INTELLIGENT TRAFFIC MANAGEMENT SYSTEM

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A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

Department of Electrical and Electronic Engineering
Brac University
October 2024

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Department of Electrical and Electronic Engineering
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October 2024

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Approval

The Final Year Design Project (FYDP) titled “Intelligent Traffic Management System” submitted by

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of Summer, 2024 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor in Electrical and Electronic Engineering on 24-10-2024.

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Ethics Statement

Throughout our Final Year Design Project, we conducted extensive research maintaining the highest ethical standards. FYDP Group 01 ensured that all data and information utilized were gathered, cited and employed ethically by following IEEE guidelines. This project was carried out with honesty, integrity, impartiality and objectivity and any conflicts of interest disclosed. Proper citation and acknowledgment were given to all sources used. Additionally, a Similarity check has been conducted through Turnitin from our ATC. The similarity index achieved was 11% without the cover pages, table of contents and references. In simple terms, the ethics statement shows our dedication to carrying out the study responsibly and following the rules set by the IEEE. It's about being transparent and committed to doing things the right way.

Abstract/ Executive Summary

This research is concerned with the design of an Intelligent Traffic Management System (ITMS) that incorporates intelligent technologies to help optimize traffic, minimize risk and articulate for the environment. Specifically, the ITMS synchronizes data from real time data acquisition, traffic adaptive signal controls, and automated violations detection system in order to effect efficient control of traffic in urban space. This showcases how connected vehicle technology and platooning algorithms ensure emergency vehicles prevail at intersections and cause less congestion and risky driving. Further, it integrates the module of renewable energy like energy, sun power, and other relevant sources to meet its goal of energy-saving. It has enhanced efficient cruising to identify traffic offenders, issue electronic challans and real time analysis for traffic surveillance and management. This research also considers functional and non-functional requirements of the system for scalability, security and reliability. The work has a positive impact on developing the best strategies for traffic organization, proper response to different emergencies, and low negative influence on the environment.

Keywords: Real-Time Information, Emergency Vehicle Prioritization, Rule Violation Detection, Eco-efficient traffic management, Solar Energy and Traffic control.

Dedication

We would like to dedicate this project to the patients with serious illnesses who are often left in ambulances as the drivers traffic their way through the streets. This work is in response to the need to escalate priority of emergency services, and traffic control in order for no life to be lost on the basis of such delay. Our aim in this project is to support and encourage society in creating wiser, quicker, and more adaptive urban systems necessary for saving lives when no moment can be spared for the ambulance.

Acknowledgement

We would like to express our heartfelt gratitude to ATC-1 members, EEE Department and BRAC University for their encouragement throughout our academic journey. We owe them a debt of gratitude for their professional guidance, support, and inspiration in the course of our work on projects as well as our further ideas' development. To all those that assisted in making this project a reality, we extend our sincerest gratitude for the chance to learn.

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1.1 Introduction

In this project therefore, the goal is to design an ITMS which optimally incorporates intelligent technologies in the management of urban traffic. The system is aimed at solving such urgent problems as traffic congestion, high risks of accidents or instances of violation of traffic rules, and negative impacts on the environment – which are constituents of the challenges arising with the development trends such as urbanization and increasing traffic intensity. This project aims at improving the efficiency and safety of the transport system, and at the same time minimizing the impact on the environment through analyzing real time data, intelligent signal control, automated violation recognition and green power solutions. The ITMS will incorporate smart sensors, connected vehicles, and decision-making for traffic flow, secure access to priority for emergency vehicles, and safer for all road users. This chapter will begin by stating the purpose and the rationale for the project before proceeding to explain its scope in detail while the following chapters will present the detailed design and implementation of the planned system, as well as its implications for urban mobility.

1.1.1 Problem Statement

Traffic congestion therefore manifests itself where many vehicles are on the road for a long time without any opportunity to move from one part of the road to another or halts completely due to a buildup of traffic density which irritates commuters, wastes time and pollutes the environment. The road accident that occurs in Bangladesh costs 4,000 lives and 5,000 people's injuries per year, also having a stress on the emergency services alongside spending a lot of money in the healthcare and vehicle repairing services [1]. The national loss from the road accidents comes to around Taka Five thousand crore per year. Also, congestion in Dhaka wastes millions of working hours and amounts to Tk 37,000 crore ($4.35 billion) annually, which a developing country such as Bangladesh should not bear [2]. According to a recent World Bank report on Global Economic transformations for developing countries, Dhaka traffic congestion costs working hours of 32 lakh daily including Tk 20,000 crore annually [2]. Also, the lack of efficient traffic police to track violators fosters all forms of impunity thus contributing to the increase of traffic related risks. This is compounded by a lack of automated defaulter tracking systems which could track defaulters with the use of surveillance cameras besides adopting accidental detection algorithms. Also, current traffic systems use non-renewable energy; which is inconvenient and useless during black outs while creating traffic jams [3]. Solar power was a viable proposition as a traffic light system independent of electricity supply; a 300W solar panel with battery backup could power the system [4].

1.1.2 Background Study

Intelligent Traffic Management System commonly abbreviated as ITMS, is a complex solution that applies intelligent technologies to improve transport systems in cities. This system comprises smart sensors which act like tools that gather data concerning traffic and/or traffic problems and inform appropriate controls to take necessary actions that help control/manage traffic problems. Their plan is to establish and implement an integrated traffic management system with requisite traffic signal system, sophisticated monitoring features, violator identification with the help of an electronic challan, priority dispensing to emergency vehicles and managed power including solar power. In ITMS, the traffic data acquisition, configuration and visualization are employed to monitor and control traffic. Current data received from the controllers is recorded and shown through rigorous graphical interfaces to enhance the traffic handling [5].

Traffic control system design and traffic signal calibration entails utilization of traffic simulation tools including VISSIM or SUMO. Fundamentally, the suggested system of operation may be applied for a traffic control system called Virtual Traffic Light plus for Emergency Vehicle (VTL+EV) while assessment can be addressed with the help of Simulation of Urban Mobility (SUMO) and Sustainability Assessment of MATrix Inventory (TRACI). With C2C technology connected vehicles, the platooning algorithms, interconnectivity and cooperative exchange of information this system was able to give precedence to the emergency vehicles at the intersecting points [6]. These tools enable the traffic engineers to simulate an intersection, link road network, and control signals. The simulation methods can take input parameters like traffic volume, kinds of vehicles, signals timings, and movements of pedestrians, and estimate the traffic flow characteristics and potential performance of sanitary inadequate signal control algorithms. In the simulation, engineers are able to examine certain signal control approaches such as actuated control or adaptive traffic signal optimization to improve traffic flow. The software also displays real-time traffic movements, queue and intersection performance which allows for adjustment of signals and timings to control traffic movement.

Network emulation of smart traffic processing entails the development of the traffic sensors, cameras, and data processing algorithms. As part of the traffic analysis software for micro-simulation PTV Vissim also provides modeling of vehicle detection sensors, video cameras and data collection points at nodes and road links. As a result of traffic and sensor modeling, the engineers can estimate the applicability of the ranges of monitoring approaches in real-time traffic data acquisition. The simulation returns various measurements such as traffic volume, velocity, density together with the occurrences of noticeable events which can be used by engineers to determine optimum location of the sensors and algorithms needed in processing the real-time information for accurate and effective traffic monitoring.

The violator tracking and electronic challan system is best fitted with the ALPR software associated with the traffic simulation platforms. ALPR simulation tools give engineers flexibility in modeling virtual camera installations at desirable places within the traffic network. The system design can concentrate on accuracy enhancement and this is done using a C++ implementation of OpenCV and touch on the use of YOLOv3 in real time learning objects. The process of violation detection entails image preprocessing, and moving object identification, as well as violation identification, which use YOLOv3 for enhanced and efficient detection. Traffic violation identifying fundamentals includes image quality improvement by preprocessing, object detection by YOLOv3 algorithm, description of CNN architecture, Darknet-53 and Object detection by bounding box. This approach ensures correct detection of traffic violations that are effective by employing computer vision technologies [7].

Moreover, the system design can accommodate different approaches to detect moving vehicles such as background subtraction, frame difference, edge detection, optical flow, and block matching. Developed by Microsoft Visual Studio C++ and OpenCV, the system has a video loading module, violation detecting module, as well as the evidence saving module. The process for violation detection involves image pre-processing, detection of target vehicle, detection of violated rule, and record storing for overall traffic violation control [8]. Engineers for instance can drive and maneuver with the vehicles around the virtual environment; traffic offenses such as speeding can be executed and ALPR cameras capture the number plates of offending vehicles. They use the simulation to produce electronic challans automatically through a set traffic violation rules to show that the system can capture and penalize the traffic offenders. Computer simulation of how emergency vehicle prioritization is done requires a number of algorithms and traffic signal preemption techniques to be programmed in the routing software in the Global Positioning System. For identifying the vehicles and the emergency vehicles OpenCV and the Yolo algorithm must be employed; for determining the density of vehicles in every lane where signal timing must be decided OpenCV is useful; and in order to implement this system practically on Raspberry Pi with camera support the same must be used [9]. Emergency vehicle dispatching can be tested and signal coordination and response conjointly viewed in real-time by engineers. Furthermore, the system can use Road Side Units (RSUs) to record siren sounds from Emergency Vehicles and use some algorithm to detect unique frequencies using Dual-tone multi-frequency signaling for EV type identification and use area level image processing for estimating traffic density to calculate times taken by EVs to clear [10]. This way engineers can assess the impact of the response time of the vehicle, as well as control and reductions in traffic disruption that result from signal preemption commands. The simulation increases the understanding of how routing plans and signal control can be improved to support emergency vehicles.

Realizing solar powered ITMS will entail formulation of solar panel installations, battery storage systems, and energy controlling algorithms through simulation software. Solar energy simulation tools can help engineers in predicting the ability of solar panels, energy production and battery storage and this depends on the type of weather condition that is being simulated. Thus, the energy consumption and storage parameters can be modeled and the suitable size and place of the solar panels as well as the batteries can be determined to supply the requirements of the ITMS. The outputs generated by the simulation include energy balance reports and prove that the system can be both sustainable and economical in the long run. The ability to use simulation-based design tools enables traffic engineers to assess and optimize every aspect of the Intelligent Traffic Management System prior to implementation. Through the realism depicted by the application of ITMS, traffic control, surveillance systems, enforcement measures, emergencies, and integration of renewable energy, engineers can determine the efficiency, dependability, and capacity of the ITMS to enhance urban traffic and safety together. Very often, simulation-based design is the key to improving system configurations or performance characteristics and identifying and eliminating potential threats prior to their use in real traffic conditions.

1.1.3 Literature Gap

Although there have been various studies done on Intelligent Traffic Management Systems (ITMS) some major areas of consideration are still unexplored. One of the major shortcomings is the partial coupling of the numerous technologies that are used in traffic management. Most of the current research tends to take an individual aspect, for example adaptive signal control, or vehicle detection, whereas few of them deal with which combination of these approaches should be used for managing intricate traffic issues of cities. The absence of such studies hinders an assessment of the benefits of a coordinated ITMS in terms of the impacts made to traffic conditions and congestion and on emergency responses [11].

Another gap is what pertains to the absence of integration of real time data analysis and machine learning models in most of the existing traffic management systems. Despite this, most of the above technologies' performance has only been shown in simulation studies without actual implementations that learn from real time traffic information. One can consider the potential for researching new systems that utilize these tools for reaction to incidents as well as flow control in real-time [12].

Another important field, related to a prioritized driving of the emergency vehicles, is not very well covered in the literature. While the role of fast emergency response is recognized, little has been published regarding the design of real-time emergency vehicle detectors and signal preemption strategies. This gap is especially important because traffic congestion in cities is rapidly becoming a problem for increasing the time that emergency services take to respond to a call [13].

Also, little research attention has been paid to the incorporation of renewable energy solutions like solar energy into traffic management systems. The limited number of existing works only hints at the capability of renewable energy to alleviate ITMS's emissions; however, detailed analysis of the practical applicability and efficiency of the solar systems in traffic control is insufficient [14].

Last of all, as a part of the implementation of ITMS needs rigorous surveillance and data collection, the ethical considerations such as public's privacy and security are not adequately discussed. A need in current literature exists in studying the public awareness concerning these ITMS technologies, and guaranteeing these systems are implemented with ethical factors into perspective [15].

1.1.4 Relevance to Current and Future Industry

They have shown that the Project is highly relevant to current and future needs of the industry and is highly suitable for the current phase of rapid urbanization and increasing transportation needs. Here are key points outlining its significance:

1. **Smart City Initiatives:** As cities are gradually transforming into 'smart cities' part played by ITMS to fit this system; other things like analysis, technologizing of sensory systems, automatic control among other things. They enhance traffic flow monitoring, violation and control, emergency among other facets which are the building blocks of

modern cityS management. A rising number of smart cities worldwide indicates that ITMS is needed as a tool in the development of cities.

2. **Automation and AI Integration:** Incorporating advanced technologies like automation, artificial intelligence, and even machine learning across multiple industries, ITMS deploys the productions in developing smart traffic signals, violator identification, and dispatch of emergent vehicles. These systems do not just intend to control traffic flow but they also can lessen driver's decision-making, which makes them more relevant in industries that aim for autonomous systems and AI-centered decisions.

3. **Sustainability Goals:** The use of solar systems in ITMS is therefore a way of fulfilling the need of environmentally friendly innovations in the transportation sector. Companies all over the globe are embracing the use of renewable power sources and the solar traffic system is one way of achieving this since it does not rely on conventional energy sources.

4. **Transportation and Mobility Industry:** Through time though, cities expand, provoking concerns with regards to traffic, security and management of transport solutions. These challenges are uniquely met by the ITMS project through simulation tools, V2V communication and connected vehicle technologies. The future use cases for this technology can envelope self-driving cars, increasing the importance of ITMS in the transportation industry.

5. **Public Safety and Law Enforcement:** The specimen of violator tracking of ITMS and automated electronic challan systems have specific relevance for improving law enforcement. These technologies assist in scrutinizing compliance with traffic laws and minimize the human component in violator identification, preparing the way for wiser and more effective law enforcement as well as traffic management.

6. **Emergency Response Systems:** In terms of deploying ITMS, emergency services will benefit from the real time tracking and subsequently providing priority to the emergency vehicles. Such technology may prove to be very helpful in lowering down the response time and hence can change the future of healthcare, fire and law enforcement agencies in which response time defines life and property.

7. **Telecommunications and IoT Integration:** Because ITMS is primarily based on vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications, it opens new prospects for industries specializing in IoT (Internet of Things), telecommunications, and connectivity. As all real-time information exchanges between control centers, vehicles, and roads relating to traffic management, these industries are crucial to intelligent transportation.

8. **Big Data and Analytics:** ITMS collects extremely a great deal of data from traffic sensors, cameras, and other monitoring equipment. This is in parallel with the increasing need for data analysis from industries. The transport and urban planning industry can tap into big data analysis in order to have the ability in predicting and

understanding traffic patterns as well as instituting better planning on the cities. Businesses operating in data analysis, cloud services, and artificial intelligence can benefit from this dealing with a larger amount of data to provide superior services.

9. **Autonomous and Connected Vehicles:** The vehicle and traffic control will be also self-organized and managed by intelligent connected vehicles in near future. Particularly, ITMS, as a concept that is built upon integration of a vehicle to everything (V2X) technology, is one of the factors that set up an environment enabling L2 and L3 autonomous cars. This makes the project highly relevant to the automotive industry, and particularly to the creation of autonomous cars where integration with traffic systems is going to be critical.

10. **Infrastructure Modernization and Investments:** Since most of the governments and private sectors would continue to invest a lot of capital in the future to modernize the traffic system ITMS is ideal for replacing the current outdated traffic systems. Most of these upgrades are vital for alleviation of traffic jams especially in urban areas, increasing safety on roads while boosting future options of mobility in cities. ITMS will be especially recognized as a fundamental element of today’s transportation systems by industries focused on infrastructure construction, civil engineering, and urban planning.

11. **5G and Advanced Communication Technologies:** One of the significant factors that are critical to the implementation of ITMS is the accustomed and high-quality communication networks for the fast, accurate, and real-time traffics and prioritize facilities for emergency vehicle applications. The use of 5G technology as a means to perform low latency and very fast communication will boost the performance of ITMS. This is a compelling argument for the business case of the telecommunications industry to promote ITMS implementations, as 5G technology brings in higher data communication rates, traffic management and reliable Vehicle to Everything (V2X) connectivity.

12. **Smart Parking Systems:** In addition, the ITMS can also further its functionality to smart parking systems which are capable of directing drivers to available parking lots, through logistical information. This is important to industries engaged in the provision of parking solutions, real estate developers and traffic control as proper parking management relieves traffic congestion and congestion resulting from drivers in search of a parking area.

1.2 Objectives

In this project, we aim to develop an advanced system designed for intelligent traffic management systems, which will be powered by solar energy. The key objectives of our project are:

- Set up and Develop Traffic Signal Infrastructure
- Prioritizing Emergency Vehicles
- Monitoring traffic density and prioritizing lane
- Real time rule violation detection
- Power the whole System by Solar Energy

1.3 Requirements

1.3.1 Functional Requirements

a. **Traffic Monitoring and Analysis:** It should actively capture and analyze traffic on broad and areas of link connection by opting for a combination of sensors and cams. These will include quantities of vehicles passing through the point, speed at which these vehicles are moving and the type of vehicle passing through the point e.g. car, bus, lorry. It will also scan traffic data in order to make assumptions on traffic flow, regularity, density as well as time density. Using the big data and the new feed of data from the system, this analysis will employ machine learning techniques in order to predict congestion levels.

b. **Traffic Signal Control:** This means that the traffic signals have to be adaptive in view of traffic information in the road network and give a short wait time for roads with little traffic while giving longer time for a green light to be displayed on busy roads. The application of ASCT will incorporate signals that will use algorithms based on real time traffic conditions. This technology will enable the system to change the time signal of the traffic light as the traffic proceeds to the next sequential order.

c. **Violation Detection and Management:** The system will include highly sophisticated techniques in detecting traffic rules and regulation offenders such as speeders, light jumpers and lane-breaking offenders. These will include utilizing image processing and machine learning innovations to process information gotten from traffic cameras. On detection of a violation, the system will issue an electronic challan/ticket containing the necessary details such as the type of violation, the registration number of the vehicle, date and time, and location. These will be done through secure transmission to the relevant authorities for further processing and enforcement.

d. **Emergency Vehicle Prioritization:** The GPS will also be used to note the position of emergency vehicles such as ambulance, fire trucks etc., and hence, when noted, the system will change signal status to reduce delay in response of these emergency cars across the junctions. It then may also help to direct emergency vehicles to the correct location taking into consideration traffic congestion and allow the emergency vehicle to get to the location quicker by being informed with current traffic details.

e. **Data Collection and Reporting:** traffic data from sensors, cameras, traffic signal controllers and other related sources will be collected by the system on a continual basis. Some of the data will be used in real time and other data will be used in strategic planning in the future. The system will log comprehensive reports of traffic patterns, traffic congestion and violation facts which are strategic in policy formulation for the city planners and traffic authority departments.

f. **Public Information System:** There would be electronic boards to show traffic updates, congestion, an incident, or other related occurrences besides reporting on available detours, at points of interest at a given instance. In addition, a mobile application and website will give the user, traffic information, warnings, and recommendations of the best route to follow. The app also has options for traffic conditions updates, road closures and emergency information for travelers, so that they can plan their journeys properly.

g. **Solar Power Utilization:** The system shall incorporate photovoltaic solar power to light the traffic signals and monitor equipment and information billboards for environmental conservation and efficient utilization of energy. The system will incorporate a battery storage solution to provide adequate power supply when the sun is not shining, or at night. Energy handling algorithms will control charging and discharging of batteries stored in the system.

h. **Safety and Security Measures:** Physical security of the hardware will also be included in the system security, such as locked cabinets, preventing vandals from destroying, or even stealing physical components of a system. That is why stringent security will be provided with the purpose of protecting the system from cyber incidents. This ranges from proper encryption of data communications, bi annual security checks, and following of proper network security protocols. It will also possess redundancy features to enable the system to continue running in the event that some parts or components are attacked by cyber criminals. Critical functions mean there will be a backup system in case of emergencies so as not to disrupt service.

i. **Maintenance and Support:** Proactive maintenance plan that covers both the hardware and the software aspect of the system will be developed so that to appropriately and regularly maintain the system. This ranges from normal physical checks on the facility and its equipment, and changes of software among other activities. Operators and users can expect to receive technical assistance from a technical support team that will be assigned within the system. Other support services will be remote monitoring and diagnostics.

j. **Compliance and Standards:** The system will meet the traffic management standards and practices of the country and other global practicing countries, thus enabling compatibility with other traffic systems and facilities. ITMS will be specially designed and integrated with the best internationally accepted environmental code of practices, and environmental compliance measures will also be implemented to reduce the ecological impact it will have in the environment to the maximum acceptable level making use of available efficiency energy levels.

1.3.2 Non-functional Requirements

a. **Reliability and Availability:** The system has to exhibit high availability to guarantee the efficient needed level matching at least 99.9% uptime to avoid interrupting traffic control. To achieve this, there will be backup and standby systems to come in in the event that one of the components fails, and the transfer will be done without having to be done manually. Reliability: They should be planned during low traffic density in order to avoid significant disruption to operations and usage can be monitored and potential problems detected so that repair work is done during the low traffic density.

b. **Performance and Efficiency:** The ITMS should be capable of processing a massive influx of real-time traffic data within a brief period of time with a view to initiating early modification of signal timings and violations. Its design should also factor in the growth of the traffic network as it will have to grow in future. Using efficient algorithms, the system will render real-time decisions on traffic signals and transfer priority for necessary vehicles to achieve efficient network flow while achieving high traffic throughput without system sluggishness or congestion.

c. **Security:** A strong security system should be adopted so that ITMS should not be exposed and hacked by a third party. Encryption methods should be applied to secure the end-to-end communication and the network should be protected by firewalls and IDS. Specific information like the driver information being captured need to be protected, only allowed access to those personnel with privileges to do so, while at the same time the system needs to be secure to protect the captured data.

d. **Usability:** The general and operator interfaces should both be easy to understand and navigate; there should be sophisticated graphics. While traffic operators must have full access to real-time data visualizations in traffic control dashboards, other citizens and riders can check traffic status and receive proper notifications without much difficulty. Recursive control, meaning that users must be able to approach the system through features such as a screen reader or vocal commands in regard to disability.

e. **Maintainability:** The ITMS should also be easy to maintain: its components should be built in a modular style to maximize the speed with which parts can be replaced or upgraded without concomitant system instability. In addition, there must be ways to monitor the device remotely so that the system can diagnose and address problems in real-time, to make the needed predictions for maintenance. Software modifications must not be made while the system is down and should be able to allow for future technology integration without having to shut down the system.

f. **Interoperability:** The system should be compatible with other traffic management systems and compatible with hardware and software types. It should also work with old platforms, as well as with other applications, in other words, being an integration kind of software. The availability of the open API will supplement this aspect to improve its compatibility with other municipal systems such as public transports, and emergency services to provide a systematic approach to traffic management in cities.

g. **Sustainability:** Energy efficiency has to be one of the fundamental concepts to follow, with the solar power for the application only used for vital systems such as traffic lights and sensors. To some extent, the ITMS should opt to use renewable energy rather than depending so much on the nonrenewable energy. Individual pieces used to make up the parts of the system must be tough, environmentally friendly and usually made to last long, so that there are little chances of having to replace the components hence making the environmental impact of the system minor.

h. **Disaster Recovery and Business Continuity:** Real-time data protection methods and the disaster recovery site as well as backup systems should be set up far from the original to maintain functionality in the case of a catastrophe. The system has to allow for quick recovery solutions to be implemented to bring back full functionality while also ensuring that traffic management services are available regardless of any situation, from fires to hurricanes and other forms of cyber warfare.

i. **Quality of Service:** Commitment and dependency are essential, and SLAs are used to define what needs to be done and when problems have to be solved. The organization should set research activities and system audits or quality assessments should be conducted to ensure that the organization retains high standards of service delivery. The ITMS needs to provide accurate information in real time so that traffic moves freely and the components of the system function at their maximum capability.

j. **Flexibility and Customizability:** The system work must also be variable to capture the various traffic conditions across the various jurisdictions so that local authorities can set signal timing, violations, and report formats. Any user interfaces that are to be implemented should be made customizable for the operators, police force, and the public in that the users have their private control panel. It should be also possible to enhance new features of them; this aspect should allow the system to be adapted to the future changes of traffic flows and the appearance of new technologies.

1.4 Specifications

Table 1: Specifications according to subsystem

Subsystems	Components	Specifications
1. Solar Power Subsystem	Solar Panels	Efficiency: ≥ 20% Power Output: ≥300W per panel, 12V
	Inverters	Efficiency: ≥ 95% Output Capacity: Matched to panel output, typically 500W - 5kW
	Batteries	Type: Lithium-ion Capacity: Minimum 5kWh, scalable as per need Backup: 48 hours
	Charge Controllers	Type: MPPT Efficiency: ≥97%
2. Traffic Surveillance Subsystem	HD Cameras	Resolution: 1080p (1920x1080) or higher Frame Rate: 30 fps Night Vision: Effective up to 50 meters
	Infrared Sensors	Range: Effective detection up to 30 meters
	Radar Detectors	Speed Detection Range: 10 km/h to 200 km/h Speed Detection Accuracy: ±5%
3. Signal Control Subsystem	Traffic Light Controllers	Control Cycles: Adjustable, typically 60-120 seconds
	LED Signal Lights	least 50,000 hours of lifespan. (LED traffic Lights)
	Pedestrian Signals	Countdown Timer Range: 10-60 seconds
6. E-Challan and Law Enforcement Subsystem	ANPR Systems	Read Accuracy: >98% Operational Range: 5-30 meters
	Handheld Devices	Battery Life: ≥8 hours Display: Minimum 5-inch screen
	Database	Encryption Standard: AES 256-bit
8. Emergency Response Subsystem	Emergency Vehicle Detection Systems	Detection Time: <1 second
	Priority Signal Controllers	Response Time: <2 seconds

1.4.1 Technical considerations

a. **Data Integration and Interoperability:** The ITMS has to pull datasets from complementary sources, in this case traffic sensor data, automatic cameras, and GPS automobiles. Integration of these systems is usually a critical success factor to the exchange of data and information. This includes employing standard protocol and API that enable interoperability between different parts of the system and the existing traffic management system.

b. **Scalability and Flexibility:** This system should be expandable so that when the size of the urban areas increases or the intensity of traffic flow varies, the system is upgraded to meet this new demand. This comprises the flexibility to incorporate more sensors, cameras and figuring out units devoid of a drastic redesign of the system. Also, some level of flexibility in system architecture will allow integration of new technologies within the system framework such as enhanced AI algorithms or extra traffic control options, when they are developed in the future.

c. **Real-time Data Processing and Analytics:** The ITMS should have powerful real time data processing systems to determine traffic flow and patterns and to detect violators and emergency vehicle precedence. This requires the use of efficient algorithms and hardware means that will allow analyzing large volumes of data to be processed with high accuracy. It is advisable to use cloud or edge computation solutions if the speed of data processing and high latency is deemed important.

d. **Reliability and Redundancy:** Maintaining high reliability and availability is paramount to the efficiency of the ITMS, a reason why it needs to be embraced. Backup sensors or server examples should be incorporated to ensure continuity when the actual set of devices are faulty. Also, failure control checks and management time lines should be set, by which signs of potential problems could be spotted and resolved early on so as to prevent frequent disruptions and downtimes regarding traffic flow.

e. **Security and Privacy:** Since the ITMS will collect large amounts of data including surveillance data, stringent safety measures need to be put in place to safeguard the information from hackers. This in a way covers issues such as data transmission, storage, and control proactively by protecting the data stored or in transit and limiting user’s access to the data strongly. Moreover, the system should observe the necessary rules of privacy legislation and ethical norms because the public is worried about surveillance and the usage of obtained information.

