

Design and Implementation of Automated Traffic Light Systems

C.Kalpana 

Assistant Professor, Department of Robotics and Automation
Sengunthar Engineering College (Autonomous), Tiruchengode, India

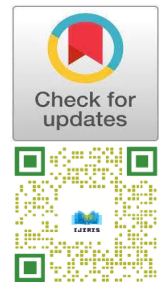
ckalpana.ra@scteng.co.in

<https://orcid.org/0009-0008-8355-5605>

S.Vinoth, S.Hemanth

Department of Robotics and Automation
Sengunthar Engineering College (Autonomous), Tiruchengode, India

selvivinoth353@gmail.com, hemanthbe.2707@gmail.com



Publication History

Manuscript Reference No: IJIRIS/RS/Vol.12/Issue03/ISMR26.MRIS10102

Research Article Open Access| Double-Blind Peer-Reviewed| Article ID: IJIRIS/RS/Vol.12/Issue03/ISMR26.MRIS10102

Received: 31, January 2026, Revised: 14, February 2026, Accepted: 17, March 2026, Published Online: 25, March 2026.

<https://www.ijiris.com/volumes/Vol12/iss-03/23.ISMR26.MRIS10102.pdf> **BibTeX Key: Kalpana@2026Design**

Article Citation: Kalpana, Vinoth, Hemanth(2026), Design and Implementation of Automated Traffic Light Systems, IJIRIS: International Journal of Innovative Research in Information Security, Volume 12, Issue 03 of 2026 pages 189-193

Doi:- <https://doi.org/10.26562/ijiris.2026.v1203.23>

IJIRIS papers should be cited as IJIRIS (International Journal of Innovative Research in Information Security, AM Publications, India 2026, ISSN 2349-7017, <https://doi.org/10.26562/ijiris.2026.v1203.23> The journal's official abbreviation is IJIRIS. Orcid: <https://orcid.org/0009-0004-9398-7488> Copyright©2026 copyright by the authors. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Abstract: Traffic congestion at road intersections is a major issue caused by the rapid growth in the number of vehicles and the inefficiency of conventional fixed-time traffic signal systems. To address this problem, this study proposes a smart traffic light control system that dynamically manages traffic based on real-time vehicle density. The system employs two sensors positioned at specific distances on each lane to monitor vehicle accumulation. When both sensors are blocked, the system detects a high traffic density condition and automatically assigns the green signal to the respective lane to reduce congestion. In addition, ultrasonic sensors are incorporated to identify relatively free lanes and display this information to approaching drivers, helping them choose less crowded routes. The system also includes an emergency vehicle detection mechanism that provides immediate signal priority for ambulances, ensuring faster and safer passage during critical situations. By integrating sensor-based monitoring and intelligent control, the proposed system enhances traffic flow efficiency, reduces waiting time at intersections, and improves overall road management.

Keywords: Smart traffic control, automated traffic light system, vehicle density detection, ultrasonic sensors, emergency vehicle priority, intelligent transportation system.

I. INTRODUCTION

Traffic congestion has become a major challenge in urban areas due to the rapid growth in the number of vehicles. Most conventional traffic signal systems operate based on fixed time intervals without considering the real-time traffic conditions of each lane. As a result, some lanes may experience heavy congestion while others remain relatively free, leading to inefficient traffic management and increased waiting time for road users. To address this issue, intelligent traffic management systems are being developed that can dynamically control traffic signals based on vehicle density. Sensor-based traffic monitoring provides an effective way to detect vehicle presence and adjust signal timing accordingly. By identifying traffic density in different lanes, the system can prioritize lanes with higher vehicle accumulation and improve overall traffic flow. In this work, a smart traffic light control system is proposed using sensors placed at specific distances in each lane to detect vehicle density. When vehicles occupy both sensors, the system identifies high traffic density and automatically provides the green signal to that lane. The system is further enhanced with ultrasonic sensors to determine the relatively free lane and display this information to drivers. Additionally, an emergency vehicle detection feature is incorporated to automatically provide signal priority for ambulances and other emergency vehicles, improving both traffic efficiency and emergency response time

