International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue:2 Volume No.10 March - April – 2026
DOI:10.46647/ijetms.2026.v10i02.012 ISSN: 2581-4621

Dynamic Traffic Signal Optimization with Acoustic Pollution Monitoring

Kavali Kavya [1], Lellela Mounika [2], Kaspa Nivas Chary [3], Dasa Sai Venkata Rakesh [4]
[1] Assistant Professor, Dept. of Electronics and Communication Engineering, MVSR Engineering College(A), Nadergul (P.O.), Telangana, India
[2,3,4] BE Students, Dept. of Electronics and Communication Engineering, MVSR Engineering College(A), Nadergul (P.O.), Telangana, India

Abstract – The escalating volume of urban vehicular traffic and widespread horn misuse have emerged as significant contributors to acoustic pollution in modern cities. Traditional traffic signal systems rely on fixed timing cycles that are incapable of responding to dynamic road conditions or fluctuating noise levels. To address these limitations, this work presents a sensor-integrated adaptive traffic signal control system that autonomously adjusts green phase durations based on real-time lane occupancy and ambient sound intensity. Infrared (IR) sensors positioned at each lane continuously monitor vehicular presence and assess lane-wise vehicular concentration, while acoustic sensors simultaneously capture horn-generated noise in decibels(dB). The acquired data is handled by an Arduino Mega 2560 microcontroller, which determines suitable signal durations for each lane. Lanes with higher traffic concentrations receive proportionally longer green intervals, thereby streamlining vehicular movement and reducing queue buildup. When ambient noise exceeds a configurable threshold, the controller imposed a temporary red phase extension on the offending lane, discouraging unnecessary horn misuse. For emergency handling, ambulances fitted with RFID transponders are wirelessly recognized by intersection-mounted readers, prompting the system to instantly switch the relevant lane to green for unhindered passage. Once the emergency vehicle clears the intersection, normal signal operations resume automatically. The proposed system delivers measurable improvements in traffic throughput, waiting time reduction, congestion mitigation, and noise pollution control, while strengthening emergency vehicle response capability.
Keywords- *Adaptive traffic signal control, lane-wise vehicular concentration, Infrared (IR) sensors, acoustic sensors, sound level monitoring, Arduino Mega 2560, RFID emergency prioritization.*

I. INTRODUCTION

Urban transportation systems are increasingly facing challenges due to the steady rise in vehicle population. Managing traffic efficiently at intersections has become difficult, particularly during peak hours. Traditional traffic control approaches depend on static timing plans, which do not dynamically adjust to changing road conditions. Because of this, vehicles may experience unnecessary delays in less crowded lanes, while heavily loaded lanes remain congested. Such an imbalance reduces overall traffic efficiency and increases fuel usage. To overcome these issues, traffic control approaches that consider real-time vehicle density have been explored, as they provide better coordination and smoother vehicle movement [1], [3].

Apart from congestion, excessive honking contributes significantly to noise pollution in cities. In dense traffic situations, drivers tend to use horns more frequently, leading to elevated noise levels. Long-term exposure to such environments can negatively impact human well-being, causing stress, hearing problems, and other health-related issues. Since road traffic is a major contributor to urban noise, monitoring sound intensity at intersections becomes essential [6].

Recent progress in embedded technologies has enabled the development of more responsive traffic control solutions. Sensors such as infrared (IR) devices can identify the presence of vehicles and help estimate traffic load in individual lanes. Using this data, signal timings can be modified in real-time to match existing conditions. This approach improves traffic distribution and minimizes congestion [3], [7]. Reducing the delays experienced by emergency vehicles in traffic is a key aspect of efficient signal control. Ambulances often encounter delays at signalized junctions due to traffic build-up, which can affect response time in critical situations. To address this challenge,

DOI:10.46647/ijetms.2026.v10i02.012 ISSN: 2581-4621

identification technologies like Radio Frequency Identification (RFID) can be implemented to detect approaching emergency vehicles and allow signal priority [8].
Considering these factors, this work introduces a traffic signal control system that combines vehicle density estimation, noise level assessment, and emergency vehicle handling. The system utilizes IR sensors for traffic measurement, an acoustic sensor for sound monitoring, and RFID for ambulance detection. Data obtained from these sensors is processed through an Arduino-based controller, enabling real-time adjustment of signal operations. The overall aim is to achieve smoother traffic flow, reduce delays, limit noise pollution, and ensure uninterrupted passage for emergency vehicles.