1.4.2 Non-Technical considerations

a. **Public Acceptance and Community Engagement:** To achieve the goals of ITMS more attention should be paid to the people and local communities. People’s acceptance plays a major role in influencing the outcome of the project. People’s misunderstandings that are tied with the work of a CCTV system, availability of their video surveillance, and other issues that the concerned population may have can be overcome with the help of informative campaigns and meetings. Stakeholders who are guaranteed a seat in the dialogue about decisions that affect them are more likely to be in a positive disposition towards the process.

b. **Regulatory Compliance and Legal Issues:** The traffic management of the project and protecting data privacy has to respect local, national and international rules. The following areas of knowledge are crucial for decision making to avoid legal pitfalls, such as data protection laws. Developing and involving legal consultants early enough on the project may come up with new compliance measures.

c. **Economic Impact and Funding:** More importantly the following questions must be addressed: What are the economic consequences of the ITMS? Note the insertion of how it will be financed, and if it is from public or private financial resources or both. Also, if one can quantify the economic gains such as the congestion cost avoiding and the benefits of faster response to emergencies, this can be used in resource mobilization.

d. **Stakeholder Collaboration:** Various parties which include the government, transport ministry, fire and rescue departments as well as other traders should be involved in carrying out the project. The documents show that cooperated communication channels and effective partnerships can enable them to collocate and coordinate for making the system closer to the needs of all the participants.

e. **Training and Capacity Building:** Because an ITMS is an information management system, personnel training has to be done so that the systems can be operated and managed correctly. As with any successful undertaking, the required skills and training needs must be evaluated to get the right people for the job. In capacity-building Programs there are provisions which can improve the employees' competencies so as they can be able to cope with new technologies and processes which the ITMS brings more often.

1.5 Constraint

a. **Budgetary Constraints**: One of the greatest challenges that come with implementing an Intelligent Traffic Management System (ITMS) is the unavailability of funds. That is because such constraints can limit the areas to be covered within the project, the kind and amount of technology and materials adopted. This may lead to the use of substandard solutions that will reduce the efficiency of the system in place. Budget management and control are of uttermost importance and discussing proposals for grants or cooperation to enhance the project's potential within the budget constraints.

b. **Technological Limitations:** The use of the ITMS depends on the present technology's advancement such as AI, sensor precision, and data analysis. This means that if the technology is inadequate, the system is incapable of correcting traffic signals or even high priority vehicles. Technological enhancement is crucial in organizations but incorporating the use of modern technology may involve handsome capital Investments thus act as a bottleneck to technologies even when they are vital in organizations.

c. **Environmental Factors:** In light of this, the ITMS has to be made with different environmental challenges like weather and temperatures. These factors can restrict options as to the kinds of materials and technologies to be used as components have to be robust and resistant to bad climates. Accomplishment of the environmental variables is critical to maintaining system reliability across different environments.

d. **Infrastructure Compatibility:** Unforeseen phenomena of interaction between the studied ITMS and the existing urban infrastructure may appear which could require significant changes and, therefore, additional costs. Old traffic signals and roads present various problems in the operation of the public transport system. System requirements should be analyzed to ascertain areas that require enhancement, so that the ITMS can operate optimally with the current infrastructure they currently possess.

e. **Public Acceptance and Privacy Concerns:** It is thus desired that at this stage the ITMS can get public acceptance on issues of surveillance and data collection. That is where privacy concerns may result in community opposition. This is why customer-oriented communication concerning data use and protection is crucial, as well as raising awareness in society to obtain the acceptance of data queued by the Internet.

f. **Maintenance and Operational Challenges:** To sustain the running of ITMS proper maintenance is needed and this cannot always be done everybody and it needs professional skills. Updates that occur timely and General deterioration of products and services come under operational management. To ensure long-term success, the maintenance plan must include the current and future inspections and fast response strategy.

g. **Power Supply Reliability:** With the use of solar energy being environmentally friendly, the energy has some down sides due to weather conditions. Energy storage is required to keep the power generated from the system afloat at those times when little solar power is being produced. There must be a proper energy management system to measure power consumption and help to make necessary changes.

h. **Installation Disruptions:** Implementation of the ITMS may interrupt temporarily the traffic stream, and therefore, traffic should be regulated skillfully to prevent congestion. There are several recommendations for project managers as follows; They should also provide a clear action plan for implementing change especially traffic management plan and public informing when undertaking the installation process.

i. **Workforce Training:** Building the necessary awareness in personnel to run and manage an ITMS remains complex, especially in cases where the technology is deeper. Hence, it is critical to develop a clear structured training program to ensure that staff is effectively trained. Training can be improved and partnered with educational institutions or hiring competent trainers or sharing the responsibility with competent trainers can also be helpful in achieving the training goals.

j. **Resource Availability:** High skill labor, good quality materials and technology can be a constraint of implementing a project especially in the developing regions. Making partnerships with educational centers can lead to creation of human capital and cooperation with reliable suppliers can allow using necessary materials. More to that, identifying other sourcing strategies could help to enhance project success and delivery with limited resources.

1.6 Applicable compliance, standards, and codes

Table 2: Description of the applicable standards and codes

Subsystem	Standards	Definition
Solar Energy & Electrical Standards	IEC 61215	For testing crystalline silicon solar modules.
	IEC 61730	Safety qualifications for photovoltaic (PV) modules.
	IEEE 1547	Standard for interconnecting distributed resources with electric power systems.
	BNBC	For electrical safety and installations.
Traffic Signal & Control Equipment:	ITE	Pertaining to traffic signal equipment.
	NEMA	Traffic control systems.
	BRTA	For local traffic regulations and signal standards.
Camera and Surveillance Systems	IEC 62676	Video surveillance systems for use in security applications
	ISO/IEC 19794-5	Standards for facial recognition, in case it's considered in the future.
Communication & Data Transmission	IEEE 802	Standards for local, metropolitan, and other area networks.
Sensors and Detection Systems	IEC 60529	Degree of protection provided by enclosures (IP Code).
Database & Software:	ISO/IEC 9075	SQL standard for database management.
	ISO/IEC 27018	Protecting personally identifiable information in public clouds.
Environmental & Equipment Protection:	IEC 60068	Environmental testing of electronic equipment

	IEC 60529	for equipment protection against intrusion and environmental factors.
Vehicle Identification & Number Plates	BRTA	Specifications for vehicle number plates and identification.

1.7 Systematic Overview/summary of the proposed project

The proposed Intelligent Traffic Management System (ITMS) utilizes a range of advanced technologies to optimize urban traffic flow, enhance road safety, and improve overall efficiency. At the core of the system are real-time traffic monitoring sensors such as cameras, radar, and induction loops that continuously collect data on vehicle movement, traffic density, and congestion patterns. This data is processed using data analytics algorithms and fed into a centralized traffic management platform that dynamically adjusts traffic signal timings based on current conditions, utilizing adaptive signal control technology.

The system integrates traffic simulation tools in SUMO to model traffic patterns and test signal optimization strategies in a virtual environment before implementation. These simulations allow for the design and testing of signal coordination, emergency vehicle prioritization, and congestion management algorithms. For violation detection and enforcement, the ITMS employs Automated License Plate Recognition (ALPR) systems powered by image processing technologies like YOLO v3 for real-time object detection. These systems capture violations such as speeding or red-light running, automatically generating e-challans for offenders through a seamless electronic processing system.

To prioritize emergency vehicles, the system incorporates GPS-based vehicle tracking and signal preemption algorithms that modify traffic light sequences to reduce wait times at intersections. Solar energy systems, including solar panels and battery storage, are integrated to power the ITMS, ensuring sustainability and reducing dependence on the grid. The system also features a public information component that displays real-time traffic data and alerts on electronic boards, mobile apps, and websites, allowing commuters to make informed decisions about their routes.

In addition, data collection and reporting modules gather extensive traffic data over time, providing city planners with insights for long-term infrastructure development. Cybersecurity measures are implemented to protect sensitive data, including encryption and secure data storage solutions. The ITMS is designed with modularity in mind, allowing for easy upgrades, compatibility with existing infrastructure, and future expansion. Redundancy systems and disaster recovery protocols ensure continuous operation even in cases of system failure or extreme weather conditions, making it a reliable and robust solution for modern traffic management.

1.8 Conclusion

In conclusion, the Intelligent Traffic Management System (ITMS) represents a transformative solution aimed at addressing the growing challenges of urban traffic congestion, road safety, and environmental sustainability. By leveraging cutting-edge technologies such as real-time traffic monitoring, adaptive signal control, automated violation detection, and renewable energy integration, the ITMS offers a comprehensive approach to improving urban mobility. It not only enhances traffic flow but also ensures safer roads and more efficient emergency responses. Additionally, the system's reliance on solar power promotes environmental sustainability, reducing the carbon footprint of urban transportation systems. As cities face increasing demands on their infrastructure due to urbanization, the ITMS provides a scalable, flexible, and future-ready solution. This chapter has provided an overview of the project’s goals, key components, and technological underpinnings, setting the stage for the detailed exploration of its design, implementation, and expected impact in subsequent chapters.

Chapter 2: Project Design Approach

2.1 Introduction

In this chapter, we present two distinct approaches for traffic management: Centralized system and Decentralized system. The idea is to determine which of them, if subject to the same conditions, can manage traffic flows more efficiently. By these systems, we would like to evaluate such factors as emission concentrations, trip distances, waiting time, and global traffic. From the following two approaches, the utilization of technologies including the automatic violation detection systems, emergency response systems, as well as the provision of solar power systems are incorporated in the Intelligent and Sustainable Traffic Management System. To compare both approaches, we require a reliable simulator with which we can model all the required conditions.

The Simulation of Urban Mobility (SUMO) software is a strong traffic simulator with intermodal traffic solutions and model validation in the current open-source [16] platform. Some of the benefits include, It facilitates the evaluation and calibration of large transportation systems in a simulated environment. The utility of SUMO in addressing traffic problems and designing approaching urban transport solutions makes them free from real life vulnerabilities and interferences as it enables planners to simulate different methods of placing them before implementing them [17]. Like SUMO, other microscopic traffic simulations also show movement of each single vehicle and analyze various characteristics like acceleration, deceleration and lane changing movements [18]. These simulators serve as an enhancement of other tools such as Synchro that are well-suited for generating foundational traffic signal designs, but are insufficient for accurate live-time optimization [17]. The availability of modeling dynamic traffic conditions by SUMO helps transporters to plan adaptive traffic signals effectively and improve intersection performance due to escalating traffic problems. Moreover, optimizing traffic signals has gone beyond the static plans and developed into the sophisticated actuated model that adapts to the 'on' situations on the roads [18]. Still, the use of methods such as adjusting cycle length, green splits, detector placements in simulation studies contributes positive outcomes to the traffic control system according to SUMO, even if it follows the high computational cost. To validate our results, we developed a SUMO traffic simulation network that mimics real-world road conditions as accurately as possible. The chapter compares outcomes derived from the two strategies from several simulation files on emission, trip information, and a summary. This comparison will give insight into the system, better hostile for different traffic conditions, it will give direction for the next traffic management system in future.

2.2 Identify multiple design approach

Approach 1: Centralized System

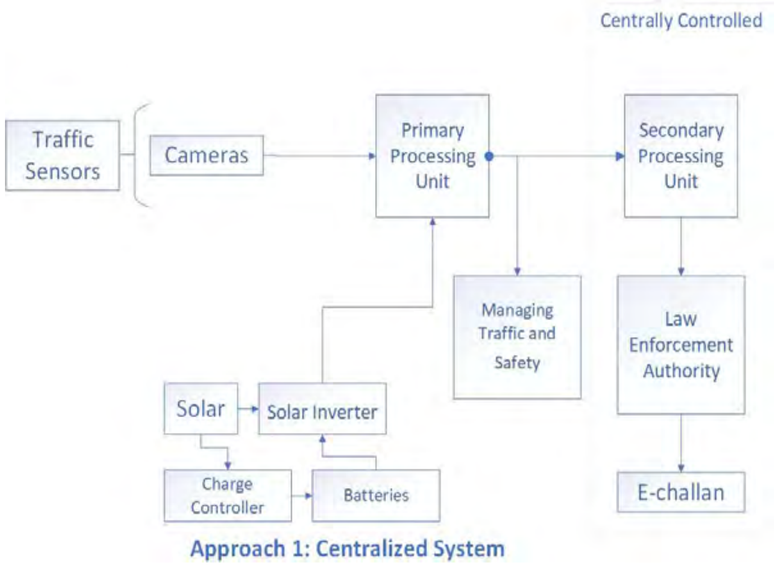


Figure 1: Block Diagram of Approach 1

Approach 2: Decentralized System

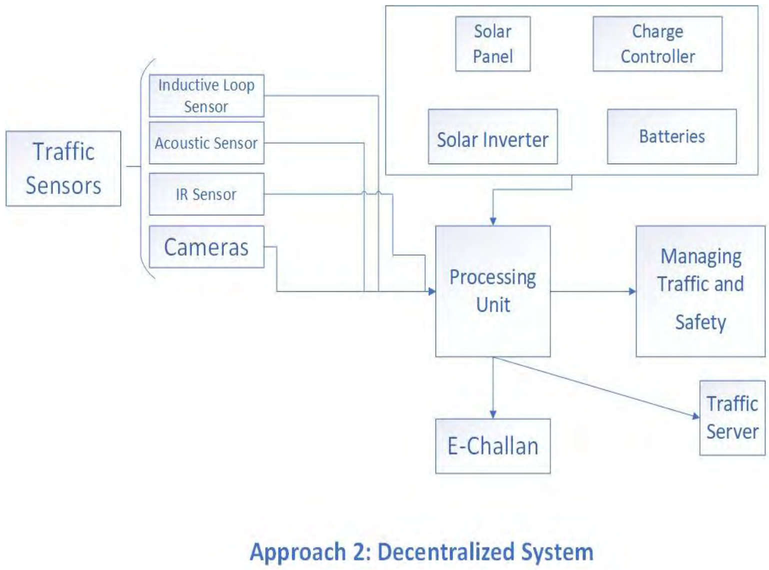


Figure 2: Block Diagram of Approach 2

2.3 Describe multiple design approach

Approach 1: Our first approach for a traffic management system is designed in such a way. At its heart, there are the two Processing units, Primary and Secondary, servers that use advanced data processing and artificial intelligence to make decisions. It's like the brain of the operation, analyzing data from a network of cameras strategically placed at busy intersections and key points on the road. These high-tech eyes and ears capture everything from speed to sound, giving us a comprehensive view of traffic conditions. A key feature of our system is the

Integrated Emergency Response System. It's specially set up to quickly identify emergency vehicles, like ambulances and fire trucks, ensuring they get through traffic swiftly and safely. This is part of the Primary processing unit, which alters the traffic flow according to different situations. Another crucial part of the system is the Automated Violation Detection and Processing. Here, we use machine learning to spot any traffic violations. This clever tech can automatically issue fines or warnings, keeping everything in line with legal requirements, which is a part of the secondary processing unit. To power all these, we've gone green with Solar Power Integration. We've installed solar panels at major junctions and along highways. These not only harness sustainable energy but also feed into battery storage units, making sure the system runs smoothly around the clock, even when the sun isn't shining. Lastly, there's the User Interface and Reporting System, designed for traffic management authorities. This dashboard gives them a real- time view of traffic, allows them to control various aspects, and provides regular reports. It's a tool for both immediate management and long-term planning, helping to keep our roads safe and efficient today and in the future.

Approach 2: Decentralized System in our decentralized traffic management system, each intersection operates autonomously with its own processing unit. These units are like mini control centers, capable of making local traffic decisions. Each intersection is equipped with smart traffic signals. These signals have sensors and cameras that process data locally, enabling them to respond dynamically to real-time traffic conditions while still being integrated into the larger network. A key feature of this system is the distributed emergency vehicle recognition. Each intersection's unit can independently detect and prioritize emergency vehicles, ensuring a coordinated response across the network to facilitate clear and swift passage. For traffic rule enforcement, we employ violation detection parts. These are specialized for different types of violations like speeding, running red lights, or illegal turns. The modular nature allows for easier maintenance and future upgrades. Powering this system, each unit has its own solar panel and battery storage, ensuring consistent operation even in parts of the network that might experience power issues. This self-sustaining approach enhances reliability and reduces dependence on external power sources. Data management is decentralized as well. Each unit handles its own data storage and processing, with periodic synchronization to a central database. This setup offers a robust solution for data handling while still providing traffic authorities with access to both local and network-wide data through a user interface, facilitating efficient monitoring and management of traffic conditions.

2.4 Analysis of multiple design approach

We ran the two approaches in the SUMO which is a traffic simulation software. We created the environment and a network based on our real-life roads and kept all the parameters the same except for the traffic controls for each of the intersections. In the first simulation all the intersections are coherence and synchronization. In the second approach the intersections all the traffic systems have their own logic sets and they work based on that. We tried to keep our sample network to resemble the real network that we are working on because keeping the original map becomes computationally heavy. We kept the diagram for both approaches the same because we want to compare the output parameters for equal scenarios.

Diagram of the network:

Approach 1:

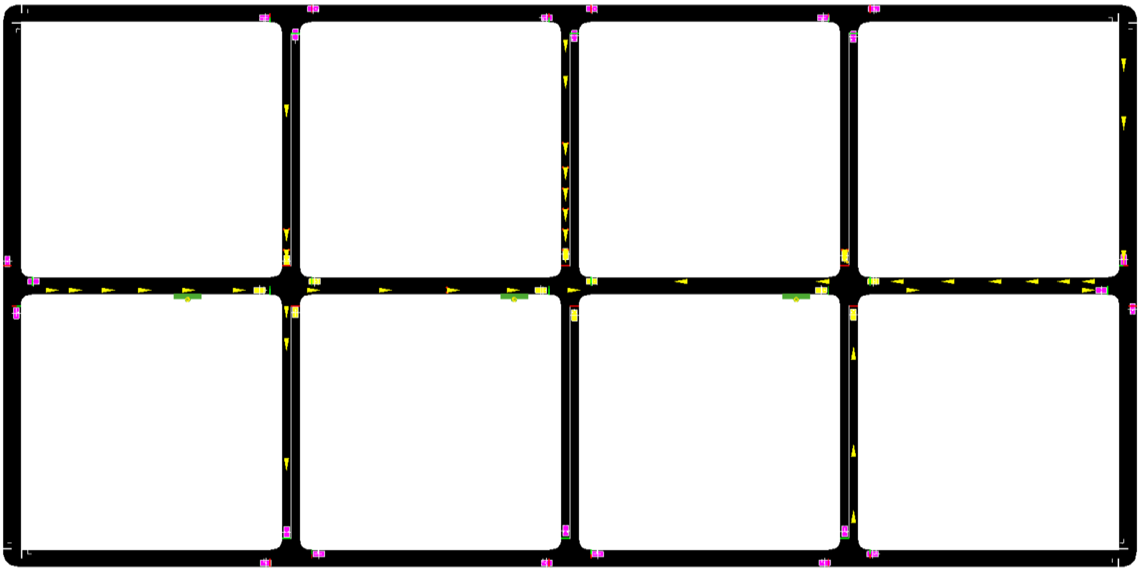


Figure 3: SUMO Network Diagram for the Centralized Approach (Approach 1)

Approach 2:

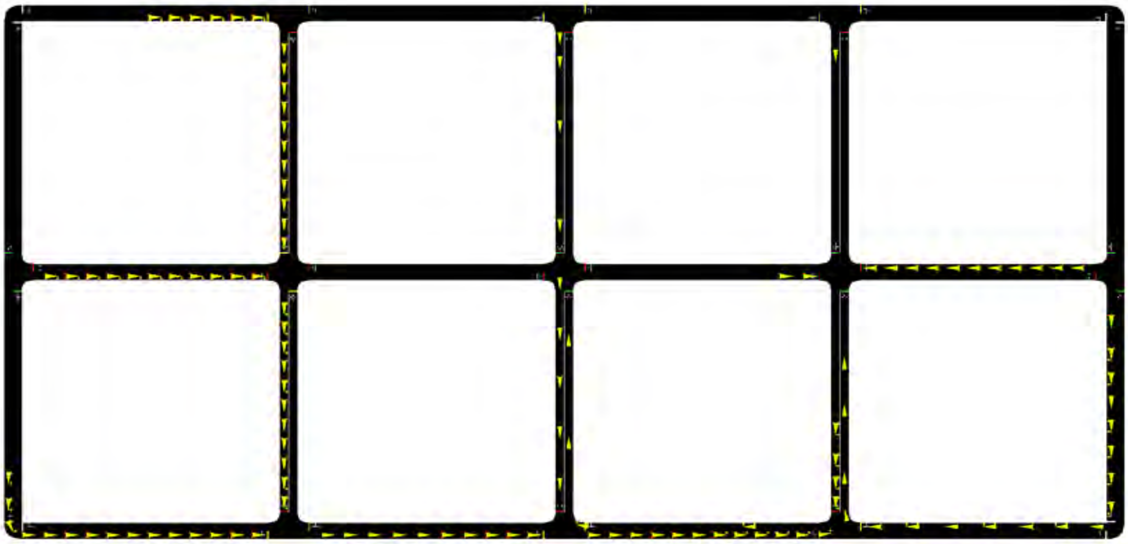


Figure 4:SUMO Network Diagram for the Decentralized Approach (Approach 2)

The flow of the car or the vehicle flowing rate we kept it the same that is 1000 cars per hour in each intersection. We ran the simulation for 3600s with the step of 0.5. We modified the SUMO config file so that we can get different output packages for our analysis. The files we took were emission file, trip info file and summary file.

File Description:

Emission File: The emission file is an essential component of SUMO's output that details the environmental impact of traffic. It records the emission of various pollutants, including carbon dioxide (CO_2), nitrogen oxides (NO_x), particulate matter (PM_x), and others, for each vehicle at different times throughout the simulation. This data is crucial for assessing the environmental footprint of traffic under various conditions, such as different vehicle types or traffic management strategies. Analyzing the emission file helps environmental researchers and urban planners devise methods to reduce vehicle emissions and mitigate their impact on urban air quality.

Tripinfo File: The trip info file provides a detailed account of each vehicle's journey within the simulation environment. This file includes comprehensive information such as travel time, waiting time, the total distance traveled, and departure and arrival times. The primary purpose of this file is to analyze the efficiency of travel and the level of congestion within the traffic network. It allows traffic engineers and city planners to gain insights into how long vehicles are spending on their journeys and how much of that time is idle, such as waiting at traffic signals. This information is vital for evaluating traffic flow, optimizing routes, and improving overall traffic management systems to enhance transportation efficiency.

Summary File: The summary file offers an aggregated view of the traffic system's performance over set intervals throughout the simulation. It includes key statistics such as the number of vehicles entering the network, those currently running, and those that have completed their trips, along with average speeds. This file serves to provide a high-level overview of traffic conditions and network performance, reflecting changes in traffic density and flow efficiency over time. Urban traffic administrators utilize the summary file to quickly assess the effectiveness of traffic measures, monitor trends in network utilization, and strategize long-term traffic management solutions.

Analysis: We took the data we got from our simulation and from the emission file we got the environmental impact dataset. From that we plotted the CO_2 emission data chart. First of all, we generated a heatmap with the data for both of the approaches.

Approach 1:

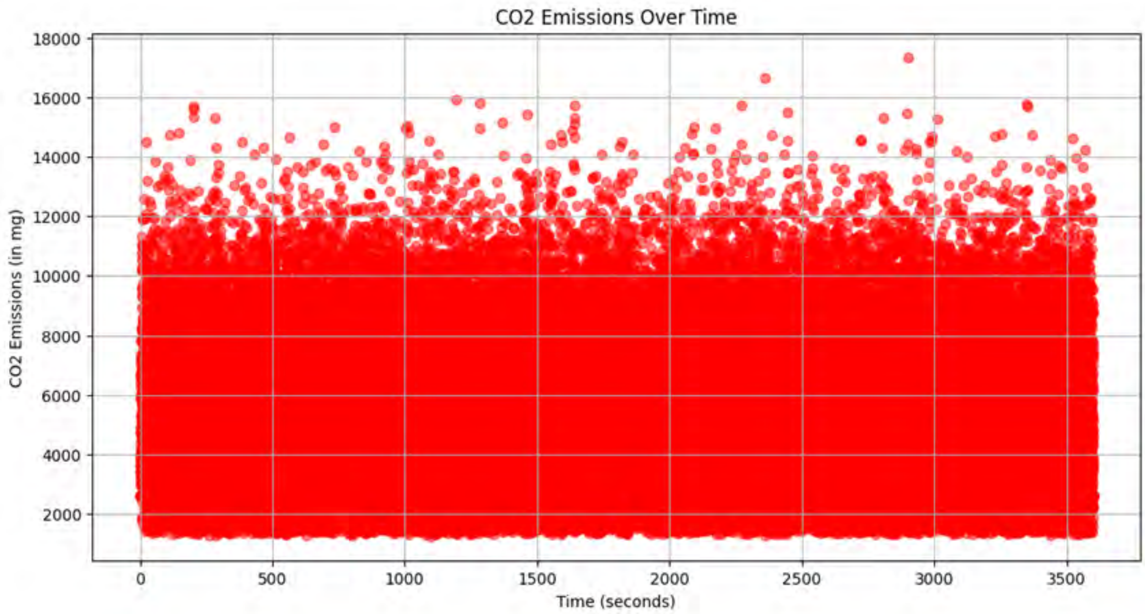


Figure 5: CO2 Emission Heat Map for Approach 1 [SUMO]

Approach 2:

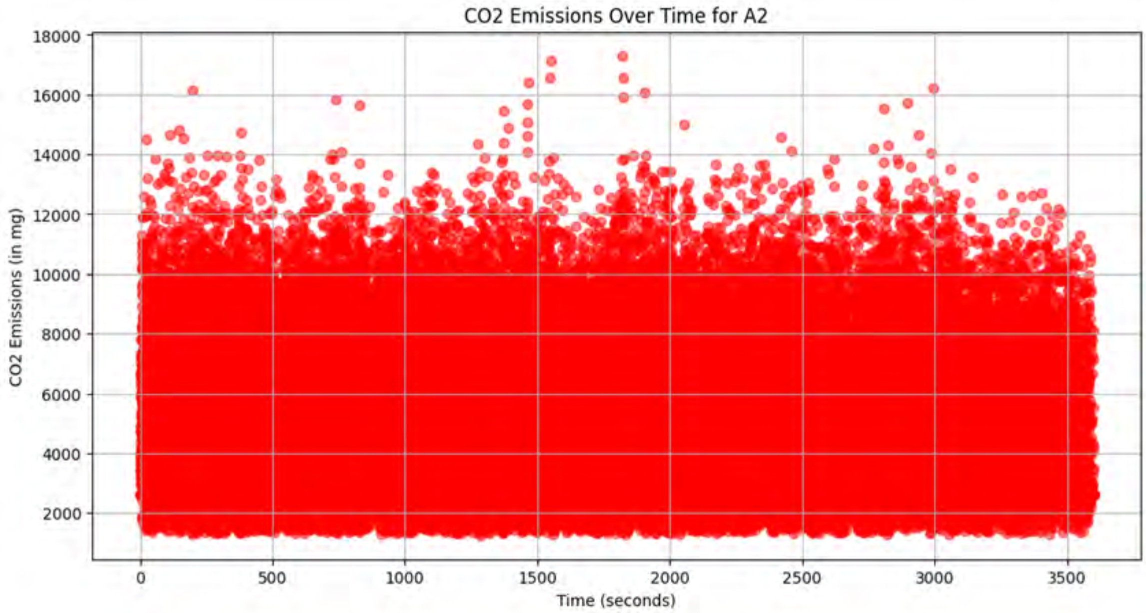


Figure 6: CO2 Emission Heat Map for Approach 2 [SUMO]

To understand the graph better and compare them we calculated the mean median and the standard deviation of the data we got so we can get a better understanding of the output of emissions.

