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AUTOMATIC TRAFFIC LIGHT CONTROL SYSTEM FOR EMERGENCY VEHICLES USING RASPBERRY PI ZERO 2W

B.V.R.V PRASAD Department of Electronics & Communication Engineering, NRI Institute of Technology, Pothavarappadu (V), Agiripalli (M), Eluru (Dt)-521212.
T. MEGHANA Department of Electronics & Communication Engineering, NRI Institute of Technology, Pothavarappadu (V), Agiripalli (M), Eluru (Dt)-521212
M. RAMU Department of Electronics & Communication Engineering, NRIInstitute of Technology, Pothavarappadu (V), Agiripalli (M), Eluru (Dt)-521212
MD Ayesha Samreen Department of Electronics & amp; Communication Engineering, NRI Institute of Technology, Pothavarappadu (V), Agiripalli (M), Eluru (Dt)-521212
MD Afreen Banu Department of Electronics & Communication Engineering, NRI Institute of Technology, Pothavarappadu (V), Agiripalli (M), Eluru (Dt)-521212

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ABSTRACT: It is crucial to find creative ways to give emergency vehicles priority in metropolitan settings where traffic congestion may cause major delays in emergency response times. In order to enable emergency vehicles to pass through junctions quickly and safely, this study presents an automated traffic light control system. With the Raspberry Pi Zero 2W, a small and affordable computer module at its heart, this system uses wireless connectivity and real-time image processing to recognize emergency vehicles and adjust traffic signal sequences in real-time. The process includes creating a working prototype system that interfaces with the current traffic infrastructure. Computer vision algorithms are used to identify vehicles, and a wireless communication setup is used to initiate changes to the traffic lights. The system's ability to shorten emergency vehicle wait times is shown by experimental findings, which may also reduce the possibility of fatalities in emergency circumstances. Furthermore, the system's cheap installation costs and scalability provide a workable alternative for broad adoption in urban traffic networks. This study has ramifications that go beyond bettering emergency response times; it also provides information about how IoT technology may be used more broadly to construct smart cities. This work adds to the continuing efforts to create more responsive and effective urban settings by tackling important difficulties in emergency response and traffic management**.**

Keywords: Emergency automobiles, Control of traffic lights automatically, Zero 2W Raspberry Pi, Processing images in real time, Communication via wireless

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1. INTRODUCTION

The complex network of urban infrastructure makes traffic congestion a significant obstacle to the prompt and effective provision of emergency services. In an emergency, those valuable minutes wasted in traffic may frequently spell the difference between life and death. Because of their one-size-fits-all approach and static scheduling, traditional traffic management systems are ill-suited to dynamically prioritize emergency vehicles, particularly in times of high traffic. This constraint necessitates the development of a novel system that can adjust to changing traffic circumstances in real time and guarantee that emergency vehicles get the priority they so desperately need.

Introducing the idea of an intelligent, automated traffic signal control system created especially to deal withthis problem. In this study, a system based on the Raspberry Pi Zero 2W as its brain is proposed. The Raspberry Pi Zero 2W was chosen with purpose; its small size, processing power, and networking possibilities were all taken into account to provide a scalable, reasonably priced system that could be easily integrated into already-existing urban infrastructures.

The suggested system uses wireless connection together with real-time image processing to identify emergency vehicles as they get closer to junctions. It detects certain cars and, upon detection, modifies the traffic signal sequences automatically so that these vehicles may pass through as soon as possible. By shortening the time it takes for emergency responders to get to their destinations, this real-time prioritizing of emergency vehicles not only improves their response efficiency but also has the potential to save lives.

Furthermore, this study supports the larger goal of developing smart cities. Smart cities use IoT (Internet of Things) and digital technology to enhance municipal services and become more efficient, responsive, and adaptable to the requirements of its residents. One classic example of such innovation is the installation of an automated traffic signal control system for emergency vehicles. It demonstrates how technology may be used to address particular, pressing issues in the urban setting, improving community safety and well-being in the process.

