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Intelligent Traffic Light Control System Using RFID And Infrared Technology

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Abstract:
Traffic congestion is a major challenge in rapidly growing urban areas, particularly in developing countries like Nigeria. This study proposes an Intelligent Traffic Light Control System (ITLCS) that integrates infrared sensors and RFID technology to improve intersection management. The system detects real-time traffic density and dynamically adjusts signal timings, while RFID enables priority for emergency vehicles. Experimental results show significant reductions in vehicle delay and queue length, alongside increased traffic throughput. Additionally, emergency response time is improved through immediate signal preemption. The proposed system offers a cost-effective, adaptive, and efficient solution for enhancing urban traffic flow and overall road safety.

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I. Introduction

Urban traffic congestion has become a critical challenge in rapidly growing cities. Increasing population, urbanization, and vehicle ownership place significant pressure on transportation infrastructure, resulting in longer travel times, higher fuel consumption, and increased greenhouse gas emissions. Efficient traffic management is therefore essential for sustainable urban mobility (United Nations, 2023). In Nigeria, road transportation remains the dominant mode of passenger and freight movement. Heavy dependence on road networks combined with rapid urban growth has intensified congestion, particularly at major intersections in cities such as Lagos, Abuja, and Port Harcourt (Aderamo & Atomode, 2023). These intersections often become bottlenecks because traffic from multiple directions competes for limited road capacity. Conventional traffic management approaches including flyovers, ring roads, traffic wardens, and fixed-time traffic signals provide basic traffic regulation but fail to address the dynamic nature of urban traffic flows. Fixed-time signal systems operate on predetermined schedules and cannot adapt to real-time traffic conditions, frequently causing unnecessary delays (Papageorgiou et al., 2022). Recent developments in Intelligent Transportation Systems (ITS) offer more effective solutions. Intelligent Traffic Light Control Systems (ITLCS) use sensors, communication technologies, and computational algorithms to monitor traffic conditions and dynamically adjust signal timings. These systems allocate green-light durations based on real-time traffic demand, thereby improving intersection efficiency and reducing congestion (Zhang et al., 2023). Advances in artificial intelligence and machine learning have further enhanced intelligent traffic control. Reinforcement learning algorithms can learn optimal signal timing strategies from real-time traffic environments, improving throughput and reducing queue lengths (Wei et al., 2022). Similarly, IoT-enabled traffic monitoring systems support continuous data collection and adaptive signal control (Khan et al., 2024). Despite these developments, many developing countries still rely on conventional traffic signal systems with limited sensing and adaptive capabilities. This study therefore proposes a cost-effective intelligent traffic light control system integrating infrared sensors for vehicle detection and RFID technology for emergency vehicle prioritization.

II. Literature Review

Traffic Congestion and Urban Transportation Challenges

Urban transportation systems across the world are experiencing increasing pressure due to rapid urbanization, population growth, and rising vehicle ownership. As cities expand, the demand placed on transportation infrastructure continues to increase, leading to congestion, longer travel times, increased fuel consumption, and environmental pollution. Efficient traffic management has therefore become an essential component of sustainable urban mobility (United Nations, 2023)

Urban traffic congestion is a major challenge in cities where vehicle growth exceeds infrastructure expansion. Intersections often become critical bottlenecks because multiple traffic streams compete for limited right-of-way, leading to delays, long queues, and increased fuel consumption (Archive Market Research, 2024).

In developing countries such as Nigeria, the problem is amplified by heavy reliance on road transportation, limited infrastructure investment, and inefficient traffic signal control systems (Aderamo & Atomode, 2023). Persistent congestion contributes to longer travel times, environmental pollution, and economic losses (Xu, 2025; Zahwa et al., 2024).

Traditional traffic signal control systems rely on fixed-time signal cycles designed using historical traffic data. Although such systems are simple and widely deployed, they lack the ability to respond dynamically to real-time traffic fluctuations. As a result, fixed-time systems frequently cause unnecessary delays during periods of low traffic demand while failing to adequately manage congestion during peak traffic periods (Papageorgiou et al., 2022; Michailidis et al., 2025).

Recent advances in Intelligent Transportation Systems (ITS) have introduced adaptive traffic signal control mechanisms capable of dynamically adjusting signal timing based on traffic conditions. These intelligent systems integrate sensors, communication technologies, and computational algorithms to monitor traffic flow and optimize signal operations (Khan et al., 2024). The objective of such systems is to reduce congestion, improve intersection efficiency, and enhance road safety.