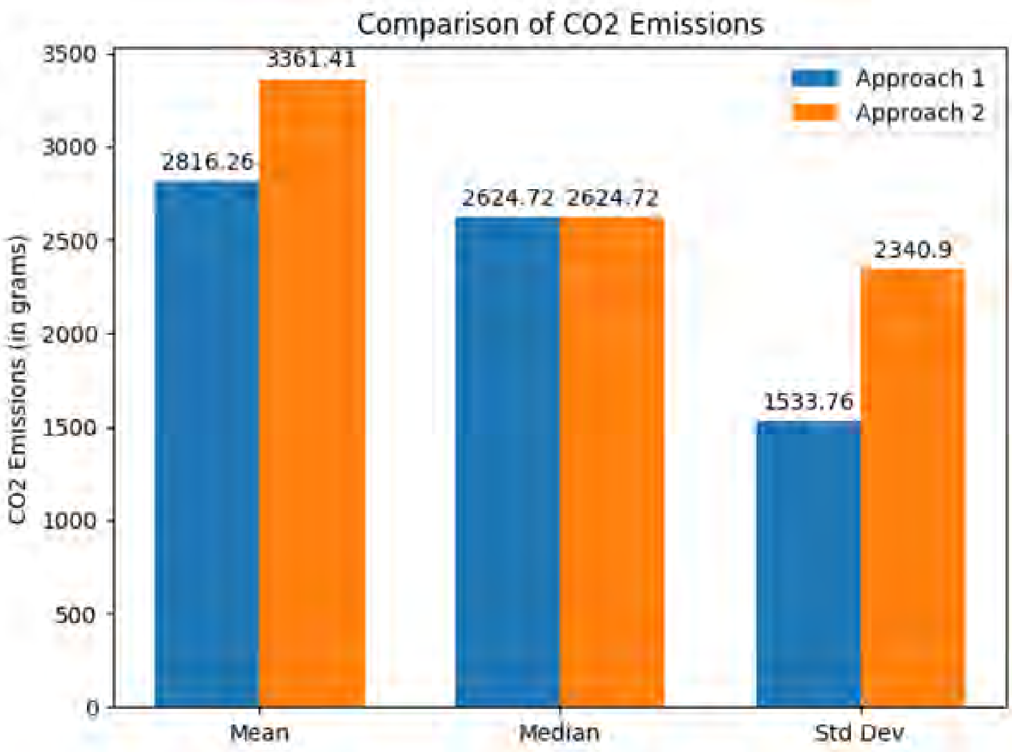


Figure 7: Mean, Median and standard deviation of CO2 Emissions of the two Approaches. [SUMO]

Here from the graph, we can see that the emission for approach 1 is lower than the emission of approach 1.

Mean CO_2 Emission: This suggests that, on average, vehicles in scenario approach 2 emit more CO_2 compared to those in approach 1. This could be due to longer idle times (such as waiting at lights or in traffic jams), less efficient driving speeds, higher congestion, or less efficient vehicle types being more prevalent in approach 2.

Median CO_2 Emission: The median value being higher in approach 2 than in A1 implies that more than half of the CO_2 emission values from vehicles are higher in approach 2. This aligns with the mean and strengthens the suggestion that overall emissions are worse in approach 2 across a broad range of vehicles, not just skewed by a few outliers.

Standard Deviation of CO_2 Emission: A higher standard deviation indicates a greater variability in CO_2 emission amounts among vehicles in approach 2. This variability could stem from a diverse range of vehicle types and conditions, or varying levels of traffic and driving patterns (stop-and-go traffic vs. smooth driving). It could also suggest inconsistent traffic flow or different types of vehicles with varying emissions profiles being used within the traffic network.

Next, we analyzed the tripinfo.xml file to get different parameters and compare them. We calculated the trip duration which is the total time taken by a vehicle from its start to the end of its journey. This includes all delays and is key for assessing overall traffic efficiency.

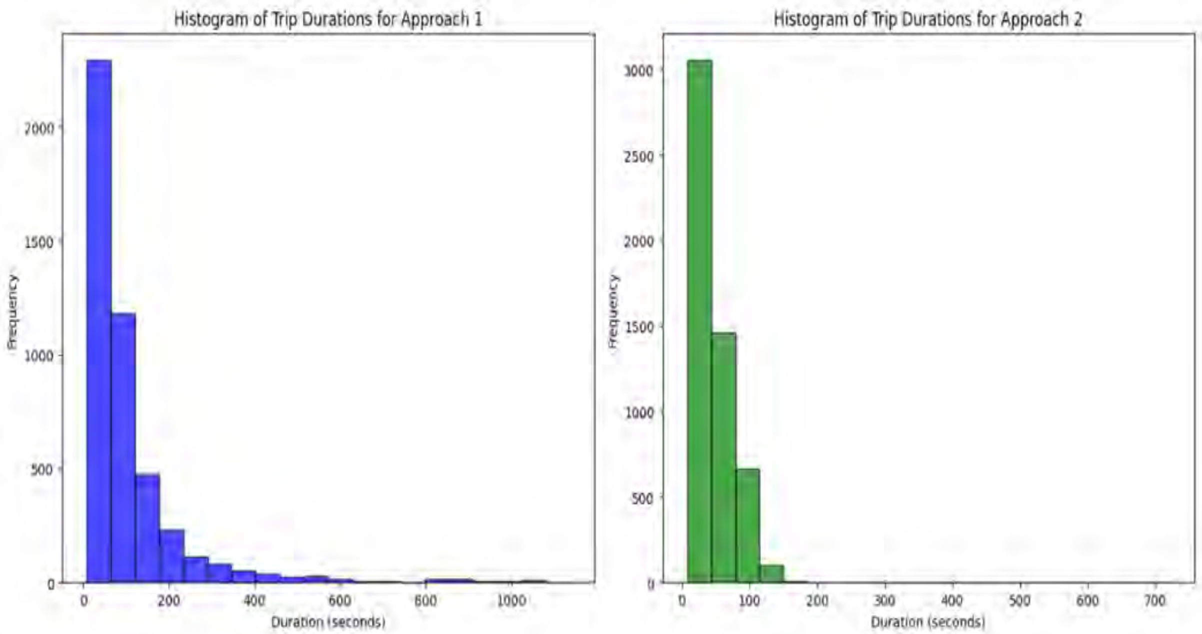


Figure 8: The histogram of Trip durations for two approaches. [SUMO]

Here frequency refers to the number of trips that fall within a certain duration range. Trip Duration is categorized into bins (intervals) along the x-axis. Each bin represents a range of trip durations, for example, 0-5 minutes, 5-10 minutes, etc. Frequency on the y-axis indicates how many trips (or data points) fall into each of these duration bins.

For the better understanding of the data set we calculated the mean, median and standard deviation of the waiting time and visualized it in a graph. Here Scenario 1 refers to Approach 1 and Scenario 1 refers to approach 2.

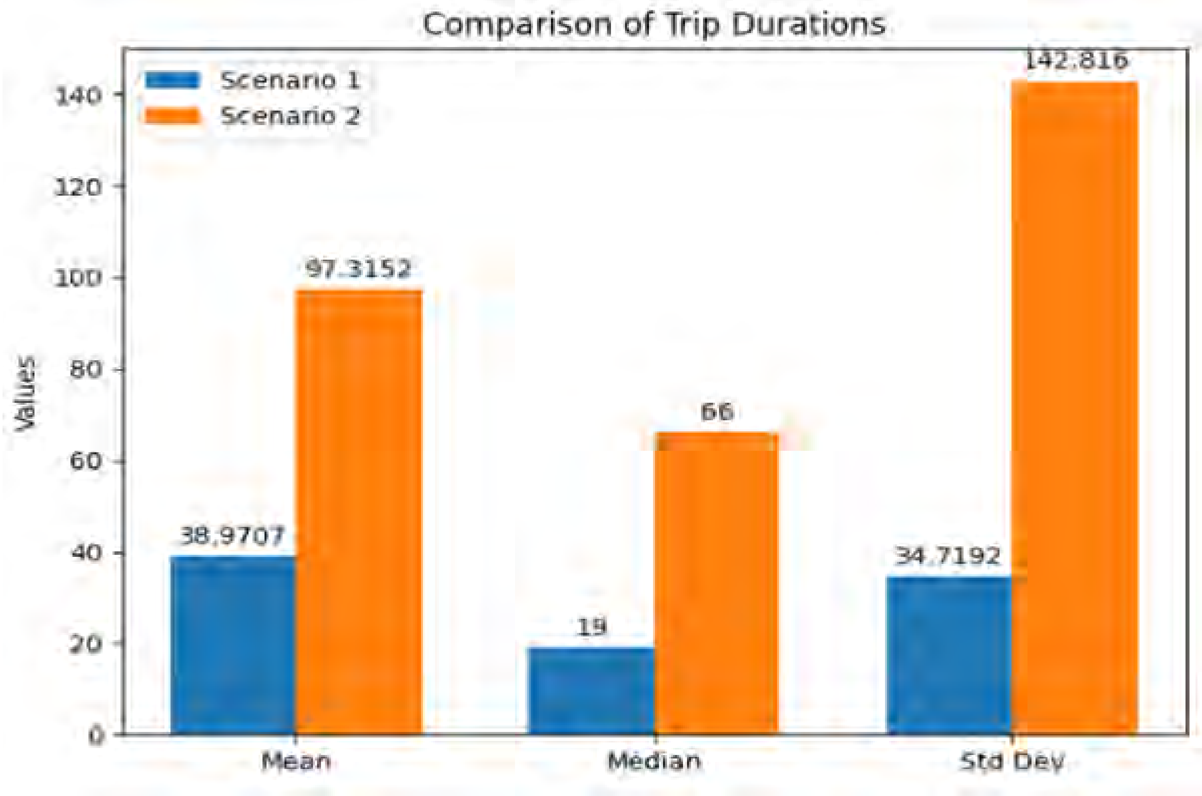


Figure 9: Mean, Median and standard deviation of Trip durations for two approaches. [SUMO]

Another type of parameters that we got from the file is waiting time. The x-axis represents different intervals or bins of waiting times. These are usually set in seconds or appropriate time units and categorize the waiting times into ranges such as 0-10 seconds, 10-20 seconds, etc. The y-axis indicates the frequency or the number of vehicles that fall into each waiting time category. This measures how many trips experienced waiting times within the specified range.

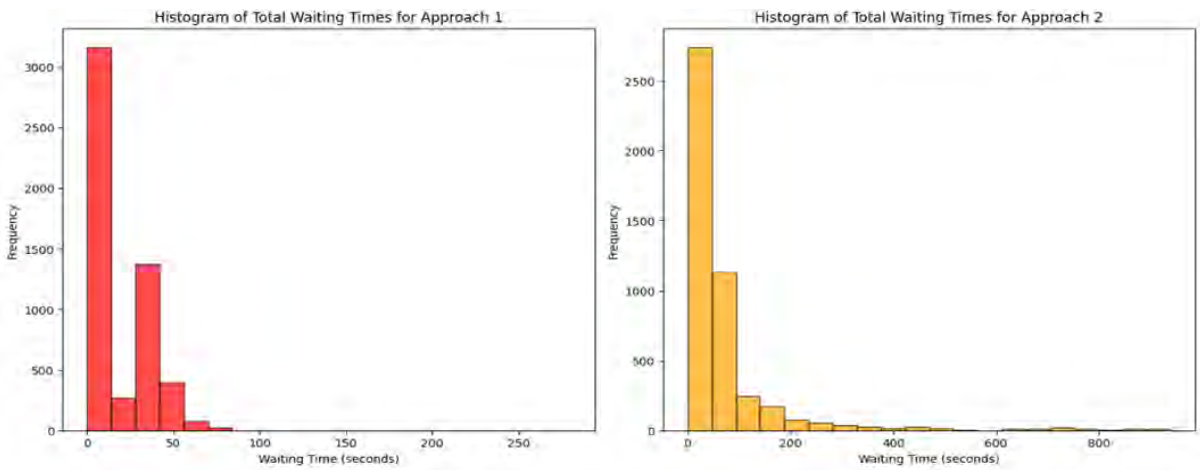


Figure 10: The histogram of Total waiting time for two approaches. [SUMO]

For the better understanding of the data set we again counted the mean, median and standard deviation of the waiting time and visualized it in a graph.

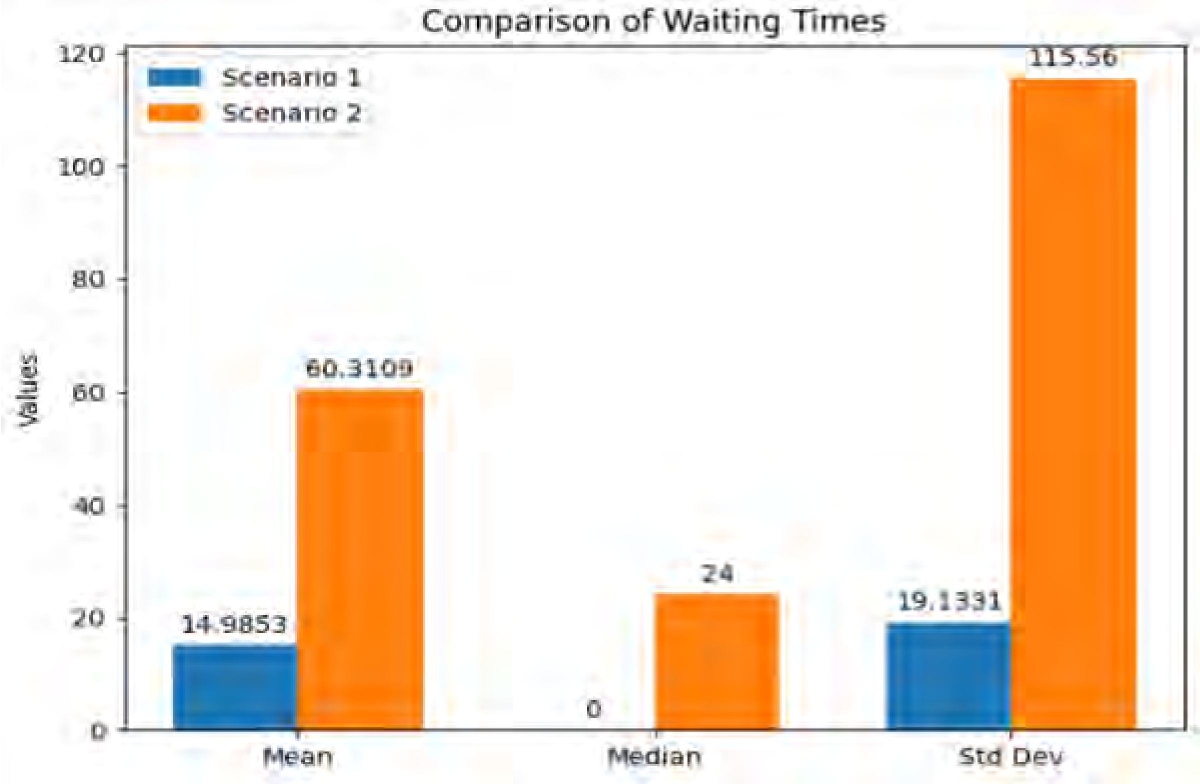


Figure 11: Mean, Median and standard deviation of Total waiting time for two approaches. [SUMO]

Approach 1:

Trip Durations

Mean: 38.970 seconds

Median: 19.0 seconds

Standard Deviation: 34.719 seconds

The average trip duration in Approach 1 is relatively short at about 39 seconds, suggesting efficient travel conditions. The median trip duration is even shorter at 19 seconds, indicating that at least half of the trips are quite quick. The standard deviation, although nearly as high as the mean, points to some variability in trip durations but not excessively so. Most trips are close to the mean, but there are some outliers with longer durations.

Waiting Times

Mean: 14.985 seconds

Median: 0.0 seconds

Standard Deviation: 19.133 seconds

The average waiting time is about 15 seconds, fairly low, which complements the short trip durations. The median waiting time of 0 seconds is particularly notable as it suggests that more than half of the trips encountered no waiting at all. The standard deviation shows some variability, similar to the pattern in trip durations, with most waiting times being short but a few experiencing longer waits.

Approach 2:

Trip Durations

Mean: 97.315 seconds

Median: 66.0 seconds

Standard Deviation: 142.815 seconds

The mean trip duration is significantly longer at over 97 seconds, indicating less efficient travel conditions compared to Approach 1. The median trip duration of 66 seconds, while lower than the mean, still shows that at least half of the trips take more than a minute, much longer than in Approach 1. The very high standard deviation suggests great variability in trip durations, with many trips taking much longer than the average.

Waiting Times

Mean: 60.310 seconds

Median:24.0 seconds

Standard Deviation: 115.56 seconds

The average waiting time is quite high at over 60 seconds, indicating significant inefficiencies and likely congestion. The median waiting time of 24 seconds also supports the presence of considerable delays in most trips. A large standard deviation points to extreme variability in waiting times, with some vehicles likely experiencing excessive delays.

Lastly from the summary file we could get different parameters but we choose mean speed and running vehicles. We tried to visualize the dataset with a graph.

Approach 1:

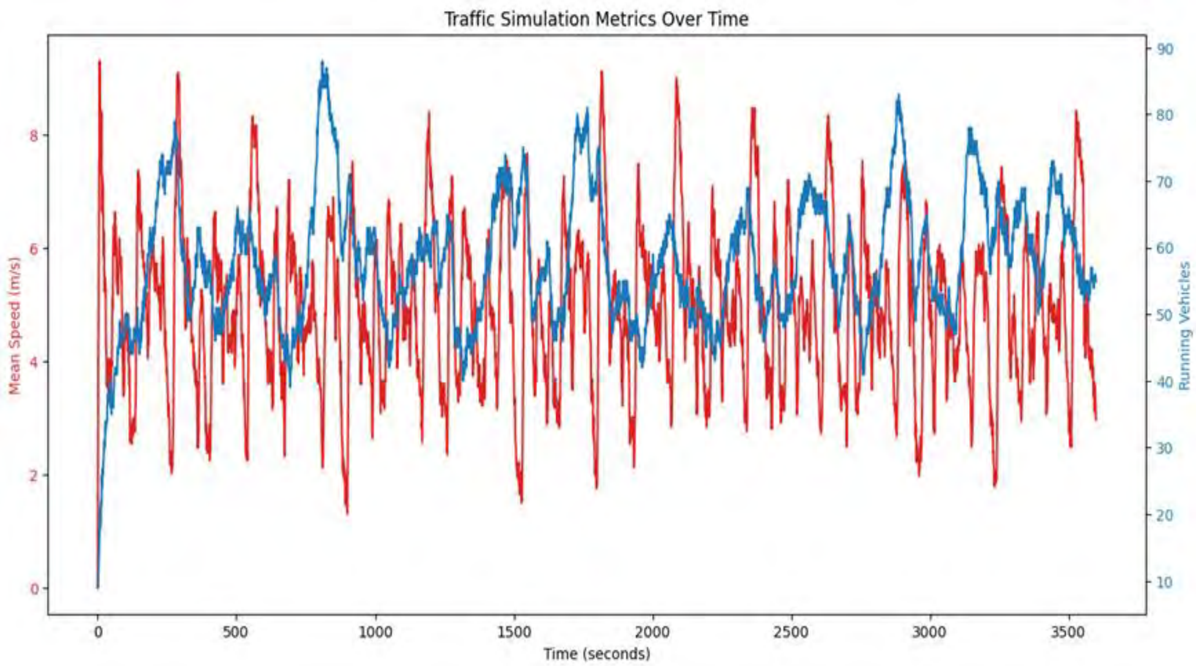


Figure 12: Traffic Simulation Metrics for Approach 1 [SUMO]

Approach 2:

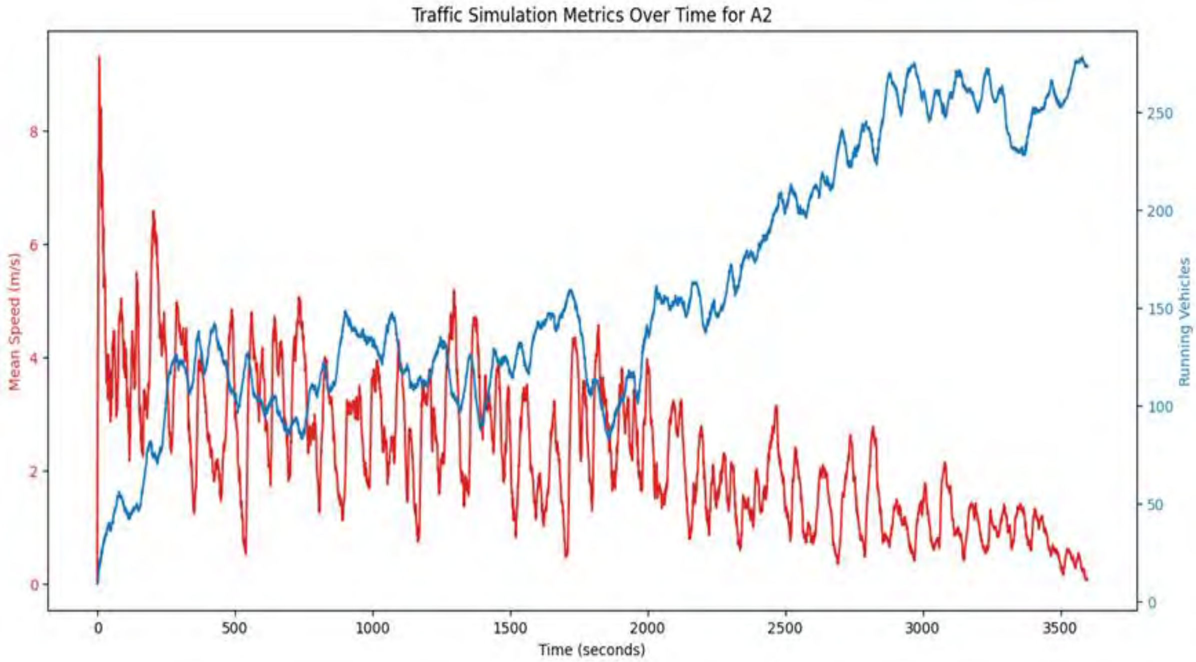


Figure 13: Traffic Simulation Metrics for Approach 2 [SUMO]

Mean Speed: This metric represents the average speed of all vehicles in the network during a given time interval. It is calculated by summing the speeds of all vehicles on the network and dividing by the number of vehicles. The mean speed can be used to measure the overall flow and efficiency of traffic. Higher mean speeds generally indicate a smoother traffic flow and less congestion, whereas lower mean speeds might suggest bottlenecks, heavy traffic, or inefficient traffic controls. Monitoring changes in the mean speed over time can also help identify peak congestion times or the effects of changes in traffic management strategies.

Running Vehicles: This refers to the number of vehicles that are on the road within the simulation at any given time interval. It does not include vehicles that have completed their trips or have not yet started. The number of running vehicles provides insights into the volume of traffic at different times. Tracking this number helps understand traffic density and load, which are crucial for assessing the capacity and performance of the road network. Spikes in the number of running vehicles can indicate peak usage times, while lower numbers might indicate off-peak times. This data is useful for planning purposes, such as scheduling road maintenance or implementing congestion management tactics during peak periods.

From the graph we can see that the mean speed for approach 1 is higher than the mean speed of approach 2 and the running vehicle is higher in approach 2 and lower in approach 1. Which indicates that approach 1 is performing well in high density areas keeping the traffic flowing.

Best Approach Selection:
From the analysis, Approach 1 consistently shows better performance across almost all metrics:
Environmental Impact: Lower mean and more consistent CO_2 emissions.

Efficiency in Traffic Management: Lower and more predictable trip durations and waiting times.
Traffic Flow: Higher mean speeds and fewer vehicles during peak times indicating less congestion.

2.5 Conclusion

The comparison of Centralized and Decentralized traffic management systems helps to identify the advantages and disadvantages of the systems. The coordinated system with interlinked intersections and consistent decision-making provided higher traffic performance, fewer average emissions per vehicle, shorter trip time and nearly no delay time. However, the decentralized system is more autonomous, and flexible, but more time-consuming, worse for emissions, and less predictable hourly traffic. Altogether, these results imply that, indeed, the cardinally different centralized design yields technically higher abilities to regulate traffic flows consistently; however, the concept behind the decentralized construction might be worth applying in the situations that indeed necessitate isolated decision-making. The outcome inferred from SUMO simulation includes the paradox that different options in free traffic management have on mobility in the urban zone, which helps in the advancement of better mobility making the urban traffic more sustainable.

