

# Adaptive Traffic Lights Control Using Iot And Image Processing

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**Abstract-** *Urban traffic congestion has become one of the major issues in modern cities. As city populations grow and vehicle usage increases, existing road systems struggle to manage the traffic load effectively. This results in long delays, energy wastage, increased pollution, and decreased mobility. Traditional traffic control methods rely on fixed-timing signals that follow preset schedules without considering real-time traffic density. This leads to significant inefficiencies and commuter frustration.*

*To tackle this issue, we propose an intelligent traffic signal control system that dynamically adjusts signal durations based on current traffic conditions. This system integrates Internet of Things (IoT) devices with image processing techniques. Specifically, Haar Cascade classifiers are used to detect vehicles and measure traffic density efficiently.*

*By adapting signal timings according to actual traffic flow at intersections, the system ensures smoother vehicle movement and minimizes unnecessary delays. The use of decentralized, IoT-based microcontrollers enhances the system's flexibility and reduces reliance on central servers, making it more resilient in practical deployments. Simulated results demonstrate notable improvements in reducing traffic delays, optimizing resource use, and enhancing travel experiences. This adaptive approach paves the way for smarter cities, contributing to reduced environmental impact and improved urban quality of life.*

**Keywords-** Urban traffic congestion, Adaptive Traffic Control, IoT, Image Processing, Haar Cascade Classifier, Vehicle Detection, Traffic Density, Smart Cities, Traffic Signal Optimization.

## I. INTRODUCTION

With cities rapidly expanding and vehicle ownership increasing at an unprecedented rate, urban road networks are under constant pressure. Roads originally designed for moderate traffic volumes are now overwhelmed, leading to significant traffic jams, wasted time and fuel, and increased

environmental degradation. Traditional traffic management systems, especially those using fixed-time signals, are inadequate in handling today's unpredictable traffic patterns.

To address this challenge, a smarter and more flexible traffic control approach is essential—one that incorporates modern technologies to better manage urban mobility. The evolution of IoT, artificial intelligence, and image processing provides new possibilities for developing intelligent traffic systems that respond dynamically to real-world conditions.

This paper introduces a smart traffic light control system that uses real-time image analysis to manage traffic signals adaptively. It processes video feeds to evaluate vehicle density at intersections and adjusts signal timings accordingly to ensure smoother traffic flow. The solution is designed to be cost-efficient, simple to implement, and scalable—ideal for cities with infrastructure constraints.

At the core of the system is the use of Haar Cascade classifiers for detecting vehicles. This method offers low computational overhead, enabling real-time processing on local edge devices without relying on cloud servers. Additionally, by using IoT-enabled microcontrollers, decision-making is distributed across intersections, enhancing system flexibility and reducing the risk associated with centralized control failures.

Besides reducing traffic congestion, the proposed method also offers environmental and economic benefits. Shorter wait times lead to lower fuel consumption and emissions, which is particularly crucial in developing areas where pollution levels are high due to inefficient transportation systems. Furthermore, improved traffic flow contributes to economic growth by minimizing delays and facilitating the timely movement of goods and people.

Overall, the proposed adaptive system supports the vision of smart cities—where digital technologies play a critical role in enhancing urban living standards. By moving away from rigid schedules toward responsive, real-time

control, this solution promotes better mobility, lower congestion, and a more sustainable urban environment.

## II. LITERATURE SURVEY

Doing a proper literature survey is one of the most important early steps in any software development project. Before starting development, it's essential for us to consider key factors like how much time the project might take, the overall budget, and the available technical resources. Once those basics are clear, the next decision usually comes down to picking the right operating system and programming language based on what best suits the project's goals.

In the context of this project an adaptive traffic signal we explored a range of studies and papers to better understand the current landscape of technologies and their practical applications.