II. LITERATURE SURVEY

A variety of approaches have been developed to enhance traffic signal control systems using sensors and intelligent techniques. A density-based traffic signal system using IR sensors is presented in [1], where signal timing is adjusted according to current traffic conditions. Although it reduces congestion, it does not provide priority handling for emergency vehicles. An adaptive traffic control approach with emergency vehicle handling is discussed in [2], but it uses Bluetooth, which has limited range and reliability.
In [3], a microcontroller-based traffic control system using IR and ultrasonic sensors is proposed. It improves traffic flow but lacks coordination between multiple intersections. A more advanced system with adaptive signal timing and emergency-vehicle prioritization is presented in [4], which incorporates image-processing methods to achieve detection accuracy; however, it increases system complexity and cost. A review of adaptive traffic signal systems is given in [5], highlighting the benefits of AI-based approaches, although they are expensive and not widely implemented. Noise monitoring using acoustic sensing is discussed in [6], but it is not integrated with traffic signal control. IoT-based traffic systems in [7] improve real-time monitoring but require higher infrastructure. RFID-based emergency vehicle prioritization is presented in [8], which facilitates faster ambulance movement; however, it does not consider traffic density or noise levels. Wireless sensor network-based systems in [9] enhance real-time traffic data collection and signal optimization; however, they result in higher system complexity due to the integration of multiple sensing and communication components. Simple Arduino-based traffic control systems presented in [10], but they lack advanced features.AI-based optimization techniques in [11] provide better performance but require complex algorithms. Integrated traffic systems in [12] combine multiple approaches but still lack proper acoustic pollution monitoring. A study on optimized sensor orientation for density-based traffic light control is presented in [13]. This work focuses on improving the accuracy of traffic detection by placing sensors effectively. Although it enhances detection performance, it mainly considers traffic density and does not address noise pollution or emergency vehicle priority.
From the above studies, it is observed that most systems focus on traffic density or emergency vehicle priority, while very few address acoustic pollution. A unified system is required that integrates traffic density detection, noise monitoring, and emergency vehicle prioritization.

III. METHODOLOGY

A. System Overview

The proposed system aims to intelligently manage traffic signals at intersections by simultaneously evaluating three critical parameters: vehicular traffic density, ambient sound intensity, and the presence of emergency vehicles. To achieve this, the system integrates infrared (IR) sensors, an acoustic sensor, an RFID module, and an Arduino Mega microcontroller as its core components.
The microcontroller continuously processes incoming sensor data and executes real-time decisions to regulate signal operations accordingly. The primary objectives of this system are to enhance the overall efficiency of traffic flow, minimize unnecessary horn-blowing by motorists, and ensure unobstructed and prioritized clearance for emergency service vehicles.

B. Block Diagram

The block diagram illustrated in Fig.1 depicts the architectural overview of the proposed adaptive

DOI:10.46647/ijetms.2026.v10i02.012 ISSN: 2581-4621

traffic signal control system with integrated noise pollution monitoring. The system comprises the following hardware components: Infrared sensors, an acoustic sensor, an RFID module, an Arduino Mega microcontroller, traffic signal LEDs, a 7-segment display, an OLED display, and a dedicated power supply unit.
The infrared sensors are positioned across each lane to continuously monitor vehicular presence and traffic density. Simultaneously, the acoustic sensor placed at the intersection detects and measures horn noise levels, relaying this information to the OLED display for real-time visualization. The RFID module serves the purpose of identifying and detecting emergency vehicles approaching the intersection. All sensor inputs are fed into the Arduino Mega, which functions as the central processing unit of the entire system.
Upon receiving and analyzing these inputs, the microcontroller regulates the traffic signal LEDs accordingly and simultaneously updates the 7-segment display to reflect the current signal countdown timer. A power supply unit operating at 5V/12V ensures consistent and stable power delivery to all system components.
As a result, the system autonomously governs traffic signal operations, effectively reduces unnecessary honking at intersections, and guarantees prioritized signal access for emergency vehicles when detected.