This chapter reviews existing literature related to traffic congestion challenges, intelligent traffic signal control systems, sensing technologies used for traffic monitoring, artificial intelligence approaches in traffic management, and emergency vehicle prioritization systems. The review also identifies research gaps that motivate the development of the proposed Intelligent Traffic Light Control System (ITLCS).

Evolution of Traffic Signal Control Systems

Traffic signal control systems have evolved significantly over the past decades, transitioning from manual traffic management to automated and intelligent traffic control technologies. Early traffic management relied on manual operation by traffic officers who controlled signal timing based on visual observation of traffic conditions. Although this approach allowed some level of flexibility, it was labor-intensive and inconsistent.

Subsequently, automated fixed-time signal controllers were introduced. These systems operate using predetermined signal cycles designed using historical traffic data. While fixed-time controllers are easy to implement and require minimal computational resources, they cannot respond effectively to real-time traffic variations (Papageorgiou et al., 2022).

To address these limitations, actuated traffic signal systems were developed. Actuated systems use vehicle detectors to adjust signal phases based on traffic presence. Although these systems improve responsiveness compared to fixed-time controllers, their decision rules remain predefined and do not fully optimize traffic flow under complex traffic conditions.

More recently, adaptive traffic signal control systems have been developed. These systems continuously analyze traffic conditions and dynamically adjust signal timing to optimize traffic flow across intersections. Adaptive traffic control technologies such as SCOOT and SCATS are widely used in several developed countries to improve urban traffic management. However, these systems require extensive sensing infrastructure, reliable communication networks, and powerful computational resources, making them difficult to deploy in resource-constrained environments.

Intelligent Traffic Light Control Systems (ITLCS)

Table no 1 Shows Intelligent Traffic Light Control Systems that improve traffic management by dynamically adjusting signal operations according to real-time traffic conditions. Unlike conventional controllers that rely on fixed schedules, ITLCS modify signal parameters such as phase duration and cycle length to optimize traffic flow. The primary objective of ITLCS is to reduce vehicle delay, queue length, fuel consumption, and emissions. Adaptive signal systems such as SCOOT and SCATS use sensor data to optimize signal timing across road networks.

However, centralized adaptive systems require extensive sensing infrastructure, reliable communication networks, and significant computational resources. These requirements limit their deployment in resource-constrained environments. As a result, researchers have explored decentralized and cost-effective alternatives based on embedded systems and lightweight algorithms. These approaches provide adaptive traffic control with lower complexity and cost, making them suitable for developing regions.

Table no 1: Shows Intelligent Traffic Light Control Systems

Technology	Primary Function	Advantages	Limitations
Inductive Loop	Vehicle presence detection	Reliable and mature technology	Pavement installation required
Infrared Sensors	Vehicle presence detection	Low cost and easy integration	Sensitive to environmental conditions
Video Detection	Vehicle counting and classification	Rich traffic data	High computational requirements
Radar Sensors	Vehicle speed and presence detection	Works in adverse weather	Higher equipment cost
RFID	Vehicle identification	Enables emergency vehicle priority	Requires tagged vehicles

Traffic Sensing and Communication Technologies

Traffic detection technologies provide the real-time data necessary for adaptive signal control. Several sensing methods are widely used in intelligent traffic management systems. Inductive loop detectors are highly reliable but require installation within road pavement, increasing maintenance costs. Infrared sensors provide a low-cost alternative and are easily integrated with microcontroller-based systems. Radar and video detection technologies offer advanced capabilities such as vehicle classification and speed measurement but require higher computational resources.

Radio Frequency Identification (RFID) enables vehicle identification and is particularly useful for emergency vehicle prioritization at signalized intersections. Increasingly, hybrid sensing architectures combine multiple technologies including infrared sensors, cameras, radar, and wireless communication modules to improve detection accuracy and system reliability. IoT-based frameworks further enhance these systems by enabling real-time communication between vehicles and traffic infrastructure as shown in Table no 2.

