# Density based Intelligent Traffic Control System using Magnetic Sensor

**Vaibhav Vikram Singh, Ritik Mathur, Akash Khare, Pranav Pandey, Prasoon Kesarwani, Pushpendra Kumar Gupta**

Department of Electronics Engineering, Institute of Engineering and Rural Technology, Prayagraj, India

## Abstract

The use of intelligent traffic control is intended to reduce congestion, decrease the chances of accidents around traffic lights and ensure the free flow of cars at the crossroads. Intelligent traffic control uses various software and wireless sensor networks for better traffic utilization at the crossroads. One of the main aims of intelligent traffic control is to optimize the waiting time in queues and as a consequence reduce the red light running phenomenon. An effective intelligent traffic control required a better data acquisition system to capture the density of the traffic at traffic lights. To better capture the density of the cars at traffic lights, copper coils are used to create a type of metal detector that measures the number of cars on the roads. After knowing the number of the cars (density) on the road, better management of traffic light duration, mainly green light duration can be done. In the presented paper, magnetic sensor, arduino uno, LEDs (Red, Yellow, Green) are used. The intrusive magnetic sensor is used because of its high accuracy, low cost and ease of installation under the roads. As the sensor is installed under the roads it can easily count the number of vehicles passing over a particular section.

**Keywords:** Intelligent Traffic Control System, Magnetic Sensor, Arduino Uno, Inductive Loop Detector, LEDs.

## 1. Introduction

As the global population increases, the number of people on the road also rises, resulting in congestion at crossroads. This problem is especially common in large metropolitan cities, where most economic trade centers are located. One way to address this issue is to increase the number of lanes on the roads. While this is an effective solution, it is also costly. Developed countries may afford these expenses, including the cost of relocating tenants from roadside areas. However, for developing countries, this is a significant challenge due to the high construction costs and the need to provide compensation to displaced tenants.

An alternative method to address road congestion is adopting intelligent traffic control systems. These systems are less expensive than constructing new and wider roads and can effectively mitigate traffic congestion [1].

The main aim of an intelligent traffic control system is to ensure road safety and reduce the number of accidents on the roads. A significant number of accidents occur near traffic lights due to poor traffic light management. Currently, traffic lights are primarily controlled in two ways:

a. Using predefined times for different periods of the day. For example, during rush hours (mainly in the morning when many people are going to work or school), the duration of the green light is longer compared to daytime when there is less traffic.

b. Manually updating, based on observed traffic density. However, this approach is prone to human error.

Road sections with low traffic volumes can use these techniques effectively. However, at high-vehicle density locations, these techniques causes several issues, including improper green-light balancing, excessive fuel consumption and accidents due to the red light running phenomenon. Red light running is a common and extremely risky driving behaviour. Depending on their current speed and distance to the traffic signal, a driver must decide whether to brake or accelerate, when approaching a traffic light that is turning from green to yellow. If the wrong choice is made, the driver will either stop suddenly at the junction or receive a red light running citation.

The proneness to violations depends on two main factors, which influence the decision to stop or keep going at an intersection [2-4]. These factors are:

a. Human factor, such as an increase in the population.

b. Road factor, such as vehicle density, road smoothness and geometric and operational characteristic.

This technology can play an important role in solving these problems. Wireless Sensor Networks [5,6] enable various measurements for traffic monitoring. Sensor nodes provide many strategies to promote energy savings and are also easy to deploy and manage anywhere. Therefore, wireless sensor networks are especially useful for monitoring high-traffic roads. Intelligent transportation systems utilize a range of sensing and connectivity devices to estimate traffic flow, density and speed, enabling the use of this information for decision-making to enhance and manage the flow of traffic [7].

For an intelligent traffic control system, one of the main components is data acquisition system. The more accurately a data acquisition system captures and predicts the data, the more effectively other components and software programs can manage the data and traffic flow. There are mainly two types of sensors, intrusive and non-intrusive. Intrusive sensors (such as inductive loop detectors, pneumatic tubes, piezoelectric sensors and weight-in-motion sensors) are highly accurate and measure pressure or mass flow. These must be pre-installed during the construction of roads and pipelines. Non-intrusive sensors (such as microwave radar, infrared, video, ultrasonic systems and acoustic sensors) use light and sound for measurement. Although the accuracy is not as high as that of intrusive sensors, these sensors do not need to be buried under roads [8-13].

