International Journal of Science and Engineering Applications
Volume 14-Issue 06, 27 – 33, 2025, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1406.1005

Raspberry-Pi Enabled Real Time Traffic Incident Detection

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ABSTRACT

This project proposes a Raspberry Pi-Enabled Real-Time Traffic Incident Detection System aimed at improving urban traffic management using smart and cost-effective technology. The system leverages a Raspberry Pi 3B+ to control infrared (IR) sensors and a USB camera to monitor real-time vehicle density and pedestrian activity at intersections.

Based on sensor input, the system dynamically adjusts traffic signal timing, minimizing congestion and wait times. The USB camera detects pedestrians on zebra crossings and captures images of vehicles violating traffic rules. These violations are reported to the Regional Transport Office (RTO) using a SIM 800C GSM module for further action.

Overall, this system offers a scalable, low-cost, and energy-efficient solution suitable for smart cities. It enhances safety, reduces traffic congestion, and supports real-time law enforcement, making urban roads smarter and more responsive.

INTRODUCTION

With rapid urbanization and the continuous increase in the number of vehicles, efficient traffic management has become a critical challenge for modern cities. Traditional traffic systems typically operate on fixed-timing signals, which do not adapt to real-time traffic conditions.

This often results in long queues, extended waiting periods, and higher chances of accidents, especially at busy intersections and pedestrian crossings.

Moreover, conventional systems lack the ability to monitor and address traffic violations such as vehicles

halting on zebra crossings. Such violations compromise both traffic flow and pedestrian safety, and are difficult to report and enforce in real time.

To address these challenges, we have developed a Raspberry Pi-Enabled Real-Time Traffic Incident Detection System. At the core of this intelligent

system is a Raspberry Pi 3B+, which processes input from various sensors and a camera to monitor traffic activity and detect incidents instantly.

The system utilizes six infrared (IR) sensors, three on each side of the road, to assess traffic density. Based on this data, it dynamically manages traffic lights by prioritizing the busier side, ensuring smoother traffic flow. In addition, a USB camera monitors pedestrian crossings to enhance safety. When a pedestrian is detected, the system triggers a red light to halt vehicles. If a vehicle violates this rule and stops on the crossing, the camera captures an image and sends a report to the Regional Transport Office (RTO) using the SIM 800C GSM module.

A key feature of the system is its emergency vehicle prioritization. When an ambulance, fire truck, or similar vehicle is detected, the system overrides normal traffic signals to create a clear path, allowing it to pass quickly and safely—potentially saving lives during critical situations.

Additionally, a 20x4 LCD screen provides real-time

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alerts and updates to road users, such as current traffic status or emergency situations.
This ensures better driver awareness and promotes safer driving behavior.

Overall, this project presents a cost-effective, intelligent, and scalable solution for modern urban traffic management systems.

LITERATURE SURVEY

Traffic management has consistently remained a crucial concern in urban infrastructure planning and development. Over the years, numerous studies have been conducted to explore methods for optimizing traffic flow, reducing congestion, and enhancing road safety. Traditional traffic control systems largely depend on fixed-timing signals, which are not responsive to fluctuating traffic volumes. This often leads to inefficient traffic movement, long delays, and increased accident risk—especially at busy junctions and pedestrian crossings.

Recent advances in technology have paved the way for the development of smart traffic management systems that incorporate sensors, cameras, and artificial intelligence (AI) to offer adaptive and real-time traffic regulation. These intelligent systems adjust to the actual conditions on the road, improving both vehicle movement and pedestrian safety.

Several studies have validated the effectiveness of sensor-based traffic monitoring. In particular, infrared (IR) sensors have proven useful for detecting the density of vehicles on different roads, allowing systems to dynamically adjust signal timing to reduce congestion. Similarly, camera-based systems that use image processing algorithms have been employed to identify pedestrians and monitor traffic violations such as red-light jumping and improper stopping on zebra crossings.

Moreover, the integration of IoT technologies and wireless communication modules like GSM and SIM 800C has enabled traffic systems to provide real-time updates, automated violation reporting, and data transmission to traffic authorities, making law enforcement more efficient.

Another significant area of research is emergency vehicle prioritization. Technologies such as RFID tags, GPS tracking, and camera-based recognition have been used to detect ambulances or fire trucks and adjust signals to grant them immediate passage. While many of these systems are part of large, centralized traffic control centers, there has been growing interest in decentralized solutions using platforms like the Raspberry Pi. These solutions offer a low-cost, scalable, and energy-efficient alternative suitable for widespread deployment in both smart cities and developing urban areas.