Chapter 3: Use of Modern Engineering and IT Tools

3.1 Introduction

Regarding the modern conditions in engineering and technology, the choice of proper tools and their application are considered to be the key factors determining the project's success. This paper considers seven principal state-of-the-art current and contemporary engineering and IT tools as development environments, simulation platforms, and data management systems. All these tools have been chosen intentionally and are geared toward their applicability, compliance with current trends within the field, and contribution to increase effectiveness of system development.

3.2 Select appropriate engineering and IT tools

Here are the engineering and IT tools with proper explanation that we want to use for our intelligent traffic management system to help the community for a smooth transition of vehicles.

Table 3: Selection of appropriate engineering and IT tools

IT Tools Used	Similar IT Tools	Purpose/Explanation
Simulink	Scilab Xcos	Lack of some advanced features like Simulink, smaller community, fewer toolboxes and less published interference.
Proteus	LTspice EasyEDA	More accurate microcontroller simulation. Better support for traffic control hardware testing
Simulation of Urban Mobility	PTV Vissim Aimsun MATSim TransModeler	Free and open-source, reducing project costs. Specifically designed for urban mobility. Better support for large-scale traffic networks. More flexible for custom modifications. Better integration with Python for automation.
Google Colab	Jupyter Notebook Kaggle Notebooks Amazon SageMaker	Requires local setup and high performance GPU/TPU cannot be used. JUpyter does not provide built-in cloud resources like Colab.
SQLite	H2 Database Apache Derby HSQLDB	Local Data Storage where Zero-configuration required and minimal resource consumption.
YOLO V5	SSD (Single Shot Detector)	Faster inference speed for real-

	RetinaNet EfficientDet	time detection. Lower computational requirements. Better accuracy in varying light conditions. Easier to train and deploy More suitable for edge computing.
Thonny	PyCharm VS Code	Simpler interface reduces learning curve Better debugging visualization

- Simulink: Complex Traffic System Modeling
- Proteus: Hardware Simulation and Testing
- Simulation of Urban Mobility: Traffic Flow Simulation
- Google Colab: Machine Learning Development for detection of emergency vehicles and density of vehicles.
- SQLite: Local Data Storage
- Yellow V5: Vehicle Detection
- Thonny: Coding IDE

A strategic and well-considered approach for utilizing these tools for this specific project needs. It's important to understand the strengths and functionalities of each tool and these are chosen based on their suitability for this design, simulation and analysis tasks.

3.3 Implementation Benefits and Best Practices

The application of all these new generation engineering and IT tools renders vast benefits to development projects. Because simulation and testing are considered in early stages, development time is greatly diminished, and prototyping costs are also minimized through the use of virtual validation, with faster reiteration of the design. As a result, detailed testing ecosystems and valid consensus mechanisms contribute to quality assurance. These tools also support team collaboration and sharing of information thus ensuring updated skills through offering forecasts on project improvements.

3.4 Use of modern engineering and IT tools

a. **Simulink:** Traffic signal algorithms were developed, simulating and validating through the MATLAB based Simulink environment. It allowed us to simulate conditions concerning the traffic movement as well as the traffic signal operation. Using Simulink:
    - Our test results emulated detection of an emergency vehicle and its implications on the traffic signals.
    - It assisted us in evaluation of signal-switching logic that defined whether in case of the appearance of an emergency vehicle, certain lanes would get the green light and others would turn red.

- The system was developed virtually for MATLAB Simulink to reduce the possibility of real- hardware difficulties during implementation.

b. **Proteus:** In the project, Proteus was employed to address the realistic emulation of the embedded systems such as Raspberry Pi, Arduino boards and sensors and traffic lights, and how they are interconnected.
   - Signal transitions and emergency vehicle priority were examined with virtual circuits connected to microcontrollers (Arduino Mega and Uno).
   - It allowed the assessment of the control of battery management systems as part of the traffic control system using solar panels in connection with the hardware components.
   - It was also easier to visualize the wiring connections for the prototype using Proteus and exercise the actual logic of the embedded system that we wanted to implement in hardware.

c. **Simulation of Urban Mobility:** Traffic flow simulation and road congestion were modeled by applying SUMO to virtual traffic. This tool gave some understanding of how the traffic management system is going to respond under certain situations.
   - Basic traffic density simulation was carried out to optimize density-based signal control principles.
   - Through SUMO we could create traffic scenarios with emergency cars so the system would be correct when identifying them.
   - In instances where traffic cameras have been put into use, we used SUMO to estimate changes in traffic flow and assess the effectiveness of the system against cases when it was not installed.

d. **SQLite:** SQLite, which is classified as the lightweight relational database, was introduced to be used for storing the data which is collected by the system.
   - All recorded traffic violations (e.g., red-light violations) were also saved in an SQLite database together with images and timestamps.
   - Apart from the various parameters mentioned above, the database also recorded emergency vehicle detections for benchmarking and report purposes.
   - SQLite proved helpful in providing rapid data storage and data access on Raspberry Pi without necessitating hierarchical data storage backing.

e. **Google Colab:** Google Colab was employed for training the model and also for developing the emergency vehicle detection model YOLOv5.
   - Colab was a cloud-based Python environment containing GPU, which aid in the training of the machine learning model.
   - All the model training and testing data were preprocessed in Colab thus avoiding the need for a locally available high-end Machine.
   - It also made it simpler for the team members to have access and run the code without having physical close proximity to the main author/owner of the code.

f. **YOLOv5:** The vehicle detection during the emergencies as well as traffic violations were done using another advanced computer vision model known as YOLOv5 which is deep learning-based for object detection.
   - The model was instructed to distinguish ambulances and fire trucks with small tolerances to avoid delays in signal changes.

- It was also used to identify vehicles in the process of violating a red signal by analyzing the existence of the live video stream.
- The detected model, YOLOv5, offered a good response time to work in real-time traffic conditions.

g. **Thonny:** Python scripts that interact with the system availed on Raspberry Pi were developed and tested using a Python IDE called Thonny.
   - The code controlling the traffic signal, video recognition using OpenCV, and management of the SQLite database was programmed and debugged in Thonny.
   - Overall, the minimalist nature of the IDE made it much easier to debug scripts on site on Raspberry Pi and make sure that both the software and the hardware were integrated.
   - Thonny also allowed rapid reevaluation during development and implementation of features such as license plate detection.

3.5 Conclusion

Every tool and technology involved in this project had its own role, toward achieving the goals of the intelligent traffic management system development, test, and implementation. These two tools proved the control logic as well as the control embedded system was in good order. Real world traffic conditions were replicated with SUMO, for the machine learning model development environment we used Google Colab and for actual machine learning we used YOLOv5. SQLite Database was used for managing data and Thonny was used for Python code drafting and testing in Raspberry Pi. Altogether, the above tools applied made the successful design and implementation of the system possible.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution.

4.1 Introduction

Within the context of TMS this means that, unlike in simpler contexts, the design of traffic management systems has to reflect the complexity of urban space and address the needs of the whole complex ecosystem, not just those of individual transportation consumers. This chapter examines the trade-off of multiple choices in traffic management systems discussing the evaluation of decentralized and centralized systems. Much of this has to do with the actual dynamics of urban settings and changing traffic patterns to locate the optimum solutions afforded by analytics. By going through a process of methodical comparison of several aspects of various designs, pertaining to the use of resources, maintainability of a product, environmental aspects, and user satisfaction, this chapter is to explain the selection algorithms which have been used to arrive at the most desirable solution. Using optimized mechanisms and decision support systems, we shall discover how integrated approaches would improve the utility and dependability of traffic control systems, towards promoting safer traffic flow in urban areas.

4.2 Optimization of multiple design approach

The approaches that have been developed in the prior researches are as follows: approach 1 We have chosen approach 1 to use in this current research. Since our project is a large one and an integrating project of many subsystems, we subdivided the total system into various subsystems. The subsystems are number plate scanning and identification of emergency vehicles, hybrid power, formation of databases and issuance of violation reports and traffic control.

Figure 14: 3D Model of the desired System

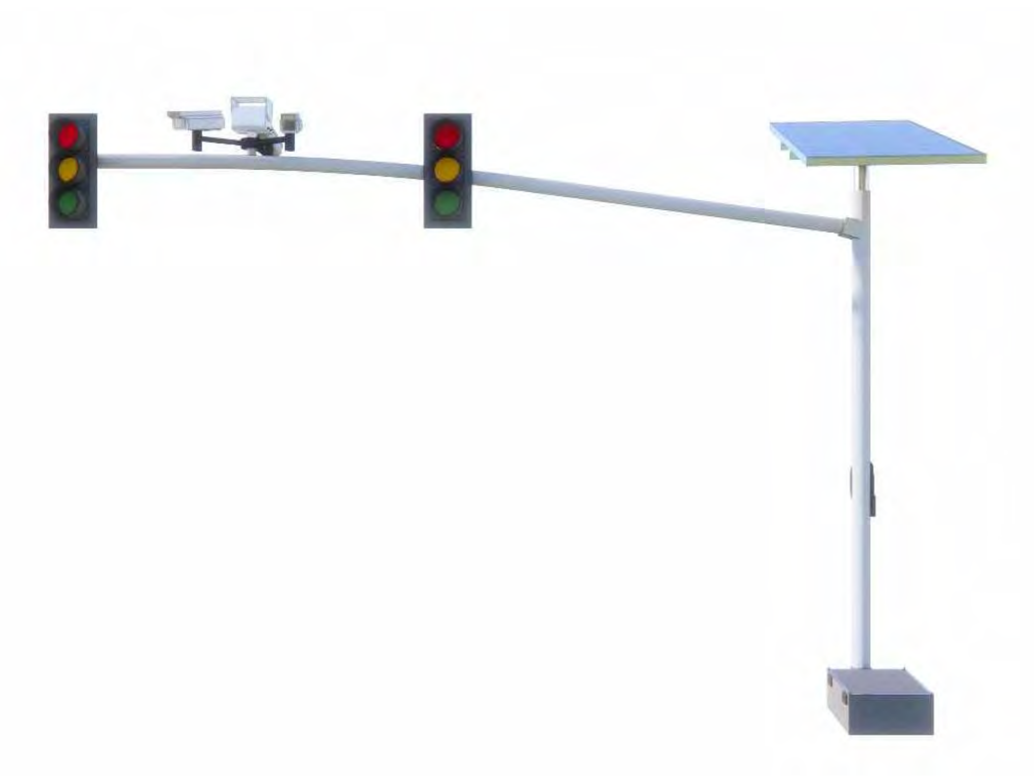


Figure 15: 3D Model of the traffic pole

Traffic System Infrastructure:

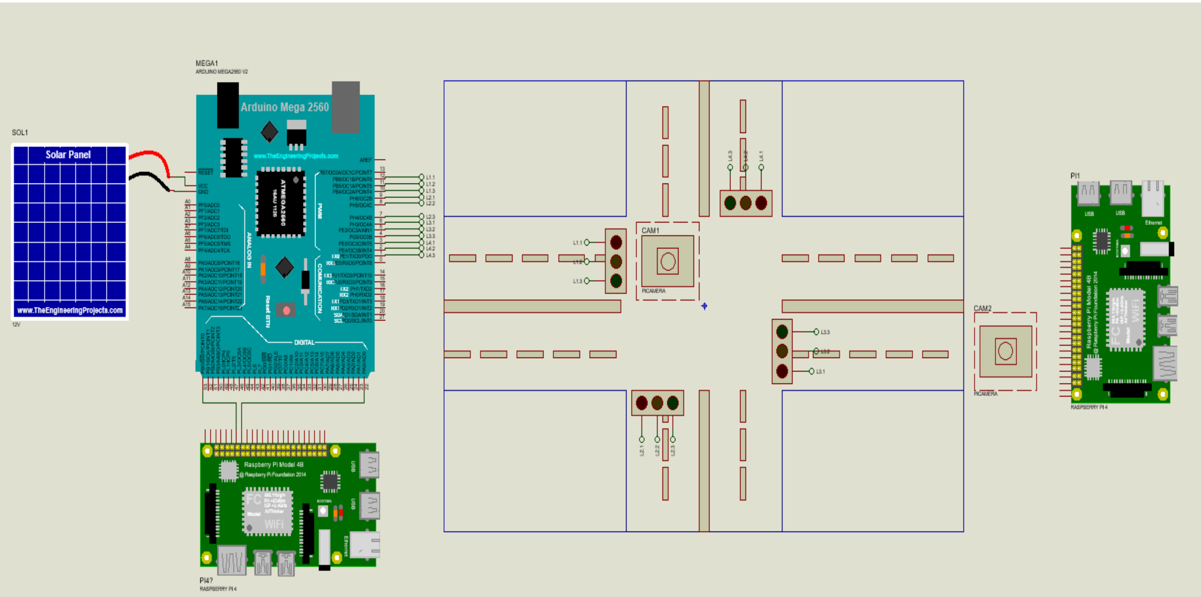


Figure 16: A traffic signal infrastructure, Object detection system for Emergency Vehicle and Signal Lights

In this part of the simulation, we have created traffic infrastructure in Proteus to test the viability of the traffic signal. Subsequently, we were able to incorporate Emergency Vehicle Prioritization with the assistance of an emergency vehicle detection model that transmits signals from Raspberry to Arduino. This leads towards the change in traffic flow by request depending on the situation of the emergency. Moreover, we applied the Rule Violation Detection with another object detection model to videos of cars that violated signal rules.

Vehicle Number Plate Detection:
We took two approaches for this part or two algorithms. First one was with EasyOCR-OpenCV and the second one was with YOLO.

EasyOCR-OpenCV:
Image Reading and Preprocessing: It starts by reading an image and converting it to grayscale. This simplification helps in reducing complexity for subsequent operations. It applies bilateral filtering to reduce noise while preserving edges, followed by Canny edge detection to identify the edges in the image.

Contour Detection: Using OpenCV, the script finds contours in the edged image. Contours are simply the boundaries of shapes, and here, the code looks for the largest contours that could potentially frame text areas.

Locating Potential Text Region: Among the identified contours, the code looks for a quadrilateral (approximated as a shape with four corners), suggesting a potential region of interest that might contain text.

Masking and Region of Interest Extraction: A mask is created to isolate the identified region, and bitwise operations are applied to extract this specific part from the original image.

Text Recognition with EasyOCR: The cropped image section is then passed to EasyOCR, which recognizes text within. The script is configured to recognize Bengali text ('bn'), although it can be adjusted for other languages.

Text Annotation: Finally, the code uses PIL to annotate the original image with recognized text. It draws the text and a rectangle around the recognized area.

Flowchart of the Program:

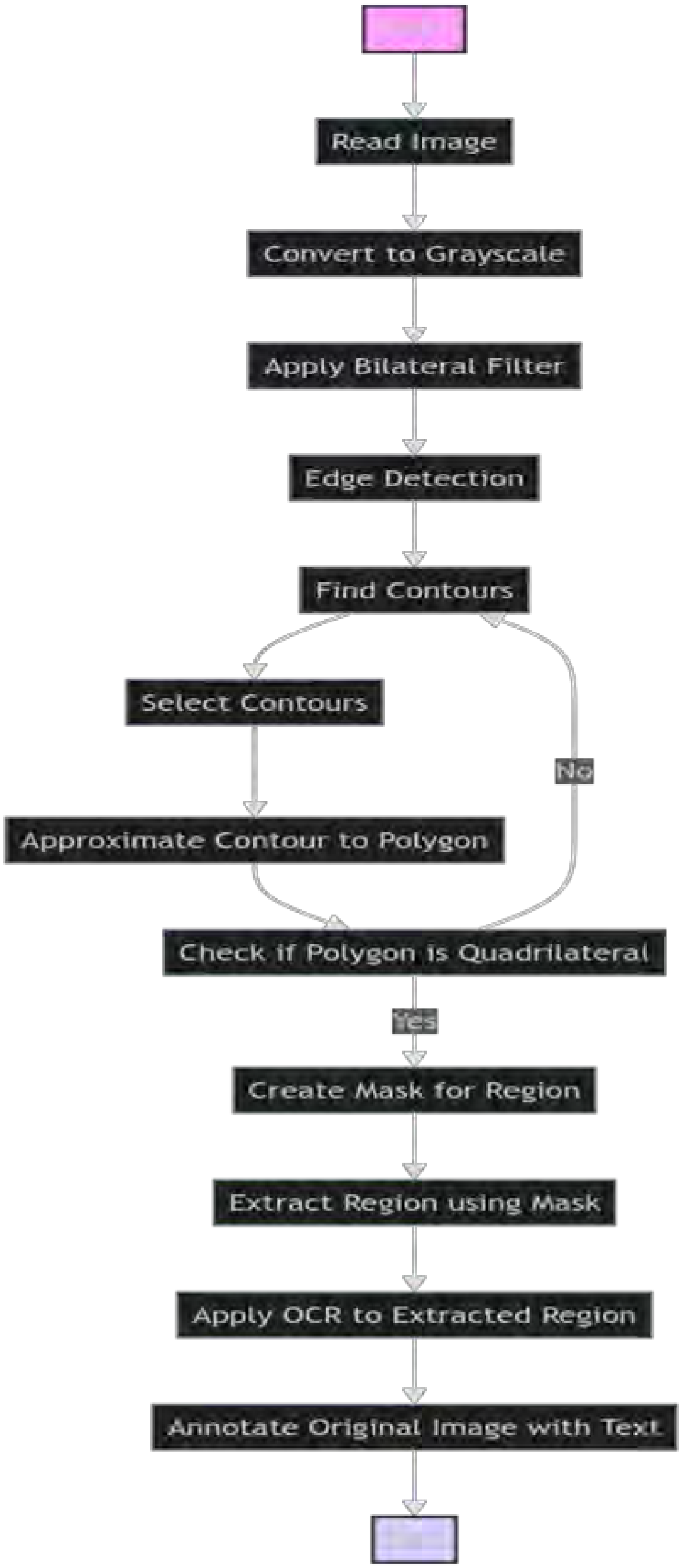


Figure 17:Flowchart of the EasyOCR-OpenCV algorithm

Input:

Figure 18: The input of the captured picture for number plate detection.

Output:

Figure 19: The output from the captured picture after number plate detection.

Constraints:

1. There is also the necessity to note that while developing TD, the accuracy of text detection as well as its effectiveness depends both on the quality of the image and the specific features of the text.
2. The script particularly searches for rectangle shaped photos as potential text areas, which can be likely offset with text regions of other shapes.
3. Parameters of noise reduction and edge detection are set up in the code, which are not necessarily the best for each image.
4. EasyOCR does not perform as expected by degrading depending on the languages used and the sharpness of the information in the text. The script currently expects that the OCR output is accurate for taking coordinates on the image and that is not always true.

YOLO:

The next code is about vehicle monitoring and license plate recognition due to its integration of high-performance tools using:

After some tuning OpenCV for image processing, YOLO for real-time object detection, and Pytesseract for OCR. It analyzes video streams in real-time, important for any application that requires real-time response such as traffic surveillance and security. Staying within a defined area is more effective, and eliminates giving a positive result from an unrelated sample. It also captures the license plates that it recognized with a timestamp specifically useful in security issues. Due to interactive parameters such as the YOLO model and the area of interest, the script can be modified to suit the operational aspects.

Processing Steps:

Video Processing: The script is as follows as the video is played using the frame-by-frame technique:

Recognizes where cars are in a frame using YOLO.

Sees if these vehicles are in some region of the frame that is of interest (like gates or a specified lane).

License Plate Recognition: If the car belongs to the area of interest, the script is on the part of the image that contains the license plate, and converts the image into format that is perfect for text recognition and then applies Pytesseract to scan the license plate number.

Saving and Displaying the Results: They also store the recognized license plate numbers along with the time stamp, in a file. At the same time, the video in which the vehicles with detected license plates are marked is playing in real time and saves a new video file.

Interactions: Thus, the script enables some interaction, for instance, pointing at check points on the video with the help of the mouse, and the process goes on until it is interrupted by hand.

Program Flow Chart

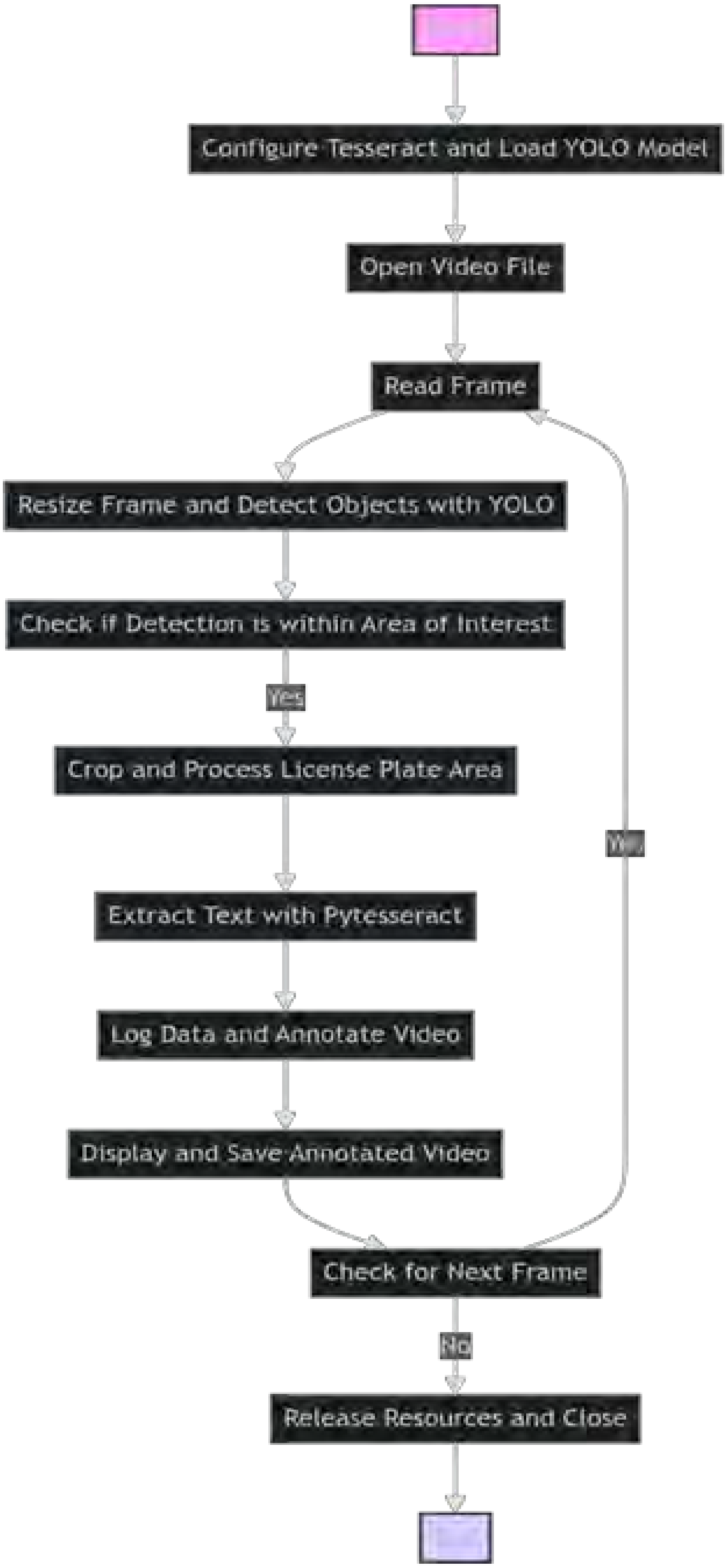


Figure 20: Flowchart of the YOLO V8 based algorithm.

Output:

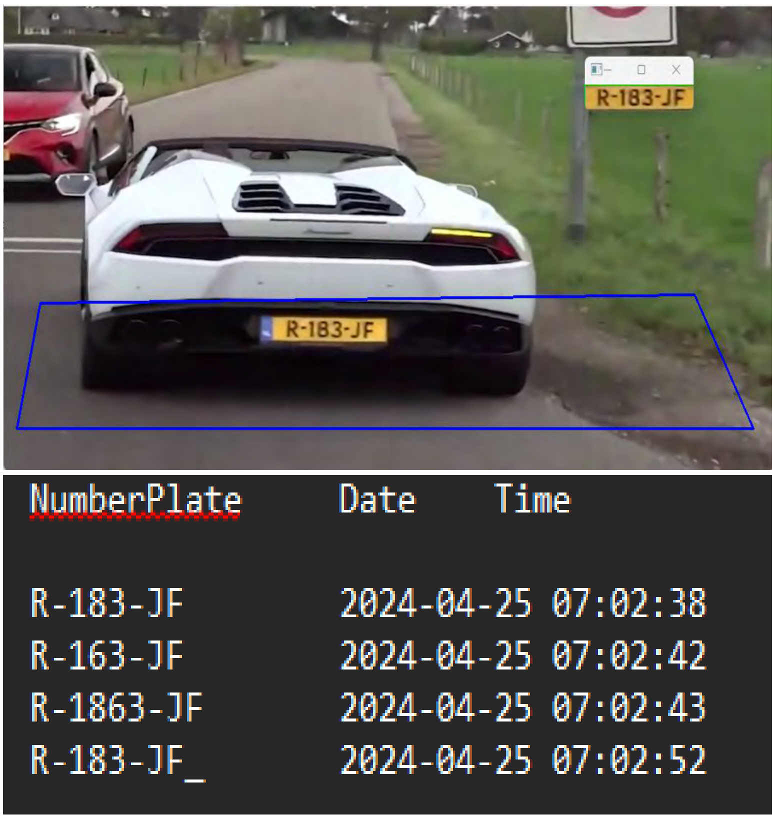


Figure 21: Output for the YOLO V8 solution.

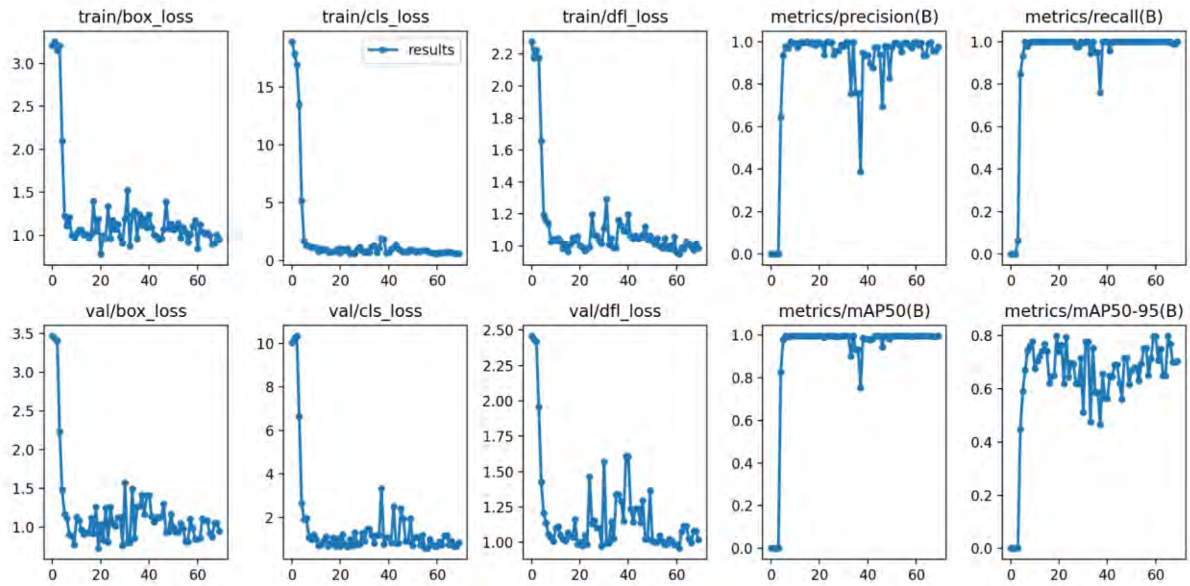


Figure 22: Performance Metrics for the YOLO V8 solution.

