International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 10 | Oct - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Road Surface Health Monitoring System Smart Shoes for Traffic Police

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Abstract - Monitoring road-surface conditions and physical fatigue is important for improving the safety and well-being of traffic police personnel. This paper presents the design and implementation of an IoT-based Road Surface Health Monitoring Smart Shoe System using embedded sensors and wireless communication technology. The system integrates Force Sensitive Resistor (FSR) sensors to measure foot-pressure variations, a piezoelectric sensor to detect impacts and vibrations, and an MPU6050 sensor to monitor movement and orientation. An ESP32 microcontroller collects and processes the sensor data and transmits the readings to the Blynk IoT platform for real-time monitoring.The prototype is implemented using Arduino IDE and verified through sensor readings and dashboard visualization. The obtained results demonstrate the functionality of sensor data acquisition and IoT-based monitoring. The proposed system provides a foundation for developing wearable safety-monitoring solutions for traffic police and other field personnel. Further improvements can focus on sensor calibration, detection accuracy, power efficiency, and experimental validation.

Keywords: Smart Shoes, Road Surface Monitoring, Internet of Things (IoT), ESP32, FSR Sensor, MPU6050, Piezoelectric Sensor, Blynk IoT.

1.INTRODUCTION

The rapid advancement of embedded systems and the internet of things (IoT) has increased the demand for smart wearable devices that improves safety and real – time monitoring. Traffic police personnel often spend long hours standing and walking on roads, exposing them to physical strain, foot – pressure variations, and uneven road surfaces. In this work, an IoT – based Road Surface Health Monitoring Smart Shoe System is developed using FSR sensors, a piezoelectric sensor, an MPU6050, and an ESP32 microcontroller. The proposed system monitors foot – pressure variations, movement, and mechanical impacts, transmitting sensor readings to the Blynk Iot platform for real – time visualization. The prototype combines wearable sensing, embedded processing, and wireless communication in a simple and portable design. The implementation demonstrates the functionality of sensor data acquisition and IoT – based monitoring, providing a foundation for future wearable safety applications for traffic police personnel.

2. LITERATURE SURVEY

Recent research focuses on improving road safety through sensor-based monitoring systems and Internet of Things (IoT) technologies. Road-surface monitoring techniques use accelerometers, vibration sensors, GPS, and mobile devices to identify potholes, bumps, and other road irregularities. These technologies support real-time data collection and help develop efficient road-monitoring systems. However, most existing approaches focus on vehicles or smartphones rather than wearable monitoring systems for traffic police personnel [1].

This paper presents an automatic pothole and hump detection system designed to improve road safety. The proposed approach uses sensors to identify road irregularities and communicates relevant information to users through wireless technology. The system demonstrates the potential of automated road-condition monitoring and notification. However, it primarily focuses on detecting road defects for drivers rather than monitoring foot pressure and physical activity through wearable footwear [2].

This work presents *The Pothole Patrol*, a mobile sensor network for road-surface monitoring. The system collects vehicle-based sensor measurements to identify potholes and other road irregularities. The collected information demonstrates how mobile sensing can support road-condition assessment over large areas. However, the system relies on sensors mounted in vehicles and does not provide a wearable solution for monitoring road impacts experienced by traffic police personnel [3].

This study investigates real-time pothole detection using Android smartphones equipped with accelerometers. The approach analyzes acceleration data to identify sudden changes caused by potholes and other road irregularities. It demonstrates the usefulness of motion sensors and threshold-based processing for road-condition detection. However, the detection performance may depend on sensor placement, device orientation, and road conditions, making further calibration and validation necessary for wearable applications [4].

This work presents *Nericell*, a mobile sensing system that uses smartphone sensors to monitor road and traffic conditions. The system collects motion-related data and analyzes sensor signals to identify relevant transportation events. The study demonstrates the potential of portable sensing devices for traffic monitoring. However, its primary focus is mobile road and traffic sensing rather than foot-pressure measurement or wearable safety monitoring [5].

