selected studies contribute to accident detection, emergency alerting, smart-road communication, and future improvements of such systems.

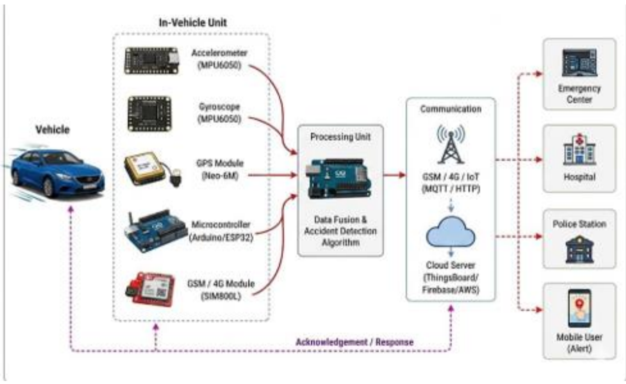


Figure-1: Proposed Smart Accident Detection System Architecture

RESEARCH BACKGROUND

IoT-Based Accident Detection and Emergency Response Systems

IoT-based accident detection and emergency response systems form one of the strongest areas in the reviewed literature. Many studies attempt to reduce emergency response delay by combining sensors, microcontrollers, communication modules, cloud platforms, dashboards, and automatic alert systems. These systems are important because they do not depend only on a person calling for help after an accident. Instead, they detect an accident or emergency event automatically and send useful information, especially the location, to responders or responsible authorities.

Zhang et al. (2025) presented a real-time IoT-based public safety alert and emergency response system. Their system used distributed heterogeneous sensors connected to edge nodes and cloud platforms, with alerts sent through secure MQTT/TLS and LoRa fallback. The system included gas, flame, vibration, and biometric sensors, as well as Raspberry Pi, ESP32, AWS IoT, Firebase, MQTT over TLS, and LoRa fallback. It was tested in a smart-city simulation for fire, traffic accident, gas leak, and medical distress scenarios. According to the table, the system achieved alert latency under 450 ms, detection accuracy above 95%, 99.1% alert success, and 99.8% uptime, while supporting more than 12,000 devices. This study is highly relevant because it provides a complete IoT emergency response architecture that includes traffic accident detection and fast alerting. However, it was mainly tested in simulation or controlled settings, and broader real-world deployment is still needed.

A more direct vehicle crash detection system was proposed by Kumar (2025). The study developed a low-cost crash detection and accident reconstruction system using an MPU6050 accelerometer/gyroscope, GPS Neo-6M, SIM800A GSM module, SD card, and Arduino Mega/control unit. The system detects crash or rash-driving behavior using threshold-based acceleration data, sends SMS alerts through GSM, and stores timestamp, GPS, and sensor data for later analysis. This study is especially useful for the present topic because it directly matches real-time crash detection using IoT sensors and emergency SMS alerts. Its strengths include affordability, open-source design, offline data logging, and configurable thresholds. However, the table also shows several weaknesses, including the need for stable power for the SIM800A module, gyroscope instability during rollover detection, and network/GPS limitations in remote locations.

Similarly, Vamshi et al. (2025) developed an IoT-based automatic vehicle accident detection system. The system uses an accelerometer to monitor sudden deceleration or impact, an Arduino Nano to process the data, GPS to obtain location, and GSM to send SMS alerts. This study is highly relevant because it directly uses IoT sensors for automatic accident detection and emergency response. The system is simple, low-cost, compact, and adaptable to different vehicles. However, detailed quantitative evaluation is not clearly mentioned in the table. The study also lacks AI-based false alarm reduction, while cloud and app features are listed as future enhancements.

A broader emergency response platform is presented by Mohsin and Muyeed (2024). Their IoT-based smart emergency response system monitors vehicle, home, and health status through a unified platform. For vehicle monitoring, the system uses temperature, gas, flame, GPS, piezo, and accelerometer sensors.

It also includes Arduino Mega2560, GPRS, MQTT, NodeMCU, a cloud server, a mobile app, and a MySQL-PHP-Laravel dashboard. The system automatically notifies responders when an emergency is detected. According to the reviewed table, it reported a server response time of 3 ms and accuracy around or above 99%. This study is useful because it provides an end-to-end emergency response platform with dashboard support and automatic notification. Still, it also shows important limitations, including big data handling, response time at scale, third-party cloud security, and the need for wider emergency service registration.