Emergency Vehicle Detection:

In this part of the work, we used a sound sensor connected to Arduino to receive the sound input and process the sound and run our algorithm which will tell us if it was an emergency vehicle or not. If it is an emergency vehicle it will do a siren and the system will release that lane for the emergency vehicle to pass. With algorithms, we identified that the siren CNN and LSTM were the outputs of the models.

CNN:

Architecture of the model:

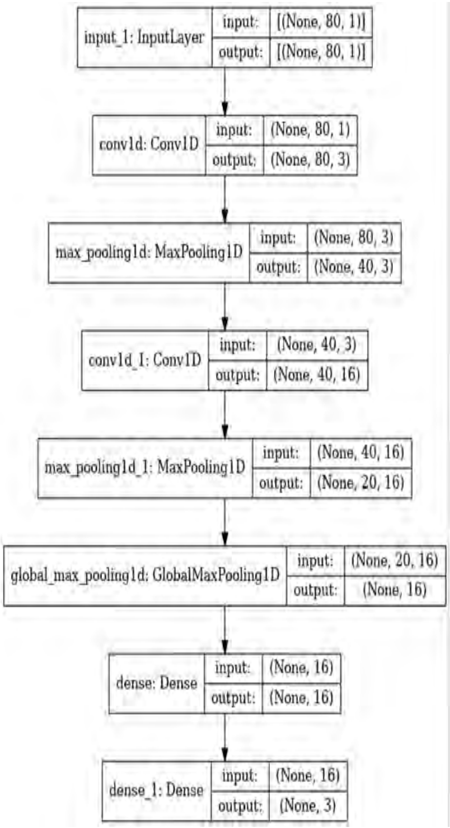


Figure 23: Architecture of the CNN model

Loss Function:

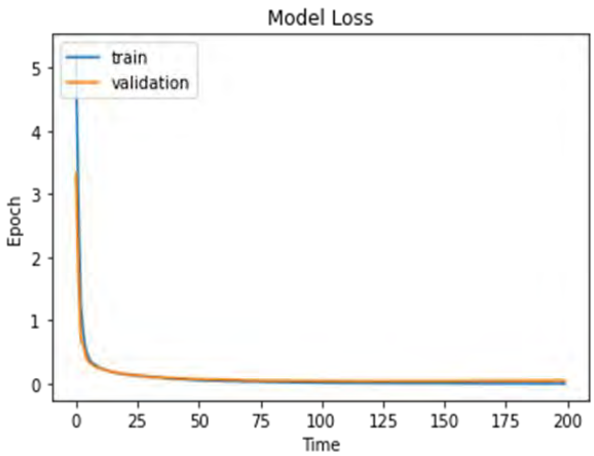


Figure 24: Loss function of the CNN Model

Accuracy of the Model: We implemented the model for 30 epochs and with Adam optimizer.
Accuracy: 0.9750000238418579

LSTM:

Model Architecture:

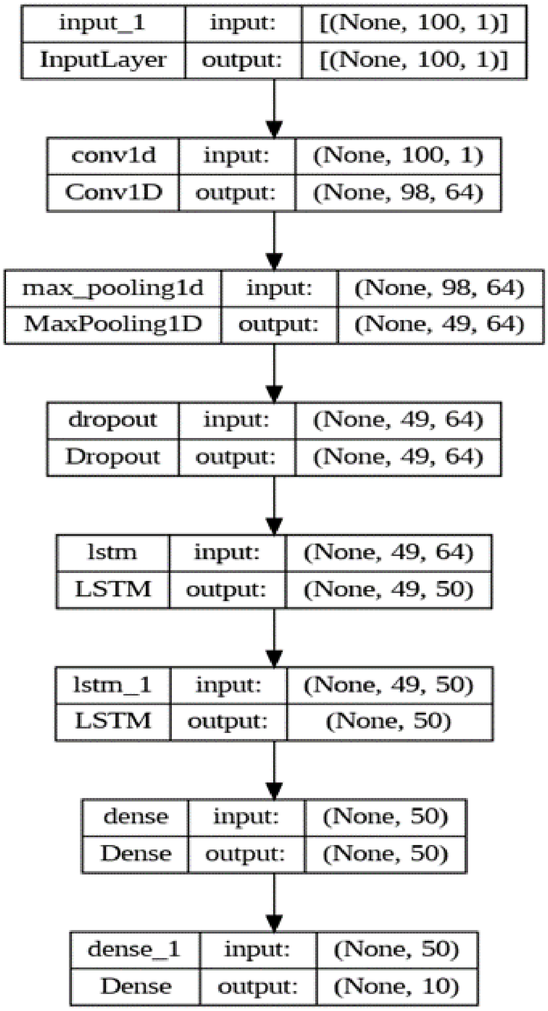


Figure 25: Architecture of the LSTM model

Loss Function:

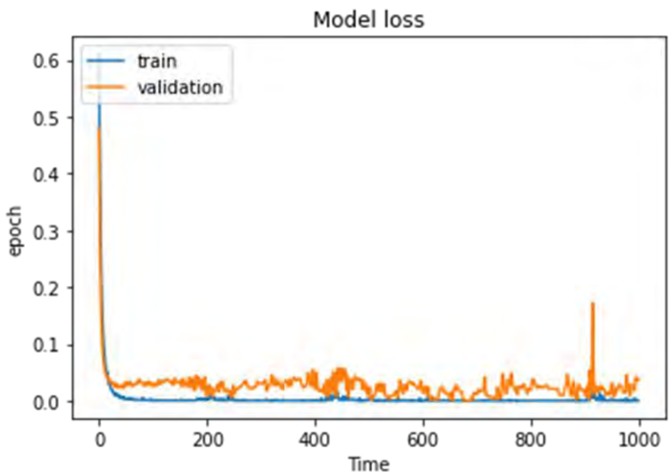


Figure 26: Loss function of the LSTM Model

Accuracy of the model: We then feed the code for 1000 iterations and use Adam optimizer. Accuracy: 0.9916666746139526

Program Flowchart:

Figure 27: Program flowchart for the LSTM Model

- **Feature Extraction:** It takes some characteristics from audio files that assist in identifying various sounds in this code.

- **Data Labeling and Saving:** All these features are labeled according to the type of vehicle and remain stored for further use.

- **Model Training:** It uses the labeled features to train neural network models to defend emergency and non-emergency vehicle sound.

- **Model Saving and Loading:** Upon training, the model is stored and can be used for differentiations of new sounds.

- **Prediction:** Users can supply new audio samples with the ability to classify them as with or without the sounds of emergency vehicles.

- **Continuous Monitoring:** The system can also monitor sounds from a device's microphone, and then predict in real time if the sounds are from emergency vehicles.

Since the LSTM algorithm has the highest accuracy then we have taken the LSTM model in the program.

Output:

```
• videoplayback (1).m4a(audio/x-m4a) - 1367820 bytes, last modified: 5/5/2024 - 100% done
Saving videoplayback (1).m4a to videoplayback (1).m4a
<ipython-input-2-c98f08f92794>:4: UserWarning: PySoundFile failed. Trying audioread instead.
  audio, sample_rate = librosa.load(file_name, sr=22050)  # Resample to 22050 Hz
/usr/local/lib/python3.10/dist-packages/librosa/core/audio.py:183: FutureWarning: librosa.core.audio.__audioread_load
        Deprecated as of librosa version 0.10.0.
        It will be removed in librosa version 1.0.
  y, sr_native = __audioread_load(path, offset, duration, dtype)
1/1 [==============================] - 1s 752ms/step
Predicted Class: Emergency Vehicle
```

Figure 28: The program successfully detected emergency vehicles.

Database and automated E-challan System:

The number plate that will be generated from the algorithm after ascertaining the violations through the sensors and processing them will be saved in our system. From the number plate we obtained from the processing database management system, we will obtain the number plate number and check our system database that has all information of the vehicle owner and the matched owner will automatically receive E-challan via mail. All the necessary command for creation of database, its running, modification and its all-necessary management is done using the python code.

```
Vehicles:
(1, 'ABC123', 'Toyota', 'Corolla')
(5, 'ABCDEF1234', 'Toyota', 'Corolla')
(6, '123ABC', 'Toyota', 'Corolla')

Owners:
(4, 'Fahim Faiyaz', 'fahim.faiyaz@g.bracu.ac.bd', 4)
(5, 'Ibbrahim Morshed', 'ibrahimmorshed01@gmail.com', 5)
(6, 'Fahim Faiyaz', 'fahim.faiyaz@g.bracu.ac.bd', 6)
```

Figure 29: Database of Vehicles and their Owners

```
Processing violation for plate number: ABCDEF1234
Found email ibrahimmorshed01@gmail.com for plate ABCDEF1234. Sending email...
Preparing to send email to ibrahimmorshed01@gmail.com...
Email sent successfully!
```

Figure 30: Violation reporting process in the Database

Figure 31: Email sent to the Owner of the vehicle about the violation and fines.

a. Load Calculation (Original)

Table 4: Real Scenario Load Calculation

Components	Power
HPE DL380 Gen 10	300~500W
Cisco ws-c2960g-24tc-l	75W
Axis Communication Cameras	40~60W
PIR Sensor 360	0.45W
Hlk ld 1115	0.35W
High sensitive microphone sound sensor module	0.025W
Ultrasonic sensor HC-SR04	0.1*4W
Vibration sensor sw 420	0.075*4W
Traffic Light Poles	15*4W
Arduino Mega 2560 R3	1.04W
Total	697.5W

b. Load Calculation (Prototype)

Table 5: Prototype Load Calculation

Components	Power
Raspberry pi 4 model b 8gb	3~5 W
Raspberry pi camera module v2-8-megapixel 1080p (rpi-cam-v2)	1.4*4W
Traffic Light Module	5V
Arduino Mega 2560 R3	1.04W
Total	~17 W

c. Solar Power Verification

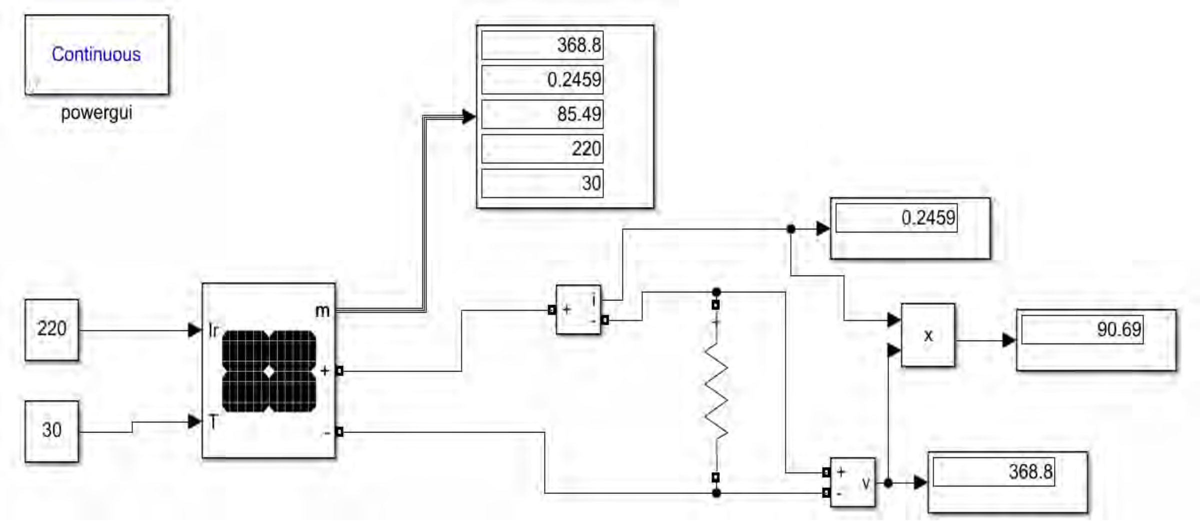


Figure 32: Solar power verification for the load calculation of the prototype.

4.3 Identify optimal design approach

a. Cost Analysis

Now, let's sum the costs for each approach by assuming there are 6 intersections.

- **Decentralized Approach:**

Cost per Intersection:

Table 6: Cost Estimation

Component	Quantity	Cost per Unit (BDT)	Total Cost (BDT)
Dell PowerEdge or HPE ProLiant Server	1	682,000	682,000
Cisco Network Switch	1	20,000	20,000
Axis Communications Cameras	1	340,000	340,000
Traffic Signal Poles	4	25,000	100,000
Arduino Mega 2560 R3	1	5,430	5,430
300W 12V Solar Panel	1	110,500	110,500
Apollo 12V 200Ah AGM Battery	1	35,000	35,000
Contingency (10%)	-	-	110,000
Total Cost per Intersection			1,303,930
Total for 6 Intersections	6	1,303,930	7,823,580

- **Centralized Approach:**

Budget Estimate for 6 Intersections:

Table 7: Cost Estimation for 6 Intersection

Component	Details	Cost (BDT)
PowerEdge R760 Server	Intel Silver 4410Y (for data processing & AI)	1,200,000
Network Infrastructure	Cisco Network Switch (for central connectivity)	20,000
High-Tech Sensors and Cameras	Axis Communications Cameras at 6 intersections (6 × 340,000)	2,040,000
Solar Power Integration	Solar Panels and Battery Storage for 6 intersections (6 × 150,000)	900,000
Traffic Signal Poles	4 pieces	100,000
Contingency	Reserve for unforeseen costs	420,000
Total Estimated Cost		4,680,000

- **Initial Investment**

Since the resources like servers, network, and advanced sensors such as thermals, pressure, and motion detectors are centralized, there occurs a net reduction of initial cost by 20 to 30%. While in previous methods each intersection required one or many individual units, one strong server and common ware are sufficient for the program, and costs decline as a result. However, the decentralized model requires separate installations at each intersection, meaning a huge amount of duplicated expenses for hardware investments and distinct infrastructure demands which contribute to the costs' rising by 50-70%.

- **Maintenance Costs**

Further cost evaluation shows that centralized traffic management systems are much cheaper than decentralized ones by 20-30%. This cost savings is due to a relatively low initial capital requirement for infrastructure compared with centralized facilities and a 15-25% reduction in recurring costs due to synergies in maintenance and repair, diagnostics, and data handling. On the other hand, for decentralized systems, extra costs are estimated to be from 30% to 40% higher because of the need for maintaining multiple independent intersections, having unique monitoring for each one, and extra expenditure from the synchronization of data among multiple differentiated units. The primary advantages of the centralized concept, namely the ability to maximize traffic and lowest cost of carrying out activities further highlight the concept as the economically sustainable and operationally competent approach to managing today's complex traffic issues.

b. Efficiency

When evaluating the centralized and decentralized systems efficiency one reveals the benefits of the first strategy in terms of the main factors of operational performance. Though decentralized systems provide control and decision making at the intersections, they have drawbacks during rush hour when density boosts up to 30-50% leaving the opportunity for the overall system optimization. The coordinated traffic control via the capability of over 10 000 data per second, provided by the centralized approach, increases the overall Traffic management coordination by 15-25% due to data analysis and, moreover, prediction. In addition, centralized resource management leads to a 20–40% wastage cut as opposed to decentralized systems, which are already known to experience up to 30% resource inefficiency if not optimized properly regarding solar power and battery storage. The coordinated centralized system in comparison to the decentralized one is capable of controlling simultaneous traffic signals at multiple intersections while the factor of signal data processing and resource optimization leads to the overall 20-30% improvement thus placing the conceptual model as a preferable solution for modern urban traffic management problems, which require adaptive and sustainable and efficient solutions.

c. Usability

Centralized traffic management controls demonstrate much higher usability in comparison with decentralized ones as they have the single interface, identical operational activities, and fewer time for user training compared to the decentralized variant, which is 40-50% less. Flexibility in remote connectivity increases real-time visibility and control, cuts down response time and overall operating effectiveness gains up to 50-70%. centralized systems also enable interconnectivity between intersections and increase system performance efficiency by 25%-30%. On the other hand, decentralized systems introduce complications arising from variation in interfaces, protocols, limited accessibility of remote sites, and higher training needs, thus raising operation complexity by 30% and training time by 20-25%. In general, centralized traffic management is more client-friendly, flexible and effective, which will make flow easier and enhance resource management.

d. Manufacturability in Intelligent Traffic Management Systems

Centralized traffic management controls demonstrate much higher usability in comparison with decentralized ones as they have the single interface, identical operational activities, and fewer time for user training compared to the decentralized variant, which is 40-50% less. Flexibility in remote connectivity increases real-time visibility and control, cuts down response time and overall operating effectiveness gains up to 50-70%. centralized systems also enable interconnectivity between intersections and increase system performance efficiency by 25%-30%. On the other hand, decentralized systems introduce complications arising from variation in interfaces, protocols, limited accessibility of remote sites, and higher training needs, thus raising operation complexity by 30% and training time by 20-25%. In general, centralized traffic management is more client-friendly, flexible and effective, that will make flow easier and enhance resource management.

e. Impact

- **Environmental Sustainability**

Decentralized traffic systems use local renewable energy, for instance solar and batteries, less dependent on the grid, but may compromise on resource utilization and expansion. On the other hand, centralized systems more intentionally locate and coordinate the distribution and usage of renewable energy in a network control manner.

- **Community Well-being**

Decentralized traffic systems give local communities the opportunity to manage traffic independently; this approach benefits from greater sensitivity and safety, but the quality of management may vary. Then again, centralized systems are better since they create high standards resulting in better traffic, better response to emergencies, and efficient delivery of resources for the communities' welfare.

- **Urban Development**

Decentralized traffic systems ultimately provide a lot of autonomy for localized AD development but reduces compatibility and Maximum Network Flow on an urban scale. However, centralized systems promote sustainability, utilization of resources for the betterment of the community, and integrated urban development, reduce risks of acc<|>idencies and provide global advances. Therefore, centralized traffic management should be considered the more efficient model that will ensure the sustainable development of cities and create new opportunities for citizens as long as needed.

f. Impact

Most of the authors have established that integrated traffic management systems provide better environmental sustainability, enhanced cohesion of the communities living in urban areas as well as better development of those areas. They enhance the efficient utilization of renewable energy sources, cut the ecological footprint by 25%, maintain standard and fairness in traffic distribution, increase flow & Segregation traffic by 20% and provide sustainable city planning for future progression. Internet-based, or decentralized, solutions involve a more distributed approach and allow for local management but can lead to non-uniform management and suboptimal resource utilization. Therefore, for the greatest public production and lasting efficiency, centralized systems take precedence.

g. Sustainability

The sustainability of traffic management systems plays a vital role in evaluating the environmental impact, resource efficiency, and long-term viability of both centralized and decentralized approaches.

- **Environmental Impact**

Decentralized traffic systems sometimes employ small grid connected renewable power such as photovoltaic, solar panels, batteries, and greatly decrease dependency on the grid by reducing their carbon footprint per intersection to one third. Nevertheless, this concept seems not to have a high prospect for scalability which is a bad thing in the long run. Integrated schemes coordinate renewable energy in networks to achieve better utilization of resources and cut network emissions by 50%.

- **Resource Efficiency**

Decentralized traffic systems do not necessarily require a central control making them more flexible but issues may arise in the efficient use of resources, size of the network, and sustaining system standards may cause strain to the future stability of such systems. Centralized systems instead facilitate procurement, maintenance, as well as making upgrades all of which are made efficient and energies are conserved across the network. For overall coordination, economy of scale and strategic operation, centralization is therefore a better ontological option for sustainable traffic management systems because they help in planning for the future and ensuring that other systems within a network are compatible.

h. Maintainability of Traffic Management Systems

Communication networks of decentralized traffic systems have heterogeneous hardware, localized maintenance, and slow response time and thus are expensive and have low reliability. The scale is done in those systems individually and it takes considerable time to upgrade them. Centralized systems, however, offer easier maintenance since all the subsystems in an organization are preconfigured, hence minimized downtime, reduced expenditure, and more efficient services. They also enhance the issues of scalability, meaning that it is easy to make it bigger and update it as well. Centralized processes provide accurate long-term support, owing to constant monitoring and quick problem-solving that reduces downtime. In sum, due to their greater maintainability, scalability, and compared to decentralized systems, longer-term support, centralized systems can be regarded as the best choice in terms of traffic reliability.

Optimal Solution

Finally, given the specifics of the situation we selected approach 1 as our approach. Since our final project is complex, hence a combination of multiple subsystems, so we subdivided this complete system into various subsystems. These are the vehicle number plate detection and emergency vehicle detection subsystems, hybrid power subsystem, creation of database and the subsystem of automated violation notification and traffic management subsystem.

4.4 Performance Evaluation of Developed Solution

Table 8: Comparison between Two Approaches on the Basis of Simulation Results.

Parameter	Approach 1	Approach 2	Comparison & Insights
CO2 Emissions (Mean)	2816.26	3361.41	Approach 1 has lower mean CO2 emissions, suggesting more environmentally friendly or efficient vehicle operation.
CO2 Emissions (Median)	2624.72	2624.72	Both approaches have the same median emissions, indicating a similar central tendency despite overall differences.
CO2 Emissions (Std Dev)	1533.76	2340.09	Higher variability in Approach 2 indicates more inconsistent emission rates, possibly due to variable traffic conditions.
Trip Duration (Mean)	38.97 seconds	97.315 seconds	Approach 1 significantly reduces trip times, suggesting more efficient traffic flow and less congestion.
Trip Duration (Median)	19 seconds	66 seconds	The median trip duration for Approach 1 is considerably lower, reinforcing its efficiency in managing traffic flow.
Trip Duration (Std Dev)	34.719 seconds	142.815 seconds	Approach 1 shows less variation in trip duration, indicating more consistent travel times.
Waiting Time (Mean)	14.985 seconds	60.310 seconds	Approach 1 greatly reduces waiting times, enhancing overall traffic efficiency and reducing congestion-related delays.

Waiting Time (Median)	0 seconds	24 seconds	A median of 0 in Approach 1 shows that over half of the trips had no waiting, indicating highly efficient traffic signals or flow.
Waiting Time (Std Dev)	19.133 seconds	115.56 seconds	Lower variability in Approach 1 points to consistent and predictable traffic conditions.
Mean Speed	50 m/s (high efficiency)	2 m/s (low efficiency)	Approach 1 supports much higher speeds, suggesting smoother traffic flow and less congestion.
Running Vehicles (Peak)	90 vehicles	250 vehicles	Approach 1 has fewer vehicles running at peak times, which may indicate better traffic dispersion or less crowded conditions.

Approach 1 (Centralized) demonstrates superior performance across multiple metrics, making it the more efficient and sustainable option. It achieves lower mean CO2 emissions (2816.26 vs. 3361.41), shorter trip durations (mean of 38.97 seconds vs. 97.315 seconds), and significantly reduced waiting times (mean of 14.985 seconds vs. 60.310 seconds). The median waiting time of 0 seconds in Approach 1 highlights that over half of the trips experienced no delays, indicating highly optimized traffic flow. Additionally, higher mean speeds (50 m/s vs. 2 m/s) and fewer vehicles running at peak times (90 vs. 250) reflect smoother traffic management and better congestion control. With less variability across metrics, the centralized approach ensures more consistent, predictable traffic operations and is the more effective solution overall.

4.5 Conclusion

Hence, the analysis of multiple design strategies for traffic management systems further demonstrates that the centralized solutions are more effective than decentralized solutions respecting the vital aspect for transport systems. Integrated systems promote the utilization of resources and specific deployment of renewable power generation infrastructure, which minimizes carbon emissions. They also enhance the general welfare of citizens, by preserving, maintaining and publishing standardized traffic control measures, safety, efficient traffic control and regulation, and fairness in the distribution of traffic resources. Moreover, centralized structures enhance higher maintainability, scalability and long-term supportability in order to deliver a high availability and highly dependable performance since networks grow in size. By rationalizing maintenance processes and enabling easier modification, centralized traffic control systems become seen as the most effective solution for simultaneously exerting a wide-ranging influence and generating the highest possible benefits for cities. Lastly, this chapter emphasizes the need to choose the appropriate design solutions with respect to their efficiency, sustainability and benefits to the communities, and opens up the topic further by outlining traffic centralization as the best approach to future city development and traffic improvement.

Chapter 5: Completion of Final Design and Validation.

5.1 Introduction

After various optimizations and considerations, we developed our final design for an intelligent traffic management system, focusing on two key functionalities: such as identification of emergency vehicles and other traffic law infringements more so instances of defiance of the red-light signals. The system is tasked with identifying emergency vehicles, including ambulances and fire tenders, and siren by turning on the green light on the occasional side of the road. Furthermore, the system records any vehicle that it observes to be breaking traffic laws such as moving through a red signal and, in addition to filming the vehicle, documents its license plate for subsequent legal proceedings. This chapter will also provide a comprehensive discussion on the final design culminating in an assessment of the performance of the system for detecting emergency vehicles and for enforcement of traffic rules violation. That is why we performed its testing, and the outcome in terms of traffic regulation and enhancement with better rule efficiency has shown a vast increase for a safer and more effective road system.