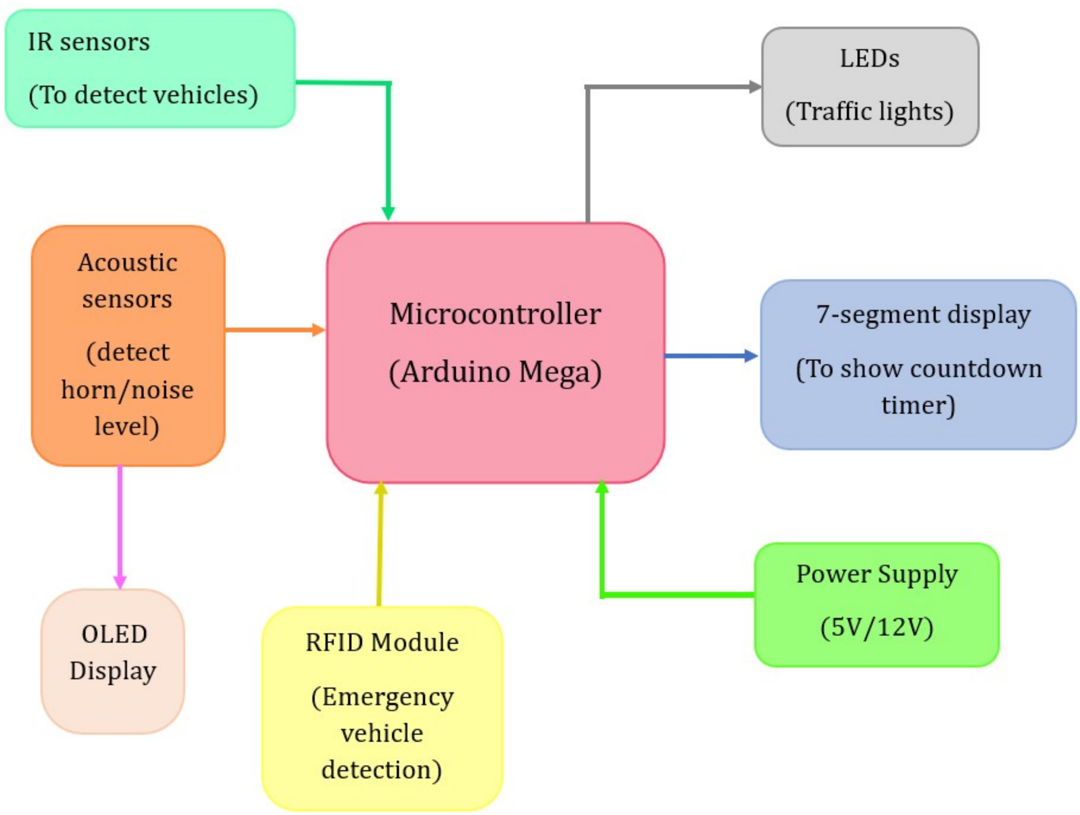


Fig.1. Block diagram illustrating the overall system architecture

C. Flow Chart

The flowchart depicted in Fig.2 demonstrates the operational mechanism of the suggested traffic signal framework. The setup starts by taking inputs from the acoustic sensor, RFID module, and IR sensors.
Initially, the acoustic sensor monitors the noise level at the intersection. If the noise exceeds the threshold, the system applies a red signal penalty for 10 seconds and increments the penalty counter. If the penalty count reaches three or more, the lane is temporarily skipped and control moves to the next lane; otherwise, normal flow continues.

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue:2 Volume No.10 March - April – 2026
DOI:10.46647/ijetms.2026.v10i02.012 ISSN: 2581-4621

Next, the system checks for a priority vehicle using the RFID module. If an emergency vehicle detected, a priority green signal is provided, overriding any skip or penalty conditions. If no emergency vehicle is detected, the system continues with the normal process.
After that, traffic conditions are analyzed using IR sensors. Based on the detected density (low, medium, or high), the green signal duration is adjusted to 10,15, or 20 seconds respectively.
Finally, once all lanes are evaluated, the system resets the skip flags for the next cycle. This process repeats continuously, ensuring efficient traffic management, priority handling for emergency vehicles, and control of excessive noise.

