# Smart Traffic Management System: Enhancing Safety at Zebra Crossings

**Jasmeet Kaur[1], Saksham Jamwal[2], Heena Khanna Kalra[3]**

School of Computer Application, Lovely professional University, Punjab, India

**Abstract**

**In our growing areas effectively managing traffic has become very important. To address this challenge, we have created a project that introduces a Smart Traffic Light Management System with safety alert at Pedestrian crossing. The feature of this paper is our system contains three modules designed to handle traffic situations: Regular Traffic, High Traffic and VIP Preferential Treatment. Our system is an approach, to controlling traffic signals according to need. We dynamically adjust the duration of lights based on real time traffic conditions. This can be done by using Infrared (IR) sensors along the road. These sensors work together to detect vehicles and use respective traffic modules accordingly. In addition to this traffic light system, we have also introduced a VIP Priority module. This module provides designated VIP vehicles with disruptions in traffic by activating a feature i.e., blinking yellow light. VIP vehicles can activate this module using a DPDT push button. Moreover, we understand the significance of ensuring pedestrian safety. To resolve this problem, we have integrated a laser sensor, along, with Light Dependent Resistors (LDR) to detect if any car is passed when signal is red or yellow and if yes then, alert the pedestrian using a buzzer. That will may prevent future accidents whenever cars break signal.**

**Keywords: Raspberry Pi PICO W, LDR Sensor,IR Sensor,Lazer Sensor**

## I. INTRODUCTION

Traffic congestion has become a serious concern in our daily lives, with vehicles contributing significantly to air pollution. The longer vehicles remain stuck in traffic, the more fuel is wasted, further exacerbating environmental pollution. In fact, studies highlight that transportation is one of the main sources of air pollution, contributing to harmful emissions [1]. Managing traffic effectively has, therefore, become crucial not only for reducing pollution but also for improving the overall flow of traffic.

One of the most effective ways to address this issue is by dynamically adjusting traffic light timings based on real-time traffic conditions [2]. Traffic lights that respond to changing traffic patterns can significantly reduce vehicle idling times, thereby minimizing fuel consumption and pollution [3][4][5]. Furthermore, pedestrian safety remains a critical aspect of traffic management. According to the NCRB 2021 report, 18,900 pedestrians lost their lives in 2021, equating to 51 daily deaths due to accidents while crossing the road or walking alongside it. This alarming statistic underscores the need for enhanced pedestrian safety measures [6].

Our project addresses both traffic and pedestrian safety concerns through the creation of a Smart Traffic Management System [7]. The system features three distinct modules—Normal Traffic, Heavy Traffic, and a VIP Module—to automatically manage traffic lights and improve road safety. Each module is designed to cater to different traffic conditions. In the Normal Traffic module, the traffic lights operate with default timers. When heavy traffic is detected using IR sensors placed on either side of the road, the system shifts to the Heavy Traffic module, extending the green and yellow light durations [8]. This module remains active as long as objects are detected by the IR sensors. The VIP module, activated via a DPDT push button, prioritizes VIP movements by flashing the yellow light continuously, ensuring smoother passage for important vehicles [9].

To further enhance pedestrian safety, our system incorporates laser sensors in conjunction with Light Dependent Resistors (LDR). These sensors are positioned at the zebra crossing to detect vehicles that cross the stop line when the light is red or yellow. If any vehicle breaks the signal, the system activates a buzzer for three seconds, alerting pedestrians to avoid crossing the road at that moment. This feature improves pedestrian safety by preventing accidents and facilitating more efficient traffic management [10].

Research on smart traffic systems, including those employing video processing techniques, has shown significant promise in reducing congestion [11][12]. For example, some systems use deep learning to predict traffic flow and adjust signals accordingly, which improves efficiency [13][14]. Others leverage neural networks and fuzzy logic to manage complex urban traffic scenarios [15][16]. Real-time data analysis and IoT-based solutions also play a crucial role in enhancing traffic light scheduling [17][18]. More advanced approaches even prioritize emergency vehicles or integrate pedestrian detection systems to ensure both driver and pedestrian safety [19][20].

By integrating these modules and safety mechanisms, our Smart Traffic Management System aims to reduce congestion, pollution, and fuel wastage while prioritizing the safety of both drivers and pedestrians.