METHODOLOGIES

A) Existing System The existing traffic management systems primarily rely on fixed-timing traffic signals that do not adapt to real-time traffic conditions. These systems are inefficient, leading to congestion, increased wait times, and frequent traffic violations. Some modern solutions use camera-based monitoring and IoT-based traffic control, but they often require high infrastructure costs, centralized control centers, and heavy power consumption. Additionally, existing systems lack an effective mechanism for emergency vehicle prioritization and real-time violation reporting**.**

B) In our project, we propose a Raspberry Pi-Enabled Real-Time Traffic Incident Detection System that efficiently manages traffic using sensor-based monitoring, image processing, and wireless communication. The system is powered by a Raspberry Pi 3B+, which receives a 5V power supply through a rectifier and regulator circuit. It integrates six infrared (IR) sensors to detect vehicle density on both sides of the road and a USB camera to monitor pedestrian crossings and traffic violations

The system operates as follows:

1. 1. Traffic Density Monitoring: IR sensors detect traffic flow and adjust signal timing dynamically to minimize congestion.
2. 2. Pedestrian Safety: The USB camera identifies pedestrians at zebra crossings, automatically triggering red lights to stop vehicles.

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3. Traffic Violation Detection: If a vehicle stops on the zebra crossing, the camera captures an image, and the system reports the violation to the Regional Transport Office (RTO) via the SIM 800C module.
4. Emergency Vehicle Prioritization: When an ambulance or fire truck is detected, the system overrides normal traffic signals to provide a clear path.
5. Real-time Driver Alerts: A 20x4 LCD screen displays current traffic conditions, incidents, and emergency alerts to keep drivers informed.

The system effectively reduces congestion, enhances pedestrian safety, and ensures faster emergency response times, making it a cost-effective and scalable solution for modern urban traffic management.

BLOCK DIAGRAM

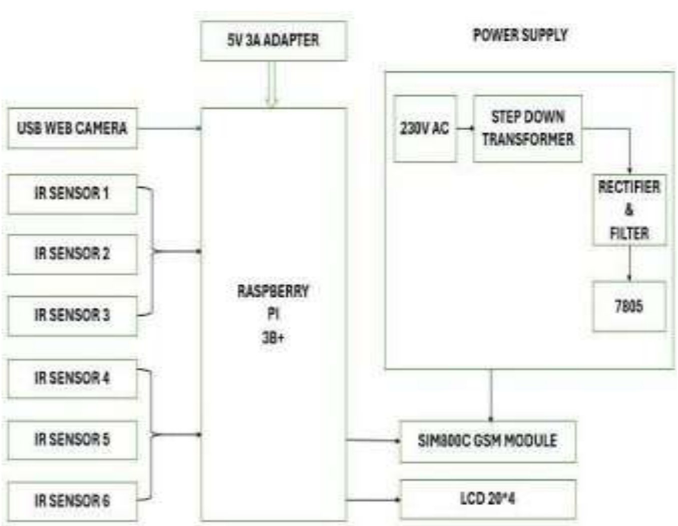


Fig. Block Diagram of Raspberry-Pi Enabled Real Time Traffic Incident Detection.

The block diagram represents a **Raspberry Pi-Enabled Real-Time Traffic Incident Detection System**. At the center of the system is the **Raspberry Pi 3B+**, which acts as the main controller, receiving input from **six IR sensors** and a **USB web camera**.

- The **IR sensors** (three on each side) detect vehicle density to adjust traffic signals dynamically.
- The **USB camera** monitors pedestrian crossings and captures images of traffic violations.

The Raspberry Pi also controls:

- A **SIM800C GSM module** that sends violation data to the **RTO**.
- A **20x4 LCD display** that shows real-time traffic status and alerts.