II SYSTEM OVERVIEW

1. Traffic Density Detection Mechanism

The traffic density detection mechanism is used to identify the level of vehicle accumulation in each lane at the intersection. In the proposed system, two vehicle detection sensors are placed at specific distances along every lane. These sensors continuously monitor the presence of vehicles near the traffic signal. When a vehicle stops near the signal and blocks the first sensor, the system recognizes that vehicles are approaching the intersection. If vehicles continue to accumulate and also block the second sensor placed farther behind, the system interprets this condition as high traffic density in that lane. The sensor signals are sent to the control unit, where the microcontroller processes the input data and determines the traffic condition. Based on this detection, the system dynamically adjusts the traffic signal by assigning the green light to the lane with higher traffic density.

This method allows the system to respond to real-time traffic conditions instead of relying on fixed signal timing, thereby reducing congestion and improving overall traffic flow at the intersection.

2. Sensor Module

The sensor module plays a crucial role in monitoring traffic conditions at the intersection. In the proposed system, different types of sensors are used to detect vehicle presence, measure vehicle distance, and identify emergency vehicles. These sensors continuously collect real-time data from each lane and send it to the control unit for processing. Vehicle detection sensors are placed at specific positions on each lane to monitor the presence of vehicles and determine traffic density. When vehicles stop and block these sensors, the system recognizes the level of traffic buildup in that lane. In addition, ultrasonic sensors are used to measure the distance between vehicles in adjacent lanes to identify which lane has relatively less traffic. This helps the system determine the faster-moving lane. Furthermore, a sound detection sensor is used to detect the siren of emergency vehicles such as ambulances. When an emergency vehicle is detected, the sensor sends a signal to the control unit, allowing the system to immediately provide a green signal to that lane. By combining multiple sensors, the system can effectively monitor traffic conditions and improve the efficiency of traffic signal control.

3. Control Unit

The control unit is the central component of the proposed smart traffic light system. It is responsible for processing the data received from various sensors and making decisions to control the traffic signals. In this system, a microcontroller such as Arduino or ESP32 is used as the control unit. The control unit continuously receives input signals from the vehicle detection sensors placed in each lane. Based on the sensor data, it determines the traffic density and identifies which lane requires priority. When high traffic density is detected in a particular lane, the control unit automatically activates the green signal for that lane while maintaining red signals for other lanes. In addition, the control unit processes data from ultrasonic sensors to compare vehicle spacing between lanes and identify the relatively free lane. It also receives signals from the emergency vehicle detection module. When an emergency vehicle such as an ambulance is detected, the control unit overrides the normal signal sequence and immediately provides a green signal to that lane. Through this intelligent decision-making process, the control unit ensures efficient traffic management and improved traffic flow at intersections.

4. Traffic Signal Control System

The traffic signal control system is responsible for managing the operation of traffic lights at the intersection based on the information received from the control unit. The system uses red, yellow, and green signal lights to regulate the movement of vehicles in different lanes. In the proposed system, the traffic signals are controlled dynamically according to the traffic density detected by the sensors. When the control unit identifies a lane with high vehicle density, the system automatically assigns the green signal to that lane while other lanes remain at the red signal. After a specific duration or when the traffic reduces, the system switches the signal to the next lane. The system also ensures a smooth transition between signals by activating the yellow light before switching from green to red. This helps maintain safety and avoid sudden stops for vehicles. Additionally, the traffic signal control system can override the normal sequence when an emergency vehicle is detected, immediately providing a green signal to the corresponding lane.

5. Lane Guidance Display System

The lane guidance display system is designed to assist drivers in selecting the faster-moving lane at an intersection. In the proposed system, ultrasonic sensors are used to measure the distance between vehicles in adjacent lanes of the same direction. By analyzing the spacing between vehicles, the system can estimate which lane has relatively less traffic.

The sensor data is processed by the control unit, which compares the vehicle spacing of the lanes and determines the relatively free lane. Once the comparison is completed, the result is shown through a display module placed near the traffic signal. The display indicates which lane has lighter traffic, helping drivers choose the lane that is likely to move faster. This feature helps distribute vehicles more evenly between lanes and reduces unnecessary congestion in a single lane. As a result, the overall traffic flow becomes smoother and more efficient at busy intersections.