## II. LITERATURE REVIEW

**Table 1**

| S.No. | Title | Year | Citation | Literature review | Limitations & additions |
|---|---|---|---|---|---|
| 1 | The Importance of Implementation of Traffic Light Optimization System: Greece Case Study | 2024 | DimitriosZavantis, DimitriosMandalozis, AnsarYasar, LumbardhaHasimi, “The Importance of Implementation of TrafficLight Optimization System: Greece Case Study” | Analyzes the impact of traffic congestion on emergency response times, focusing on how traffic delays can reduce the chances of survival for seriously injured road users. Using real data from a hybrid environment (motorway and urban roads), the study identifies traffic issues, with a focus on how traffic lights contribute to congestion and long travel times, even in low traffic volumes. The study emphasizes the importance of optimizing traffic lights to reduce congestion and improve emergency response times, particularly as traffic volumes rise.2 | It lacks specific solutions for real-timetrafficmanagement and pedestrian safety. In contrast, the second abstract presents a comprehensive system with dynamic traffic light control, VIP preference, and pedestrian safety features using sensors. The limitation of the first abstract is its narrow focus on analyzing issues rather than offering concrete, actionable technologies or solutions |
| 2 | A novel pedestrian road crossing simulator for dynamic traffic light scheduling systems | 2024 | Dayuan Tan, Mohamed Younis, WassilaLalouani, Shuyao Fan, Guozhi Song, A novel pedestrian | This project creates a novel simulation environment for modeling human movement on signalized crosswalks with high resolution. The simulation depicts typical pedestrian behaviors and scenarios in which large groups cross in multiple | It focuses on simulation rather than real-world applications. It may not address the practical challenges of deploying and integrating such systems in real-world traffic environments. In contrast, the second abstract describes |

| | | | | | |
|---|---|---|---|---|---|
| | | | road crossing simulator for dynamic traffic light scheduling systems | directions. It aims to improve road management by taking into account pedestrian experiences such as waiting time and achieves high accuracy in estimating crossing times. | a practical implementation of a Smart Traffic Light Management System with real-time traffic and pedestrian safety features, making it more suitable for immediate deployment. |
| 3 | Intelligent traffic light systems using edge flow predictions | 2024 | AdamRizvi Thahir, Mustafa Coşkun, Sultan KübraKılıç, VehbiCagriGungor, Intelligent traffic light systems using edge flow predictions | Propose a graph-based semi-supervised learning approach for managing traffic lights at multiple intersections. The method entails predicting road congestion and then dynamically adjusting traffic signals at connected intersections based on these predictions. The approach seeks to achieve comparable vehicle wait times while significantly shortening the time required to learn effective traffic light configurations, outperforming traditional deep learning methods in terms of training efficiency. | It lacks detail on how the system addresses real-time dynamic changes in traffic conditions beyond the basic prediction of congestion. In contrast, the second abstract describes a comprehensive Smart Traffic Light Management System that includes modules for various traffic conditions, VIP prioritization, and pedestrian safety features. This system offers a more practical and multi-faceted approach but does not address the efficiency of learning and adaptation times |
| 4 | Intelligent Traffic Light Solution for Green and Sustainable Smart City | 2023 | O. Jafari, S. Kolosov, N. Vo, A. T. Magar, J. Heikkonen and R. Kanth, "Intelligent Traffic Light Solution for Green and Sustainable Smart City. | In this project they are using the MATLAB toll box for computer vision and also using type of algorithm mixtures in the special era. In the they are using some sort of algorithms which means to make easy adjustable while using some AI algorithms. | They are using complex algorithms which may be difficult to implement and maybe very costly. The project has limitation of Maintenance. We are using cheaper components and introducing additional features, we are giving special privileges to VIP's by introducing a VIP module. Also, we are alerting the people who are crossing the road on red light and yellow light using laser sensor and buzzer. |
| 5 | Smart System of a Real-Time PedestrianDetection forsmart city. | 2020 | M. S. Ali Muthanna,Y. T. Lyachek, A. M. ObadiMusaeed, Y. Ahmed HazzaaEsmail and A. B. M.Adam, | In this project smartsystem of a Real-TimePedestrian detection forsmart city.In this project they mainly focus on detecting the pedestrians through surveillance Cameras and controlling the speed accuracy of vehicles while alerting through signals. It means controlling | The cost of surveillance cameras will be high. We are providing a solution to the same Problem at lesser cost. Additionally, we are giving special privileges to VIP's by introducing a VIP module. Also, we are alerting the People who are crossing the road on red light |