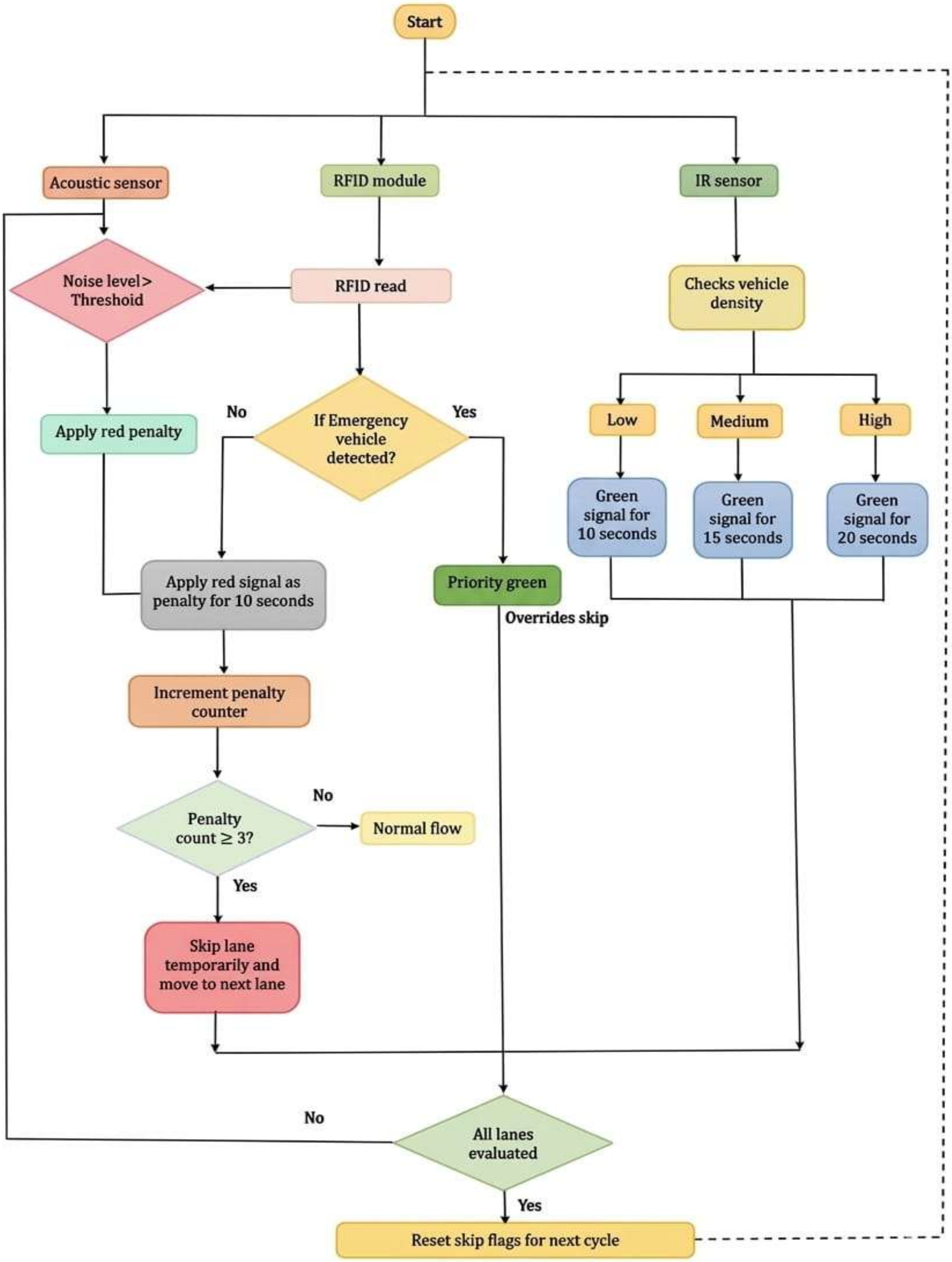


Fig.2. Flowchart of the Proposed System

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue:2 Volume No.10 March - April – 2026
DOI:10.46647/ijetms.2026.v10i02.012 ISSN: 2581-4621

D. Circuit Diagram

The circuit diagram shown in Fig.3 illustrates the hardware architecture of the proposed system using an Arduino Mega 2560 microcontroller. The microcontroller serves as the core processing unit, establishing connections with multiple input sensing elements and output devices to govern overall system functionality.