Supporting Sensor and IoT Architecture Studies

Some studies are not directly accident detection systems but still support the design of smart accident detection architecture. Ahmed et al. (2023) investigated MEMS accelerometers for dynamic vehicle vibration monitoring. Their work used laboratory and commercial MEMS accelerometers placed on different vehicle locations, including the hood, exhaust pipe, and dashboard. The study applied time-domain, frequency-domain, FFT, and PSD analysis to understand vehicle vibration. Although this is not an accident detection system, it provides useful sensor-level understanding for interpreting accelerometer behavior in vehicle environments. The table also notes that noise and temperature effects can affect MEMS data, and that vibration sensing needs to be adapted into reliable crash detection algorithms.

Tseng et al. (2025) developed a wearable fall detection system with real-time localization and notification. Although this study focuses on human fall detection rather than vehicle crashes, it is indirectly relevant because it uses an MCU, inertial sensor, GPS, NB-IoT module, server, and communication application for real-time emergency notification. The system used a low-complexity finite-state-machine algorithm and reported average sensitivity of 97.9%, specificity of 99.9%, and overall accuracy of 99.7%. This study shows how sensor-based event detection can be combined with GPS and emergency notification, even though the same method may not directly transfer to vehicle crash dynamics.

Pandey et al. (2025) provide general support for IoT sensor network design. Their review discusses IoT-enabled sensor networks, MQTT, CoAP, smart cities, agriculture, healthcare, manufacturing, blockchain, 5G, and AI. Although the study is not specifically about road accident detection, it is relevant for understanding IoT architecture, communication protocols, scalability, energy efficiency, and security challenges. The previous identifies the need for domain-specific implementation for vehicle accident detection with low latency, energy efficiency, and security.

Smart-Road Communication, V2V, V2I, and IoV Systems

IoT communication and smart-road connectivity are also important themes in the reviewed literature. Naeem et al. (2024) reviewed V2V-enabled intelligent transportation systems. Their paper discusses decentralized mesh, cloud-integrated, edge-based, blockchain-enabled, cellular, ad-hoc, hybrid, and AI-driven V2V networks. Although the study does not implement a new accident detection prototype, it shows that V2V systems can support real-time data exchange among vehicles for safety, traffic efficiency, and connected mobility. This is useful for the communication side of a smart road accident detection system, especially for sharing accident alerts between vehicles. However, practical deployment and protocol evaluation remain challenging.

Oliva et al. (2025) studied V2I communication strategies for emergency vehicle priority and pedestrian safety in urban environments. Their work used OBU, RSU, DSRC, a traffic sensor with neural network capabilities, a mobile application, and intelligent intersections. The system was tested at two intelligent intersections in Lioni, Avellino, Italy. According to the reviewed table, it reduced emergency vehicle response times and increased driver awareness of pedestrians. This paper is relevant because it shows how infrastructure can support emergency response after accident detection, especially by helping ambulances or emergency vehicles pass through intersections more quickly. However, its main focus is emergency vehicle priority and pedestrian warnings, not automatic crash detection.

Visconti et al. (2025) reviewed driver monitoring systems and on-board vehicle devices in a smart-road scenario based on the Internet of Vehicles paradigm. The study covers driver health and anomaly monitoring, vehicle condition monitoring, road monitoring, OBD-II, wearable devices, cameras, ECG, PPG, EDA, HR, BAC, RR, SpO2, tire sensors, emissions sensors, road sensors, and different machine learning algorithms. Although no single new model is implemented, the paper is useful for understanding broader IoV-based driver, vehicle, road, and traffic monitoring systems. The table notes that data accuracy, road coverage, fragmented platforms, cyber-security, and real-time computation remain important limitations.

AI and Machine Learning-Based Accident Detection and Traffic Monitoring Systems

AI and machine learning-based accident detection systems are another important part of the reviewed literature. These systems aim to improve accident recognition, traffic monitoring, vehicle damage assessment, and emergency response coordination. While many IoT systems depend mainly on sensor thresholds, AI-based studies use machine learning, deep learning, computer vision, YOLO-based models, and multi-agent frameworks to recognize incidents and support decision-making.