| | | | | | |
|---|---|---|---|---|---|
| | | | "Smart System of a Real-TimePedestrian Detectionfor Smart City. | the speed the accuracy of vehicles while it is moving towards the pedestrian crossing to avoid accidents and traffic jams. | and yellow light using laser sensor and buzzer. |
| 6 | Signaling and Vehicle Crossing with Smart Intelligent system (SVCSIS) | 2019 | R.O.Singh,P. S.Suryavanshi, R. R. Gandhi and M. H. Mulla,"Signalingand Vehicle Crossing withSmart IntelligentSystem (SVCSIS). | The "signaling and vehicle crossingwith smart intelligent system (SVCSIS)". Itmainly focusseson decreasingaccidents whileusing some smartauto Intelligentsystems while it is a led based sensors they have used. It is place is junction or 3 Junction Road where they take traffic lights and use laser sensors to get quick alerts from the car. If any vehicle touches the laser beam light during the red signal period it gives an alerting buzzer and if the vehicle is out of control the smart computer manages the traffic to avoid collateral damage. This is the focus of their project. | Our project is very similar to this work. But additionally, we are givingspecial privileges to VIP's by introducing a VIP module in our project. |
| 7 | Smart Traffic light control in the junction using Raspberry PI | 2019 | J. Hosur, R. Rashmi and M. Dakshayini, "Smart Traffic light control in the junction using Raspberry PI. | The focus of the project is on heavy power consumption. It means sometimes the vehicles had to wait for green signal even if there is no traffic like the road on all sides were empty. To avoid this problem, they have used some sensors which will detect the presence of vehicles on certain junctions of the road if there are no vehicles. It provides the green signals for the waiting vehicles that is the scope of this project | The cost of Raspberry pi is very high. We made a cost-efficient project.Additionally, we are giving special privileges to VIP's by introducing a VIP module. Also, we are alerting the people who are crossing the road on red light and yellow light using laser sensor and buzzer. |
| 8 | Intelligent traffic management System | 2011 | D. -x. Hu and Z. -p.Zheng, "Intelligent traffic management system. | The project mainly focuses on one thing which is for safe pedestrian crossing. They have designed a smart barricade which will auto open and close the road. For safe pedestrian crossing and | We have introduced three different traffic modules. Normal Traffic, Heavy Traffic and VIP module. |

| | | | | | |
|---|---|---|---|---|---|
| | | | | also for letting the people cross the road as some of the vehicles were standing on the pedestrian. If anyone tries to open that barricade, there is a Buzzer that will rise. So, this project so for safe pedestrian crossing. | |
| 9 | Density Based Smart Traffic System with Real Time Data Analysis Using IoT | 2018 | H. J. Naga, N. Nair, S. M. Jacob and J. J. Paul, "Density Based Smart Traffic System with Real Time Data Analysis Using IoT. | This is like controlling the duration of the traffic signals with the use of raspberry pi and. It will do manually while adjusting the duration of the signals according to the vehicles. | Our project also involves the safety of pedestrian crossings. To ensure safe crossing on pedestrians we used the laser sensor which is placed in between pedestrian crossing and vehicle standing. We also introduced VIP module. Also, we are using cheaper board. |

## III. Research gaps

In this project it is subdivided into two parts, one is for traffic control and second for pedestrian crossing. There are many studies done on this topic as we have studied the few mentioned above. The task of all the research's is to optimize the traffic. Many studies have used expensive components and boards, but we tried to create this project at lesser cost and with extra functionality of VIP module. To execute our objective, we have created a project, in our project we build a two-way road along with a zebra crossing. The main addition thing we did in our project is giving alert to the walkers crossing the road. We have used the buzzer to alert the intendent party if any vehicle crosses the road. This may help in preventing the road crossing people to cross the road carefully and attentively.

## IV. Objective of Paper

1. The main objective of our project is to manage the traffic efficiently.
2. Alert the intendent party to avoid any sort of accidents while crossing the road.
3. Providing special traffic module to manage VIP's.
4. Will help in reducing the traffic during the peak hours of the day.
5. This traffic control will also help in reducing pollution and save fuel.
6. This can help in detecting the data of traffic and analyse where heavy traffic is and at what hour.
7. Helps in getting real time data of traffic of a specific area and use for other purposes.
8. It can also help in adapting to special occasions like construction of road or blocking of road for any reason, by checking the traffic at peak hours we can avoid that time for blockage of road.

## V. Methods and Material

In this section, we describe the components used in our project, focusing on their basic functionalities and how they integrate into our system:

### 5.1 COMPONENTS USED

**Raspberry Pi PICO W:**
It is a microcontroller board with Bluetooth Low Energy (BLE) and Wi-Fi connectivity. It is used for different IoT projects, for example: Smart home appliances wearable technology Automation in industry Environmental Assessment Automation of the process You can program Pico W in Micro Python and C, and it has many libraries and programs available to help you get started in your projects. A powerful customizable microcontroller board, the Raspberry Pi Pico W is perfect for a variety of applications. It's very affordable, making it a fantastic option for novice and experienced architects alike. Figure 1 represents Raspberry Pi PICO W:-

Features:

- It is a microcontroller with a space of 2mb flash memory capacity 2.4 GHz Wi-Fi network.
- Micro USB B port for data and power (including flash reprogramming). .
- 26 The general purpose of multifunction 3.3V is evident. Input and output (GPIO): 23 GPIOs are digital only, only 3 are used as ADCs.
- As a module, this can be backloaded.
- ARM Serial Wire Debugging Port (3-pin). A simple yet incredibly adaptable power supply system.
- It can be powered via micro-USB, external accessories, or batteries.
- Great availability, verycheap cost and with great quality
- Detailed documentation, software samples, and SDK
- It is a dual core cortex with M0+ processor clocked at 133MHz..
- The frequency can be adjusted.
- 264kByte high performance multi-bank SRAM.