5.2. Completion of the Final Design

5.2.1 Components used in the Model

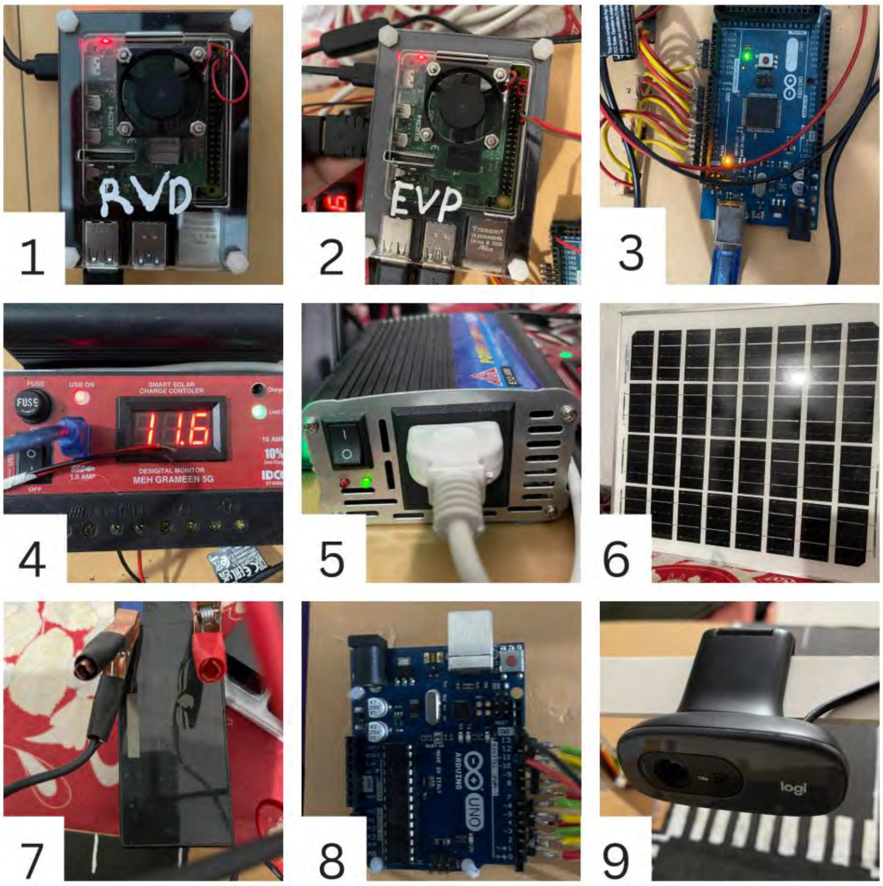


Figure 33: (1) Raspberry Pi for Rule Violation Detection, (2) Raspberry Pi for Emergency Vehicle Prioritization and Density Based Traffic Control, (3) Arduino Mega to control Traffic Lights, (4) Charge Controller, (5) Power inverter, (6) 20W Solar Panel, (7) 12V

5.2.2 Hardware Implementation

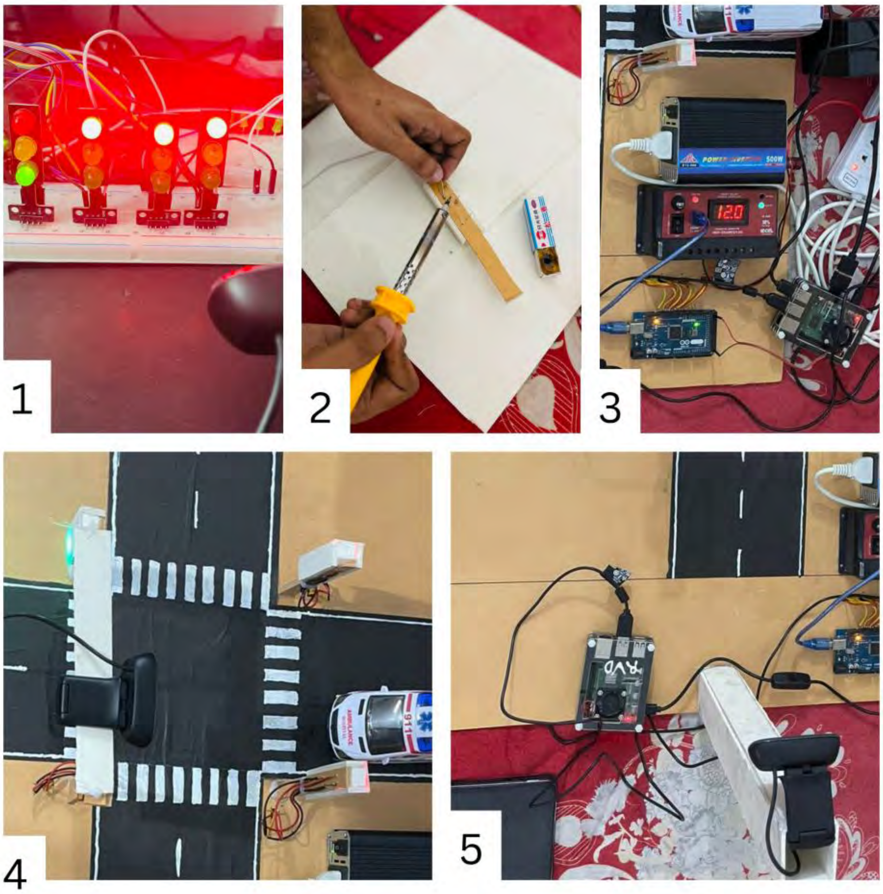


Figure 34: (1) Implementation of Pre-prototype, (2) Soldering the Components, (3) Installing Raspberry pi and Arduino with Solar Powered Battery, (4) Installation of the traffic poles and and the Emergency Vehicle detection camera, (5) Installation of the 2nd Ras

Some of the traffic scenarios that we used to train our emergency vehicle detection model include YOLOv5 below. Fire Truck and Ambulances will be counted for our emergency vehicle and as soon as it is detected with the camera the respective lane will go green, and all other roads will go red. Once the emergency car is located the trained model is very precise and once it has detected the emergency vehicle it gives a signal to the Arduino.

While it comes to the detection of rule violation detection, the feed received through the camera will be processed to check whether there is any red or yellow signal in the feed. It first converts the input frame from BGR to HSV color space and here we set HSV thresholds for the colors red and yellow. By using OpenCV we have adopted a region of interest and when the signal is anything related and excluding green.

The image processing segment within the system applies OpenCV in a bid to identify traffic lights together with vehicles to help monitor traffic rule offenders. The frames in the video are then transformed from the BGR format to the HSV and this makes color detection easier by splitting pictures into hue, saturation and value. HSV of the images contains a specific red, yellow, and green range, while masks are used to remove pixels that lie outside these specific ranges. The images are passed through the Hough Circle Transform technique in order to identify circular patterns that represent traffic lights. Once red or yellow color is sensed, a pretrained Haar Cascade Classifier is used to detect vehicles in the region of interest (ROI). This method enables the system to identify both traffic lights and cars, record infractions like jumping of red lights and record the car information for the…bgcolor=transparent This real-time detection is particularly efficient in the tracking and monitoring of traffic conditions in the roadway.

5.2.3 Final Design

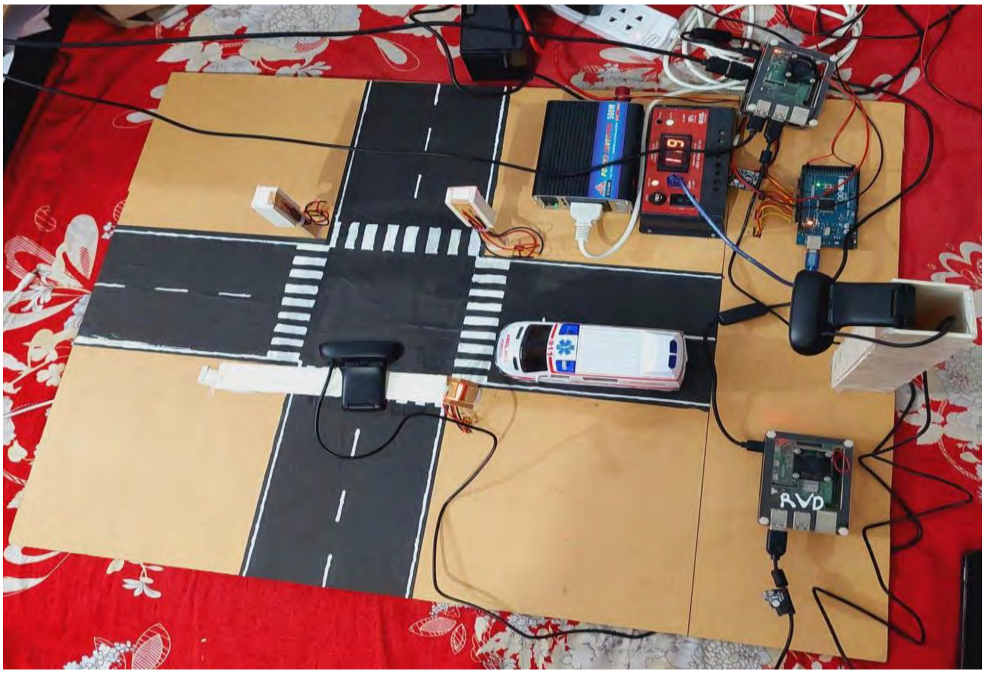


Figure 35: Final Design of Intelligent Traffic Management System

5.3 Evaluation of the Solution to Meet Desired Needs

5.3.1 Emergency Vehicle Detection

As mentioned earlier our aim was to identify the occurrence of emergency vehicles and narrow down their position. This was done under the premise of achieving a very accurate detection in order that the specified safety vehicle could be identified in the real time. After the detection of the target, the system continued to lock on the target and offered the correct directional movements to isolate it swiftly. This made it possible to closely monitor the movement of the emergency vehicle and reduce on any form of delay or hatchet job that would be caused by lack of proper coordination.

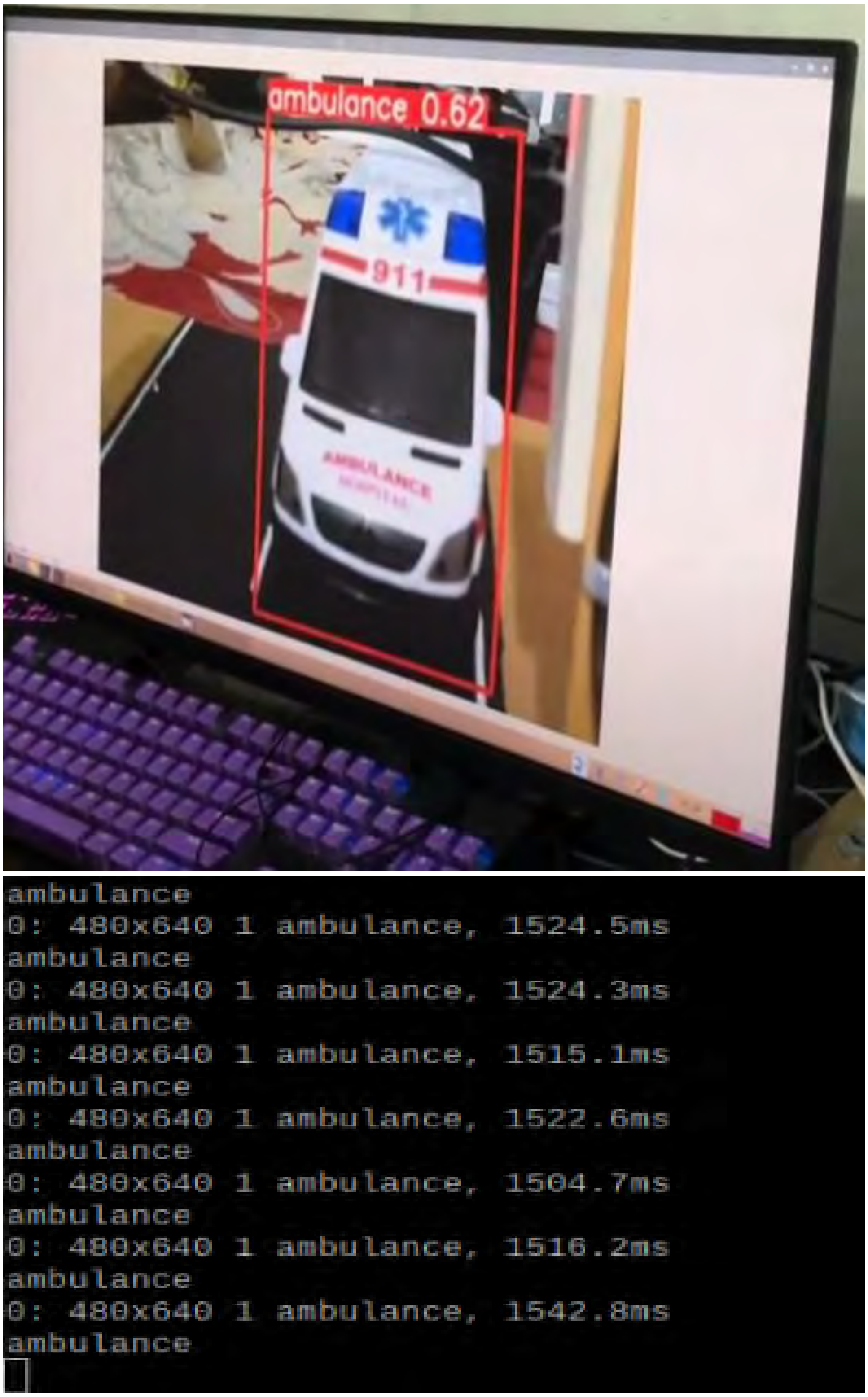


Figure 36: Emergency Vehicle (Ambulance) Detected

As we can see from the figure above it is already successful in detecting the ambulance. Since the test was conducted inside the car; we provided a model car and it was able to identify either the emergency vehicle or the car.

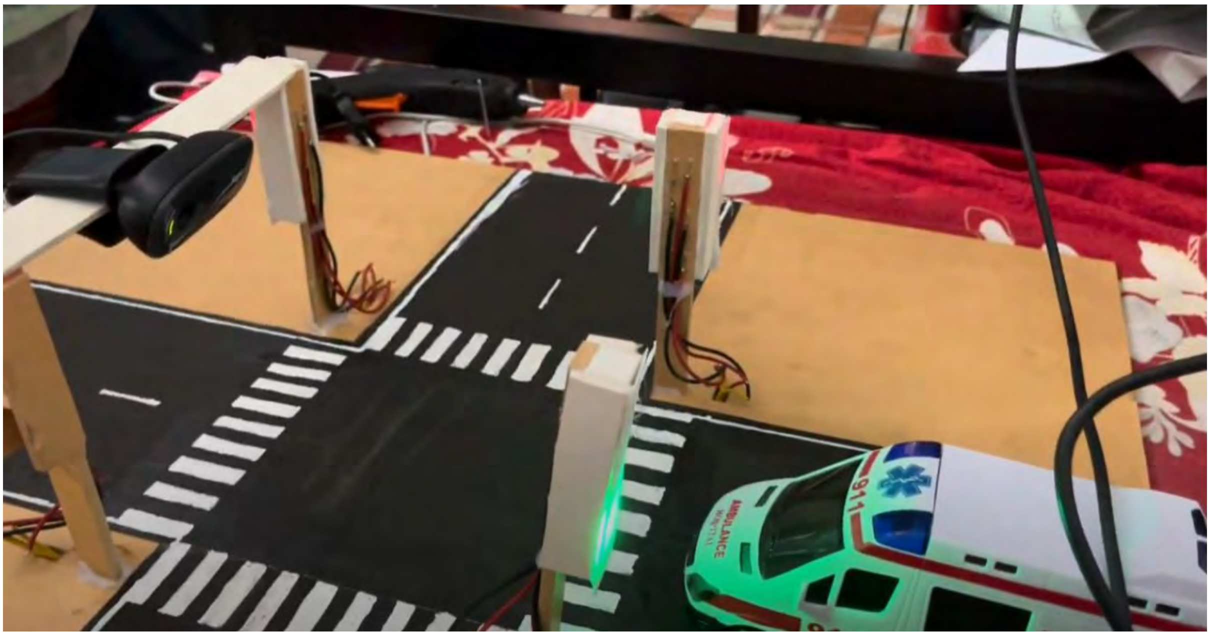


Figure 37: The Signal Turns Green After Emergency Vehicle Detection

As shown in the figure above, as soon as the system sensed the convex prism indicating the presence of the emergency vehicle, it proceeded to switch the signal of the approaching lane to green. At the same time, all the other signals blinked in red to make sure that the way was clear for the emergency vehicle and no other vehicle had to cross its path. This mechanism serves the purpose of the emergency vehicles reducing chances of congestion caused by other traffic by halting cross traffic. The prompt signal changes represent not only the effectiveness of the system to work with the traffic, but unsafety and response speed in important conditions.

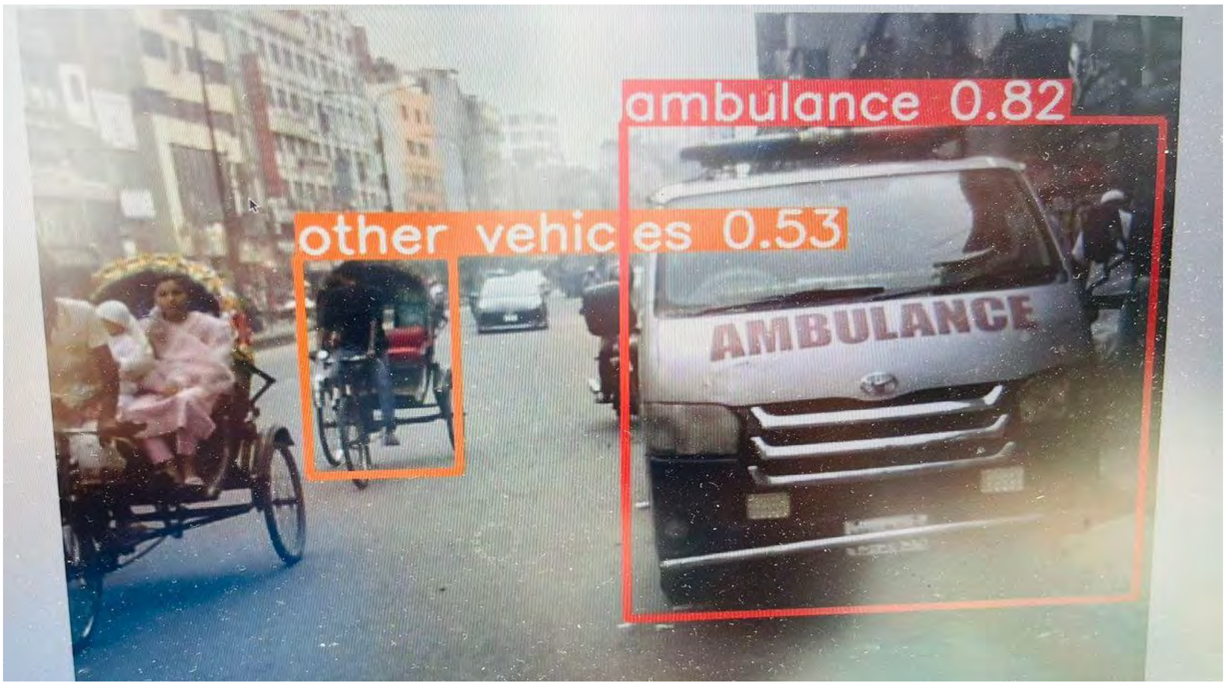


Figure 38: Emergency Vehicle detection In Real Life

Figure 39: Emergency Vehicle detection In Real Life

The two pictures above demonstrate the real-life implementation of our emergency vehicle detection system. From the images, we can observe that the model identified the vehicle with an 85% confidence level, indicating a high level of accuracy in recognizing it as an emergency vehicle. This performance reflects the reliability of both our detection algorithm and the model in practical scenarios. The successful operation in a real-world environment confirms that the system functions as intended, ensuring timely identification of emergency vehicles and supporting smooth traffic management to prioritize their movement.

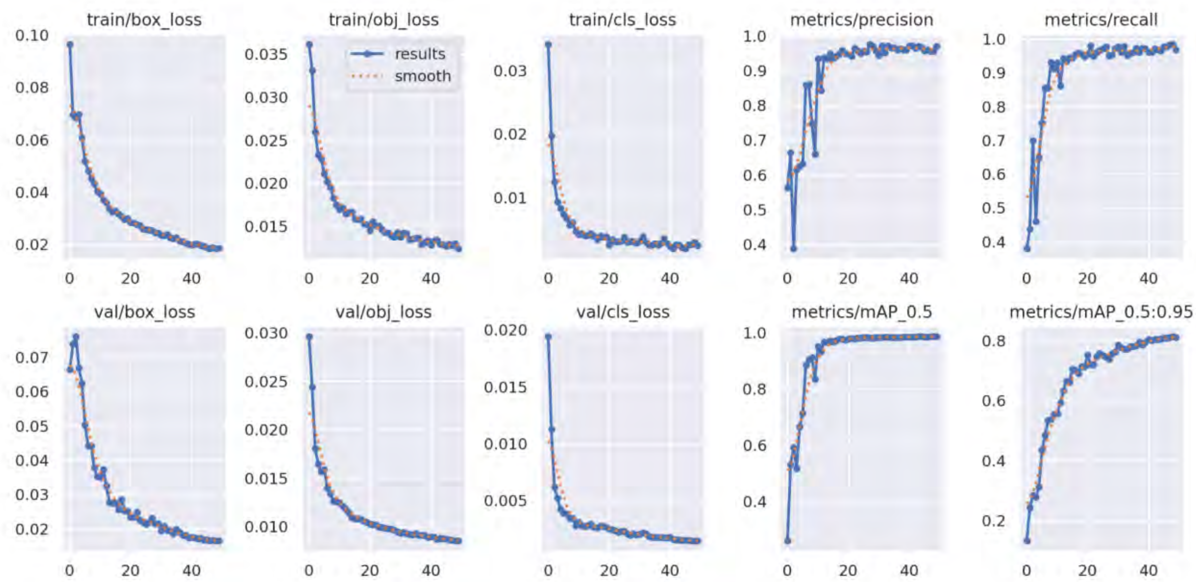


Figure 40: Emergency Vehicle detection model Metrics

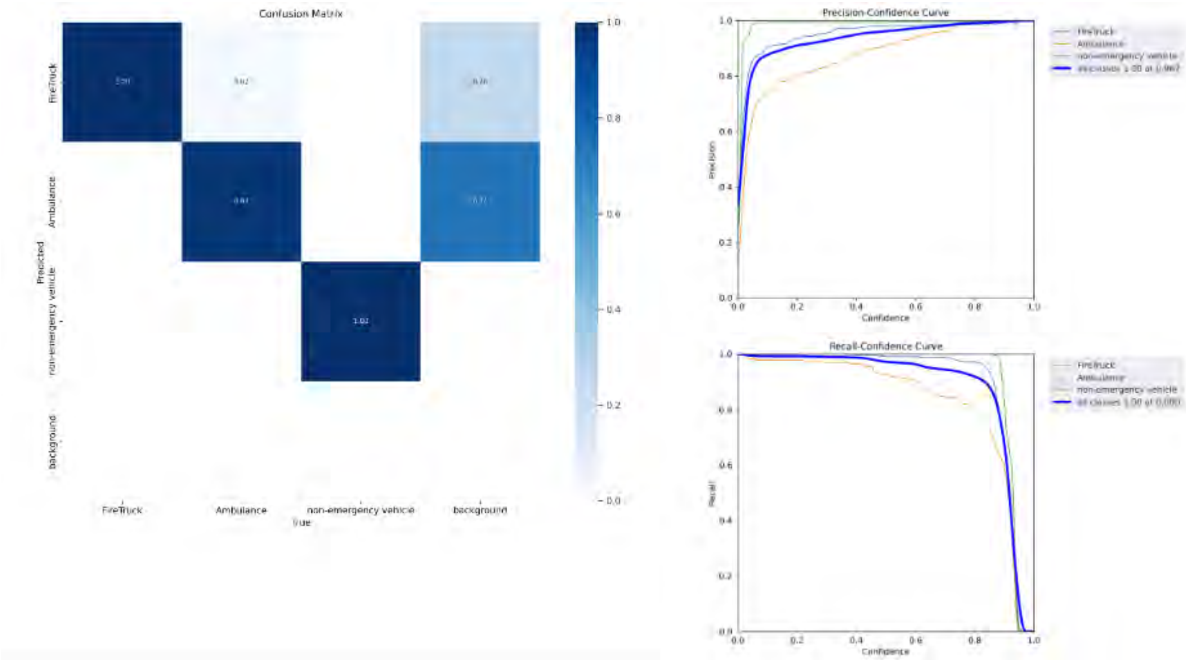


Figure 41: Training Accuracy of the Model

5.3.2 Rule Violation Detection

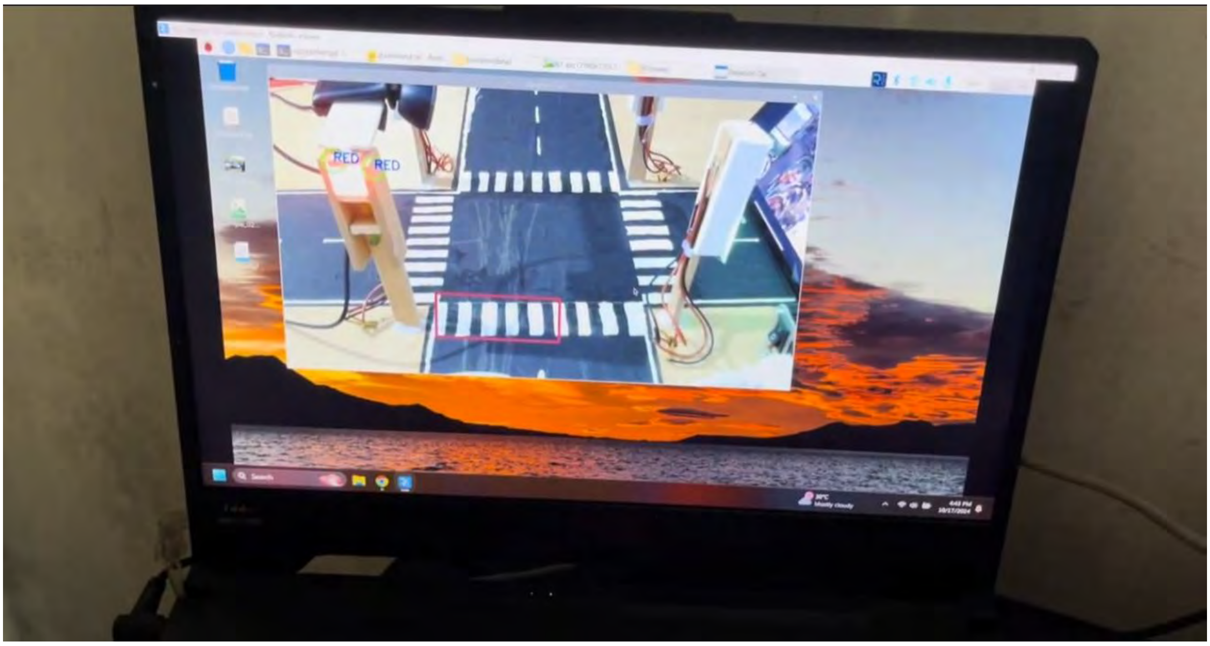


Figure 42: Red Light Detection.