In this paper, some of the key objectives are:

- Develop an intelligent traffic control system to significantly alleviate congestion at intersections, offering a cost-effective alternative to expansive road constructions.
- Prioritize road safety by dynamically adjusting light durations based on real-time traffic density data, effectively minimizing accidents around traffic lights and mitigating red light running incidents.
- Implement advanced traffic management techniques using magnetic sensors to accurately predict traffic density, thus enabling dynamic adjustments to traffic light durations for smoother traffic flow and reduced driver waiting times.
- Highlight the critical role of reliable data acquisition systems in modern traffic management strategies, leveraging wireless sensor networks and intrusive magnetic sensors to ensure efficient traffic monitoring and management.

## 2. Literature Work

There are various researches already done on intelligent traffic system and also practically implemented around the world using different type of sensors, some of the works done are described below:

Duzdar, A. and Kompa, G. [8] introduces a low-cost baseband pulsed microwave radar sensor designed for non-contact measurement applications. The sensor transmits baseband Gaussian pulses and employs a pulse sharpening circuit for radiation. It incorporates two ultra wide band antennas for transmission and reception of picosecond pulses, demonstrating accuracy within 1 cm in range measurements. The paper presents the sensor's performance in time-domain scattering and ranging measurements with metallic targets, highlighting its potential in diverse non-contact measurement scenarios. Additionally, the sensor successfully performed volume gauging of a lossy fluid and calculated the upper limit on the power spectral density of radiated pulses. Overall, the paper demonstrates the sensor's promising applications in non-contact measurement scenarios, offering cost-efficient and effective solutions. Utilizing the information from the document excerpt, the summary encompasses the key points regarding the baseband pulsed radar sensor's functionality, performance in measurements and its potential applications.

Kastrinaki, V. et al. [10] addresses the development of an intelligent traffic monitoring and guidance system integrated within smart cities and IoT. It focuses on automating real-world scenarios with the deployment of sensors and the utilization of graph theory and formal methods. The system's key functionalities include verifying vehicles and persons through a registration system, enabling users to trace their destinations and select appropriate paths and observing traffic flow on roads using cameras. By deploying formal methods using VDM-SL, the system ensures correctness, efficiency and responsiveness, making it well-suited for urban environments and traffic management within smart cities.

Hill, S. E. and Lindly, J. K. [3] conducted research to address the critical issue of red light running, a significant traffic safety concern. This study focused on developing statistical models to predict red light violation frequency (violations/hour) at four-approach intersections. Data collected from 19 intersection approaches across Alabama, Texas, Iowa and California highlighted a total of 1,775 violations observed over 554 hours, indicating an average rate of 3.2 violations/hour. By analyzing fourteen key geometric and traffic operational characteristics for each intersection, the research produced regression equations, including linear, curvilinear and multiple linear models, to forecast red light running frequency. Variables such as average daily traffic, number of approach lanes, speed limit, lanes crossed and distance to neighboring intersections proved instrumental in predicting red light violation occurrences accurately.

Vanajakshi, L. et al. [7] presented intelligent transportation systems which are classified within cyber-physical systems due to the close interaction between physical vehicles and an extensive information infrastructure comprising wired and wireless networks, sensors, processors and software.

The development of intelligent transportation systems is primarily steered by socio-economic and environmental needs. A research report forecasts that the global market for intelligent transportation systems is anticipated to reach US $18.5 billion by 2015, with the United States holding a significant share of almost 40% of the revenue globally. The intelligent transportation system market exhibits promise in the Asia-Pacific and Latin American regions, propelled by swift infrastructure advancements. Among various intelligent transportation systems programs, advanced traffic management commands the highest demand, followed by electronic toll collection systems. This framework underscores the importance and widespread implementation of intelligent transportation systems for efficient and effective transportation systems.

Ackaah, W. et al. [1] focuses on comparing the effectiveness of Variable Speed Limit (VSL) systems and Real-Time Traffic Information sources in providing accurate traffic information for navigation. Through a comprehensive study, it was found that the VSL system generally outperforms the RTTI in terms of quality and consistency. Factors contributing to this superiority include shorter distances between VSL gantries, the primary data source used for the VSL system and differences in congestion thresholds between the systems. The study emphasizes the importance of continuous research and development in Advanced Traveler Information Systems and VSL technology to enhance road safety, traffic flow and overall transportation efficiency.

Elmitiny, N. et al. [4] investigated the implementation and effectiveness of a proposed pavement marking, "Signal Ahead," as a countermeasure against red light running violations at signalized intersections. The study involved field testing at a test intersection with the marking and a control intersection without it, recording red light running behaviors for comparison. Results indicated that the marking significantly reduced red light running rates at the test intersection, suggesting its potential effectiveness in aiding drivers' stop/go decisions during signal changes. The marking design, positioning at the stop sight distance, aimed to assist drivers in making safe decisions, thereby potentially decreasing the risks of red light violations and associated crashes. Additionally, survey data highlighted the importance of media campaigns in promoting awareness of such safety measures among motorists, emphasizing the significance of effective communication strategies in enhancing road safety initiatives.