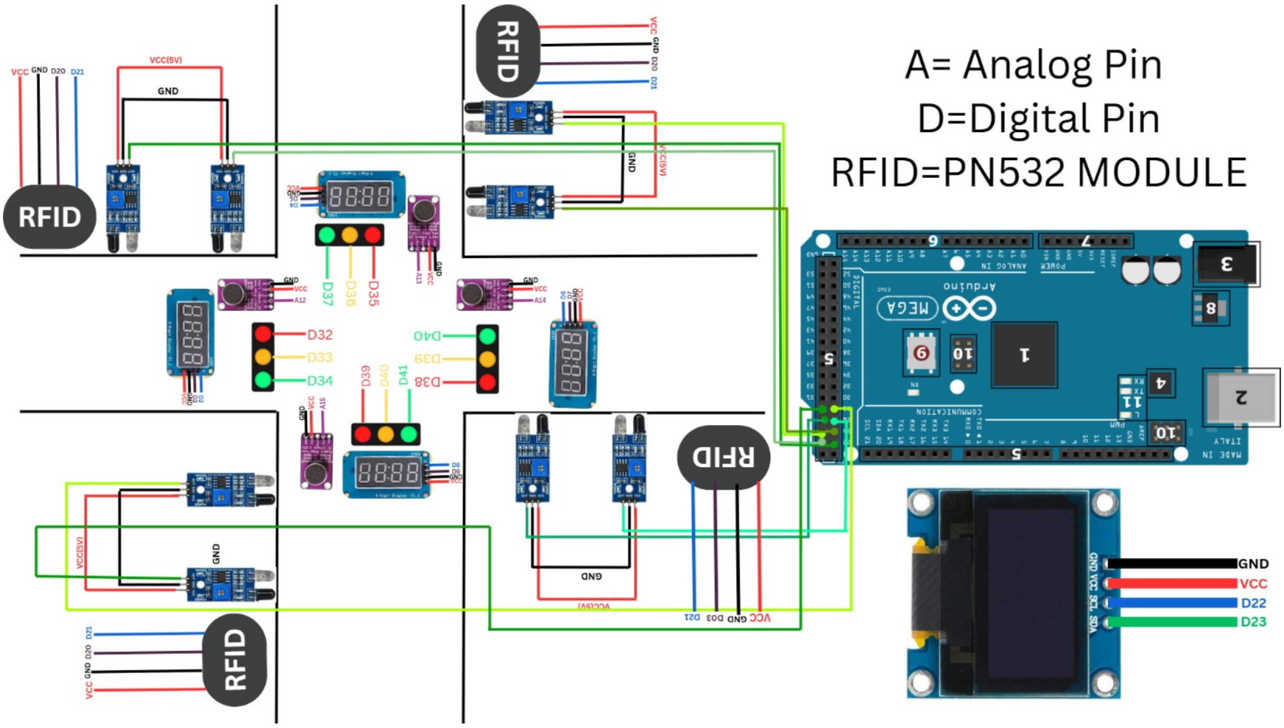


Fig.3. Circuit Diagram of the Proposed System

Infrared (IR) sensors are wired to the digital input pins of the controller to detect vehicle presence in different lanes.
An acoustic sensor is interfaced with an analog input pin to capture ambient acoustic intensity and detect abnormal horn activity at the intersections. The output from this sensor is used to determine whether the ambient noise intensity breaches the programmed tolerance limit.
The PN532 RFID Module communicates with the Arduino Mega using serial communication. The module facilitates recognition of emergency vehicles at the intersection, preventing siren-generated sound from being erroneously flagged as excessive honking, and provides immediate green signal priority.
The signal indicator LEDs are wired to the digital output terminals of the controller to represent halt, transition, and proceed signal states for each lane. The 7-segment displays serve to show the countdown timer for signal duration.
An OLED display module is connected to the controller to display system parameters such as noise levels and operational status, and a regulated power supply provides the required voltage to all components. The microcontroller processes all sensor data and regulates all output peripherals according to the programmed logic, ensuring proper traffic signal operation.