In the picture above, the algorithm is well capable of identifying the red-light situation hence the right response by vehicles. We selected the ROI at the crosswalk since before this line the cars are compelled to halt if the signal is red or yellow. It controls that none of the vehicle enter the limit during such signal phases for times; it discourages improper traffic behavior by enhancing road safety. This configuration not only avails protection against accidents at intersections but also ensures that all vehicles adhere to traffic laws by tracking movement with reference to the ROI.

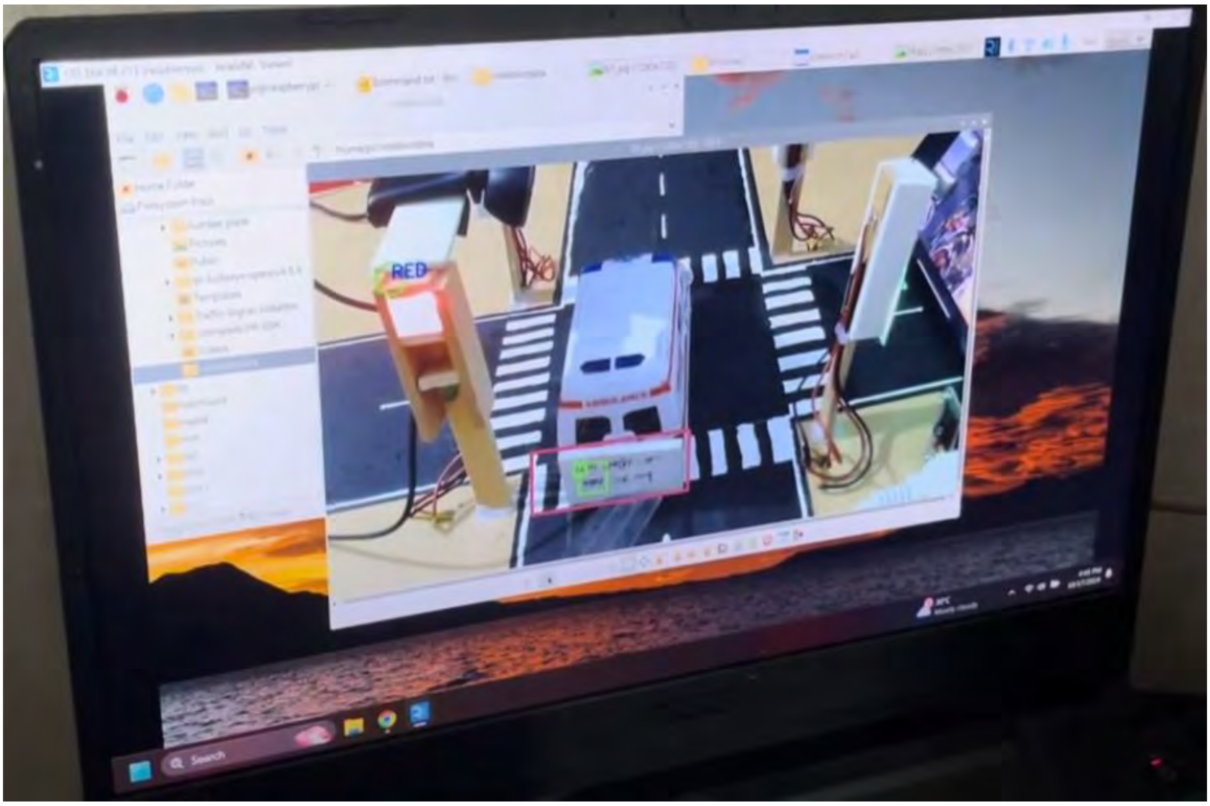


Figure 43: The Number Plate Capturing After Red Light Detection.

In this picture, we can WHOSE car crossing the intersection when he realizes that the traffic light is red? To which the algorithm simply answers by taking a picture of the car with the number plate being clearly shot. This functionality aids in ensuring that laws associated with traffic are observed, by recording infringements, with authorities being able to take corrective measures like drawing fines. The system makes it possible to track vehicles that ignore the red light and this helps to enhance safer roads and reduce reckless driving.

5.3.3 Density Based Traffic Control

In this section, we use image processing techniques to make the algorithm to detect the levels of vehicle concentration in real time. However, since it is cumbersome to simulate real life traffic conditions in a home environment, the system was developed to interface with live feeds. The algorithm can be to take feed from a live camera or can be set to work on recorded video feed. This approach is done to ensure that the system can monitor the density of traffic and verses of vehicles which contributes to the decision-making processes like changing signal intervals or identifying congestion levels.

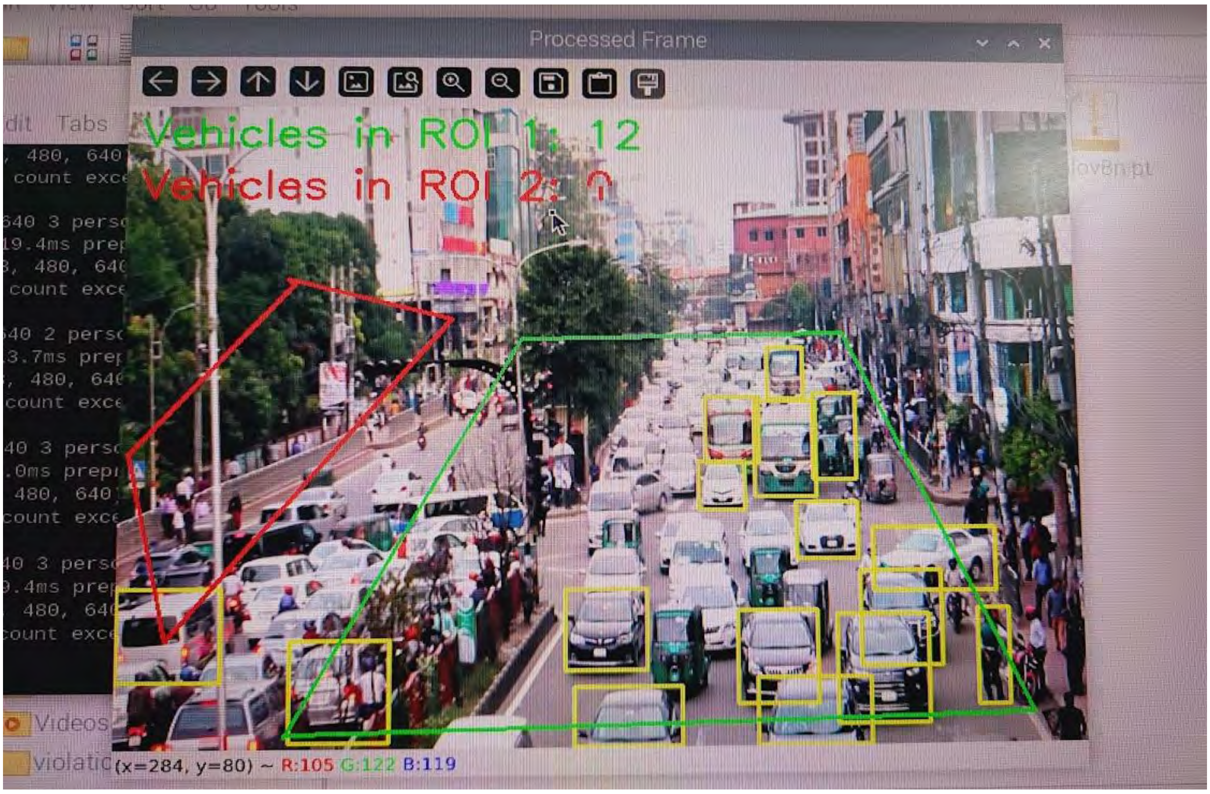


Figure 44: Implementation of Density based traffic control.

In the above photo, we are able to confirm that our algorithm is also detecting the vehicles on the road. The detected vehicles are shown in real time at the top left of the monitor which gives the user clear information of the traffic situation. This feature lets constant tracking of the presence and the number of vehicles and this will be helpful in traffic directing, density or subsequent decisions.

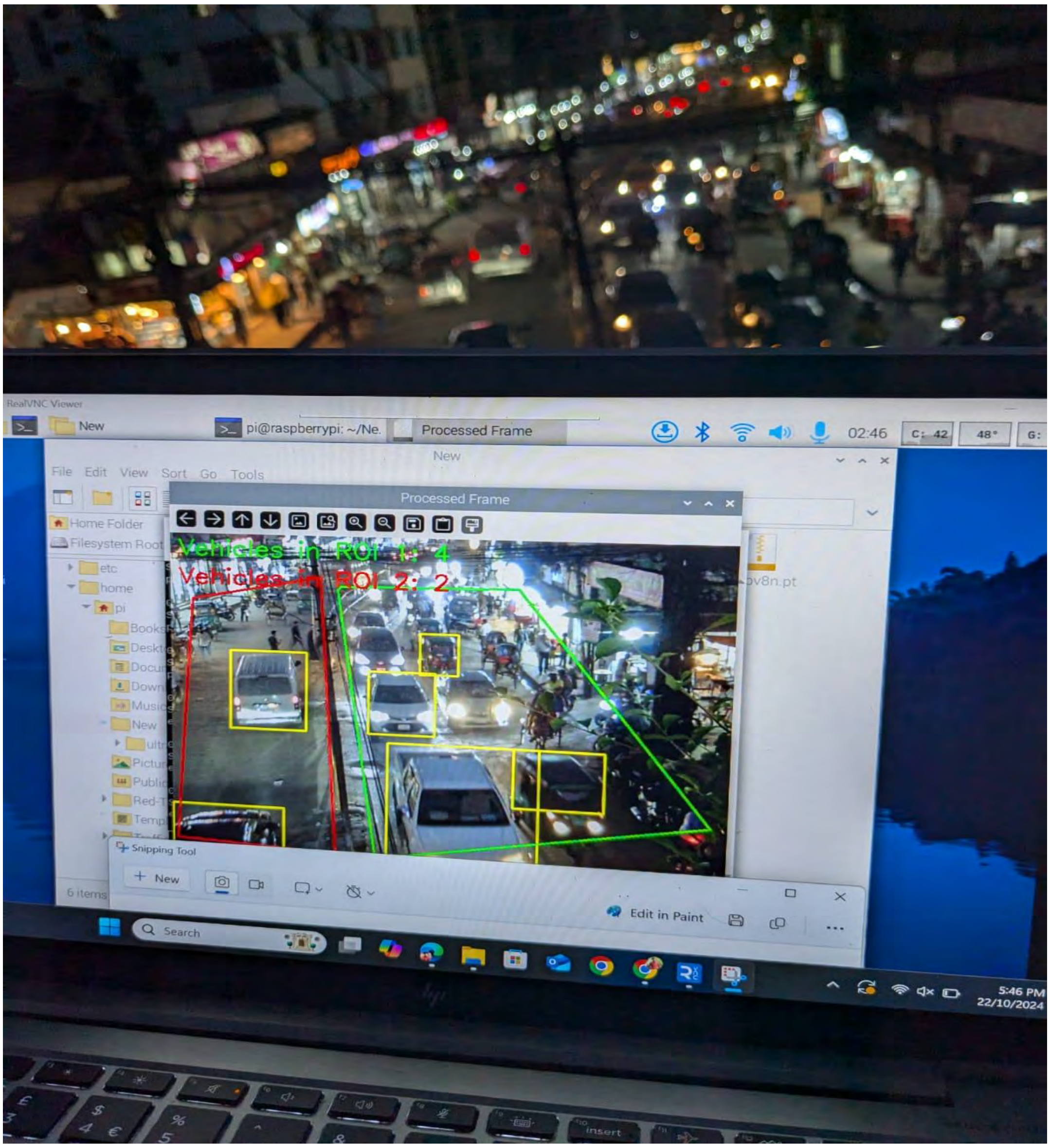


Figure 45: Density detection in real life

We can see from the next two photos that our model and algorithm is working and detecting vehicles on the road. And, in the next photo we can see that the traffic light is green on that road that has the highest density.

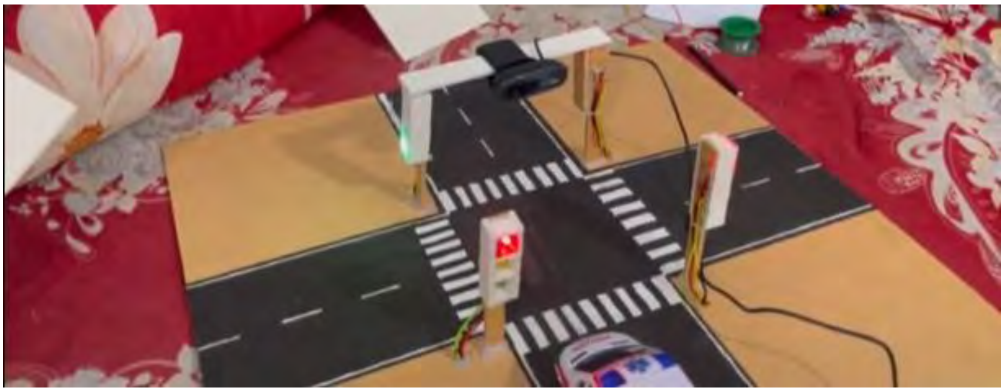


Figure 46: Modified Traffic flow due to density control

5.3.4 Performance Analysis

We ran several tests regarding our red-light violation detection and emergency vehicle detection and capturing the vehicle that violated the rule. By this we tried to determine the accuracy of our traffic system on different criteria and different scenarios.

Table 9: Performance Analysis

Operations	No. of tests	Successful Operations	Accuracy
Detecting Emergency Vehicle	30	28	93%
Turning the signal green after emergency vehicle detection.	30	30	100%
Detecting the Red Light	45	31	68%
Capturing the Red Light violated vehicle	45	36	80%
Detecting Vehicle Density	35	31	88%
Turning the Signal Green After Vehicle Density Detection	35	35	100%

We did some real-life detection with our models:

Table 10: Performance Analysis in Real Life

Operations	Average Accuracy	Time Spent
Turning the signal green after emergency vehicle detection.	85%	2 Hours 12 Minutes
Detecting Vehicle Density	90%	1 Hour

5.4 Conclusion

The final design and implementation of the intelligent traffic management system have yielded promising results in achieving the objectives of improving traffic flow and enforcing road safety regulations. The system successfully integrates two core functionalities: emergency vehicle detection and traffic rule violation detection, particularly for red-light violations. By leveraging advanced machine learning models like YOLOv5 for emergency vehicle identification and OpenCV-based image processing techniques for traffic light and vehicle detection, the system demonstrated high effectiveness in real-time scenarios.

The emergency vehicle detection system proved to be highly reliable, achieving a detection accuracy of 93%, and successfully turning the signal green 100% of the time when an emergency vehicle was detected. This functionality ensures that ambulances, fire trucks, and other priority vehicles can navigate through intersections more efficiently, minimizing delays during critical situations. The red-light violation detection system, while functional, had a moderate accuracy rate of 68% for detecting red lights, with 80% success in capturing vehicles violating the red-light rule. The vehicle density detection, which dynamically adjusts traffic signals based on road congestion, demonstrated a strong performance with an 88% detection accuracy, ensuring optimal traffic flow based on real-time conditions.

Despite these achievements, certain areas such as the accuracy of red-light detection could benefit from further refinement. Nonetheless, the system, through extensive testing, showed significant potential in real-world applications, successfully detecting traffic violations and prioritizing emergency vehicles. The results indicate that this intelligent traffic management system can serve as an effective solution for modernizing traffic control, improving safety, and enhancing overall traffic efficiency. Future enhancements and deployment in larger, more complex environments will further validate its scalability and robustness.

Chapter 6: Impact Analysis and Project Sustainability.

6.1 Introduction

A critical overview of the traffic problems coupled with the importance of project sustainability makes an impact analysis indispensable when creating and implementing an Intelligent Traffic Management System (ITMS), especially in light of growing metropolitan population illustrating current traffic issues such as congestion, safety, and environmental pollution. The following are part of thinking and planning: Impact analysis; this looks at the economic, social and environmental effects that are likely to be occasioned by the ITMS and allows stakeholders to make rational decisions concerning the application of the ITMS. This assessment measures short-term benefits, like changes in traffic congestion and decreased crash frequency, along with long-term consequences, like change in commutation patterns and improvement of populace wellness. Sustainability is the concept of finding a way of solving an existing problem in a manner that shall not harm the environment, other people or deplete sources of power in future. This consists of incorporating renewable power in the energy mix of a Reporting Entity, for instance by reducing dependency on non-renewable power sources such as thermal electricity to reduce its carbon index as in the case of the ITMS where solar power was suggested. Importantly, the maintenance requirements of the system are integrated into its design, as is the capacity to accommodate new geographical contexts of the city or sudden disruptions. This chapter will outline the methodological approaches to impact analysis to outline relevant measures and indices to assess ITMS and present an outline of how this project can be made sustainable by engaging stakeholders and developing a culture of ownership over the system. Through the enhancement of AA within the broad framework of the ITMS, the latter will not only reflect impact analysis, but will also involve the codification of principles of sustainability and will be able to make its specific contribution towards the development of smarter, safer, and more sustainable cities.

6.2 Assess the impact of solution

Below are the following social, economic, environment, health and safety, social, cultural, technological and legal consequences that will be brought about by our system.

1. Economic Impact: The ITMS can radically decrease the traffic density that in its turn means that productivity and economy of nations would increase. By cutting down the time needed to travel as well as enhancing car circulation, which in turn aids organizations in saving expenses, citizens also spend less on fuel. It has also been established that by managing traffic congestion, the city can save billions of dollars in terms of Economics. For instance, managing congestion in cities has been valued at up to $3 billion in terms of the money that will be saved through fuel and time wastage [19].

2. Environmental Impact: Solar powered ITMS also supports sustainability through reducing the use of the non-renewable energy resources. Shell does not only reduce carbon emissions from its production processes but also uphold energy conservation. Combined with the fact that less vehicles are standing idle in traffic due to improved flow, it is apparent that the quantity of greenhouse gasses and other pollutants in urban environments is reduced. Studies show that with ITS it is possible to decrease emissions by up to 30% [20].

3. Social Impact: The ITMS working better for traffic signal control and automated violation detection seems to help in decreasing the number of accidents, and thus saving lives. When roads are well managed and traffic laws obeyed and ways given to more emergency vehicles, the public feels safer on the roads. According to research, ITS can lower the average accident rates by about a quarter, or around twenty-five percent [21]. Further, the real-time traffic information helps users to improve their time use while commuting and, therefore, come up with meaningful travel plans.

4. Technological Impact: The use of technology including artificial intelligence, machine learning, and IoT sensors in the ITMS changes the way flow of traffic is handled. These technologies produce a more efficient method of data acquisition and processing to determine real time traffic signal control. Additionally, the project can act as a blueprint for other smart city endeavors, which will in turn trigger the development of additional technologies for smart mobility cities [22].

5. Governance and Policy Impact: This may in turn mean that the ITMS needs to develop adjustments of traffic regulation and policies recognizing new technologies and practices on the road. It facilitates partnership between different governmental agencies, as well as other associated parties, and leads to increased coherence of the processes of urban development. This collaborative governance model can contribute to the development of a successful management model of traffic in large cities.

6. Safety Impact: The ITMS greatly contributes to better movement management and observation of traffic conditions thus increasing road safety. The probability of traffic mishaps is minimized by putting into practice automatic traffic control programs with detection of traffic offenses and orderly incorporation of priority sirens for emergency vehicles. In addition, real-time data analytics involve analysis of live data which can be responded to quickly hence allowing timely interventions for traffic incidents. The evidence shows that by implementing intelligent traffic systems, one can reduce traffic accident fatalities by as much as 40% [23].

7. Behavioral Impact: The implementation of the ITMS can alter the driving behavior of an individual through the use of vídeo based supervision and automatic compliance checks. When human drivers have a cue about the automated monitoring systems, they are likely to minimize their dangerous behaviors like speeding or even ramming through the red lights. Furthermore, offering the possibility of giving real-time traffic updates can assist the drivers in making better decisions about their driving, being able to decrease frustration and create more courteous driving behaviors [24].

8. Urban Planning and Development Impact: The integrated traffic management system thus makes it easier for the city planners to deduce effective traffic data for city development plans.

Through traffic analysis, and identification of some of the choke points in the transport network urban planners can be able to address issues affecting transport by identifying the necessary equipment and structures to install on the network so as to ease traffic flow consistently. The ability to make decisions with regard to the improvement of public transport and infrastructure can be made precisely by incorporating this big data, hence making great contributions to greater livability within cities [25].

9. Integration with Smart City Initiatives: The ITMS is a key building block for and supportive of other smart city developments. On that note, the ITMS does not exist in isolation, but can link into other smart systems that co-develop an integrated smart environment, for instance in public transport management, environmental monitoring and energy management." A good example is the combination of social, economic and infrastructural perspectives that will enhance synergy that promotes utilization of resources and reduce the cost of running the city so as to foster the wellbeing of its inhabitants [26].

10. Technological Advancement Impact: The ITMS facilitates advancement in tech technology in transport and communication. Going deep into the use of innovations like IoT and AI, big data analytics not only improve traffic management in this project but also contribute to creating new sectors. By putting in place such a system, cities will foster development of skilled labor relating to technology development and maintenance of such systems, thus a positive boost to the workforce education and training on areas of technical advancement [27].

11. Community Engagement Impact: Evaluating the framework calls for the involvement of the people in the community in order to plan and put in place the ITMS. Engaging citizens in decisions of traffic management solutions makes the project its own itself and be answerable to traffic problems. Closely involving the public is another way to get ideas that can complement organizational ones, thus improving public satisfaction with urban infrastructure.

12. Accessibility Impact: The ITMS may increase accessibility for all road users, both the PS and transport users such as pedestrians and cyclists. With aspects such as pedestrian detection, bicycle lanes, and information regarding the state of roads it raises the number of safety and convenience within the urban traffic and transportation systems. This inclusion has been a way of encouraging people to transport themselves through other means besides the private car; hence, they enhance health among others [28].

6.3 Evaluate the sustainability

As a tool of measuring sustainability, traffic impacts have an environmental, social, and economic part in an Intelligent Traffic Management System (ITMS). Below are key aspects of sustainability concerning the ITMS:

1. Environmental Sustainability

- **Reduction of Carbon Footprint:** Through traffic control and congestion minimization, the I/TMS makes efficient contributions towards containment of auto emissions, and thus enhanced environmental quality. Research has also revealed that congested traffic flow systems can be made to release fewer greenhouse gasses [29].

- **Use of Renewable Energy:** Use of solar power in the ITMS brings about sustainability. Solar lights; Traffic light solar systems can power the traffic lights and other parts and so require less power from nonrenewable sources hence cutting down on expenses [30]. They further erode emissions while also gaining credibility for operations continuity during periods of power interruption.
- **Encouragement of Sustainable Transport Modes:** When it comes to enhancing broad strain of traffic the ITMS can favorably affect public transport and pedestrians as well as cyclists. This way, sharing real-time information about public transportation and applying such novelties as pedestrian detection contributes to a degree of transition to more ecological means of transport [31].

2. Economic Sustainability

- **Cost Savings:** Thus, optimization of traffic flows has the potential for generating considerable economic effects, deriving from fuel savings and lower cost of vehicle usage. According to research done in the traffic management in the major urban centers, it has proved to reduce the economic costs in the traffic flows by reduced time taken in traffic and thus increase in productivity [32].

- **Job Creation:** Effectively utilizing and maintaining ITMS generates employment particularly for technology, engineering and urban development specialists. It also fosters skills in the renewal areas of AI, IoT, and big data analysis [33].

- **Increased Property Values:** Proper management of traffic within cities, may lead to better quality of life and better returns on properties in those areas. Better access and traffic demand decrease attraction of neighborhoods to residents and business entities, simultaneously [34].

3. Social Sustainability

- **Enhanced Public Safety:** The ITMS has the potential of cutting down on the number of road accidents, and resulting fatalities, as it is fitted with real-time accident and violation identification mechanisms. They have therefore enhanced safety leading to increased acceptance from the community in the implementation of traffic regulation measures [35].

- **Community Engagement:** Citizens who are involved during the planning as well as the implementation stage feel part of the project. Public participation assists in implementation of the ITMS and satisfaction with the needs of the various populaces is likely to be higher [36].

- **Improved Quality of Life:** In doing this, ITMS cuts down on travel time and congestion; thereby improving the quality of life for residents. Efficient traffic control results in reduced driver stress, congestion, and more time, as well as health benefits if people walk or cycle for transport [37].

4. Technological Sustainability

- **Integration of Advanced Technologies:** As an emerging technology system, the innovative technologies including IoT, AI and Big data, are also encompassed by the ITMS to support flexibility to dynamic environment and expansion of the system. Such technologies facilitate the ability to work in real time and make improvements periodically so that the system is continually effective, not just for a short time frame [38].

- **Interoperability:** The integration of the system with currently existing infrastructure and other smart city projects enhance its sustainability and effective elimination of duplication. Such compatibility is critical in ensuring that there is a smooth running of the transport system in compliance with the traffic demand for the urban transport network [39].

5. Resilience and Adaptability

- **Response to Climate Change:** With regard to environmental fluctuations, such as unusual climatic conditions, the ITMS can be optimized for operation in such conditions. The application of adaptive traffic signal control can guarantee continuous function during adverse conditions to increase the system robustness [40].

- **Disaster Recovery Plans:** Effective Disaster Recovery and Business Continuity plans, under the ITMS framework, allows traffic management to continue during the occurrence of disasters disrupting operations in the cities minimally [41].

6.4 Conclusion

In conclusion, the Intelligent Traffic Management System (ITMS) expounds on several dimensions for improving sustainability in urban transportation. The secondary improved environmental goals focus on: Energy—the ITMS considerably cuts carbon emissions, supports the use of renewables, and enhances public safety. Not only does it result in saving costs and job opportunities, but also increases residents' quality of life due to better traffic circulation and provision of incentives for eco-friendly transport means. Due to the incorporation of the current technologies and the involvement of the community, the ITMS stands better placed to enhance the aspects of flexibility and sustainability so that the current and future transportation systems need are met. In total, the ITMS reflects a positive trend in developing intelligent cities that will be more suitable for people to live in.

Chapter 7: Engineering Project Management.

7.1 Introduction

Engineering Project Management is the fundamental structure of managing projects and it can be said that for the execution of these complex projects like ITMS. This chapter focuses on the systems that provide an organized method of addressing all components of the undertaking, including its planning, acquisition of resources, implementation, and control for risks. This project involves elements of technology as well as planning and coordination for the deadlines, costs, government agencies, engineers, and vendors. This chapter explains how to manage ITMS development, implementation, and operation to create an efficient traffic system by using a set of equally efficient project management tools, including task planning and scheduling, resource allocation, and performance control.