[1] **Real-Time Traffic Light Optimization Using AI and IoT by Aniket Phand et al. (2022)**, is an IoT sensor-based and artificial intelligence smart traffic management system to control real-time traffic using artificial intelligence-based control. The system is proposed to collect real-time traffic information from sensors and filter it with AI algorithms to dynamically optimize signal timing in real-time. It will minimize waiting time for vehicles and fuel consumption and increase road efficiency. This approach differs from conventional systems since it prevents static timers and adjusts according to real circumstances. The authors focus on low-cost hardware components and simplicity of implementation to integrate with smart cities. The solution provided here provides improved traffic movement and minimal human dependency for signal control.

[2] **An Intelligent IoT-Based Traffic Light Management System by Shima Damadam et al. (2022)**, suggests a fuzzy logic and Internet of Things-based intelligent traffic light control system. It manages traffic light cycles based on real-time vehicle numbers with ultrasonic sensors and surveillance cameras. The architecture is a centralized controller that takes sensor data as input and calculates the green signal duration based on fuzzy inference rules. This method improves traffic flow in rush hours and adapts itself dynamically to emergency vehicle presence. Energy efficiency and less emission are listed as secondary advantages in the article. Simulation outcomes validated the suggested approach as better than other conventional time-of-day models.

[3] **Smart Traffic Light Control System Using Image Processing by Asha S.M. et al. (2023)**, suggests an image processing-based traffic control system to identify vehicle

number and queue length at intersections. The system uses OpenCV and camera feeds to recognize congestion levels in each lane, upon which it decides the green light allocation. In contrast to sensor-based models, the image processing method saves maintenance costs and offers visual monitoring. Authors trained their detection model to identify vehicles under changing climatic and lighting conditions. Their findings provided better throughput and reduced mean wait time. The system is most appropriate in the third world where it is more concerned with effectiveness than with expenditure.

[4] **Adaptive Traffic Control Using Machine Learning Algorithms by P. Gowri et al. (2023)**, describes a machine learning framework with algorithms such as Decision Trees and K-Nearest Neighbours for executing dynamic signal control. The system learns patterns from past traffic data and real-time data to infer optimal possible signal durations depending on varying traffic densities. It adjusts its logic based on the fluctuating traffic and adapts over a period of time. The authors highlight scalability and integration capacity with city-size traffic networks. Experimental testing confirms enhanced vehicle throughput and reduced idle time for the signal. The method is better than fixed-time signal systems in high-traffic conditions by real-time learning and adaptation.

## III. METHODOLOGY

The methodology of the Smart Traffic Light Control System based on Image Processing and IoT is a logical, real-time system that handles urban traffic flow efficiently with minimum infrastructure. The system takes in real-time video inputs from road junctions, identifies vehicle concentration through image processing, and controls traffic light time dynamically based on real-time jamming instead of fixed timers. The approach provides the minimum waiting time, best fuel economy, and smooth traffic movement, especially during rush hours. The system begins with setting up a camera on each traffic light that captures continuous video of approaching cars. Using image processing methods such as background subtraction and edge detection, the system recognizes and counts the number of cars per lane. This quantity of vehicles is then fed into an embedded microcontroller (e.g., Raspberry Pi or Arduino) at the signal post, which computes optimal green light times for all lanes in accordance with current traffic density. The microcontroller controls the signal lights in a decentralized way so that each intersection operates independently. Data from the intersections is saved and can be processed for tracking long-term traffic trends or identifying anomalies. The light hardware requirements and decentralized logic also make the system scalable and appropriate for resource-poor cities that want to implement smart infrastructure. This approach

guarantees a smart, responsive traffic system that maximizes road utilization in a cost-efficient and affordable way. The real-time traffic light control process through image processing and IoT.

### **1. Real-Time Video Capture: Seeing the Traffic as It Happens**

Imagine standing at a busy intersection during rush hour. Some lanes are packed with cars stretching as far as the eye can see, while others have just a handful of vehicles. Traditional traffic lights don't care—they stick to their routine, switching at fixed intervals whether traffic is heavy or light. But in a smarter system, cameras placed strategically around intersections constantly monitor the flow of vehicles. These cameras don't just record footage; they feed live data into the system to help make real-time decisions on how long each light should stay green.