6. Emergency Vehicle Detection

The emergency vehicle detection system is designed to provide priority for ambulances and other emergency vehicles at traffic intersections. In the proposed system, a sound detection sensor is used to identify the siren of emergency vehicles. When the sensor detects the specific siren sound of an ambulance or emergency vehicle, it sends a signal to the control unit. The control unit then overrides the normal traffic signal sequence and immediately activates the green signal for the lane where the emergency vehicle is approaching. At the same time, other lanes are switched to red signals to ensure a clear path for the emergency vehicle. This feature helps reduce delays for emergency services and allows ambulances to pass through intersections quickly and safely. By integrating emergency vehicle detection into the traffic signal system, the overall efficiency of traffic management and emergency response time can be significantly improved.

III METHODOLOGY

The proposed smart traffic light system is designed to improve traffic management at road intersections by dynamically controlling traffic signals based on real-time vehicle density and lane conditions. The system integrates vehicle detection sensors, ultrasonic sensors, a microcontroller-based control unit, and a display module to monitor traffic flow and make automated decisions. The methodology consists of traffic density detection, signal decision logic, lane comparison, and emergency vehicle priority mechanisms.

1. System Design

The system is designed using multiple sensors placed at predefined positions on each lane of the intersection. Two vehicle detection sensors are installed at different distances from the traffic signal to monitor vehicle presence and accumulation. These sensors continuously collect data regarding vehicle movement and send the signals to the microcontroller.

The microcontroller acts as the central processing unit of the system. It processes the sensor inputs and determines the traffic condition of each lane. Based on the detected traffic density, the controller dynamically manages the traffic signal lights. Additional modules such as ultrasonic sensors and a display unit are integrated into the system to improve traffic monitoring and driver guidance.

2. Traffic Density Detection

Traffic density detection is performed using two sensors placed sequentially on each lane. The first sensor detects the arrival of vehicles near the intersection, while the second sensor detects vehicle accumulation behind the first sensor. When vehicles block both sensors simultaneously, the system interprets this condition as high traffic density in that lane. The sensor signals are continuously monitored by the control unit. When high traffic density is detected, the lane is given higher priority in the traffic signal sequence. This approach allows the system to respond dynamically to real-time traffic conditions instead of relying on fixed signal timing.

3. Signal Decision and Control Logic: The signal decision process is handled by the microcontroller based on the inputs received from the sensors. The controller compares the traffic density of all lanes and determines which lane requires immediate signal priority. The lane with higher traffic density is assigned the green signal, while other lanes remain in the red signal state. Before switching from one lane to another, a yellow signal is activated to ensure safe transition for vehicles. The signal control logic continuously evaluates traffic conditions and dynamically adjusts the signal timing to reduce waiting time and congestion.