Pour et al. (2022) proposed a machine learning framework for automated accident detection using multimodal sensors in cars. The study evaluated five feature extraction approaches and found that CNN features with an SVM classifier achieved promising results and outperformed the other tested approaches. It used the SHRP2 Naturalistic Driving Study crash dataset. This paper is highly relevant for adding a machine learning layer to sensor-based accident detection. However, it does not focus on IoT alerting or emergency dispatch, and exact metric values are not clearly mentioned in the table

Ramazhan et al. (2025) used an enhanced YOLOv9 model with CBAM attention and SIoU loss for smart car damage assessment. Their system detects six types of vehicle damage and uses a Damage Severity Index to estimate severity. The study used the CarDD dataset and reported that the proposed model outperformed state-of-the-art YOLO algorithms by 1.75%. Although this work is not mainly about immediate accident detection or emergency alerting, it is useful for post-accident damage analysis and severity assessment. The table also identifies the need to integrate this kind of image-based damage assessment with real-time IoT crash sensors and emergency alert systems.

Alzamzami et al. (2025) presented Passable, an intelligent traffic light system with integrated incident detection and vehicle alerting. The system uses computer vision to analyze traffic-light camera images and deep learning to detect incidents. It also adjusts signal timings based on vehicle density, sends wireless alerts to drivers, and reports incidents to authorities through a centralized dashboard.

This study is highly relevant because it combines detection, traffic control, driver alerting, and authority reporting. However, the exact deep learning model is not clearly mentioned in the table, and exact metric values are also not clearly mentioned. The study also needs real-world testing with multiple coordinated intersections, and pedestrian and emergency vehicle detection are future work.

Ayesha et al. (2025) proposed CIRS, a multi-agent machine learning framework for real-time accident detection and emergency response. The system addresses complex traffic, low-resolution CCTV, occlusion, weather effects, false positives, and weak emergency coordination. It uses a multi-agent architecture with perception, classification, description, communication, and decision-making agents. The framework integrates YOLOv11 for accident detection and VideoLLaMA3 for scene description. It uses CCTV video streams, video frames, and a custom dataset of 5200 accident frames and 4800 non-accident frames. According to the table, YOLOv11 achieved 86.5% top-1 accuracy and 100% top-5 accuracy, while VideoLLaMA3 achieved BLEU 0.0755, METEOR 0.2258, and ROUGE-L 0.3625. This study is very relevant for AI-based accident detection and coordinated emergency response, especially if combined with IoT sensors. However, it mainly depends on video-based infrastructure, and sensor-based IoT integration is still limited.

Overall, the reviewed literature shows that IoT-based systems are practical and suitable for real-time accident alerting, especially when they use accelerometers, GPS, GSM/GPRS, microcontrollers, dashboards, and emergency notification systems. AI-based systems can improve accident recognition, scene understanding, traffic monitoring, and severity analysis, but they often depend on cameras, datasets, or stronger computing resources.

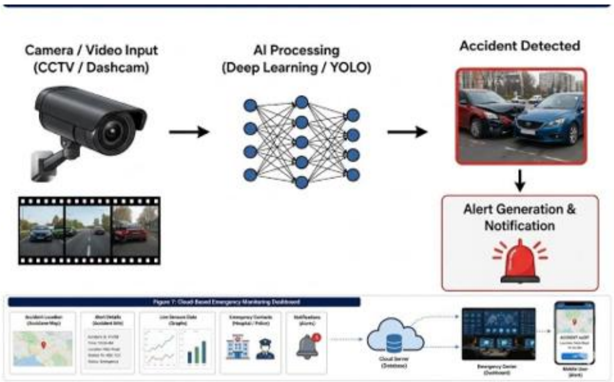
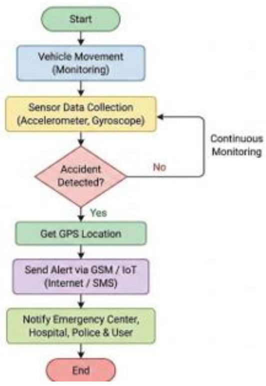


Figure-2: AI-Based Accident Recognition Process

V2V, V2I, and IoV studies show that communication infrastructure is essential for sharing alerts, supporting emergency vehicle priority, and improving smart-road coordination. A clear gap in the reviewed previous studies is that many IoT systems and AI systems are still treated separately. Therefore, the literature supports the need for a practical hybrid approach that connects IoT sensors, location tracking, reliable communication, dashboard-based emergency coordination, and optional AI-based validation or classification.