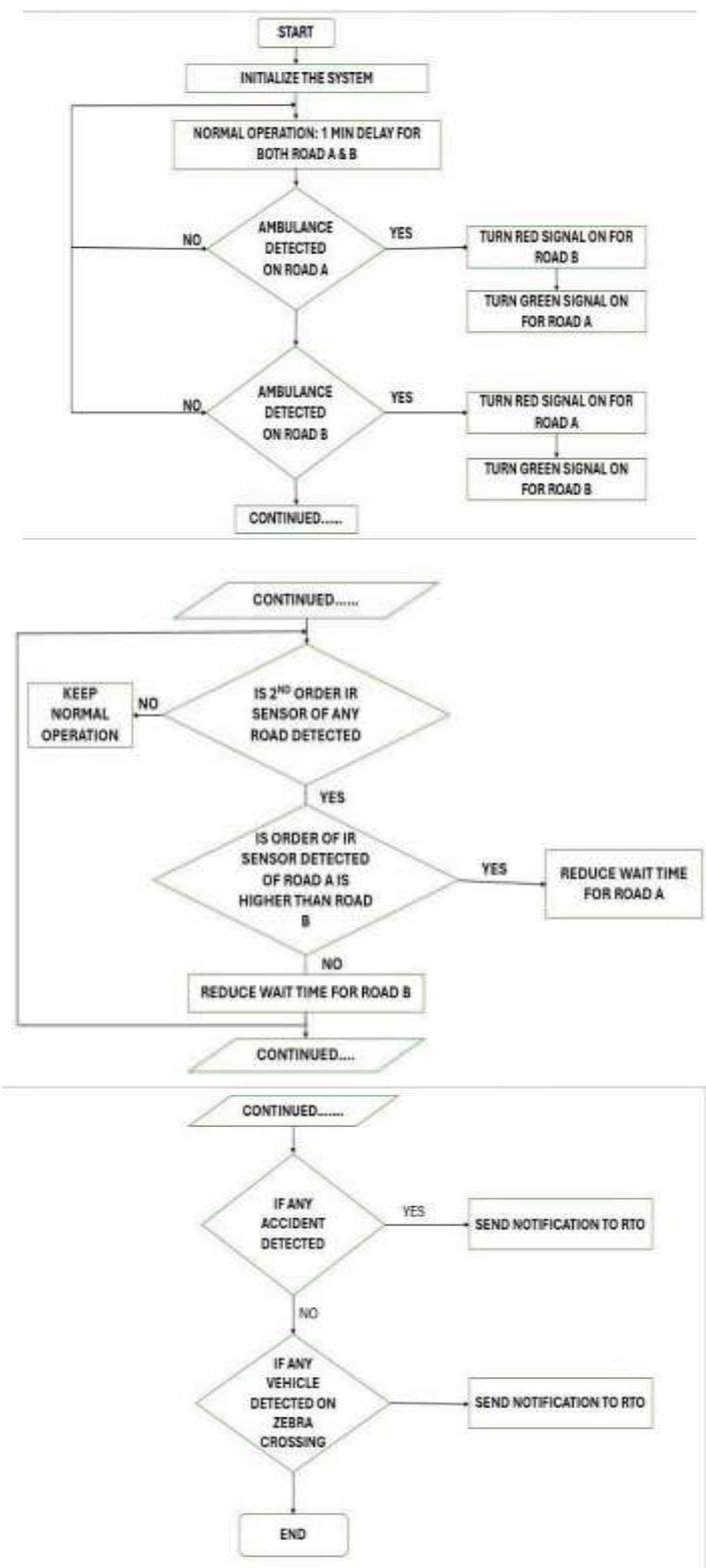
Power is supplied in two ways:

- A **5V 3A adapter** powers the Raspberry Pi.
- A **230V AC source** goes through a **step-down transformer**, **rectifier**, and **7805 voltage regulator** to supply 5V DC for the other components.

This setup ensures **smart traffic control**, **rule enforcement**, and **emergency vehicle prioritization** in a cost-effective and scalable way.

In addition to its practical benefits, the system promotes the integration of low-cost embedded technologies into public infrastructure, highlighting the potential of decentralized solutions in addressing large-scale urban problems. Its modular design allows for easy upgrades and customization based on city-specific traffic patterns. By reducing reliance on manual traffic monitoring and enforcement, the system not only improves operational efficiency but also helps create safer, more responsive, and environmentally sustainable transportation networks. As cities continue to grow, adopting such intelligent systems will be essential for building the smart cities of the future.

FLOW CHART



1. Initialization and Emergency Handling

The system begins by initializing all components and entering a normal operational mode, where each road (A and B) is given a 1-minute signal delay alternately. During this phase, the system continuously monitors for emergency vehicles, such as ambulances.

- If an **ambulance is detected on Road A**, the system overrides the standard signal pattern:
  - Road B is given a **red signal**.
  - Road A is given a **green signal** to clear the path for the emergency vehicle.
- Similarly, if an **ambulance is detected on Road B**, the system does the reverse, ensuring rapid passage.