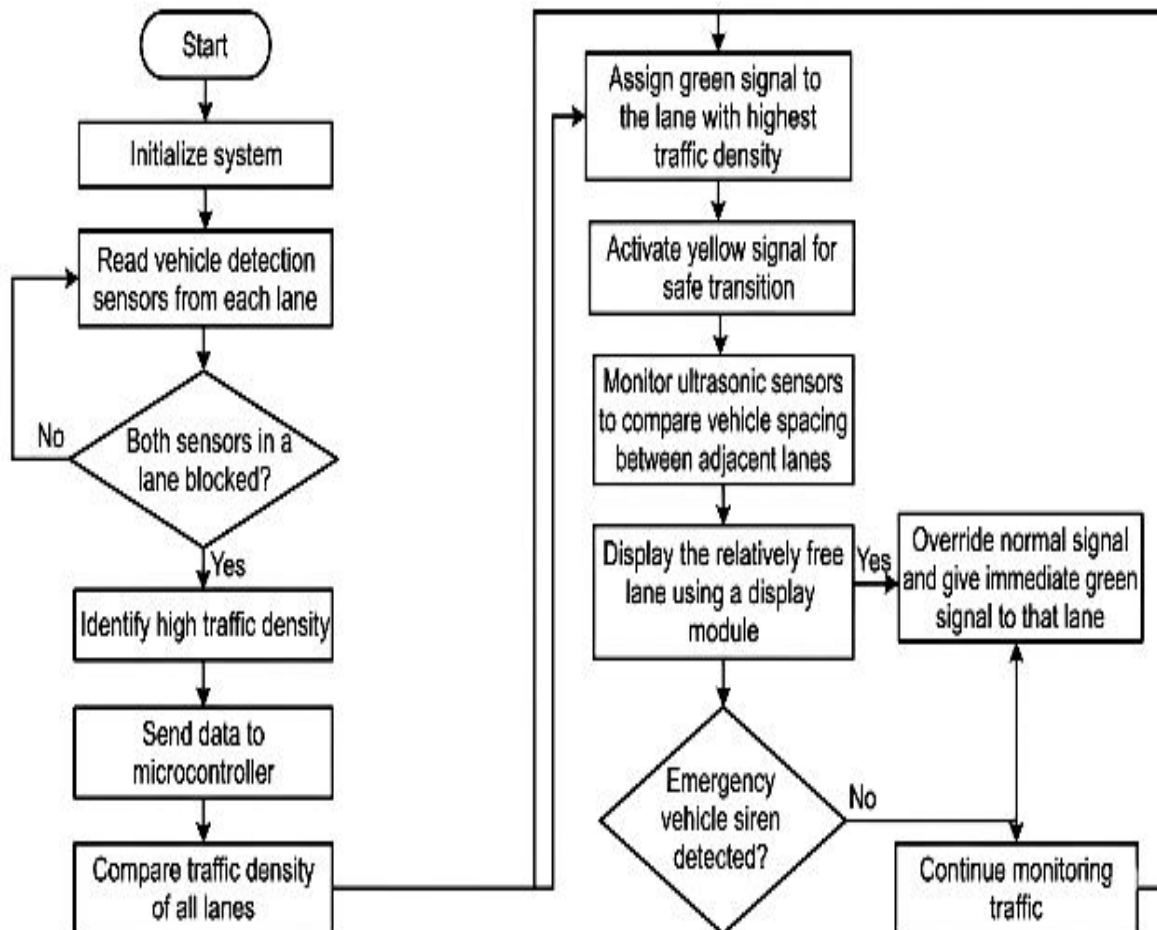
4. Lane Comparison and Guidance:

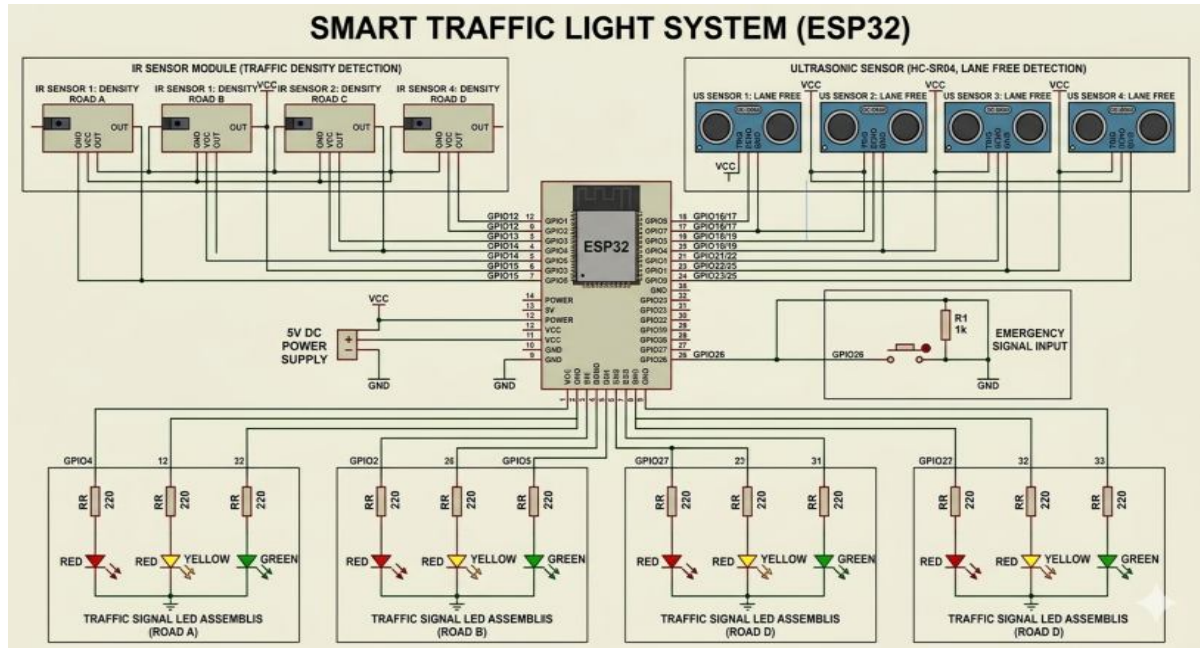
To further improve traffic efficiency, ultrasonic sensors are used to measure the distance between vehicles in adjacent lanes of the same direction. By analyzing the spacing between vehicles, the system estimates which lane has relatively less traffic. The microcontroller compares the measured distances and identifies the relatively free lane. This information is displayed using a display module installed near the traffic signal. The display guides drivers to choose the faster-moving lane, which helps distribute vehicles more evenly and reduces traffic buildup in a single lane.