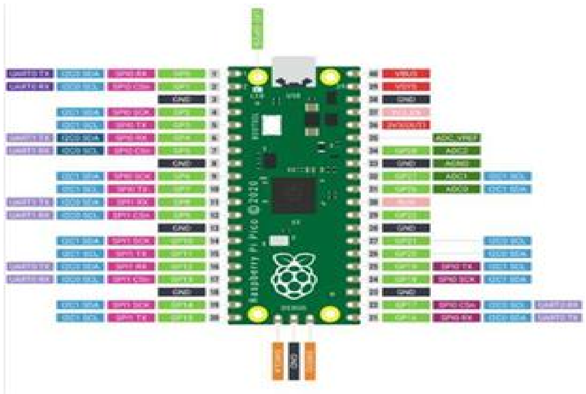

*Figure 1: Raspberry pi Pico W pin configuration*

**Laser Sensor:**
A laser sensor is a device that is basically used to measure position, distance, or other physical parameters. Laser sensors are usually used by many different industries such as robotics, construction, and automotive safety. Two types of laser sensor are; Triangulation and time-of-flight (ToF). ToF sensors measure the length of time the laser pulse takes to reach and return to an object to determine object spacing. Triangle sensors measures the distance between an object by measuring the angle of the reflected laser beam.

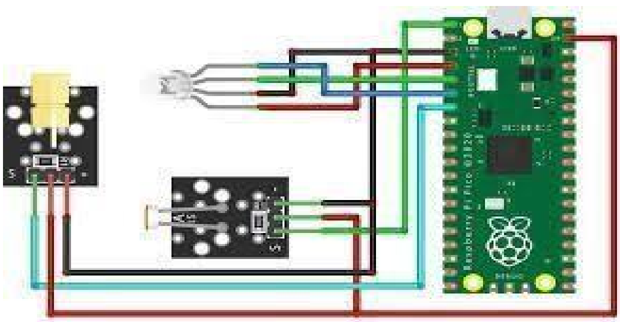

*Figure 2: Laser sensor connection with Raspberry Pi Pico W*

**IR Sensor:**

It is an electromagnetic device that basically scans and captures the infrared radiation around. IR is still the sameelectromagnetic spectrum, its wavelengths are longer than visible light,giving off infrared radiation that is invisible to the human eye with no heating element for example anything with a temperature that is about five degrees Celsius).

*Figure 3: IR sensor*

**LDR Sensor:**

LDR module is a device that detects the existence of light and measures the intensity of light. Once there is light then the intensity is high and when there is absence of light the intensity will be low. The module comes with an M3 mounting hole for attaching an object and it provides an LDR with highsensitivity, which is used for light detection. How it works:

1. With the module light conditions once the light intensity reaches the set required output then D0 port will be high else if it exceeds the threshold then the D0 output will be low.
2. D0 connected to MCU will detect light intensity changes.

Pin details:

Vcc— 3.3 to 5v DC

Gnd --- ground

D0 ---- Digital output

*Figure 4: LDR sensor*

**Buzzer Sensor:**

This component can be connected to emit a tone when the output is digital when using an analogy pulse width modulation output. The duration of PWM signal is generated by the number of squares generated in internet. It is basically used to generate a sound. The buzzer operates at both 3.3 and 5.5 volts with a sound of 85 decibels. It can make beeping sounds at different durations and frequencies. The most benefit of buzzer is that it has a wide spectrum of volume, for example it is used as an alarm detection system for both high and low volumes. Figure 5 represents Buzzer.

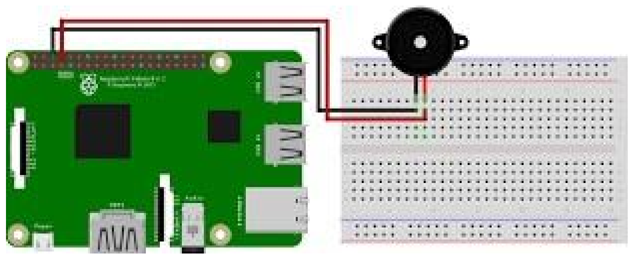

*Figure 5: Buzzer*

**DPDT PUSH BUTTON:**

It is basically a Double Pole Throw switch which consists of 6 terminals and 2 which are independent input terminals. It has poled that two different circuits for example each input terminal can connect with two output terminals and the rest of the terminals are separate. Figure 6 represents DPDT push button.