Zhang, W. et al. [14] address the challenges of urban traffic congestion through the integration of wireless sensor networks and mathematical modeling for traffic flow evaluation and signal optimization. The study emphasizes the significance of real-time traffic flow monitoring and proactive congestion avoidance, where wireless sensor networks play a crucial role in providing high spatial-temporal resolution data for effective traffic surveillance. The paper delves into the complexity of urban traffic congestion as a nonlinear dynamic process and discusses the application of intelligent transportation systems, congestion evaluation model and traffic light control optimization algorithms. By introducing congestion factors and cost functions, the paper evaluates and optimizes signal control to manage traffic efficiently, aiming to reduce congestion and improve overall traffic management. The research also emphasizes the need for quantitative evaluation of traffic congestion with real-time precision and supports integrating traffic surveillance sensor networks with traffic control systems to predict future traffic conditions and avoid congestion. Overall, the study offers insights into innovative approaches for addressing urban traffic congestion through the utilization of wireless sensor networks and mathematical modeling techniques.

Sadhukhan, P. and Gazi, F. [15] presents an innovative IoT-based intelligent traffic congestion control system designed to tackle the increasing issue of traffic congestion at road crossings. It highlights the challenges posed by traffic congestion, emphasizing its negative impacts on fuel consumption, health and economic growth. The proposed system dynamically adjusts signal operation times based on traffic congestion density, offering potential improvements in traffic flow efficiency. The paper discusses related work, challenges, innovations and future directions, showcasing the significance of addressing traffic congestion through IoT-based solutions. Additionally, it acknowledges the support of the School of Mobile Computing and Communication, Jadavpur University, emphasizing the relevance of vehicular ad-hoc networks and advanced traffic monitoring technologies.

Zitouni, R. et al. [16] explores the prototyping of urban traffic-light control in IoT using a combination of technologies and protocols such as wireless sensor networks, UPPAAL model checker software, IEEE802.15.4/6LowPAN packets and MQTT protocol. The study creatively addresses the challenges of traffic flow congestion, adaptive traffic light color changes and prioritizing high-priority vehicles by integrating WSN, cloud platforms and actuator devices. The proposed IoT architecture and protocols are evaluated, with a focus on the impact of messages' size and round-trip delays. The paper also makes a compelling case for the scalability and adaptability of the system to interconnect heterogeneous wireless technologies through the Internet. Through this research, the authors demonstrate a holistic approach to developing a robust and adaptive urban traffic-light control system that integrates various cutting-edge technologies and protocols, offering valuable insights for future work and potential real-world implementation.

Kulkarni, A. P. and Baligar, V. P. [17] focuses on monitoring traffic flow and addressing challenges related to vehicle detection, tracking and counting using computer vision. The need for an automated and efficient road transportation system to alleviate traffic congestion, fuel wastage and environmental pollution is emphasized. The proposed system design involves the integration of Raspberry Pi 3 with a camera module, pre-processing techniques like Histogram Equalization and background subtraction to tackle challenges such as vehicle segmentation in various atmospheric conditions and instructions for remote access. The system's implementation encompasses vehicle detection, tracking and counting, with an emphasis on object detection, background subtraction, vehicle classification and region of interest selection. The paper presents an analysis of the system's performance and potential future enhancements, alongside referencing related research papers and conference proceedings.

Collotta, M. et al. [18] discusses a novel technique for dynamically managing traffic light cycles using wireless sensor networks to reduce queues in road sections and minimize accidents caused by the Red Light Running phenomenon. By gathering real-time information about road congestion and processing it through a central node equipped with a specialized module, the proposed algorithm dynamically adjusts traffic light cycles to optimize queue waiting times and reduce drivers' frustration. The authors emphasize the significance of real-time knowledge of traffic light junction information in alleviating congestion and minimizing accidents, highlighting the potential of wireless sensor networks for intelligent transportation systems. The paper also delves into related literature on road monitoring techniques using wireless sensor networks and red light running and concludes with a performance evaluation of the proposed architecture. This research contributes to the development of innovative solutions for enhancing road safety and traffic management, addressing the growing challenges posed by increasing traffic volumes and congestion in urban areas.