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2. Dynamic Traffic Signal Adjustment

In the absence of emergency vehicles, the system checks the vehicle density using **second-order IR sensors** (indicating heavier traffic).

- If no higher-order sensors are triggered, the system continues in normal mode.
- If sensors detect higher traffic density:
  - It compares the traffic on **Road A and Road B**.
  - The road with **greater vehicle density** gets a **reduced wait time**, ensuring smoother traffic flow and minimized congestion.

This dynamic adjustment ensures the system adapts to real-time traffic conditions rather than using fixed signal cycles.

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3. Incident and Violation Detection

The final part of the flowchart focuses on **traffic violations and safety incidents**.

- If the system detects an **accident**, it immediately **sends a notification to the RTO** (Regional Transport Office).
- If a **vehicle is found stopping on a zebra crossing**, the system similarly **sends a violation report** to the RTO.

This section supports **real-time law enforcement** by enabling authorities to act quickly on reported violations and incidents, enhancing road safety.

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HARDWARE

1. Raspberry Pi 3B+

- **Processor**: Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
- **RAM**: 1GB LPDDR2 SDRAM
- **Connectivity**: 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE
- **Ethernet**: Gigabit Ethernet over USB 2.0 (maximum throughput of 300 Mbps)
- **GPIO**: 40-pin header
- **Ports**: 4 USB 2.0, HDMI, microSD slot, 3.5mm audio jack, CSI (camera) & DSI (display) interfaces
- **Power**: 5V/2.5A DC via micro USB

2. Infrared (IR) Sensors (6 units)

- **Type**: Infrared reflective sensors for vehicle detection
- **Quantity**: 6 (3 for each side of the road)
- **Range**: 2cm to 80cm
- **Operating Voltage**: 3.6V to 5V
- **Detection Angle**: 35°
- **Main Chip**: LM393

3. USB Camera

- **Resolution**: 640x480 (VGA) or higher
- **Interface**: USB 2.0
- **Lens**: 5G lens, F2.0/f3.60
- **Frame Rate**: 30fps (VGA), 15fps (XVGA)
- **Operating Current**: <120mA

4. SIM 800C GSM Module

- **Functionality**: GSM-based communication for traffic violation reporting
- **Frequency Bands**: Quad-band 850/900/1800/1900MHz
- **Power Supply**: 3.4V to 4.4V
- **Communication Interface**: RS232 for direct communication
- **Features**: Supports SMS, GPRS, voice calls, and internet connectivity

5. 20x4 LCD Display

- **Type**: Alphanumeric LCD for real-time message display
- **Interface**: I2C or parallel communication
- **Backlight**: STN Blue Negative

6. Power Supply

- **Power Source**: 12V, 1.3Ah Rechargeable Lead Acid Battery
- **Regulation Circuit**: Step-down transformer, rectifier, and 7805 voltage regulator (12V to 5V conversion)
- **Output Voltage**: 5V DC for Raspberry Pi and other module

SOFTWARE

1. Operating System

- Raspbian OS Raspbian is a Debian-based Linux operating system optimized for the Raspberry Pi. It provides a stable environment with support for Python, GPIO libraries, and hardware interfacing.
- Lightweight and efficient for embedded applications
- Supports multitasking and I/O operations
- Comes with built-in Python interpreter and package manager

2. Programming Language

- Python is the core language used to write the application logic that handles sensor inputs, processes camera feeds, and manages GSM communication.
- Easy to read and maintain
- Well-supported libraries for GPIO access, image processing, and serial communication
- Enables real-time event handling

3. Libraries and Modules Used

- **RPi.GPIO**: To interact with the Raspberry Pi's GPIO pins for IR sensors and LCD control.
- **OpenCV**: For image processing tasks like detecting pedestrians or identifying vehicles on zebra crossings.
- **pySerial**: To communicate with the SIM800C GSM module via serial port.
- **time & threading**: For signal timing, delays, and managing concurrent tasks like sensor monitoring and display updates.
- **smtplib or HTTP APIs (optional)**: For sending alerts over SMS or to a central server (if internet access is available).

Conclusion

The Raspberry Pi-Enabled Real-Time Traffic Incident Detection System presents a practical and intelligent approach to modern traffic management. By integrating infrared sensors, a USB camera, and GSM communication (SIM800C), the system is capable of dynamically adjusting traffic signals, improving pedestrian safety, and prioritizing emergency vehicles in real time.