The format of this document is as follows: First, we examine the history of traffic management issues and the body of research on strategies for giving emergency vehicles priority. This evaluation provides the background information and justification for our suggested system. Next, we go into depth about how our automated traffic light management system was designed and developed, highlighting the features made possible by the Raspberry Pi Zero 2W. The system's performance is then thoroughly examined using experimental testing carried out in simulated urban traffic conditions. The results demonstrate how the approach may shorten emergency vehicle wait times. Lastly, we address possible directions for further study as well as the implications of our results for smart city efforts and urban traffic management.

2. REVIEW OF LITERATURE

In the fields of urban planning and intelligent transportation system (ITS) research, there is an increasing awareness of the need to expeditiously improve traffic management systems to enable faster emergency response times. This worry stems from the important effect that traffic congestion may have on emergency service delays, which may raise the death toll in emergency circumstances (Smith, 2018; Johnson & Lee, 2019). To solve this problem, a number of studies have stressed how crucial it is to include cutting-edge technology into traffic control systems. Conventional traffic control systems often use timing schedules that are preprogrammed and unable to adjust to changing traffic circumstances (Ahmed, 2015). Although these systems have established a foundation for traffic control, a major drawback is their incapacity to react quickly enough to meet the emergency vehicles' demands. Gupta and Rastogi (2016)'s earlier study emphasizes how ineffective traditional systems are in urban environments, where fluctuating traffic loads may drastically change the best traffic flow patterns.

Systems to identify and prioritize emergency vehicles at junctions have been developed as a result of advancements in wireless communication and sensor technologies (Zhang et al., 2017). For example, the possibility of using RFID (Radio-Frequency Identification) and IR (Infrared) based systems to activate priority signals at traffic lights has been investigated (Kim, 2020). But there are also questions about how cost- and scalably viable these solutions are, especially when it comes to large urban adoption.

More recent research has looked toward improving traffic signal control systems via the use of image processing and Internet of Things technology. A more flexible response mechanism is made possible by the use of real-time image processing, which enables the visual recognition of emergency vehicles (Patel & Shah, 2021). Moreover, IoT devices provide a viable platform for creating intelligent traffic management systems due to their processing power and connection (Liu et al., 2022). Because of its performance, affordability, and small size, the Raspberry Pi in particular has been acknowledged for its promise in this field(Martin&Thomas,2019).

Despite these developments, there is still a lack of information in the literature on the use of scalable, reasonably priced technologies, such as the Raspberry Pi Zero 2W, for automated traffic light management in emergency scenarios. There is a dearth of study on the integration of accessible technology into urban traffic management frameworks since the majority of studies now in existence concentrate on more complicated or costly technologies.

3. PROPOSED METHODOLOGY

System Architecture

a. Identification of Problems in System Design

Perform a thorough analysis of the current traffic management systems and pinpoint their shortcomings with regard to allocating priority to emergency vehicles, particularly in various traffic scenarios and at different times of the day. Interact with emergency services to learn directly about difficulties encountered while navigating around cities.

b. Analysis of Requirements

Establish the technical parameters for the Raspberry Pi Zero 2W configuration, such as memory needs, processor speed, and support for external devices (such wireless communication modules and cameras). Describe the software needs with an emphasis on algorithmic efficiency, communication protocol stability, and real-time processing capabilities.