Table no 2: Traffic Detection and Sensing Technologies

Technology	Function	Advantages	Limitations
Inductive Loop Detectors	Detect vehicle presence using electromagnetic induction	Highly reliable and widely deployed	Requires pavement installation
Infrared Sensors	Detect vehicles using infrared beams	Low cost and easy integration	Sensitive to environmental conditions
Radar Sensors	Measure vehicle speed and presence	Effective under adverse weather conditions	Higher equipment cost
Video Detection Systems	Provide vehicle classification and traffic monitoring	Rich traffic information	High computational demand
RFID Systems	Identify tagged vehicles approaching intersections	Enables emergency vehicle prioritization	Requires equipped vehicles

Artificial Intelligence in Traffic Signal Control

Artificial intelligence has significantly improved modern traffic signal control systems. AI-based approaches analyze complex traffic patterns and dynamically optimize signal operations.

Reinforcement learning (RL) is widely used in adaptive traffic control. RL-based controllers learn optimal signal timing policies through interaction with traffic environments while evaluating performance indicators such as delay and queue length.

Deep reinforcement learning (DRL) extends this approach by combining RL with deep neural networks, enabling traffic controllers to process large volumes of traffic data. Algorithms such as Deep Q-Networks (DQN) and Deep Deterministic Policy Gradient (DDPG) have demonstrated strong performance in multi-intersection traffic optimization (Liu et al., 2023). Computer vision technologies further enhance AI-driven traffic control by using convolutional neural networks (CNNs) to detect vehicles and pedestrians from camera feeds (Ayoubi et al., 2024).

Despite these advantages, AI-based traffic control systems often require substantial computational resources and advanced communication infrastructure, which may limit their deployment in developing regions.

Emergency Vehicle Preemption Systems

Emergency Vehicle Preemption (EVP) systems provide priority passage for emergency vehicles by temporarily overriding normal traffic signal operation. Several detection technologies have been used for EVP, including optical sensors, acoustic detectors, GPS tracking, and RFID. Optical and acoustic systems can be affected by poor visibility or background noise, while RFID-based systems provide more reliable identification. In RFID-based EVP systems, emergency vehicles carry RFID tags while readers installed at intersections detect approaching vehicles and automatically trigger green signals. This mechanism reduces emergency response times and improves road safety.

Embedded Systems and Microcontroller-Based Implementations

Embedded systems provide a practical platform for cost-effective intelligent traffic control. Microcontrollers integrate processing units, memory, and input/output interfaces in compact and energy-efficient devices.

The PIC16F87x microcontroller family is widely used in embedded control applications due to its reliability and integrated hardware features, including timers, analog-to-digital converters, and multiple I/O ports. Microcontroller-based traffic control systems integrating infrared sensors and RFID modules have demonstrated improved intersection performance in resource-constrained environments. These systems dynamically allocate green time based on traffic demand while maintaining low implementation cost.

Research Gaps

Despite significant progress has been made in intelligent traffic control, several challenges remain. Many advanced systems rely on expensive infrastructure such as high-resolution cameras, large sensor networks, and powerful computing platforms (Michailidis et al., 2025).

Low-cost alternatives often provide only limited functionality and lack adaptive signal timing or emergency vehicle prioritization. Furthermore, many studies focus primarily on simulation rather than real-world implementation.

Another limitation is the lack of solutions specifically designed for developing countries, where infrastructure limitations, heterogeneous traffic conditions, and power instability affect system performance.

This study addresses these challenges by developing a cost-effective intelligent traffic light control system based on a PIC microcontroller. The system integrates infrared vehicle detection, RFID-based emergency vehicle prioritization, and adaptive signal timing within a unified embedded architecture suitable for developing urban environments.

III. Methodology

Research Design

This research adopts an experimental and analytical design approach for the development and evaluation of an Intelligent Traffic Light Control System (ITLCS) that integrates infrared vehicle detection sensors and RFID-based emergency vehicle identification. The objective is to dynamically regulate traffic signals based on real-time traffic conditions while providing priority access to emergency vehicles. The proposed system combines hardware-based traffic sensing, algorithmic signal control, and traffic flow modeling. Infrared sensors detect the presence of vehicles approaching the intersection and estimate traffic density, while RFID technology identifies emergency vehicles and triggers signal priority. The system is evaluated under controlled experimental scenarios and compared with a conventional fixed-time traffic signal system. The performance of the proposed system is assessed using widely accepted traffic engineering performance metrics:

Average vehicle delay
Queue length
Traffic throughput
Emergency vehicle response time
Intersection efficiency

These metrics are commonly used in intelligent transportation system (ITS) research to evaluate traffic signal optimization strategies.

System Architecture

The Intelligent Traffic Light Control System consists of four interconnected subsystems:

Traffic Detection Subsystem

Infrared sensors are installed at each approach of the intersection to detect the presence of vehicles. The sensors continuously monitor traffic flow and transmit signals to the control unit indicating vehicle density.