5. Emergency Vehicle Priority Mechanism:

The system also includes an emergency vehicle detection mechanism to provide priority for ambulances and other emergency services. A sound detection sensor is used to identify the siren sound of emergency vehicles approaching the intersection. When the sensor detects the siren, a signal is sent to the microcontroller. The controller immediately overrides the normal traffic signal sequence and activates the green signal for the corresponding lane. This ensures that emergency vehicles can pass through the intersection without delay, improving emergency response time and road safety.

IV CIRCUIT DIAGRAM



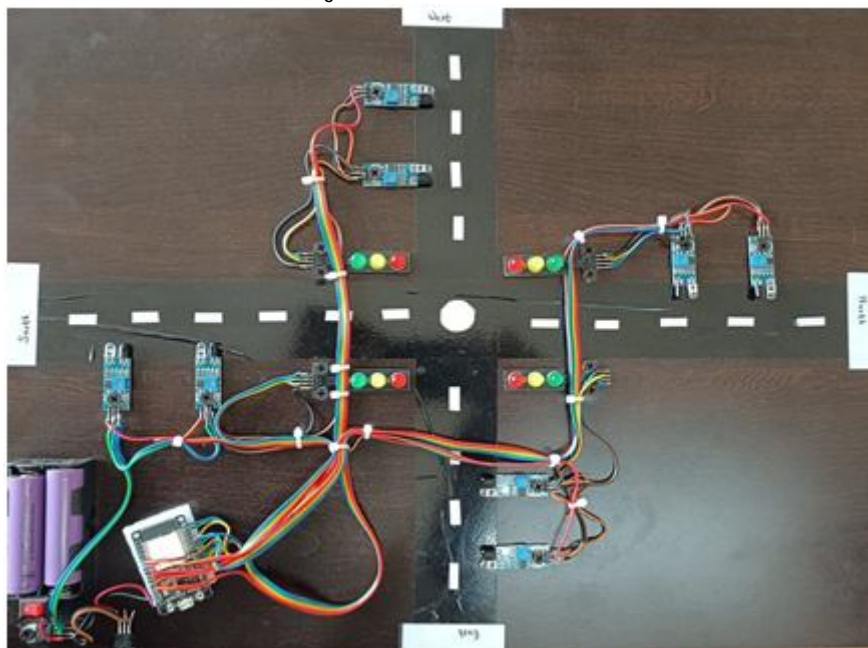


Description

The diagram illustrates the architecture of a Smart Traffic Light System based on the ESP32 microcontroller. The system uses multiple IR sensors to detect vehicle density in four different road lanes (Road A, B, C, and D). These sensors provide real-time traffic density data to the ESP32 through GPIO pins. Additionally, ultrasonic sensors (HC-SR04) are used for lane-free detection, allowing the system to identify whether a lane is occupied or empty. The ESP32 processes the sensor inputs and dynamically controls the traffic signal LEDs (Red, Yellow, and Green) for each lane through current-limiting resistors. A 5V DC power supply powers the controller and sensors. The design also includes an emergency signal input module, which allows priority override for emergency vehicles such as ambulances or fire trucks. Based on sensor data and emergency signals, the ESP32 intelligently adjusts traffic light timings to optimize traffic flow and reduce congestion.