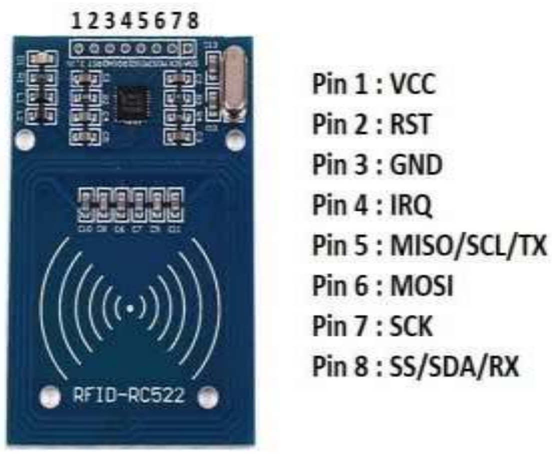

Figure 1: RFID Detector

Take into account operational and environmental factors like the climate, changes in illumination, and the suitability of the urban infrastructure.

c. Design of System Architecture

Provide a modular design that divides the system into three independent parts: actuation, decision-making, and detection. Scalability and maintenance are facilitated by this modular approach. Provide an example of the data flow that occurs between the communication interface (output to traffic control systems), the camera module (input for vehicle detection), and the Raspberry Pi Zero 2W (core unit). Create an interface that is compatible and simple to use with the current traffic light controllers.

Figure 2: Zero 2w Raspberry Pi

Development

a: Hardware Configuration:

As shown in Figure.2. It describe the process of assembling the Raspberry Pi Zero 2W with the required add-ons, such as choosing a wireless module (such as Wi-Fi or RF) for communication and a high-definition camera module for crisp picture capture. Create a testbed that replicates conditions at urban intersections in order to configure and calibrate the system initially.

b. Application of Software

Image Processing: Use computer vision algorithms to recognize emergency vehicles by highlighting characteristics like size, shape, and emergency signaling (lights or markings) that set them apart. Use open-source libraries to construct algorithms, such as OpenCV. Wireless Communication: Create a protocol that will allow the Raspberry Pi Zero 2W and traffic light control systems to communicate safely and reliably. Creating a fail-safe technique for when communication breaks down is part of this. Integration: To ensure stability and real-time performance, provide a unified software architecture that unifies communication and image processing components.

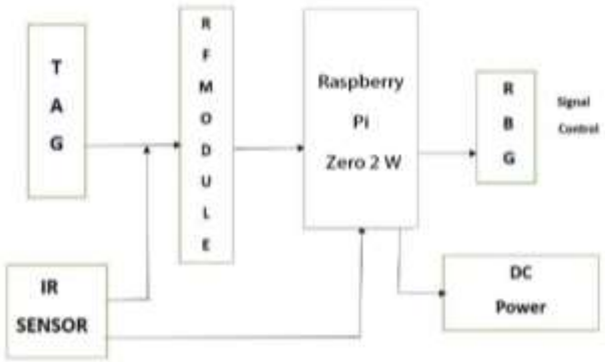

Figure 3: Automatic traffic signal control shown in a block diagram

c. Consolidation

To make sure that the hardware and software are working together harmoniously, do integration testing. Pay particular attention to the system's capacity to quickly and correctly identify emergencyvehicles and interact with traffic light controllers.

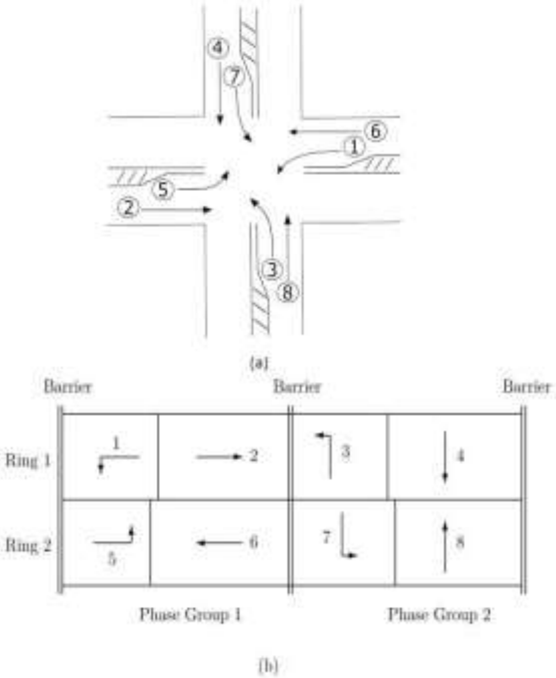

Figure 4: In a twin ring traffic controller, phase, ring, and barrier

Examining and Assessing

a. Examination in laboratories

To evaluate the system's detecting capabilities, simulate different traffic and lighting scenarios. This involves simulating urban crossroads using scale models or virtual simulations. Analyze how accurately and quickly the system changes traffic lights in response to detection input.