IV. RESULTS AND ANALYSIS

The experimental evaluation of the proposed traffic management system, conducted using a hardware prototype under real-time conditions, yields results that confirm the effectiveness of adaptive signal control driven by traffic density, emergency vehicle prioritization, and acoustic noise monitoring in enhancing overall system performance.

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue:2 Volume No.10 March - April – 2026
DOI:10.46647/ijetms.2026.v10i02.012 ISSN: 2581-4621

Fig.4 illustrates the developed hardware prototype used for system validation. The setup represents a multi-lane intersection equipped with IR sensors for traffic density detection, an RFID module for emergency vehicle identification, and an acoustic sensor for noise monitoring. The signal units display dynamic timing based on real-time inputs, demonstrating effective adaptation to varying traffic conditions. The prototype validates the system's capability to regulate traffic flow and provide priority handling under practical scenarios.

Fig.4. Hardware Prototype used for Experimental Evaluation

A. Experimental results

1.Adaptive Signal Timing Based on Vehicle Density

Table I summarizes the test cases based on the data acquired from IR sensors for different traffic density levels. The system adjusts the signal duration based on the vehicle presence detected in each case. The results demonstrate effective adaptation of signal timing under low, medium, and high traffic conditions.

Table I. Test Cases for Traffic Density and Signal Timing based on IR sensors

Test case No.	IR1	IR2	Density Level	Green Time (sec)
1.	0	0	LOW	10
2.	1	0	MEDIUM	15
3.	1	1	HIGH	20

The variation in traffic density corresponding to different test cases is illustrated in Fig.5

Test case 1: Low Density

In this scenario, both IR1 and IR2 remain inactive (0,0), indicating no vehicle detection within the

DOI:10.46647/ijetms.2026.v10i02.012 ISSN: 2581-4621

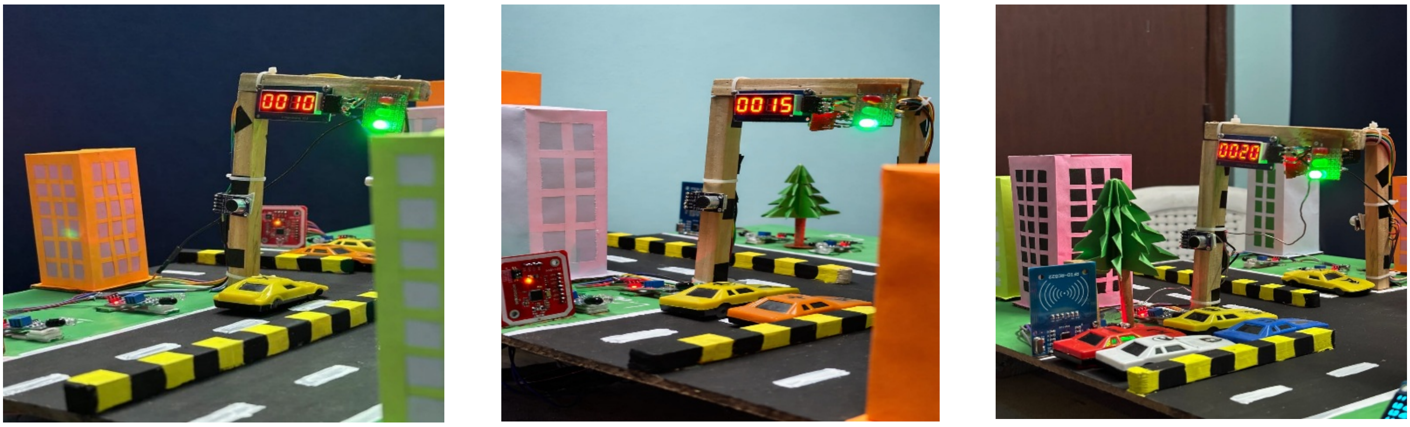
sensing region, although vehicles may be present upstream. Based on this input, the system categorizes the traffic as low density and assigns a green signal duration of 10 seconds.

Test case 2: Medium Density

For the condition where IR1 = 1 and IR2 = 0, only the first sensor is activated, indicating that a vehicle has entered the initial sensing region but has not yet reached the second detection point. This state represents partial occupancy within the monitored segment. Based on this observation, the traffic condition is classified as medium density, and a green signal duration of 15 seconds is assigned to regulate the flow efficiently.