Kafi, M. A. et al. [19] explores the use of wireless sensor networks for intelligent traffic management systems, addressing the increasing vehicular traffic in urban areas. It highlights the advantages of wireless sensor networks, such as cost-effectiveness, flexibility and scalability, over traditional wired methods for traffic management. The application of wireless sensor networks –based intelligent transportation systems aims to enhance safety, reduce travel time and optimize traffic flow through the use of miniature sensors, easy installation and scalable wireless communication. The study also presents various wireless sensor networks architectures and projects for traffic light monitoring, focusing on addressing challenges like reliability, security, interoperability, real-time communication and multimodal sensing. Promising future developments in integrating wireless sensor networks and Vehicular Sensor Networks show potential for comprehensive traffic management, paving the way for further impactful research in this field.

Nellore, K. and Hancke, G. P. [20] delves into the utilization of Programmable Logic Controllers (PLCs) and Supervisory Control and Data Acquisition (SCADA) systems in intelligent transportation systems to enhance traffic flow efficiency. It suggests future research directions, emphasizing the incorporation of information variables like accidents and traffic violations into traffic management systems to aid policymakers in formulating effective traffic rules and policies. The paper reviews various congestion avoidance schemes proposed by researchers, such as circuit and greedy patrol algorithms, VANET-based strategies and traffic model implementations, highlighting their outcomes in terms of traffic efficiency improvement and emission reduction. Furthermore, it discusses the challenges faced in real-time traffic management systems, advocating for the integration of cloud computing and advanced technologies like PLCs and SCADA systems for smoother traffic flow in non-recursive congestion scenarios, outlining a promising path for future research in the field of intelligent transportation systems.

Hilmani, A. et al. [21] outlines an intelligent traffic control system utilizing innovative IoT technologies like WSN, RFID and a mobile application to enhance urban traffic management. The system integrates hybrid RFID and WSN sensors to monitor parking spaces and traffic density in real-time, connecting drivers to this information via an Android mobile application. By implementing efficient algorithms and database management techniques, the system optimizes network longevity, reduces unnecessary data transmission and enhances energy efficiency. The simulation results demonstrate improved network lifetime, energy consumption and packet delivery ratio compared to existing traffic control systems, showcasing the effectiveness and innovation of the proposed system in addressing urban traffic challenges.

Appiah, O. et al. [22] presents a proposal for the use of overhead mounting of ultrasonic sensors to estimate traffic flow and suggests the fusion of mount positions for more accurate results. The paper advocates for the implementation of a limited number of ultrasonic devices, making it relatively cheaper to install and maintain, especially in resource-constrained areas. By utilizing a concept called Occupancy Ratio to report the state of road congestion, the system can effectively detect congestion with minimal computational resources and energy usage. The proposed technique holds promise for developing countries, where road network infrastructure is often inadequate, road traffic regulations are poorly observed and the financial pressure of road expansion contributes to congestion. This research provides insights into a cost-effective and efficient approach to traffic flow estimation, congestion detection and intelligent transport system implementation.

Yogesh, G. K. V. et al. [23] introduces an innovative approach to enhance lane-by-lane detection by modifying existing serially connected inductive loop detectors . By proposing advanced circuitry and signal processing algorithms, the study aims to eliminate trade-offs between operational efficiency and space utilization in transportation systems. The improved loop design not only facilitates accurate vehicle classification but also enables direction detection for enhanced traffic monitoring. Leveraging techniques like random forest and support vector machine for data processing, the research achieves significant accuracy rates in vehicle classification and direction identification, showcasing the potential for cost-effective and efficient deployment of these technologies in real-world scenarios.

Latif, S. et al. [24] focuses on the development of an intelligent traffic monitoring and guidance system utilizing graph theory and formal methods within the context of smart cities and IoT integration. The system is designed to automate real-world scenarios by deploying sensors at various locations like roads, buildings and traffic signals. By creating a graph-based model, the system can efficiently compute shortest paths in terms of time and distance, identify heavy traffic areas and offer alternative routes when necessary. Through the use of Vienna Development Method-Specification Language (VDM-SL), the formal model ensures correctness and accuracy, enhancing the effectiveness and responsiveness of the traffic guidance and monitoring system for urban environments. The effects of delays, nonlinearities, parameter uncertainties for the system is given in [25-27].

Despite the existence of various researches, there is still some scope here, the primary focus of this paper is the development and implementation of an intelligent traffic control system aimed at mitigating congestion and enhancing safety at intersections. The system utilizes magnetic sensors, arduino uno microcontrollers and LEDs to dynamically adjust traffic light durations based on real-time traffic density data. By accurately predicting traffic density through the use of intrusive magnetic sensors installed beneath road surfaces, the system optimizes traffic light timings to reduce congestion, minimize accidents and improve overall traffic flow efficiency. Furthermore, the paper underscores the importance of reliable data acquisition systems, highlighting the integration of wireless sensor networks to support efficient traffic monitoring and management, thereby contributing to the creation of more efficient urban transportation networks. In the model, a centralized traffic monitoring system is implemented using a single arduino and magnetic sensor.