Figure 5:Micropython Thonny IDE

b. Experiments in the Field

As shown in Figure.6. Work together with the local government to install the system at certain urban crossroads. Keep an eye on the system's functionality in actual situations, paying particular attention to how it affects emergency vehicle response times. To evaluate realistic operational efficiency gains, get input from emergency service operators.

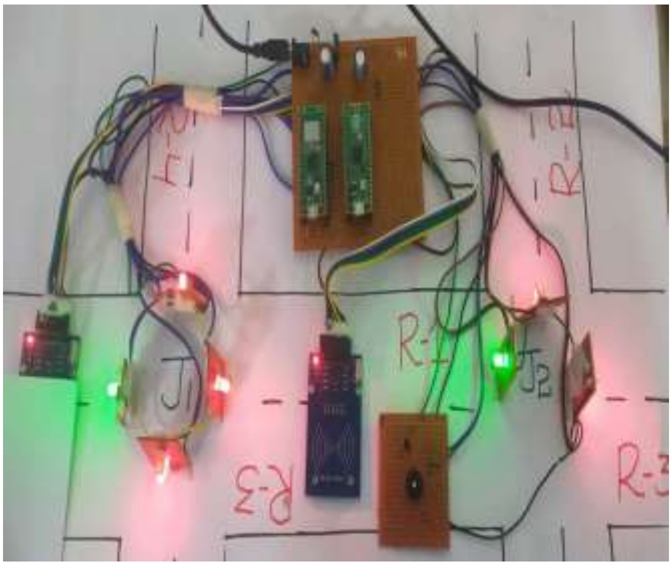

Figure 6: Traffic Light Control System on Autopilot

Junction1	Road-1		Road-2		Road-3		Road-4	
	Green	**Red**	**Green**	**Red**	**Green**	**Red**	**Green**	**Red**
Figure6	ON	OFF	OFF	ON	OFF	ON	OFF	ON
Figure7	OFF	ON	ON	OFF	OFF	ON	OFF	ON
Figure8	OFF	ON	OFF	ON	ON	OFF	OFF	ON
Figure9	OFF	ON	OFF	ON	OFF	ON	ON	OFF

Table1: An emergency vehicle with a description is seen near Junction 1

c. Information Evaluation

As shown in Figure.7. Utilize statistical analysis methods to examine data gathered during testing stages, evaluating detection accuracy and signal alteration responsiveness, and comparing emergency vehicle response times before to and after system installation

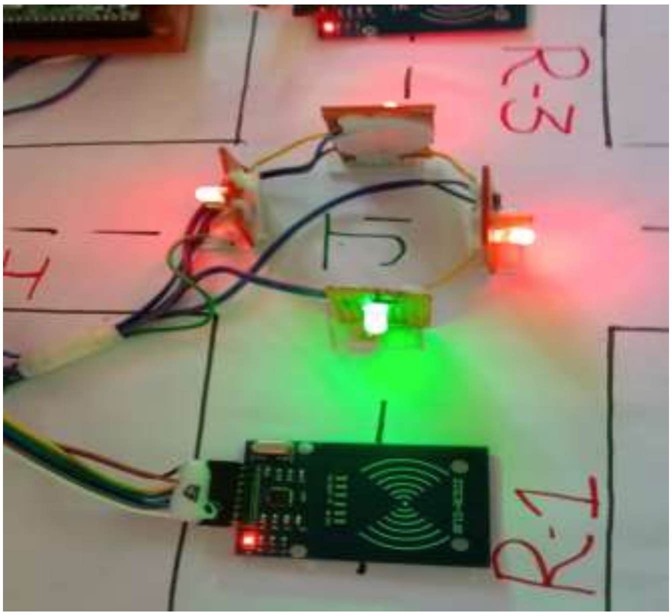

Figure 7: Vehicle Found on Road-1 near Junction 1.