*Figure 6: DPDT push button switch*

**5.2 FLOW OF PROPOSED METHOD**

Smart Traffic Management System: Enhancing Safety at Zebra Crossings Using Raspberry pi Pico W. In this project, we have used three modules which are Normal traffic module, heavy traffic module and VIP module.

Normal traffic is the default module, it gives balanced time to all traffic lights. Heavy traffic is detected by using IR sensors placed along the road, two on each side of the road. If there is detection of object on all sensors, it means road have more traffic. Then the heavy traffic module will activate, it will give more duration to the green light.

Third one is VIP module, if any VIPs like ministers or Businessmen's or any other VIPpasses through that road there is a function which will be activated using a DPDT push button. That will activate yellow light blinking. It works for Emergency cases like for ambulance and in fire Emergency etc., also.

**Graphical Abstract of the proposed architecture**

Figure 7 describes the flow chart of pedestrian crossing it depicts the logic for activating a buzzer to alert pedestrians when a vehicle crosses a zebra crossing while the traffic light is red or yellow.

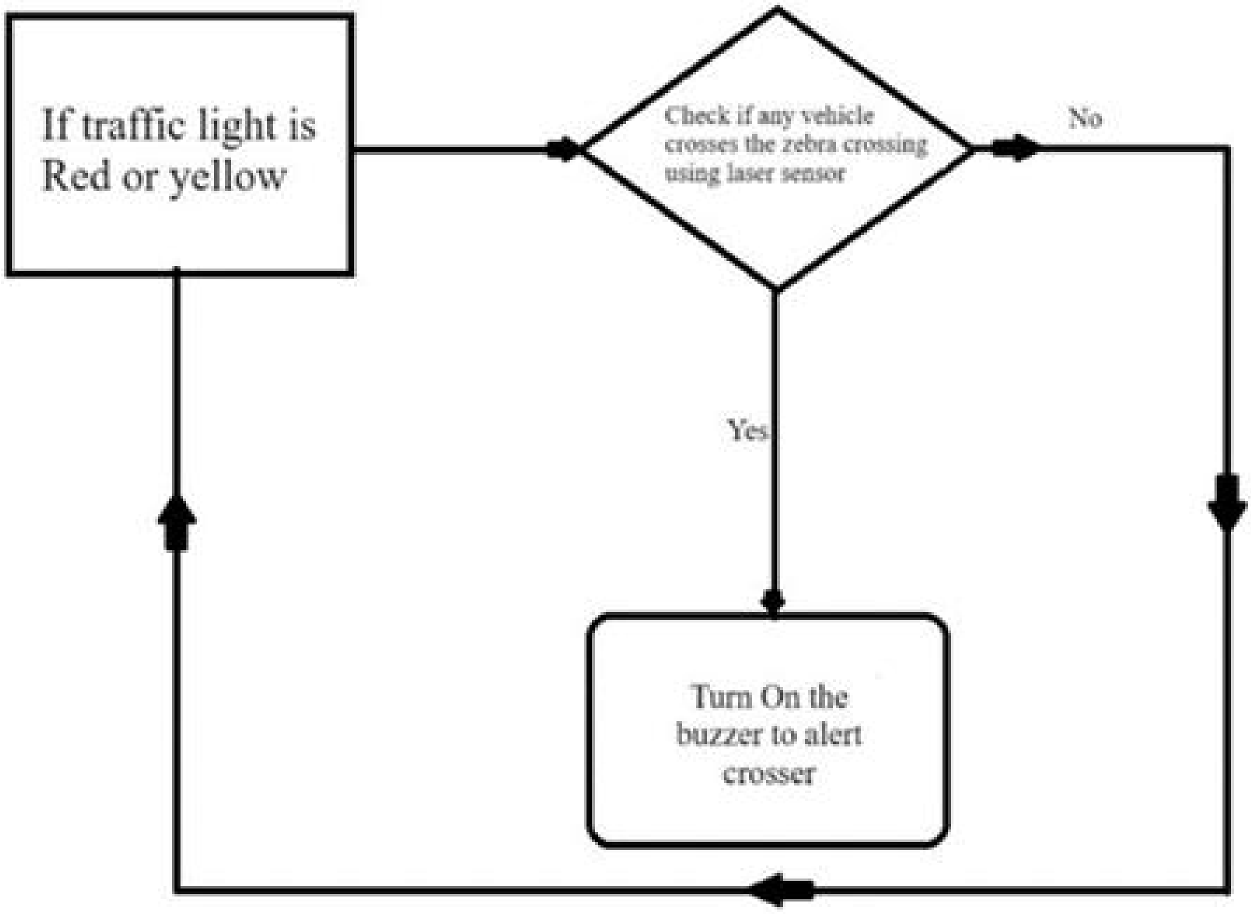


**Figure 7: Flow chart of pedestrian crossing**

Figure 8 shows a flowchart depicting a traffic control system. It illustrates the decision process for determining normal or heavy traffic based on IR sensor readings, and includes a branch for activating a VIP module under certain conditions.