The proposed **Road Surface Health Monitoring Smart Shoe System** integrates Force Sensitive Resistor (FSR) sensors, a piezoelectric sensor, and an MPU6050 inertial measurement unit to monitor foot-pressure variations, mechanical impacts, and movement. An ESP32 microcontroller collects and processes the sensor readings and transmits them to

the Blynk IoT platform for real-time visualization. This approach combines wearable sensing and wireless monitoring in a single prototype. Further experimental testing is required to establish the accuracy of road-surface anomaly detection and the reliability of fatigue-related indicators.

S. Sattar, S. Li, and M. Chapman reviewed smartphone-based road-surface monitoring techniques in their paper, "Road Surface Monitoring Using Smartphone Sensors: A Review" (2018). The study examined methods for identifying potholes, bumps, and other road anomalies using accelerometer data and signal-processing techniques. It discussed threshold-based detection, machine-learning approaches, and factors such as sensor placement and vehicle speed that influence detection performance. The review highlights the importance of selecting suitable sensors and processing methods for reliable road monitoring. However, the study primarily focuses on smartphone-based sensing rather than wearable smart shoes [6].

A. Mednis et al. investigated real-time pothole detection using Android smartphones equipped with accelerometers. The proposed approach analyzed acceleration signals to identify road irregularities using different detection algorithms. The study demonstrated the potential of low-cost motion sensors for detecting sudden impacts associated with potholes and road defects. However, the performance of acceleration-based detection depends on sensor orientation, sampling conditions, and the movement of the device. These considerations are relevant when integrating motion sensors into smart footwear [7].

3. PROPOSED SYSTEM

The proposed model of the **Road Surface Health Monitoring Smart Shoes for Traffic Police** integrates multiple sensors with an ESP32 microcontroller to monitor foot-pressure variations, movement, and road-surface impacts. Force Sensitive Resistor (FSR) sensors are placed at selected positions inside the shoe to measure pressure distribution, while a piezoelectric sensor detects mechanical impacts and vibrations. The MPU6050 sensor measures acceleration and angular velocity to monitor foot movement and orientation. The ESP32 collects and processes the sensor readings and transmits the data wirelessly to the Blynk IoT platform for real-time visualization. Based on predefined threshold values, the system can display sensor readings and indicate normal or potentially abnormal conditions through the dashboard. The proposed model provides a wearable monitoring solution for traffic police personnel, with further calibration and experimental testing required to validate its accuracy and reliability.

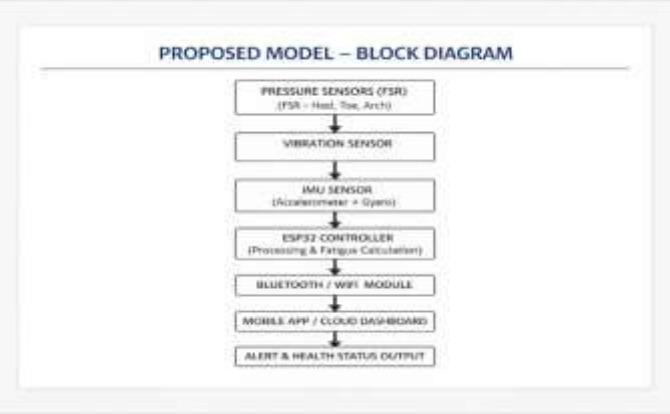


Fig 1: Block Diagram of the Proposed Model

Fig. 1 shows the overall block diagram of The proposed block diagram consists of FSR pressure sensors, a vibration sensor, and an MPU6050 IMU sensor to monitor foot pressure, impacts, and movement. The ESP32 processes the sensor data and transmits it through Wi-Fi or Bluetooth to the Blynk IoT dashboard. The dashboard displays sensor readings and provides alerts based on predefined threshold values, supporting preliminary health and road-impact monitoring for traffic police personnel.

Pressure Sensors (FSR – Heel, Toe, Arch)

Force Sensitive Resistor (FSR) sensors are placed at the heel, toe, and arch positions inside the shoe to measure foot-pressure variations during standing and walking. These readings help monitor pressure distribution across different parts of the foot.

Vibration Sensor

The piezoelectric vibration sensor detects mechanical impacts and vibrations generated when the shoe contacts uneven road surfaces. The sensor produces electrical signals corresponding to these impacts, which can be analyzed to identify possible road-surface irregularities.