## 3. System Architecture and Requirement

There are two major parts of the project, hardware and software. Hardware part comprises arduino uno, magnetic sensor and the software part comprises programming of arduino which is done in C++ language.

### 3.1. Wireless Sensor Network System Requirement

For better management of the traffic light various methods are adopted which can be used for better management of traffic at the crossroads. For this wireless sensor networks are used for making the intelligent traffic light system. The main function of the wireless sensor network is Data Acquisition, which helps in better management of the traffic light. For data acquisition an inductive loop detector is used, which uses copper coils laid underground. Whenever any car or bike passes over the coil, the inductance across the copper coil changes, due to the change in the value of inductance, flux around the copper coil changes, which changes the Electric field around the coil which is done according to Faraday law. This change in the inductive loop detector is being counted and which is used to count to the number of vehicles present on the road. The arduino is programmed in such a way that it will count the number of times the sensor output changes which equals the number of vehicles and on the basis of number of vehicles, the green light duration is changed.

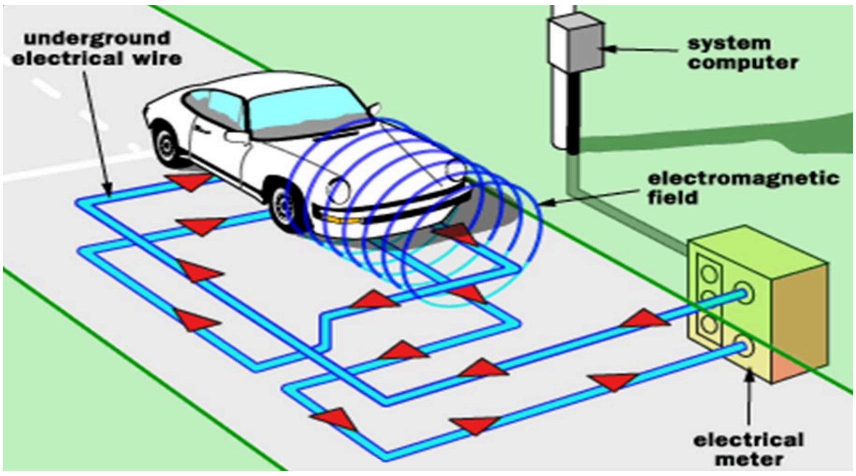


**Fig. 1 Inductive Loop Detector [28]**

### 3.2. System Design

The presented model primarily utilizes a copper coil, arduino uno, capacitor as an inductive loop detector and several LEDs for the traffic lights. Copper coil is being deployed inside the road so whenever the car or bike passes through the coil, the inductance of the loop changes, which changes the frequency of oscillation, that depends upon the inductance and capacitance of the system, as the capacitance is fixed, so change occur in the inductance only. Then the change in the inductance causes changes in the frequency which is being observed. The number of times the frequency or electric field changes is being counted, to know about the density of the cars and bikes on the roads. On the basis of density the duration of green is changed.