Emergency Vehicle Identification Subsystem

RFID technology is used to detect emergency vehicles approaching the intersection. Each emergency vehicle carries an RFID tag that transmits identification information when within the detection range of the RFID reader.

Adaptive Control Unit

The adaptive signal control algorithm is implemented using a microcontroller such as AT89C52 or PIC16F873A. The controller processes sensor data and dynamically determines signal timing based on traffic density.

Signal Actuation Module

The signal actuation module controls LED-based traffic lights representing red, yellow, and green phases for each lane.

Traffic Density Estimation

Traffic density is an important parameter for adaptive traffic control systems. It represents the level of congestion at an intersection approach. This equation provides a normalized measure of congestion. The density value typically ranges between 0 and 1. This normalized metric allows the control system to proportionally allocate signal time according to traffic demand. Traffic density is estimated using the following model:

$$D = \frac{N}{C}$$

D = traffic density, N = detected vehicles, C = lane capacity

- **D ≈ 0** → low traffic conditions
- **D ≈ 1** → heavy congestion

Adaptive Green Time Allocation

To optimize traffic flow, the green signal duration is dynamically adjusted based on the measured traffic density. This adaptive model ensures that lanes with higher traffic density receive longer green signal durations. When traffic density increases, the green signal time increases proportionally, reducing congestion and improving intersection efficiency

$$Tg = Tmin + (D \times (Tmax - Tmin))$$

Where: **Tg** = allocated green signal time, **Tmin** = minimum green signal duration, **Tmax** = maximum green signal duration and **D** = traffic density.

Vehicle Arrival Modelling

Vehicle arrival patterns at intersections are often random. These arrivals can be modelled using the **Poisson distribution**, which is commonly applied in traffic flow theory. The Poisson model describes the probability distribution of vehicle arrivals and helps estimate traffic demand at the intersection. It is particularly useful in evaluating signal timing strategies under stochastic traffic conditions

$$P(k) = \frac{\lambda^{\kappa} e^{-\lambda}}{k!}$$

Where: **P(k)** = probability of k vehicle arrivals during a time interval and **λ** = average vehicle arrival rate

Queue Length Model

Queue formation occurs when the rate of vehicle arrival exceeds the rate at which vehicles are served by the traffic signal. If the arrival rate exceeds the service rate, vehicles accumulate and queues grow. Adaptive signal timing aims to increase the effective service rate to prevent excessive queue formation. The queue length is estimated using

$$Q(t) = (\lambda - \mu)t$$

Where λ is arrival rate and μ is service rate and **Q(t)** = queue length at time t

Average Waiting Time

$$W = \frac{(\Sigma\, Ti)}{n}$$

Webster Delay Model

Webster's model estimates delay based on signal timing and traffic demand. Lower delay values indicate more efficient signal control. Vehicle delay at signalized intersections can be estimated using Webster's delay formula

$$d = \frac{C(1 - g/C)2}{2(1 - X)}$$

Where: **d** = average vehicle delay, **C** = signal cycle length, **g** = effective green time and **X** = degree of saturation

Traffic Throughput Model

Traffic throughput measures the efficiency of the intersection in processing vehicles. Higher throughput indicates improved intersection performance and more efficient signal control. Throughput measures vehicles processed per unit time.

$$Th = \frac{Nv}{T}$$

Where: **Th** = traffic throughput, **Nv** = number of vehicles passing the intersection and **T** = observation time

Emergency Vehicle Priority Mechanism

Emergency vehicles are equipped with RFID tags that transmit identification signals. When detected by the RFID reader, the control unit immediately overrides the normal signal cycle and assigns a green signal to the emergency vehicle lane. The signal remains green until the vehicle clears the intersection. This mechanism significantly reduces emergency vehicle delay and improves response times.

IV. Result

Experimental Setup

The proposed Intelligent Traffic Light Control System (ITLCS) was evaluated using a prototype model representing a four-way road intersection. Infrared (IR) sensors were installed on each lane to detect the presence and density of vehicles approaching the intersection. In addition, an RFID reader was positioned upstream of the intersection to enable the identification and prioritization of emergency vehicles. To assess the performance of the system under varying traffic conditions, experiments were conducted using three different traffic scenarios: low traffic density, medium traffic density, and high traffic density. These scenarios were designed to simulate realistic traffic flow patterns and to evaluate the adaptability of the proposed system. The performance of the proposed system was subsequently compared with that of a conventional fixed-time traffic signal system. This comparative evaluation enabled the assessment of improvements in traffic management efficiency achieved by the intelligent control approach.