One of the key advantages of this system is its ability to capture and report traffic violations instantly, assisting authorities in enforcing road safety more effectively. The use of a Raspberry Pi 3B+ makes the solution both cost-efficient and easily scalable, suitable for smart city applications.

The system contributes to reduced traffic congestion, quicker emergency response, and better law enforcement support, making urban transportation safer and more efficient. While it faces certain limitations, such as dependency on stable power and network connectivity, its overall performance and flexibility mark it as a promising innovation for intelligent traffic control in future urban infrastructure

Future Work

To further enhance the capabilities of the Raspberry Pi-Enabled Real-Time Traffic Incident Detection System, several improvements can be considered. One major enhancement is the integration of AI-driven traffic prediction models that can forecast congestion patterns based on historical and real-time data, enabling even smarter signal control.

Implementing cloud-based monitoring would allow centralized access to traffic data, incident logs, and performance metrics, making it easier for authorities to make data-driven decisions. Additionally, integration with autonomous vehicles and smart vehicle communication protocols can lead to a more synchronized and efficient traffic flow in the future.

The use of advanced image processing techniques and GPS tracking can further increase the accuracy of vehicle detection, rule violation identification, and emergency vehicle recognition. Providing users with mobile applications or web-based dashboards will improve public accessibility by offering real-time updates, alerts, and traffic visualizations.

These future enhancements will make the system more adaptable, intelligent, and suitable for deployment in large-scale smart city projects.

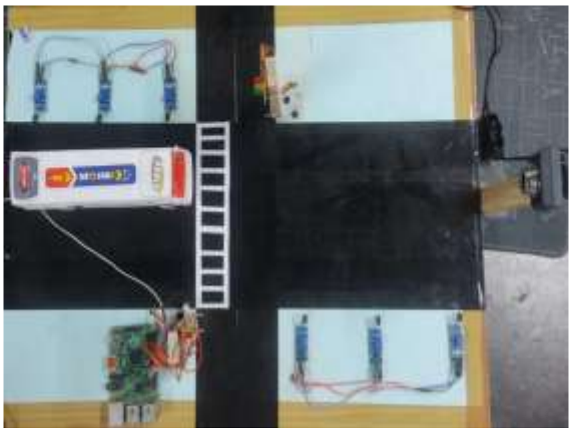
RESULT

The implementation of the Raspberry Pi-Enabled Real-Time Traffic Incident Detection System yielded promising results during testing. The system successfully monitored traffic density using six IR sensors and dynamically controlled traffic signal timing based on real-time data. This resulted in a noticeable reduction in vehicle wait times and smoother traffic flow at simulated intersections.

The USB camera accurately detected pedestrian presence on zebra crossings and triggered red signals for vehicle stoppage, ensuring pedestrian safety. Additionally, traffic rule violations—such as vehicles stopping on crossings—were effectively captured and transmitted to the Regional Transport Office (RTO) via the SIM800C GSM module.

Emergency vehicle prioritization was also tested and found to be efficient. When an emergency vehicle was simulated, the system provided an immediate clear path by adjusting signal controls. The 20x4 LCD display consistently provided real-time updates to road users, enhancing situational awareness.

Overall, the system demonstrated high reliability, responsiveness, and adaptability in real-time traffic scenarios, proving its potential as a smart, cost-effective, and scalable solution for urban traffic management.



Here is a sample Table of Result for your Raspberry Pi-Enabled Real-Time Traffic Incident Detection System. You can include this in your project report to present outcomes clearly and professionally.

Test Scenario	**Input Condition**	**System Response**	**Outcome**
Traffic Density Detection	Varying number of vehicles detected by IR sensors	Adjusted green/red signal timing dynamically	Reduced wait time and congestion
Pedestrian Detection	Pedestrian detected on zebra crossing via USB camera	Triggered red light for vehicles	Ensured safe pedestrian crossing
Traffic Rule Violation (Zebra Crossing)	Vehicle stopped on pedestrian crossing	Captured image & sent alert via SIM800C to RTO	Violation reported successfully
Emergency Vehicle Priority	Emergency vehicle detected manually/simulated	Immediate green signal given to clear path	Fast and uninterrupted emergency vehicle passage
Real-time Display	System running with various inputs	Displayed traffic status and alerts on 20x4 LCD	Users informed of current road conditions
Power Supply Stability	12V battery with step-down regulator	Provided stable 5V DC to components	Continuous and stable system operation
GSM Module Communication	Violation data triggered	Sent SMS to predefined number (RTO)	Verified real-time communication

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