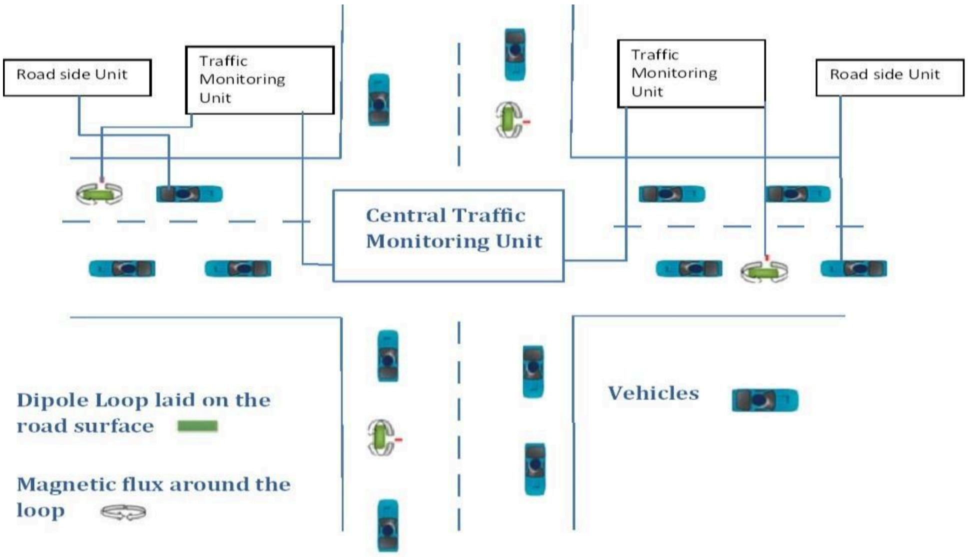


**Fig. 2 System Architecture [29]**

### 3.3. Flowchart

When Arduino is powered on, it reads the sensor output, which is in the form of voltage. This voltage changes as vehicles pass over the magnetic sensor, altering the voltage across the copper coil. Arduino processes this output and counts the number of times the voltage across the copper coil changes, thus determining the number of vehicles. If the vehicle density is at level 3 (high density means  more than 25 cars), the green light duration is set to 60 seconds. For level 2 density (moderate density means 15 to 24 cars), the green light duration is 40 seconds and for level 1 density (low density means 5 to 14 cars), it's set to 20 seconds; otherwise, green light time is set to 10 seconds. After completing one cycle, program restarts.