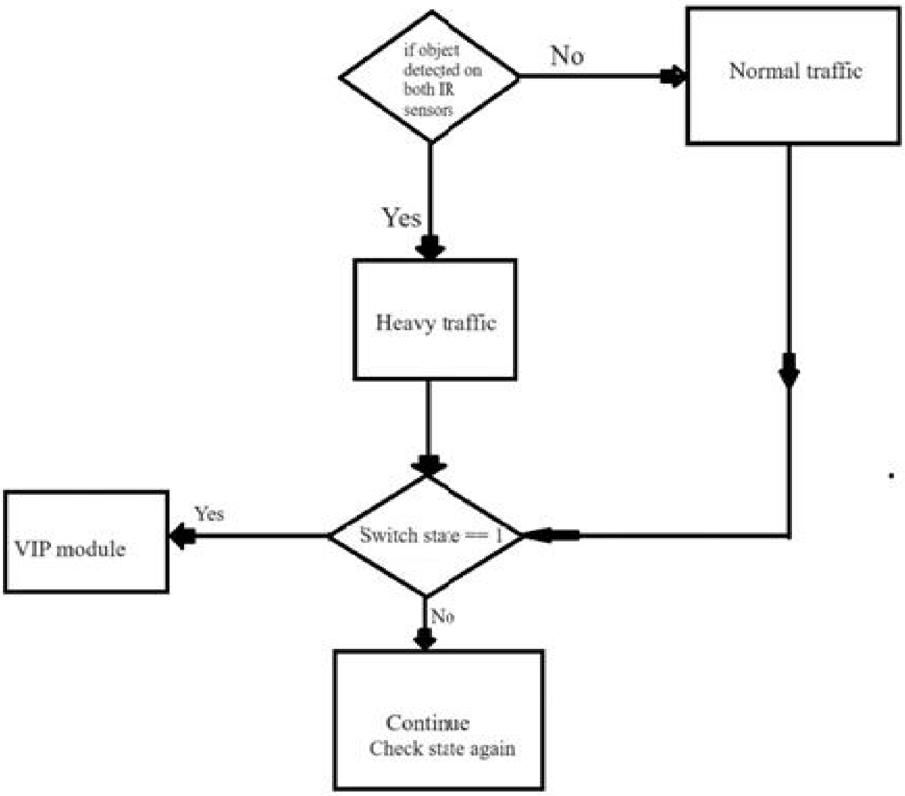


**Figure 8: Flow chart for Traffic vehicles**

Figure 9 shows a schematic diagram of a circuit board layoutfeaturing a central Wi-Fi enabled microcontroller connected to multiple LED lights and sensors or buttons. The components are interconnected with colored wires on what appears to be a breadboard.

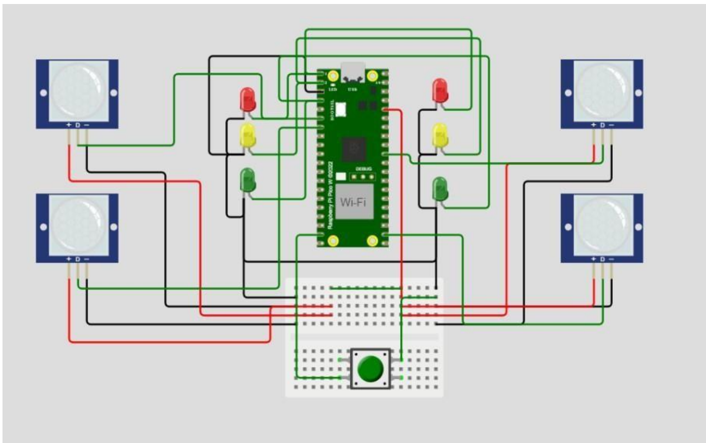


**Figure 9: Circuit Diagram of Traffic System**

Figure 10 displays a block diagram of a system centered around a Raspberry Pi Pico W. It shows various input devices (LDR, DPDT Push Button, IR Sensor) connected to the Pico W, and output devices (Laser sensor, Traffic lights, Buzzer) controlled by it.