METHODOLOGY

This study follows a literature-based methodology because the work is developed from the uploaded literature review. The reviewed studies were first examined to identify the main research areas, the methods used in the reviewed studies, the technologies applied, the reported results, and the limitations mentioned by each paper. No outside sources were used in preparing this section. The purpose of this methodology is to explain how the reviewed studies were organized and how their findings support the direction of a real-time smart road accident detection system using IoT, sensors, and emergency response mechanisms.



The first step was to classify the reviewed studies according to their main technical focus. Papers that used accelerometers, gyroscopes, GPS, GSM/GPRS, Arduino-based boards, MPU6050, cloud platforms, dashboards, and SMS or mobile alerts were grouped under IoT-based accident detection and emergency response systems. This group includes studies such as Kumar (2025), Vamshi et al. (2025), Mohsin and Muyeed (2024), and Zhang, Zhang, and Sun (2025). These papers were considered central because they directly support automatic event detection, location sharing, and emergency notification.

The second step was to examine the sensor and hardware methods used in the reviewed systems. The table shows that several studies depend on low-cost sensors and embedded devices to detect sudden movement, crash-like behavior, vibration, or emergency conditions. For example, Kumar (2025) used MPU6050, GPS Neo-6M, SIM800A GSM, SD card, and Arduino-based control, while Vamshi et al. (2025) used an accelerometer, GPS, GSM, Arduino Nano, and a DC-DC buck converter. These studies were reviewed to understand how sensor-based detection is commonly implemented and what limitations appear in practice, such as false alarms, manual threshold tuning, unstable sensor behavior, and limited real-world testing.

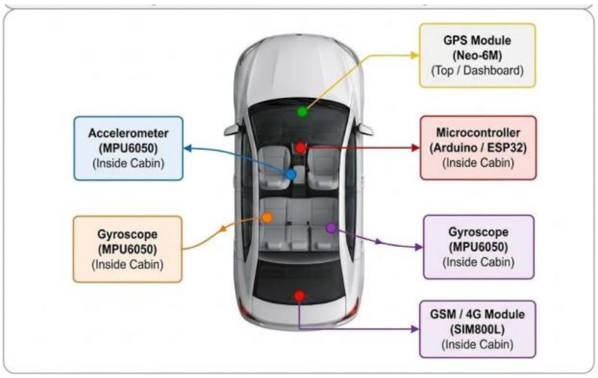


Figure-3: Vehicle Sensor Placement Diagram

The third step was to review communication and emergency coordination methods. Studies related to cloud platforms, MQTT, LoRa fallback, dashboards, V2V, V2I, and IoV were examined to understand how accident or emergency information can be transmitted to users, responders, authorities, or smart-road infrastructure. Zhang, Zhang, and Sun (2025) provided a real-time IoT emergency response architecture using edge/cloud platforms, MQTT, Firebase, AWS IoT, and LoRa fallback. Mohsin and Muyeed (2024) showed how dashboard and mobile application support can be used in a wider emergency response system. Naeem, Chaudhary, and Meng (2024), Oliva et al. (2025), and Visconti et al. (2025) were also reviewed for their contribution to smart-road communication, emergency vehicle priority, driver notification, and IoV-based monitoring.

The fourth step was to analyze AI and machine learning-based approaches. Papers that used machine learning, deep learning, computer vision, YOLO-based detection, or multi-agent systems were reviewed separately because they focus more on intelligent recognition, scene understanding, traffic monitoring, or post-accident assessment. Pour et al. (2022) used multimodal in-car sensor data with CNN features and an SVM classifier. Ramazhan, Bustamam, and Buyung (2025) used enhanced YOLOv9 for vehicle damage assessment. Alzamzami et al. (2025) used computer vision and deep learning for incident detection and intelligent traffic-light control, while Ayesha, Aslam, Zaheer, and Khan (2025) proposed a multi-agent framework using YOLOv11 and VideoLLaMA3. These papers were used to understand how AI can support accident detection and emergency response, while also noting that many AI-based systems are not fully integrated with low-cost IoT alerting devices.