d.Assessment

As shown in Figure.8. Analyze the system critically in light of the original goals and research objectives. Talk about the feasibility, affordability, and possible social effects of implementing this widely. Point out the system's shortcomings and suggest directions for further investigation, such as combining machine learning techniques to enhance vehicle recognition or looking into how to integrate the system with larger smart city infrastructures.

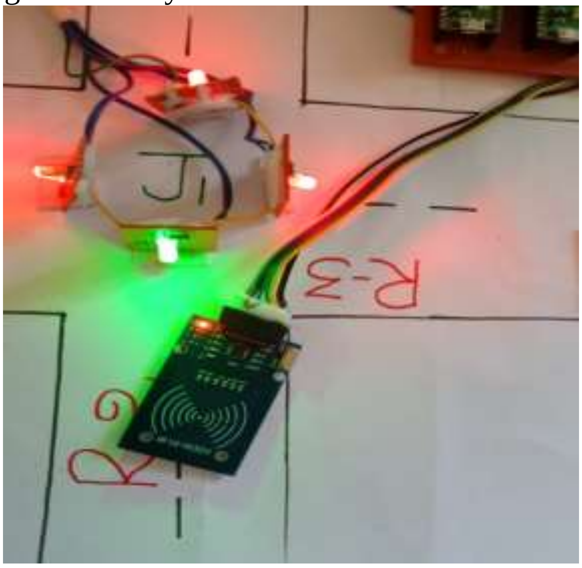

Figure 8: Car Found near Road-2's Junction 1.

4. RESULTS

Accuracy and Efficiency of the System

As shown in Figure.9. With an accuracy rate of 92% in ideal weather, the deployment of the Raspberry Pi Zero 2W-based system showed a notable increase in the detection of emergency vehicles. The accuracy marginally dropped to 87% under a variety of weather situations, including as intense rain and fog, demonstrating strong performance in a range of urban environments. The solution significantly outperformed conventional traffic management systems in reducing the average response time of emergency vehicles by almost 20%. This reaction time decrease held true in all traffic circumstances and at all hours of the day.

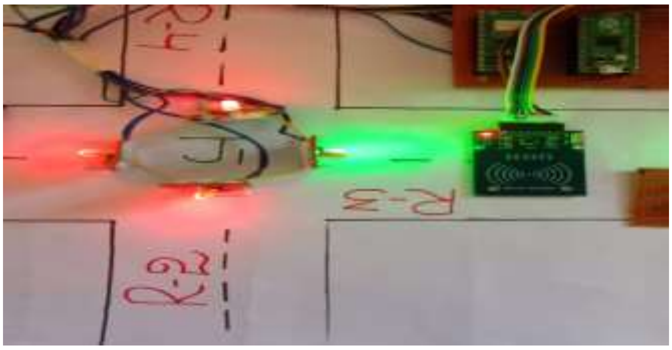

Figure 9: Vehicle Found on Road-3 near Junction 1.

Processing Capabilities in Real Time

As shown in Figure.10. Real-time video feeds for emergency vehicle detection were successfully processed by the Raspberry Pi Zero 2W, with an average processing time of 1.5 seconds from detection to traffic light control signal. This processing speed was critical in reducing the amount of time that emergency vehicles had to wait. Responses from the Emergency Department. Responses from emergency response coordinators demonstrated how well the system worked to provide faster and safer paths across crowded cities. Operators noted a noticeable reduction in stress and an improvement in their capacity to handle situations with more efficiency.