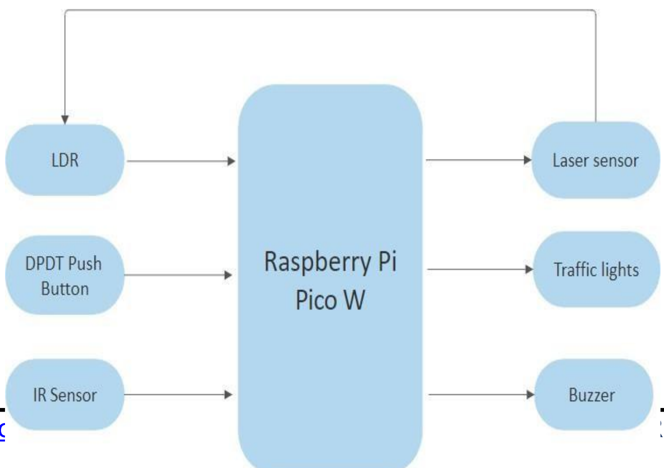

**Figure 10: Architectural Diagram**

Figure 11 shows a model of a road system with traffic lights, crosswalks, and a toy car to demonstrate the traffic control system.

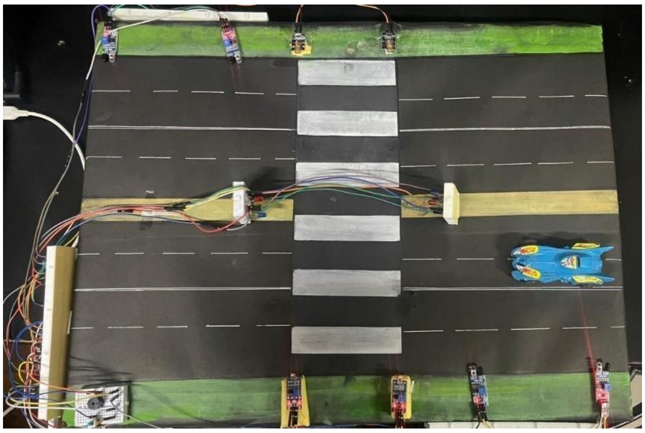

**Figure 11: Pictures of project**

## VI. CONCLUSION & FUTURE SCOPE

In conclusion, we have developed an intelligent, cost-effective traffic management system designed to efficiently manage traffic flow by incorporating innovative features such as a VIP preference module. This system dynamically shifts between three modules—Normal Traffic, Heavy Traffic, and VIP—based on real-time traffic conditions. By prioritizing VIP movements and adjusting to traffic congestion, it not only enhances traffic efficiency but also plays a significant role in reducing air and noise pollution, conserving fuel, and minimizing energy consumption.

Additionally, pedestrian safety is a key focus of our system. By integrating advanced laser sensors and LDR technology, the system detects vehicles that violate traffic signals and promptly alerts pedestrians through a buzzer, ensuring safer crossings. This approach aligns with local traffic regulations while offering significant potential for future scalability and development. Through IoT integration, the system can provide real-time traffic analysis, offering valuable insights to further optimize urban and metropolitan traffic management. Ultimately, our project paves the way for a safer, more sustainable, and efficient transportation environment, addressing modern traffic challenges and improving daily life for both commuters and pedestrians.

## References

[1] S. Javaid, A. Sufian, S. Pervaiz and M. Tanveer, "Smart traffic management system using Internet of Things,"2018 20th International Conference on Advanced Communication Technology (ICACT), Chuncheon, Korea (South),2018, pp. 393-398, doi: 10.23919/ICACT.2018.8323770.)

[2] R. O. Singh, P. S. Suryavanshi, R. R. Gandhi and M. H. Mulla, "Signaling and Vehicle Crossing with Smart Intelligent System (SVCSIS)," 2019 International Conference on Smart Systems and Inventive Technology (ICSSIT), Tirunelveli, India, 2019, pp. 1128-1131, doi: 10.1109/ICSSIT46314.2019.8987872.

[3] O. Jafari, S. Kolosov, N. Vo, A. T. Magar, J. Heikkonen and R. Kanth, "Intelligent Traffic Light Solution for Green and Sustainable Smart City," 2023 12th Mediterranean Conference on Embedded Computing (MECO), Budva, Montenegro, 2023, pp. 1-5, doi: 10.1109/MECO58584.2023.10154954

[4] K. K. Kumar, S. Durai, M. T. Vadivel and K. A. Kumar, "Smart traffic system using raspberry pi by applying dynamic color changer algorithm," 2017 IEEE International Conference on Smart Technologies and Management for Computing,

[5] Communication, Controls, Energy and Materials (ICSTM), Chennai, India,2017, pp.146-150, doi: 10.1109/ICSTM.2017.8089141.J. Hosur, R. Rashmi and M. Dakshayini, "Smart Traffic light control in the junction using Raspberry PI,"2019 3rd International Conference on Computing Methodologies and Communication (ICCMC), Erode, India, 2019, pp. 153-156, doi: 10.1109/ICCMC.2019.8819695.