### **2. Image Processing & Vehicle Detection: Recognizing the Chaos**

Once the live video is captured, it's not enough to simply stare at the footage. The system needs to understand what's happening. This is where image processing comes in. With tools like OpenCV (a powerful library for computer vision), the system scans each frame and detects vehicles.

Instead of treating the video like a regular recording, the system identifies moving cars separately from stationary objects like buildings, sidewalks, and street signs. Techniques like contour detection (which finds the edges of objects) and background subtraction (which isolates moving objects from the scene) help differentiate vehicles from their surroundings.

### **3. Vehicle Count Analysis: Figuring Out Who Needs to Move First**

Once the cars are recognized, the system starts counting. It measures how many vehicles are present in each lane and compares this number across all directions at the intersection. It's a bit like a traffic officer looking at every road and deciding which one is the most congested.

If one side has significantly more cars than others, it's logical to allow that road a longer green light to clear out the vehicles efficiently. Conversely, a road with only a few cars shouldn't hold up a long line of drivers unnecessarily.

### **4. Dynamic Signal Timing through IoT Controller: Smart Decision-Making**

Here's where things get really interesting. Instead of relying on fixed-timer logic, an IoT microcontroller steps in to make intelligent decisions based on live data. The microcontroller acts as the brain of the operation, processing the vehicle count and deciding the optimal green light duration for each direction.

For example, if the system detects heavy congestion on the eastbound road but only a few cars on the westbound side, the eastbound lane will get a longer green light while the west bound one gets a shorter duration. This dynamic adjustment ensures that traffic flows as efficiently as possible.

### **5. Traffic Light Actuation: Making the Change Happen**

Once the microcontroller computes the ideal signal timing, it directly controls the traffic lights, activating them in real-time. This means the system isn't just collecting data—it's acting on it immediately.

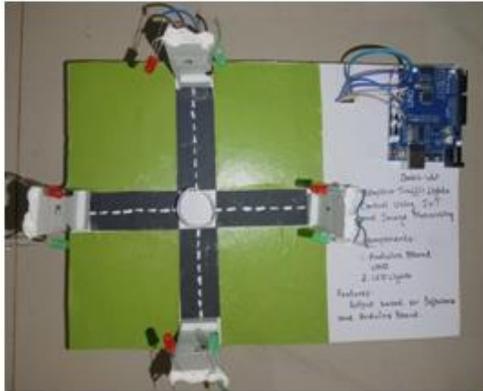
The beauty of this approach is that there are no unnecessary waits. Traffic lights shift intelligently, giving priority to busier roads while ensuring smoother movement across the intersection.

### **6. Data Logging and Monitoring: Learning from Past Patterns**

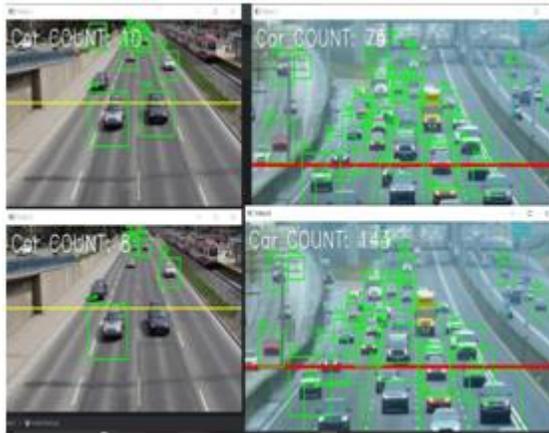
The system doesn't just forget everything once a signal cycle ends. All traffic-related data—vehicle count, waiting times, signal durations, and flow efficiency—is logged for future analysis.

This historical data becomes incredibly useful for city planners, engineers, and AI systems looking to refine traffic optimization further. Over time, trends can be identified, bottlenecks predicted, and even forecasts made to prepare for events like rush hours or seasonal changes in traffic flow.