Average Vehicle Delay

Table no 3 presents a comparison of the average vehicle delay observed under the conventional traffic control system and the proposed adaptive traffic management system. The results indicate that the proposed system consistently reduces vehicle waiting time across all evaluated traffic scenarios. Furthermore, the findings show that the magnitude of delay reduction becomes more pronounced as traffic density increases. This trend demonstrates the effectiveness of the adaptive signal timing mechanism in dynamically responding to varying traffic conditions. By adjusting signal phases according to real-time traffic flow, the proposed system is able to manage congestion more efficiently, particularly during periods of high traffic demand.

Table no 3: Comparison of Average Vehicle Delay

Traffic Density	Fixed-Time Delay (s)	Proposed System Delay (s)	Reduction
Low	25	18	28%
Medium	45	30	33%
High	70	42	40%

Queue Length Reduction

The results in Table no 4 indicate that the proposed system significantly reduces queue formation at signalized intersections. Queue length refers to the number of vehicles waiting at an intersection during a red signal phase. The observed reduction in queue length occurs because the adaptive signal timing mechanism dynamically allocates longer green phases to lanes experiencing higher levels of congestion. By prioritizing heavily congested approaches, the system improves traffic flow efficiency and minimizes vehicle accumulation across varying traffic conditions.

Table no no 4: Comparison of Queue Length

Traffic Scenario	Queue Length (Fixed)	Queue Length (Proposed)
Low Traffic	8 vehicles	5 vehicles
Medium Traffic	15 vehicles	9 vehicles
High Traffic	25 vehicles	14 vehicles

Throughput Comparison

Traffic throughput increases significantly under the proposed system due to the efficiency of the adaptive signal controller. The controller minimizes idle signal time and dynamically adjusts signal phases to improve overall traffic flow efficiency. Traffic throughput refers to the number of vehicles that successfully pass through an intersection within a specified period. As presented in Table no 5 the proposed system substantially increases the number of vehicles processed at the intersection. This improvement can be attributed to the adaptive signal timing mechanism, which reduces unnecessary signal delays and optimizes the allocation of green time according to real-time traffic conditions, thereby enhancing the overall capacity and operational efficiency of the intersection.

Table no 5: Traffic Throughput Comparison

Scenario	Vehicles Passed (Fixed)	Vehicles Passed (Proposed)
Low Traffic	120	150
Medium Traffic	210	280
High Traffic	300	420

Emergency Vehicle Priority

The results in Table no 6 indicate that RFID-based detection enables the immediate prioritization of emergency vehicles at traffic intersections, thereby significantly reducing intersection crossing time. This reduction is particularly important for emergency response operations, where even small delays can adversely affect rescue outcomes and public safety. By allowing rapid identification and prioritization of approaching emergency vehicles, the system ensures that traffic signals adjust accordingly to provide a clear passage. This capability is especially critical for emergency services such as ambulances and fire trucks, where minimizing response time is essential for saving lives and mitigating damage.

Table no 6: Emergency Vehicle Priority Performance

Scenario	Conventional System	RFID-Based System
Emergency vehicle arrives at red	Wait full cycle	Immediate green
Crossing time	75 seconds	20 seconds
Improvement	-	≈73% faster

Overall Performance Analysis

The overall performance analysis indicates that the proposed Intelligent Traffic Light Control System (ITLCS) significantly enhances the operational efficiency of signalized intersections. The experimental evaluation demonstrates notable improvements across several critical traffic performance indicators when compared with conventional fixed-time traffic signal systems.

First, the proposed system effectively reduces vehicle delay by dynamically adjusting signal timing based on real-time traffic conditions. Unlike traditional fixed-time systems that operate on predetermined schedules, the adaptive mechanism of the ITLCS allows traffic signals to respond to fluctuations in vehicle flow, thereby minimizing unnecessary waiting times at intersections.

Second, the system contributes to a substantial reduction in queue length. Through continuous monitoring of traffic density on each approach, the system allocates green signal durations more efficiently, preventing excessive vehicle accumulation on congested lanes and maintaining smoother traffic movement across the intersection. In addition, the results reveal a significant increase in traffic throughput. By optimizing signal phase allocation and responding intelligently to varying traffic demands, the proposed system allows a greater number of vehicles to pass through the intersection within a given time interval, thereby improving overall intersection capacity.