Test case 3: High Density

In this case, simultaneous activation of IR1 and IR2 (1,1) confirms that vehicles are present at successive sensing points along the lane, indicating significant traffic accumulation within the monitored region. This level of occupancy is interpreted as a high-density condition, leading the controller to extend the green signal duration to 20 seconds to ensure efficient vehicle discharge.



(a)Low traffic density condition *(b) Medium traffic density condition* *(c) High traffic density condition*

Fig.5. Illustration of traffic density variations under different conditions

2. Acoustic-Based Noise Level Monitoring

Fig. 6(a) illustrates the acoustic-based monitoring mechanism, which identifies excessive horn noise levels using a predefined threshold of 700dB (scaled value based on sensor output) which may vary based on real-time sensor readings. When the noise levels exceeds this limit, a 10-second red signal penalty is applied and the status is displayed on the OLED in the real time.

Each violation increments the counter, and when it reaches three or more, the lane is temporarily skipped and control shifts to the next lane that is shown in Fig.6(b).

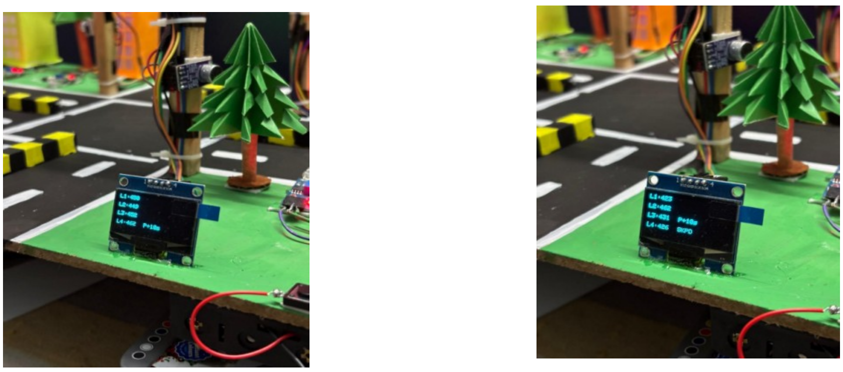


Fig.6(a) Red signal penalty activation *Fig.6(b) Temporary lane skipping due to repeated violation*

International Journal of Engineering Technology and Management Sciences
Website: ijetms.in Issue:2 Volume No.10 March - April – 2026
DOI:10.46647/ijetms.2026.v10i02.012 ISSN: 2581-4621

3. Emergency Vehicle Identification and Signal Priority

The hardware implementation enables reliable RFID-based detection of emergency vehicles. As shown in Fig.7, a priority green signal is immediately assigned to the detected lane, with status indicated on the OLED.

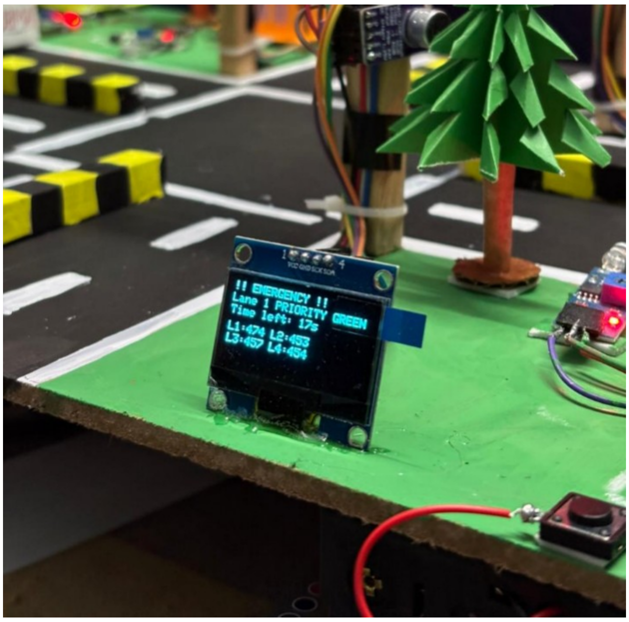


Fig.7 RFID –Based Emergency Priority with Signal Override

The priority control overrides all existing conditions, including penalty-based lane skipping, ensuring uninterrupted passages. The response is consistent with minimal delay, confirming effective integration of detection and signal control.