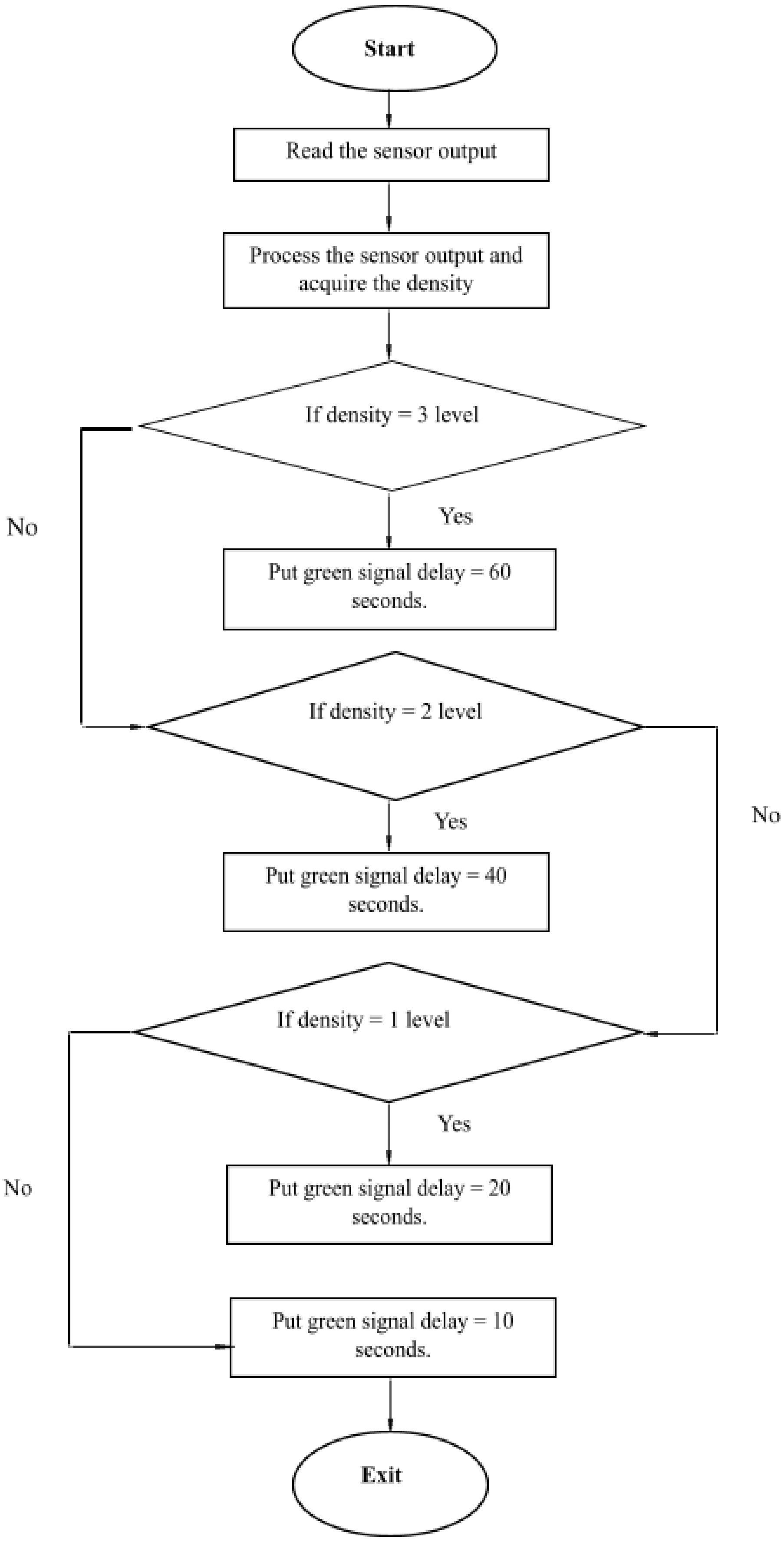


**Fig. 3 Flowchart of Presented Model**

### 3.4 Programming

Arduino is an open-source platform designed for creating electronics projects. It consists of a programmable circuit board and Integrated Development Environment software, which is installed on computer for developing and uploading code to the board. Arduino utilizes an open-source microcontroller and finds application in various electronic projects and equipments. In this scenario, arduino is programmed to adjust the duration of green light based on the detection of specific numbers of vehicles. The flowchart illustrating arduino programming is presented in Fig 3. Initially, the arduino receives input from the sensor, processes the sensor data and then gathers information regarding traffic density.

## 4. Presented Model

The presented model aims to reduce road congestion, thereby minimizing the time people spend on the road. The model worked as, magnetic sensor counting the number of vehicles passing through the lane. The red light for the one side of the traffic is turned on, the magnetic sensor start counting the number of vehicles passing through the sensor, before the green light is turned on it will calculate the number of vehicles on the lane and manipulate the green light time on the basis on the number of vehicles and the same process is continued for the other side of the crossroads.

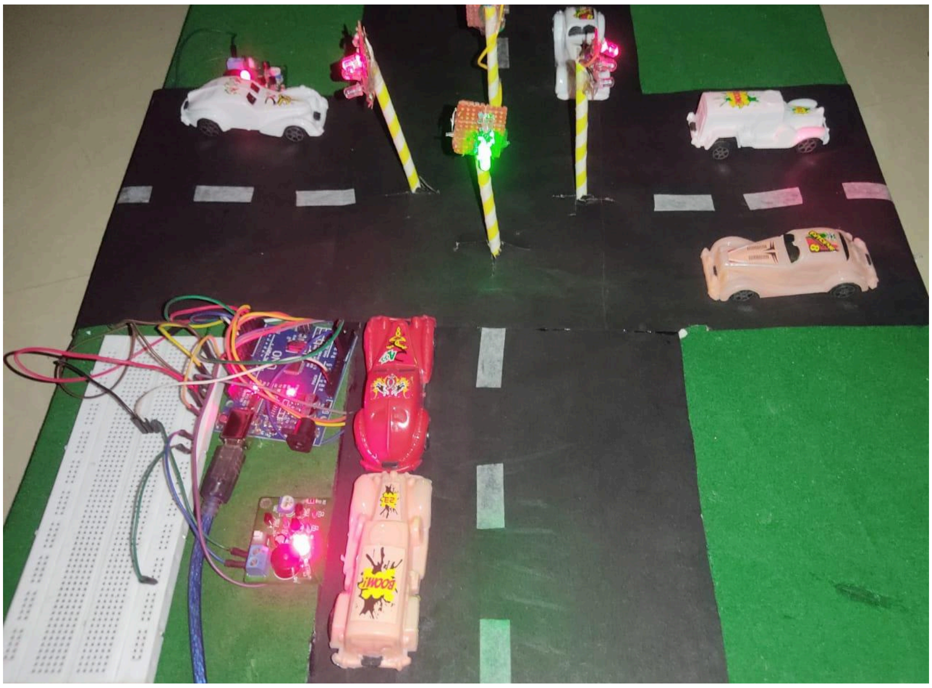

**Fig. 4 Prototype of Presented Model**

## 5. Comparative Study

Comparative study of the presented model and existing model mentioned below:

| Reference Number | Components | Features |
|---|---|---|
| Appiah, O. [24] | HR-SR04 Ultrasonic sensor, USB cable, laptop, arduino uno | Ultrasonic sensor is used as the signal acquisition device. A USB cable connects the uno to the laptop to transmit the state of traffic flow data, laptop is computer server to which traffic data is transmitted for further analysis and processing. Arduino |