Furthermore, the system improves emergency vehicle response time by incorporating priority-based traffic signal control. This mechanism enables the system to temporarily adjust signal phases to create a clear path for emergency vehicles, reducing delays and supporting faster response to critical situations.

Overall, the experimental findings confirm that the proposed Intelligent Traffic Light Control System provides a more adaptive, responsive, and efficient traffic management approach compared to conventional fixed-time traffic signal systems. The integration of real-time traffic monitoring and intelligent decision-making mechanisms significantly enhances intersection performance and contributes to improved urban traffic flow

V. Discussion

The findings of this study indicate that the proposed Intelligent Traffic Light Control System (ITLCS) significantly enhances the operational efficiency of signalized intersections. The experimental results demonstrate that dynamically adjusting signal timings according to real-time traffic density leads to notable improvements in traffic flow. Unlike conventional fixed-time traffic signal systems, which operate on predetermined schedules regardless of traffic conditions, the proposed system adapts to variations in traffic demand. This adaptability contributes to a measurable reduction in vehicle delay, a decrease in queue lengths, and an overall increase in intersection throughput.

The reduction in vehicle delay observed in the experiments suggests that adaptive signal control can more effectively allocate green time to heavily congested approaches. By prioritizing lanes with higher traffic density, the system prevents prolonged waiting times and improves the movement of vehicles through the intersection. Similarly, the observed reduction in queue buildup indicates that dynamic signal adjustments help distribute traffic more evenly across the intersection, preventing excessive congestion on specific approaches.

Another important outcome of the study is the improved response time for emergency vehicles. The integration of Radio Frequency Identification (RFID) technology enables the system to detect approaching emergency vehicles and automatically modify signal phases to grant them priority passage. This capability ensures that emergency vehicles can traverse intersections with minimal delay, which is critical for time-sensitive services such as ambulance, fire, and law enforcement operations. In addition to improving emergency response efficiency, this mechanism also contributes to enhanced road safety by reducing the likelihood of accidents that may occur when emergency vehicles attempt to navigate congested intersections.

Overall, the results suggest that the proposed system provides a practical and scalable approach for intelligent traffic management in urban environments. The combination of adaptive signal control and RFID-based emergency vehicle prioritization demonstrates the potential of intelligent transportation technologies to improve traffic efficiency, reduce congestion, and enhance public safety. These findings support the adoption of intelligent traffic control systems as a viable strategy for addressing increasing traffic demands in modern cities.

VI. Conclusion

This study presented the design, implementation, and evaluation of an Intelligent Traffic Light Control System (ITLCS) that integrates infrared sensing and RFID technology to improve traffic management at signalized intersections. The proposed system addresses key limitations of conventional fixed-time traffic signal systems by introducing adaptive signal control based on real-time traffic conditions and priority handling for emergency vehicles.

The experimental results demonstrate that the system significantly enhances intersection performance across multiple traffic scenarios. Specifically, the adaptive control mechanism effectively reduces average vehicle delay, minimizes queue length, and increases traffic throughput. These improvements become more pronounced under higher traffic densities, highlighting the system's ability to dynamically respond to congestion and optimize traffic flow.

In addition, the incorporation of RFID-based emergency vehicle prioritization provides a critical advantage in time-sensitive situations. By enabling immediate signal adjustment upon detection of emergency vehicles, the system substantially reduces response time and improves operational efficiency for emergency services. This feature contributes not only to improved traffic management but also to enhanced public safety outcomes.

Furthermore, the use of a microcontroller-based embedded architecture ensures that the proposed system remains cost-effective, scalable, and suitable for deployment in resource-constrained environments such as developing urban regions. Unlike complex AI-driven or infrastructure-intensive systems, the proposed approach balances performance and practicality, making it a viable solution for real-world implementation.

Overall, the findings confirm that integrating real-time traffic sensing with adaptive control logic significantly improves the efficiency, responsiveness, and reliability of urban traffic systems. The proposed ITLCS offers a practical and effective strategy for mitigating congestion, enhancing intersection performance, and supporting emergency response operations.

Future research may focus on extending the system through integration with Internet of Things (IoT) platforms, incorporating machine learning algorithms for predictive traffic control, and conducting large-scale field deployments to validate performance under real-world traffic conditions.

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