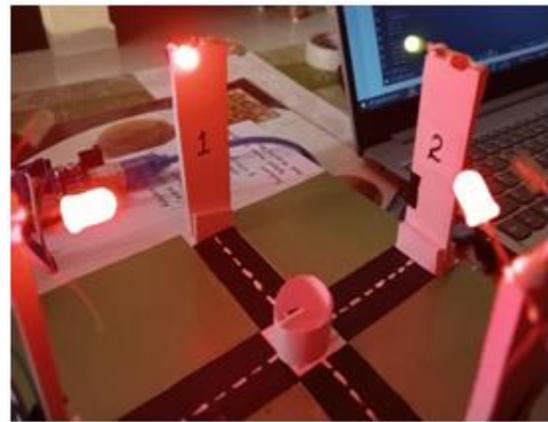
IV. SNAPSHOTS



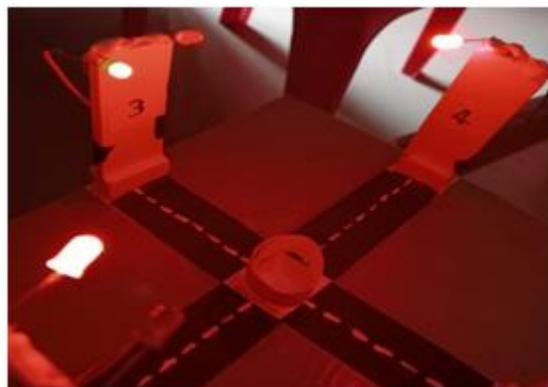
Snapshot1: Adaptive Traffic Signal System



Snapshot2: Videos Showing 4 different Lanes



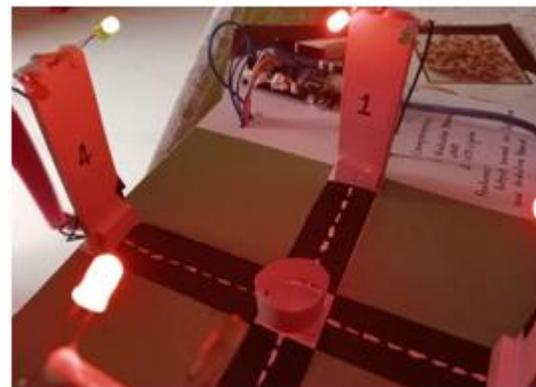
Snapshot4: System Showing Green for Lane 2



Snapshot5: System showing Green Light for Lane 3



Snapshot3: System Showing Green for Lane 1 and Red for all other lanes



Snapshot6: System Showing Green for Lane 4



Snapshot7:Dashboard Showing Traffic Summary

## V. CONCLUSION

The research suggests that there is a huge possibility of light image processing and distributed IoT architecture for transforming adaptive traffic control systems. With the authority of efficiency and scalability as dominant forces, the solution significantly simplifies technological complexity and resource loads with guaranteed optimum performance in very dynamic urban scenarios.

The suggested system not only optimizes real-time traffic handling but also yields a cost-saving and adaptable solution which is adaptable both for quick developing cities as well as advanced metropolitancities. One of the strengths of this system is that it can function in full synchronization with no computation burden, and hence its mass deployment is very likely. By combining smarter object classification and detection techniques, traffic management can be made responsive and intelligent to altered conditions. Furthermore, by combining predictive analytics as a component of the system, its forecasting ability of traffic flows will even be further augmented, with city planners and transport authorities having the capacity to take better-informed decisions. The future upgrade will be in the optimization of object classifying algorithms for increased detection rates for improved identification accuracy of pedestrians and vehicles. Traffic congestion behavior patterns will be forecasted using prediction models and pre-emptive adjustment of control mechanisms enabled. The architecture also will be enabled to be connected to wider smart city data platforms such that it is interoperable with other city systems. This hybrid scheme keeps traffic management reactive, data-driven, and responsive to the evolving needs of modern cities.

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