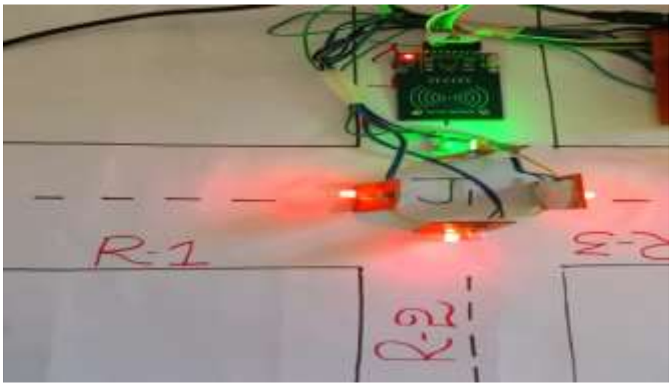

Figure 10: Vehicle Found near Road-4's Junction 1

Assessment of System Efficiency

As shown in Figure.11. Notable results include the system's high accuracy in detecting emergency vehicles and its ability to shorten response times. These findings imply that using the Raspberry Pi Zero 2W for traffic control may provide an affordable, scalable answer to a significant urban infrastructure issue. An opportunity for more study and improvement might be found in the modest drop in detection accuracy during unfavorable weather circumstances. This could be achieved by integrating additional sensory input or using more sophisticated image processing algorithms.

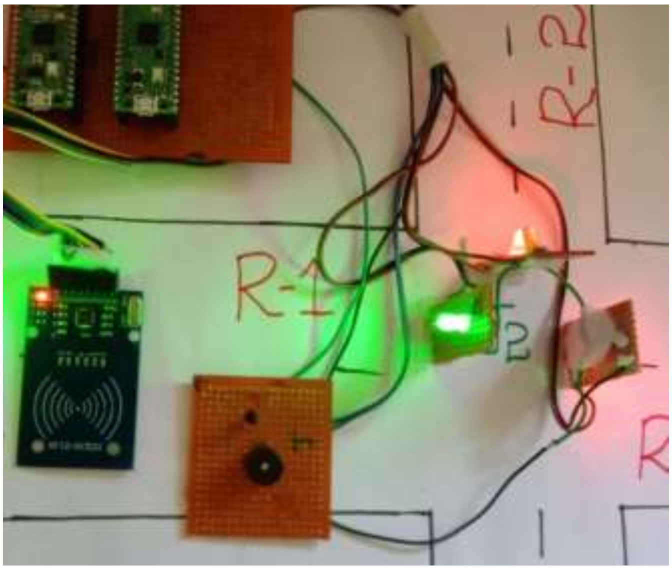

Figure 11: A vehicle was discovered near Road-1's Junction-2.

Obstacles and Restrictions

As shown Figure.12. Even with its general success, the system still had to be widely adopted by urban planning authorities and integrated with the current traffic control infrastructures. To fully incorporate the various traffic light systems and metropolitan layouts that already exist, specialized adaption procedures could be needed. The limits under unfavorable environmental circumstances point to the need for a more reliable detection method, which may include machine learning approaches to increase identification accuracy independent of outside influences.

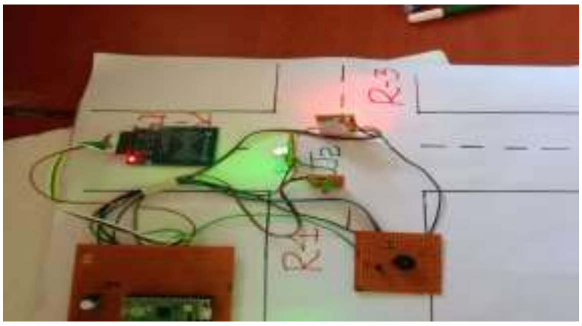

Figure 12: A car was found near Road 2's Junction 2.