| | | |
|---|---|---|
| | | is a microcontroller board used for processing signals captured by ultrasonic sensors. |
| Kulkarni, A. P. [17] | Raspberry Pi 3, raspberry pi camera module, power supply, micro SD card, Wi-Fi USB adaptor | The Raspberry Pi 3 is utilized for computing tasks, while a camera module captures video. Power is supplied via a dedicated source and a micro SD card handles storage requirements. A Wi-Fi USB adaptor enables network connectivity for remote access and data transfer. |
| Yogesh, G. K. V. [23] | Inductive loop detectors, data acquisition system, advanced signal processing unit, band pass filter, capacitor, arbitrary function generator, power supply unit, single board processor | Inductive loop detectors are used for vehicle detection, supported by data acquisition systems and an advanced signal processing unit. Along with band-pass filters, the system extracts lane-specific data. Capacitors facilitate resonant circuits for lane separation, while an arbitrary function generator and power supply unit aid in testing. A single-board processor executes algorithms for vehicle classification and direction determination, employing random forest classifiers and support vector machines. |
| Sadhukhan, P. [15] | Ultrasonic sensor node, Wi-Fi module, microcontroller, serial port, relay module, laptop, traffic signal LED | The ultrasonic sensor gauges vehicle queues, guiding traffic signal adjustments via the microcontroller. Wi-Fi connects traffic monitoring to signal management and relays control to LED signals. Serial ports enable data transfer between the microcontroller and laptop for efficient traffic control. |
| Duzdar, A. [8] | Baseband pulsed microwave radar, step recovery diode (SRD), sampling gate, analog to digital (AD) converter, ultra wide band (UWB) antenna, clock synchronization circuit | The radar sensor enables time-domain measurements and fluid volume gauging. SRD is used for pulse generation and sampling gate capture to capture precise time-domain signals. AD converters digitize signals for processing. UWB antennas handle pulse transmission and reception. The clock synchronization circuit ensures accurate timing for signal sampling. |
| In this work | Magnetic sensor, arduino uno, LEDs (Red, Yellow, Green), | The magnetic sensor detects vehicles by monitoring changes |

| | | |
|---|---|---|
| | capacitor | in the magnetic field. Arduino uno processes this data to adjust traffic light durations. LEDs (Red, Yellow, Green) are used as the visual signals for the traffic lights, with their illumination duration regulated by the arduino uno. Capacitors are utilized in conjunction with the magnetic sensor to stabilize the voltage. A centralized system is achieved using a single arduino. |

## 6. Result and Discussion

Congestion was measured at various instances and times on both sides of the crossroads to derive practical values for the presented model. The congestion level was quantified based on the number of vehicles on each side during these measurements for optimizing green light durations to alleviate congestion. The following table presents data collected from observations of congestion at a crossroads, detailing the number of vehicles on each side and the corresponding green light durations. The "Number of Vehicles" columns indicate the quantity of vehicles observed on both sides during each measurement instance, while the "Green Light Duration" columns specify the duration for which the traffic signals were set to green for each side. These measurements serve to analyze the relationship between congestion levels and the effectiveness of different green light durations in mitigating congestion.

| S. No. | Number of Vehicles | | Green Light Duration | |
|---|---|---|---|---|
| | Side 1 | Side 2 | Side 1 | Side 2 |
| 1. | 25 | 9 | 60 sec. | 20 sec. |
| 2. | 22 | 13 | 40 sec. | 20 sec. |
| 3. | 4 | 27 | 10 sec. | 60 sec. |
| 4. | 11 | 2 | 20 sec. | 10 sec. |

## 7. Conclusion

The implementation of an intelligent traffic control system, utilizing a combination of software and hardware components such as intrusive magnetic sensors, arduino uno and LEDs, holds significant promise for reducing congestion, enhancing road safety and optimizing traffic flow at intersections. By accurately capturing traffic density through magnetic sensors installed beneath road surfaces, this system enables dynamic adjustment of traffic light durations, thereby minimizing waiting times and mitigating the risk of accidents caused by red light running. This paper emphasizes the significance of effective data acquisition systems in modern traffic management strategies. It also underscores the potential of intelligent technologies to address urban mobility challenges and promote more efficient and safer transportation networks.

## 8. Future Scope

Incorporating advanced communication systems like 5G and Vehicle-to-Infrastructure (V2I) technology will enable real-time data transmission, facilitating direct communication between vehicles and traffic control systems. This enhances traffic management, reducing congestion. Implementing machine learning algorithms and advanced analytics allows for dynamic adjustment of traffic light durations, enhancing management efficiency. Extending the system to integrate with smart city initiatives, along with coordinating traffic lights across intersections, optimizes flow in dense areas. Future research can focus on energy efficiency through integrating renewable energy sources and monitoring environmental impacts with air quality and noise pollution sensors. Developing mobile apps for user feedback, as well as prioritizing emergency vehicles, improves system effectiveness and response times.

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