IMU Sensor (Accelerometer + Gyroscope)

The MPU6050 Inertial Measurement Unit (IMU) consists of a three-axis accelerometer and a three-axis gyroscope. It measures acceleration and angular velocity to monitor foot movement, orientation, and motion variations during walking.

ESP32 Controller (Processing and Fatigue Calculation)

The ESP32 microcontroller receives data from the FSR, vibration, and IMU sensors. It processes the readings and compares them with predefined threshold values to generate sensor-based status indications. These values can support preliminary monitoring of pressure variations and possible fatigue-related patterns.

Bluetooth / Wi-Fi Module

The wireless communication function transfers the processed sensor data from the ESP32 to a compatible monitoring platform. The ESP32 has built-in Wi-Fi and Bluetooth capabilities, enabling wireless data transmission without requiring a separate communication module.

Mobile App / Cloud Dashboard

The Blynk IoT platform displays the sensor readings and system status through a mobile application or dashboard. Users can observe pressure values, vibration readings, and movement-related data in real time, provided the device is connected and communicating properly.

Alert and Health Status Output

The final stage presents the monitored data and status indications to the user. Based on predefined thresholds, the system can display normal or potentially abnormal conditions and provide alerts when configured limits are exceeded. These alerts are preliminary indicators and require experimental validation before being treated as reliable fatigue or road-anomaly detection results.

4. RESULTS & DISCUSSIONS

The proposed Road Surface Health Monitoring Smart Shoes for Traffic Police system was implemented using FSR pressure sensors, a piezoelectric sensor, an MPU6050 IMU sensor, and an ESP32 microcontroller. The sensor readings were displayed on the Arduino Serial Monitor and transmitted to the Blynk IoT dashboard for monitoring. The prototype responded to applied pressure and displayed changing sensor values during operation.

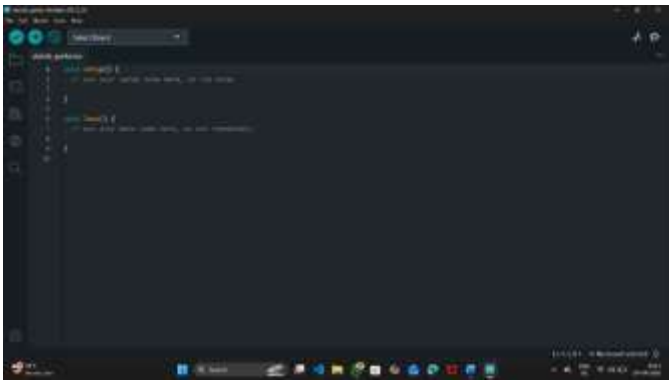


Fig 2: Arduino interface

Fig. 2 shows the Arduino IDE software interface used in the Road Surface Health Monitoring Smart Shoes for Traffic Police project. According to the project report, the Arduino IDE is used to program the ESP32 microcontroller to collect data from FSR pressure sensors and piezoelectric and MPU6050 sensors, process the readings, and transmit the information to the Blynk IoT platform through Wi-Fi. The Serial Monitor is used to display sensor values, fatigue levels, and alert status during testing. The shown screen contains a blank sketch with the basic setup() and loop() functions, ready for program development.