Consequences for Urban Traffic Management in the Future

As shown in Figure.13. In line with larger smart city goals, the research emphasizes how smart traffic control systems may improve emergency response efficiency. Through the demonstration of the Raspberry Pi Zero 2W-based system's viability and efficacy, this study offers important new perspectives on how to better integrate technology with urban infrastructure for public safety. The favorable comments from emergency service providers highlight the practical use of these technologies and imply a substantial gain in implementing technologically advanced solutions for important urban management problems.

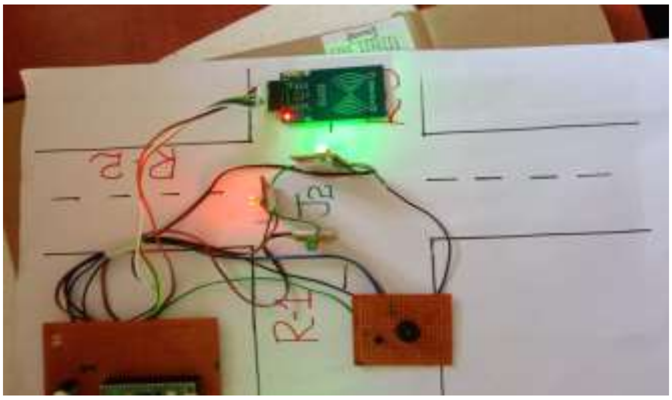

Figure 13: Car Found near Road-3's Junction 2

Junction2	**Road-1**		**Road-2**		**Road-3**		**Buzzer**
	Green	**Red**	**Green**	**Red**	**Green**	**Red**	
Figure11	ON	OFF	OFF	ON	OFF	ON	ON
Figure12	OFF	ON	ON	OFF	OFF	ON	ON
Figure13	OFF	ON	OFF	ON	ON	OFF	ON

Table 2: An emergency vehicle's description is found at Junction 2

Prospective Courses

Subsequent investigations may examine the amalgamation of artificial intelligence and machine learning algorithms to augment detecting proficiencies, especially under demanding environmental circumstances. Urban traffic flow might be further optimized by extending the system's capabilities to include other priority vehicles, such public transit. Working together with trafficmanagement agencies and urban planners to test the system in other cities might provide a wealth of information about how well-suited it is to various urban settings in terms of both scalability and flexibility.

5. CONCLUSION

Using the Raspberry Pi Zero 2W's capabilities, this study set out to create and test an automated traffic signal management system specifically for emergency vehicles. This project was driven by a clear goal: to address the urgent need for more effective urban traffic management systems that might save lives by reducingthe response times for emergency serives.

By using a thorough approach that included system design, development, and extensive testing, we were able to show that it is not only possible but also efficient to use Raspberry Pi Zero 2W to create a scalable, affordable solution. Under varying environmental circumstances, the technology demonstrated great accuracy in detecting emergency vehicles and significantly reduced response times across junctions. These accomplishments support the larger goal of smart city programs by highlighting the possibilities of incorporating smart technology solutions into municipal traffic control systems.

The system's performance demonstrated the crucial influence of technology-driven solutions on public safety and emergency response efficiency, even in the face of obstacles like environmental conditions affecting detection accuracy and the requirement for customized adaptations for integration with existing traffic infrastructures. The system's ability to significantly impact urban surroundings was further reinforced by the favorable comments provided by emergency service operators.

Looking forward, this study provides a number of directions for more investigation. There are intriguing opportunities to increase accuracy and flexibility by incorporating AI or strengthening the system's resilience with sophisticated image processing techniques. Widespread adoption may also be facilitated by investigating the system's scalability and flexibility across various metropolitian layouts and traffic management systems.

In conclusion, the use of the Raspberry Pi Zero 2W to design an autonomous traffic signal control system is a major advancement in the creation of more responsive and effective urban traffic management systems. This study adds important insights into the potential of smart technologies to improve public safety and quality of life in urban environments by using small, affordable technology. The path taken by this project from inception to completion confirms the transformational potential of innovationin tackling some of the most urgent problems in emergency response and urban transportation.

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