Finally, the research gaps were extracted from the limitations and overall findings. The main gaps include limited real-world testing, false alarms and threshold sensitivity, connectivity problems, weak emergency coordination, limited sensor fusion, security and privacy concerns, and the gap between AI-based detection and physical IoT emergency response systems. These gaps were then used to guide the conclusion and future work. Therefore, the methodology of this review is not based on external searching or invented assumptions; it is based only on organizing, comparing, and interpreting the information already available in the uploaded literature review table.

CONCLUSION

The reviewed studies show that real-time smart road accident detection requires more than one technology. Sensor-based IoT systems provide a direct and low-cost way to detect possible accidents and send emergency alerts using accelerometers, gyroscopes, GPS, GSM/GPRS, microcontrollers, and cloud or dashboard platforms. These systems are especially useful for fast location sharing and automatic notification, but they often face problems such as false alarms, threshold sensitivity, unstable sensor behavior, limited real-world testing, and network dependency.

The literature also shows that AI and machine learning methods can improve accident detection and traffic monitoring. Computer vision, YOLO-based models, multimodal sensor learning, and multi-agent frameworks can support accident recognition, scene description, incident detection, and post-accident damage assessment. However, many AI-based systems are not fully connected with physical IoT sensors, GPS/GSM alerting modules, or emergency response workflows.

Communication-based studies, including V2V, V2I, and IoV systems, show that accident detection should be linked with smart-road infrastructure, emergency vehicle priority, driver alerts, traffic-light control, and authority dashboards.

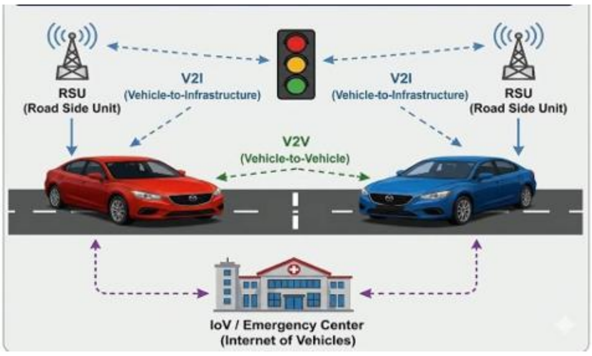


Figure-4: Smart Road Communication Using V2V and V2I

Overall, the literature supports the development of a hybrid smart road accident detection system that combines sensing, decision-making, communication, and emergency coordination for faster response.

FUTURE WORK

Based on the research gaps found in previous studies, future work should focus on improving the practical reliability of real-time accident detection systems. First, more real-world testing is needed because several studies were tested in simulation, controlled environments, small prototypes, or limited road conditions. Future systems should be tested under different speeds, road conditions, traffic situations, signal coverage levels, and accident-like events.

Second, false alarms and threshold sensitivity should be reduced. Several sensor-based systems depend on accelerometer thresholds, which may confuse harsh braking, bumps, rash driving, or sudden movement with real accidents. Future work should consider calibrated thresholds, multi-sensor fusion, and, where supported by previous studies, AI or ML-based validation to reduce false positives.

Third, communication reliability should be improved. The reviewed studies show that GPS, GSM, cloud, and network connectivity can be weak in remote or low-network areas. Future systems may need stronger communication options such as 4G/5G, LoRa fallback, dual-SIM support, offline logging, or delayed synchronization, where these are suitable for the system design.

Fourth, stronger emergency coordination is needed. Some systems detect accidents but do not fully connect with hospitals, police, ambulances, traffic lights, or emergency centers. Future work should include emergency dashboards, location maps, contact databases, authority reporting, and possible ambulance route or traffic-light priority integration.

Fifth, future systems should improve sensor fusion. Many studies use only accelerometer, GPS, and GSM. The studies suggest that additional sensors such as gyroscope, OBD-II, brake pressure, proximity sensors, road-condition sensors, or camera validation may improve reliability where feasible.

Finally, security and privacy should be considered because IoT emergency systems transmit sensitive location, health, and safety-related data. Future work should include authentication, secure communication such as MQTT/HTTPS where appropriate, and privacy-aware handling of emergency data. A practical future direction is to design a hybrid architecture that combines low-cost IoT sensors with optional AI-based validation or classification for more reliable accident detection and faster emergency response.

Figure-5: Cloud-Based Emergency Monitoring Dashboard

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