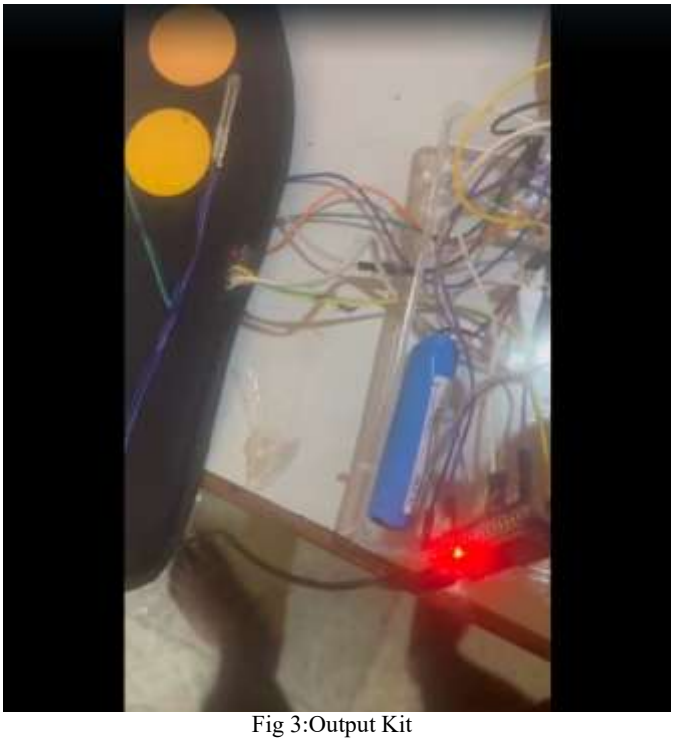


Fig 3:Output Kit

Fig. 3 shows the hardware prototype of the proposed smart-shoe system, including pressure sensors, connecting wires, an ESP32 controller, and a lithium-ion battery. The glowing LED indicates that the circuit is powered on. The ESP32 processes sensor readings for monitoring foot pressure, vibrations, and fatigue-related status. The sensors collect data during standing and walking activities. The processed readings can be displayed on the Arduino IDE Serial Monitor for testing and debugging. The system can also transmit sensor data to the Blynk IoT dashboard through Wi-Fi for remote monitoring.

Fig 4: Serial Moitor Output



Fig. 4 shows the Arduino IDE Serial Monitor output of the Road Surface Health Monitoring Smart Shoes for Traffic Police project. It displays real-time sensor readings collected by the ESP32, including FSR pressure values, time readings, vibration sensor values, and piezoelectric sensor outputs. These readings change as the sensors respond to pressure and movement. The Serial Monitor helps verify sensor data acquisition and monitor the system during testing. The processed data can also be

transmitted to the Blynk IoT dashboard for remote monitoring and display of fatigue-related status indications.

Fig 5: Dash Board of Smart Shoes

Fig. 5 shows the Blynk IoT mobile dashboard of the Road Surface Health Monitoring Smart Shoes for Traffic Police project. The dashboard displays four gauge readings: FSR



pressure value 880, fatigue level 17, vibration sensor value 17,601, and piezoelectric sensor output 2,554. The green indicators and the "Normal" status show that the readings are within the predefined limits set in the system. The dashboard enables users to monitor sensor data remotely and observe changes during walking or when pressure is applied to the shoe. This output demonstrates the integration of the ESP32 microcontroller with the Blynk IoT platform for sensor-data visualization and status monitoring. However, these readings alone do not establish clinically validated fatigue detection or confirmed road-surface anomaly detection.

5. CONCLUSIONS

The Road Surface Health Monitoring Smart Shoes for Traffic Police project presents an IoT-based wearable monitoring system using FSR pressure sensors, a piezoelectric sensor, an MPU6050, and an ESP32 microcontroller. The system collects and processes sensor data and displays the readings through the Arduino IDE Serial Monitor and Blynk IoT dashboard. The prototype demonstrates sensor integration, real-time data visualization, and threshold-based status indications. This approach provides a foundation for monitoring foot-pressure variations, movement, and road-surface impacts among traffic police personnel. Further improvements in sensor calibration, detection accuracy, power efficiency, and experimental validation can enhance the system's reliability and practical applicability.

ACKNOWLEDGEMENT

We wish to convey our heartfelt thanks to **Nagarjuna Tanikonda,** Department of Electronics and Communication Engineering, **CMR Technical Campus, Hyderabad**, for her valuable guidance, constant encouragement, and support during the completion of our project entitled **"Road Surface Health Monitoring Smart Shoes for Traffic Police."** His suggestions and guidance helped us improve our understanding and implement the proposed system. We also extend our appreciation to the faculty members and fellow students for their helpful suggestions and cooperation throughout this work. We are grateful to the institution for providing the laboratory facilities, technical resources, and academic environment necessary for developing and testing the proposed smart shoe prototype. Finally, we thank everyone who supported us directly or indirectly in completing this project successfully.

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