V.CONCLUSION

This project presents a simple and effective approach towards enhancing intersection signal management by combining traffic management with acoustic pollution monitoring. The system helps in reducing unnecessary honking while still ensuring that emergency vehicles are given proper priority.

The developed prototype shows that integrating multiple factors into a single system can improve overall traffic behavior and efficiency. It also highlights that such solutions can be implemented using basic components in a cost-effective manner. Overall, the project contributes towards creating a more efficient and less noisy traffic environment.

VI. FUTURE SCOPE

The developed framework is capable of being further enhanced by implementing a smart lane selection mechanism, where the system automatically identifies the most congested lane and allocates signal priority accordingly. Such an enhancement would optimize vehicular movement by making more efficient use of available road space.

The system can also be improved by using dynamic noise threshold adjustment, where the noise limit changes based on time and surrounding conditions. This will make the system more adaptable to real-world environments.

Additionally, the system can be extended to handle situations where emergency vehicles arrive simultaneously from multiple lanes. In such cases, a priority-based control mechanism can be implemented, where priority is assigned based on parameters including vehicle type, proximity to

Website: ijetms.in Issue:2 Volume No.10 March - April – 2026
DOI:10.46647/ijetms.2026.v10i02.012 ISSN: 2581-4621

the intersection, or arrival time. The framework would then be able to dynamically allocate signal timing to facilitate secure and coordinated passage of all emergency vehicles.

Furthermore, data logging features can be included to store traffic and noise information for further analysis and performance improvement. These such upgrades would render the overall system increasingly efficient, informative, and suitable for practical implementation.

REFERENCES

[1] S. Rudhra, S. Vinod, A.Arthi, and P. L. Kunjirajkumar, "Density based traffic signal system," Proc. 2024 *International Conference on Power, Energy, Control and Transmission Systems (ICPECTS)*, Chennai, India, 2024.

[2] A. Laddha, A. Awate, J. Awere, A. Deokar, A. Patil, and O. Awatade, "Intelligent Traffic Management System with Adaptive Signal Control and Emergency Vehicle Prioritization," *International Journal of Research in Applied Science and Engineering Technology (IJRASET),* 2023.

[3] C.Venkatesh Kannan ,"Vehicle density based traffic control system using microcontroller," *Proc. IEEE Conference*, 2024.

[4] Devika S. G., Govind A., and Lekshmi D.,"Next-Generation Traffic Control: Adaptive Timer and Emergency Vehicle Priority in Intelligent Traffic Management,"*IEEE International Conference on Smart Systems*, 2024.

[5] M. B. Alazzawi, H. Lu, and A. Yassin, "Adaptive traffic signal control systems: A review," *IEEE Access*, 2021.

[6] World Health Organization, Environmental Noise Guidelines for the European Region, *WHO Press*, 2018.

[7] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of Things for smart cities," *IEEE Internet of Things Journal*, vol. 1, no. 1, pp. 22–32, Feb. 2014.

[8] R. Want, "An introduction to RFID technology," IEEE Pervasive Computing, vol. 5, no. 1, pp. 25–33, Jan.–Mar. 2006.

[9] Q. N. Naveed, H. Alqahtani, and R. U. Khan, "An intelligent traffic surveillance system using integrated wireless sensor network and improved phase timing optimization," Sensors, vol. 22, no. 9, 2022.

[10] S.Sharma, S.Pithadia, and M. Gupta, "Intelligent traffic light system using microcontroller," *Proc. International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, IEEE, 2015.

[11] Y. Zhang et al., "Artificial intelligence based traffic flow optimization," *IEEE Trans. Intelligent Transportation Systems,* 2021.

[12] K. R. Rajesh and R. K. Rao,"Smart Traffic Control Systems Using IoT and Embedded Systems,"*International Journal of Advanced Research in Electronics and Communication Engineering*, 2022.

[13] C. Gadekari , G.Tudavekar , P. Patil, G. Rudrappa , N. Maidwale , and A. Tigadi, "Optimized sensor orientation for density based traffic light control," *Proc. 6th International Conference for Emerging Technology (INCET)*, Belagavi, India, May 23–25, 2025, IEEE.