V RESULTS

The proposed smart traffic light control system was successfully implemented and tested to evaluate its performance in managing traffic at road intersections. The system was able to detect vehicle density in each lane using the installed sensors. When vehicles blocked both sensors in a lane, the system correctly identified the condition as high traffic density and automatically assigned the green signal to that lane. The system also demonstrated the ability to monitor vehicle spacing using ultrasonic sensors and identify the relatively free lane. The display module successfully indicated the lane with less traffic, helping drivers choose the faster-moving lane.



In addition, the emergency vehicle detection mechanism worked effectively by detecting the siren of ambulances and providing immediate green signal priority. The overall results show that the proposed system can improve traffic flow efficiency and reduce congestion at intersections. The results obtained from the proposed smart traffic light control system demonstrate its effectiveness in improving traffic management at road intersections. By using sensors to detect vehicle density, the system can dynamically adjust traffic signals based on real-time conditions rather than relying on fixed signal timing. This helps reduce unnecessary waiting time and improves the overall flow of vehicles. The use of ultrasonic sensors for lane monitoring further enhances the system by identifying the relatively free lane and providing guidance to drivers through a display module. This feature can help distribute vehicles more evenly across lanes and minimize congestion in heavily occupied lanes. Additionally, the emergency vehicle detection mechanism plays an important role in improving road safety and emergency response time. By automatically giving priority to ambulances and other emergency vehicles, the system ensures faster movement through intersections. Overall, the proposed system provides an efficient and intelligent approach to traffic signal management and has the potential to support smart city traffic infrastructure.

VI CONCLUSION

This paper presented a smart traffic light control system designed to improve traffic management at road intersections using traffic density detection. The system utilizes sensors placed at specific distances in each lane to monitor vehicle accumulation and dynamically control traffic signals based on real-time traffic conditions. By identifying lanes with higher traffic density, the system automatically assigns the green signal to reduce congestion and improve traffic flow. The integration of ultrasonic sensors further enhances the system by identifying the relatively free lane and displaying this information to assist drivers in selecting the faster-moving lane. In addition, the emergency vehicle detection mechanism ensures that ambulances and other emergency vehicles receive immediate signal priority, enabling quicker and safer passage through intersections. Overall, the proposed system demonstrates an effective approach to intelligent traffic signal control and has the potential to improve traffic efficiency and reduce delays in urban transportation systems.

REFERENCE

1. S.Sharma, S.Chatterjee, and S.Bhunia, "Smart traffic light management system using IoT," *International Journal of Engineering Research and Technology*, vol. 9, no. 5, pp. 1123–1127, 2020.
2. M. A. Jabbar, H.S.Choi, and M. A.Habib, "Real-time traffic monitoring and control system using sensors," *IEEE Sensors Journal*, vol. 19, no. 8, pp. 2955–2963, 2019.
3. P.K.Singh and A.Gupta, "Intelligent traffic light system based on vehicle density detection," *International Journal of Advanced Computer Science and Applications*, vol. 10, no. 6, pp. 430–435, 2019.
4. A.K.Mittal and D.Bhandari, "A novel approach to implement green wave system and detection of emergency vehicles," *IEEE Conference on Intelligent Transportation Systems*, pp. 1–6, 2016.
5. K.M.Yousef, J.N.Al-Karaki, and A. M. Shatnawi, "Intelligent traffic light flow control system using wireless sensors," *Journal of Information Science and Engineering*, vol. 26, no. 3, pp. 753–768, 2010.
6. R.Sundar, S.Hebbar, and V.Golla, "Implementing intelligent traffic control system for congestion control, ambulance clearance, and stolen vehicle detection," *IEEE Sensors Journal*, vol. 15, no. 2, pp. 1109–1113, 2015.