[6] S. Ashwin, R. A. Vasist, S. S. Hiremath and H. R. Lakshmi, "Automatic control of road traffic using video processing," 2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon), Bengaluru, India, 2017, pp.1580-1584, doi: 10.1109/SmartTechCon.2017.8358631.

[7] Aizuddin bin Onn, S. Salim, M. S. Ahmad and M. Mahadi Abdul Jamil, "Development of a network-enabled traffic light system," 2014 IEEE International Conference on Control System, Computing and Engineering (ICCSCE 2014), Penang, Malaysia, 2014, pp. 241-244, doi: 10.1109/ICCSCE.2014.7072723.

[8] H. J. Naga, N. Nair, S. M. Jacob and J. J. Paul, "Density Based Smart Traffic System with Real Time Data Analysis Using IoT," 2018 International Conference on Current Trends towards Converging Technologies (ICCTCT), Coimbatore, India, 2018, pp. 1-6, doi: 10.1109/ICCTCT.2018.8551108.

[9] M. S. Ali Muthanna, Y. T. Lyachek, A. M. ObadiMusaeed, Y. Ahmed HazzaaEsmail and A. B. M. Adam, "Smart System of a Real-Time Pedestrian Detection for Smart City," 2020 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus),St. Petersburg and Moscow, Russia, 2020, pp. 45-50,doi:10.1109/EIConRus49466.2020.9039333.

[10] M. Razavi, M. Hamidkhani and R. Sadeghi, "Smart Traffic Light Scheduling in Smart City Using Image and Video Processing," 2019 3rd International Conference on Internet of Things and Applications (IoT), Isfahan, Iran, 2019, pp. 1-4, doi: 10.1109/IICITA.2019.8808836.

[11] S. Bhattacharya, M. R. Saad, S. Teoh, and S. A. Suandi, "An Efficient Traffic Management System Using Deep Learning and IoT for Smart Cities," IEEE Access, vol. 9, pp. 54239-54252, 2021, doi: 10.1109/ACCESS.2021.3070907.

[12] A. Shokry, M. Elhamshary, and M. Youssef, "DeepTrCL: A Deep Learning Approach for Traffic Light Control," IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 7, pp. 4483-4495, 2021, doi: 10.1109/TITS.2020.3031917.

[13] Y. Xu, H. Chen, Q. Kong, X. Zhai, and Y. Liu, "Urban Traffic Flow Prediction: A Spatio-Temporal Variable Selection-Based Approach," Journal of Advanced Transportation, vol. 2019, Article ID 4145353, 2019, doi: 10.1155/2019/4145353.

[14] M. Bani Younes, A. Boukerche, and G. Mammeri, "Context-Aware Traffic Light Self-Scheduling Algorithm for Intelligent Transportation Systems," IEEE Wireless Communications Letters, vol. 5, no. 1, pp. 40-43, 2016, doi: 10.1109/LWC.2015.2496166.

[15] Z. Li, M. Shahidehpour, S. Bahramirad, and A. Khodaei, "Optimizing Traffic Signal Settings in Smart Cities," IEEE Transactions on Smart Grid, vol. 8, no. 5, pp. 2382-2393, 2017, doi: 10.1109/TSG.2016.2526032.

[16] R. A. Khandekar, S. S. Thorat, and A. G. Patil, "Implementation of Smart Traffic Control System Based on Density Using Convolutional Neural Network," Journal of Engineering Science and Technology Review, vol. 11, no. 1, pp. 156-160, 2018, doi: 10.25103/jestr.111.19.

[17] J. Guo, Y. Kong, Z. Li, W. Jin, and H. Zhao, "Exploiting Macro and Micro Structures for Adaptive Traffic Signal Control," IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 6, pp. 3325-3336, 2021, doi: 10.1109/TITS.2020.2990436.

[18] S. Tarapiah, S. Atalla, and B. Alsayid, "Smart On-Board Transportation Management System Using GPS/GSM/GPRS Technologies to Reduce Traffic Violation in Developing Countries," International Journal of Digital Information and Wireless Communications, vol. 3, no. 4, pp. 96-105, 2013.

[19] M. Collotta, L. Lo Bello, and G. Pau, "A novel approach for dynamic traffic lights management based on Wireless Sensor Networks and multiple fuzzy logic controllers," Expert Systems with Applications, vol. 42, no. 13, pp. 5403-5415, 2015, doi: 10.1016/j.eswa.2015.02.011.

[20] P. Jagtap, A. Joshi, P. Bhawtankar, and A. Abraham, "Intelligent Traffic Light Control System for Ambulance Clearance and Stolen Vehicle Detection," International Journal of Computer Applications, vol. 178, no. 39, pp. 36-40, 2019, doi: 10.5120/ijca2019919251.