7.2 Define, plan and manage engineering project

We handled and completed our engineering project through a well-organized, step-by-step process, ensuring everything proceeded efficiently and all objectives were achieved as planned.

7.2.1 Planning:

This paper is classification of plausible I/O types determined by reviewing theoretical literature and formulating possible I/O types permitted throughout the ITMS planning phase: objectives, scope and deliverables. It involves determining other features that include traffic signal management, violation detection using image-processing techniques, and issues to do with prioritizing emergency vehicles. We draw out a clear time frame and cost estimate, with a view of resource management. Furthermore, a risk assessment of possibility threats is conducted, and measures regarding their prevention are described. Stakeholder involvement is important in this project to capture needs and expectations so as to meet both the community and legal requirements.

7.2.2 Formulating:

Development of the project entails translating the planning observations into decisions and determining the features of the ITMS. This includes the determination of system structure and establishing that the cameras shall be used for image processing. In cooperation with team members, we develop documents stating the shape of the project as well as system interfaces, data transfers, and efficiency parameters. Stakeholder's approval and legal and environmental requirement seeking are also required at this stage.

7.2.3 Implementation:

In practice, we introduce the ITMS through installing cameras for image processing and connecting them to the traffic signal controls and emergency vehicle prioritization. The key benefits result from efficient integration of different components and smooth cooperation of the team members. As such, where timelines and budgets are at risk, we track these actively in order to mitigate the underlying issues. Training is also organized for the sake of the operational personnel so that they can gain exposure with the system and how to tackle any problems that may show up regarding deployment.

7.2.4 Regulating:

Monitoring of the ITMS entails a comparison of the system with specific benchmarks which have to be complied with. Here information received from the image processing systems is studied to evaluate the efficiency of the traffic management and safety measures. Feedback from the users and stakeholders can be collected to discover more gaps that need to be rectified and other regulation needs to be met. It therefore can always be updated hence ensuring that the system can be adjusted to suit the needs of the community.

7.2.5 Finalization:

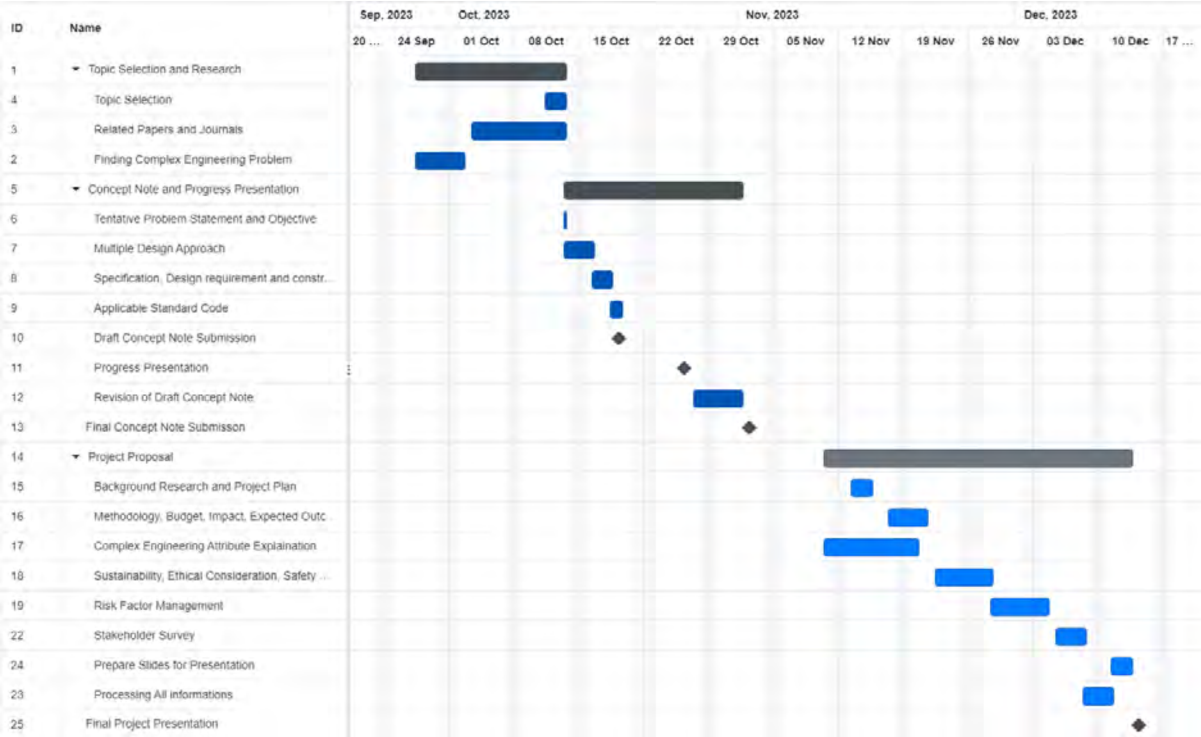
When all goals formulated at the onset of the ITMS project have been met, the finalization phase of the project is reached. Documentation We maintain records, Lessons learnt and best practice checklists for future references. A final report is a synthesis of system performance, evaluations from people who used the system, and effects on traffic control and safety. Strategies are put in place for the maintenance of the ITMS and there is consultation in relation to the presentation of results and some prospective improvement suggestions hence promoting a shared approach to traffic management initiatives.

7.3 Evaluate project progress

For the completion of our project, we followed three key stages: The three courses are EEE499P: Project Planning, EEE499D: Project Development, and EEE499C: Project Completion. Each stage was done systematically and for the entire year so that all the stages would be well-covered. To maintain momentum, the deadlines for the particular tasks were set and a close watch was kept on time-line with documentation on time required to accomplish that particular section. In this structured manner they helped maintain a time schedule and overall facilitated the accomplishment of the project throughout the phases.

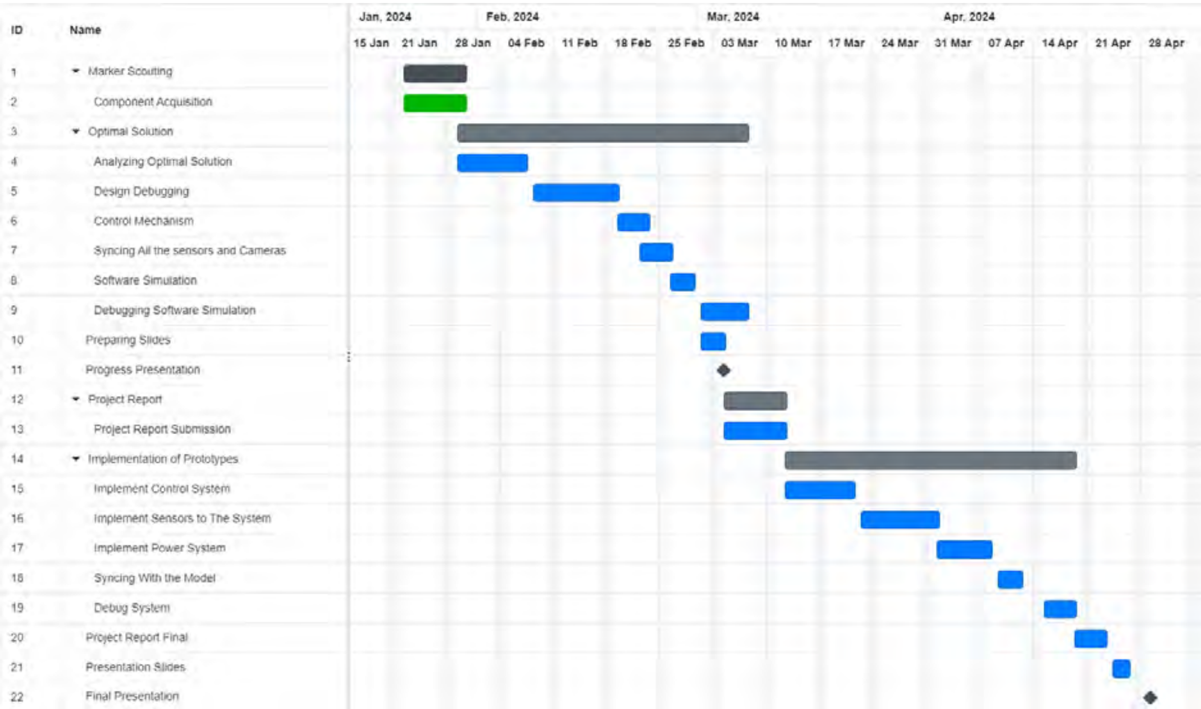
7.3.1 EEE499P

Table 11: Gantt chart for FYDP-P



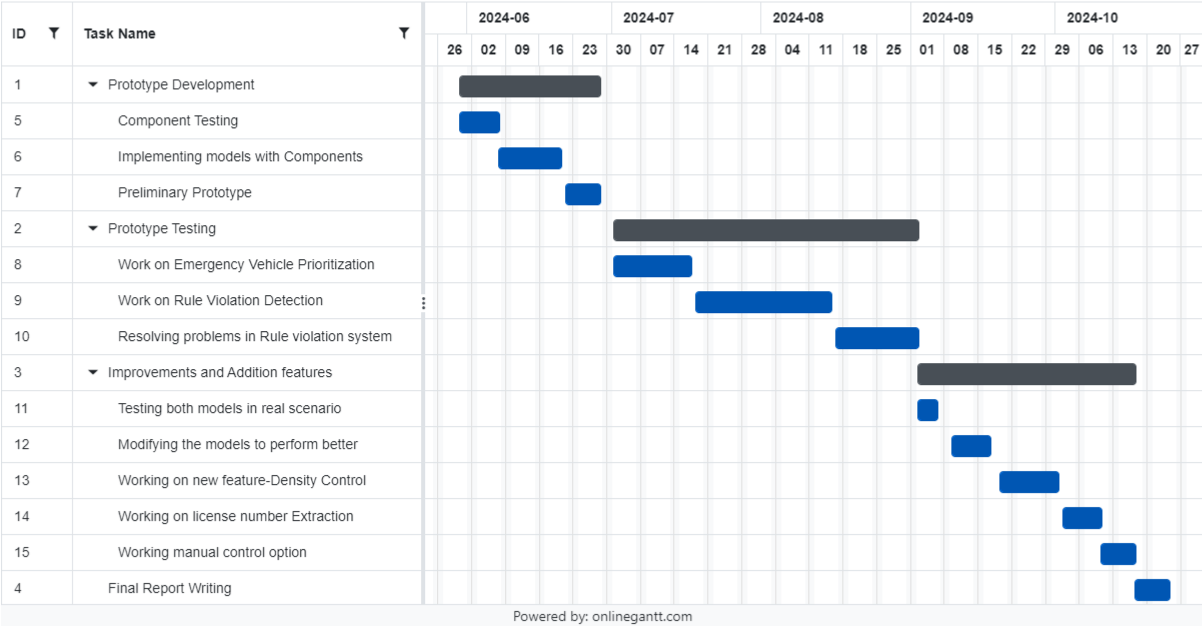
7.3.2 EEE499D

Table 12: Gantt chart for FYDP-D



7.3.3 EEE499C

Table 13: Gantt chart for FYDP-C



7.4 Conclusion

Lastly, the systematic framework that was used in our project which includes; planning, development, and completion has prominently contributed to the project's success. I documented the components of the project, broke it down systematically and assigned deadlines to the sub tasks in a way that we could keep track of time and work in a smooth and steady pattern. This methodology, apart from ensuring timely accomplishment of the activities, also helped to address the occurring problems flexibly. Looking to the future from here, we will be equipped with insight on how to better approach future projects focusing on organization and tracking to get things done.

Chapter 8: Economical Analysis.

8.1 Introduction

Intelligent Traffic Management Systems are the radical change from the traditional approach and the attempt to scale up urban mobility control using technologies such as IoT-based sensors, artificial intelligence and big data, real-time data analysis. These systems are intended to improve both the escalating problems of traffic congestion in cities around the world which results in billions incurred by worldwide economies in terms of time and fuel, not to mention the congestion's impact on the environment. Generally, as the size of the cities grow and congestion by vehicles increase, ITMS comes in as a great solution for improving on transport and making cities more habitable.

8.2 Economic Analysis

The implementation of ITMS affects multiple economic stakeholders and sectors:

Direct Economic Impact

a. Less traffic jams that contribute to use of less fuel.
b. Reduced vehicle operating cost based on most efficient path selection
c. A less demand for traffic enforcement personnel
d. Hours saved from traveling resulting in improvement of working productivity.
e. Youth employment in Technology and System maintenance industry

Indirect Economic Benefits

a. Higher business productivity by reducing risks of damage to goods and delays through transport.
b. New retail outlets opening especially where accessibility has been enhanced
c. Fewer expenses for cleaning the environment
d. Elimination of pollution costs from the society via reduced cases of illnesses associated with environmental pollution
e. Improved tourism because people are able to navigate round cities better.

8.3 Cost-Benefit Analysis

Final Component Budget

Here's the detailed budget breakdown for the components used in Design Approach C of us project.

Table 14: Prototype Budget Calculation

Components	**Unit Price BDT**	**Quantity**	**Price BDT**
Raspberry pi 4 model b 2gb	16000	2	32000
20W solar panel	1000	1	1000
Webcam	2500	2	5000
12V 9A Battery	1200	1	1200
Charge Controller	400	1	400
Arduino Mega 2560 R3	2500	1	2500
Traffic Light Module	100	4	400
		Total	42500

8.4 Evaluation of Economic and Financial Aspects

Here is the summary of the annual financial evaluation for our system:

Financial Indicators

Table 15: Evaluation of economic and financial aspects

Category	**Description**	**Amount**
Investments		
Units Produced and Sold	Number of system sold annually	50
Unit Production Cost	Cost of producing each system	42,500
Total Investment Require	Total cost of production annually	21,25,000
Revenue		
Selling Price	Price per system sold	70,000
Total Revenue	Revenue from units sold annually	35,00,000
Profit		
Annual Gross Profit	Total revenue - total production cost	13,75,000

Annual Profit Rate	(Annual Gross Profit/Total Production Cost)*100	64.70%
Return of Investment		
Research and Optimization	5% of the annual profit	68,750
Annual Profit of the Investors	(64.7-5) =59.7%	13,06,250

From the table one can have a clear picture on the financial dimension as it relates to the sale of the system. More than a year that showed the revenue due and cost essential in the production and. sales. As seen from table 10, our total cost is 42,500 BDT. If we are selling the above-mentioned product at the rated price of 70,000 BDT then we get a net of 27,500 BDT from each of the systems sold. Where it makes 64.7 percent profit from each of the products.every year while 5% of the capital is to be retained for more research, the investors would earn 13,06,250 BDT. Over a year that highlights both the revenue and costs associated with production and sales. In the production method, the organization is also dependent on economies of scale where bulk purchase is done. Parts in large quantities, the ramifications of which will be dramatic reductions in costs across each component.

In this process, different components are manufactured in the factory to also maintain efficiency and quality during the manufacturing process. Moreover, development of components that afterwards cannot be procured from anyone else but the developer helps. Extra cost and size extension and will as a result bring about an enhancement of the general value of the system.

Economic Indicators:

a. **Direct Economic Impact**
   - GDP contribution: 6-10 % increase in GDP of Bangladesh
   - Reduce working hours wasted which can boost the economy by almost $4-5 billion annually.

link: https://businessinspection.com.bd/economic-impact-of-traffic-jam-in-bd/

b. Sustainability Metrics
   - Carbon emission reduction: 15000 tons annually in HongKong
   - Energy efficiency improvement: 10-12%
   - Resource optimization: 20-25%

Yusuf, Jamiu. (2024). Economic Evaluation of Smart Traffic Management Systems in Reducing Carbon Emissions. Journal of Economics Business and Accountancy Ventura. 1. 30-35. 10.69739/jebc. v1i1.82.

8.5 Conclusion

The economic justification suggests further that the adoption of an ITMS scheme forms an economically rational decision undertaking towards enhancing urban traffic management. The initial capital investments in this system are rather significant; however, the latter provide multiple opportunities to generate equitable economic profit. Fixing both, tangible financial gains and overall optimizing social returns give ITMS a powerful push towards being a solution for current and future transport problems in large metropolitan regions. The fact that the system brings about economic benefits in the short and long run, and enhances the environment reveal it as a core infrastructure asset in sustainable urban growth. The projected values of the financial profitability point to high financial feasibility, and the calculated values of social profitability show significant positive externality for the community. Cities should think about an incremental approach to control costs and risks within the implementation of the system but achieve the maximum coverage of the stakeholders. It is therefore important to perform constant checks with reference to influencing variables that may impede or facilitate service continuity; in addition, this will form the basis of the tweak strategy to sustain, as well as improve on the economic value proposition of the system as time progresses.

Chapter 9: Ethics and Professional Responsibilities

9.1 Introduction

We present a list of the research questions which contribute to raising awareness of the ethical concerns and the professional responsibilities arising from the implementation of the Intelligent Traffic Management System (ITMS): More and more technology is becoming a part of the urban fabric of a city and engineering, planning, and policy professionals must make difficult discretionary decisions about data privacy, surveillance, and public safety. Due to the fact that real time traffic data is actually collected and analyzed, there are high privacy and security risks, which mandates high degrees of protection against misuse of the statistics collected. Besides, it is critical to minimize variations in traffic management distribution, in a way that none of the demography benefits more than others regarding technology. The most significant aspect which should be made clear is the decision-making process, in specific the use of the automated enforcement measures and consequences it has for the citizens' freedom. Those professionals, who participate in the ITMS project, are responsible for their ethical behavior and report their performance in compliance with integrity, fairness and accountability for the public good adhering to societal norms. Furthermore, it is increasingly important to have a sustained response to concern and distrust by engaging community members, stakeholders or the public. Through its own adherence to the said ethical principles and professional responsibilities, the ITMS project is capable of advancing safer, efficient, and fairer cities for all citizens.

9.2 Identify ethical issues and professional responsibility

Realizing the ethical components as well as the professional roles in the area of ITMS is based on the following factors:

9.2.1 Ethical Issues

1. **Data Privacy:** The acquisition and manipulation of real-time traffic information present privacy risks for people. How one acquires, processes, and utilizes data must be clear to prevent abuse and compromise of the privacy of that information.

2. **Surveillance:** The introduction of cameras and traffic sensors can give people an impression of excessive attention, creative prejudices related to infringement of civil rights, and the possibility of misuse by the authorities.
3. **Equity and Access:** Thus, equity should play a major role in any strategies deployed under the ITMS technologies, in order to ensure that all communities regardless of margins, have equal access to the benefits accrued from efficient traffic management systems while at the same time, ensuring that the systems in place do not disproportionately affect the margins.
4. **Automated Decision-Making:** Machine learning algorithms used for traffic enforcement type of tasks can reinforce or introduce bias or unfairness to the process if not audited periodically for fairness.
5. **Environmental Impact:** Despite the fact that the function of the ITMS is the decrease of emissions and congestion, the environmental impact of utilization of such a tool, including energy usage, and amounts of waste released from hardware, has to be taken into consideration.
6. **Community Engagement:** The lack of proactive participation of local communities in the elaboration of ITMS and their subsequent processes may lead to their suspicion and opposition, which underlines the necessity of communication and feedback processes inclusion.

9.2.2 Professional Responsibilities

1. **Transparency:** People associated with ITMS development need to work with full disclosures regarding data availability, operations, and usage, and then effectively communicate those aspects to the general public concerning the capacity of the system as well as its drawbacks and shortcomings.

2. **Accountability:** For this reason, developers and stakeholders must take responsibility for the decisions made in the usage of ITMS and especially in handling the resulting undesirable effects of the technology.
3. **Ethical Use of Technology:** Technology should be used in a manner that is ethical. This has to be ensured by the professionals without violation of rights of individuals as well as improvement of safety of the public should be aimed at.
4. **Continuous Improvement:** It also contains a commitment for on-going evaluation of the ITMS and the commitment for making the necessary changes to fit changes within the community as well as advances in technology.

5. **Training and Education:** Another approach involves conduct of training on the ethical factors or the appropriate use of technology so that all users can be in a position to promote the required ethical behavior.
6. **Collaboration:** Any relevant project of developing or reassessing the system of care respectively requires awareness of the sources of various needs and expectations of stakeholders that include the members of the community, policy makers, and advocacy groups.

9.3 Apply ethical issues and professional responsibility

Evaluating ethical issues and professional responsibilities when implementing an Intelligent Traffic Management System (ITMS) involves developing an ethic of ethics, where the subject is considered in order to come up with a system that can ethically express itself throughout the processes of developmental and implementation phase. Here's how these ethical issues can be addressed in practice:

9.3.1 Application of Ethical Issues

1. **Data Privacy:** use many and varying techniques about data management as a means of protecting the privacy of users. This includes procedures like avoiding publishing of identity numbers, restricting access to special data, and conducting review from time to time to confirm compliance to privacy act like (GDPR) or any other laws of the country.

2. **Surveillance:** It should also be noted that the allowable use of surveillance technologies and some of their key application settings should be defined. This might include transparent information on what type of data is harvested, how this data will be utilized and measures, which allow involving your average Joe to oversee the proper usage of the harvested data and prevent authorities from misusing it. Surveillance should not be managed secretly; the community should be consulted to find out which type of surveillance is best for them.
3. **Equity and Access:** Carry out a significant measures analysis to discover that the innovative system impacts the minority groups adversely. This could entail discussing with community stakeholders to get their grievances and / or ensuring that system offers equal opportunity to all people. For example, deploying the system in areas that have many incidents of motor vehicle accidents and the like.
4. **Automated Decision-Making:** Forever check and also verify each algorithm for bias and fairness. This is done through having teams with diversity assess the algorithms as well as considering public inputs in the occurrence of any negative impacts on communities.
5. **Environmental Impact:** Ensure that an excellent green solution is incorporated into the development and deployment of the ITMS, for example; the use of green energy, recycling of electronic items. Make sure to evaluate the environmental impact of the system as often as possible and present the data gained to other participants.
6. **Community Engagement:** Develop the best framework for involving the community in the entire project implementation process. This includes engagement of espoused

stakeholders, reception of their feedback, and guaranteeing that these stakeholders participate in decision making processes.

To Whom It May Concern

Subject: Request for Permission to Install Traffic Monitoring Cameras and System

Dear Sir/Madam,

We are writing on behalf of BRAC University regarding our research and development project, Intelligent Traffic Management System (ITMS). This project aims to address urban traffic challenges such as congestion, road safety, and traffic rule violations by utilizing advanced technologies like real-time data processing, traffic sensors, and cameras.

As part of this initiative, we seek permission to install traffic monitoring cameras and related equipment at key intersections and roadways under your jurisdiction. The cameras will perform the following key functions:

- Traffic Monitoring
- Violation Detection
- Emergency Vehicle Prioritization
- Environmental Impact Analysis

The system adheres to all legal and ethical guidelines concerning data security and privacy. Data will be used solely for research and remain confidential. The cameras and equipment will be powered by solar energy, supporting environmental sustainability. We kindly request your approval for the following:

- Permission to install cameras at designated locations.
- Authorization to access and analyze traffic data.
- Coordination with relevant authorities to ensure smooth installation.

We believe ITMS will benefit the public by improving traffic flow, enhancing safety, and reducing environmental impact. We look forward to collaborating with you to ensure the installations meet local standards. Please find attached the project details for your reference.

Yours sincerely,

Group - 01

Md Abdulla al Sakib

Labib Rokoni

Fahim Faiyaz

Md Ibrahim Morshed

Department of Electrical and Electronics Engineering,

Brac University

9.3.2 Application of Professional Responsibilities

1. **Transparency:** It is essential to inform key stakeholders about the status of the ITMS project: Regarding what goals are followed, effective processes, and achieved results. Make available information as to how the information is collected, processed and protected and disseminate on a routine basis performance and the measures taken to ensure privacy.

2. **Accountability:** Make sure there is sufficient reporting responsibility of activities that are performed throughout the project. This may include the formation of increasingly complex committees composed of community members that are tasked with the job of assessing the effects of the project for the community and handling complaints.
3. **Ethical Use of Technology:** Establish and use principles of moral integrity for the ITMS project as concerns the use of especially computers. Make it a policy that all members understand the ethical consequences of work done for and the impact of society's welfare and civil rights.
4. **Continuous Improvement:** Make an ITMS feedback reporting system through which those using ITMS can be able to report any issues or make some recommendations to the developers of the system. This feedback should be taken to make iterative enhancements on the system and also to counter other challenges that arise.
5. **Training and Education:** Update ITMS personnel on ethical practice, data privacy and being an active contributing member of the community. It’s therefore recommended that this training should undergo a continuous process of revision in regard to newer ethical issues as well as new technology.
6. **Collaboration:** Develop cooperation with local NGOs, universities and other advocacy groups to achieve a strategic view on traffic management. Such an approach will foster the determination of needs within the communities of practice and ensure the ITMS is appropriately developed to meet those needs.

9.1 Conclusion

Therefore, it is important to submit the considerations of ethical issues together with the professional responsibilities in the establishment as well as functional facets of the Intelligent Traffic Management System (ITMS) in the society. Through proper focus on the data privacy, equal access and active participation of the stakeholders, a system with improved public safety and efficiency can be developed without infringing on people’s rights and entailing their trust as active users of the system. As technology slowly transforms, so do societies and therefore professionals participating in this project are encouraged to uphold utmost ethics and embrace otherness for both ends to work towards a fair and just urban transportation that will equally benefit every citizen.

Chapter 10: Conclusion and Future Work.

10.1 Project summary/Conclusion

The Intelligent Traffic Management System (ITMS) is the project, the major goal of which is to adopt new technologies to increase the efficiency, safety, and sustainability of transport systems in cities. Working with real-time monitoring of traffic flow, adaptive signal control, and automatically identifying violations, the ITMS solves essential problems such as traffic congestion, road safety, and priority for emergency vehicles. Through the use of data and analytics and the integration of machine learning components, the system is capable of producing real time responses to traffic conditions in order to enhance the general flow of traffic within cities.

Additionally, the project focuses on sustainability through the use of sustainable methods such as utilization of renewable power like solar power when undertaking traffic management activities. The several outlined goals of maintaining environmentally friendly practices reflect states, regions, or even simple city developments' efforts to build smarter and greener. However, the project also takes into consideration relevant non-technical factors for the ITMS so that the proposed solution is not only sound technically, but also acceptable and enforceable socially and legally.

Thus, the ITMS project can be an innovative and effective solution of the current problem in traffic management as a whole, with the focus on the application of the highest technologies and ethical standards for the formation of a safe, efficient and environmentally friendly system of urban transportation. Through the certain technical developments within this project, yet combining these with care for the social effects of practical applications, the goal of raising the quality of life of city dwellers and acting as a reference point for future traffic control systems is planned to be achieved. In the next steps, only the constant study and practice of the system in cooperation with its stakeholders are to be continued to improve the system and maintain the effectiveness for future challenges that the urban transportation system may face.

10.2 Future work

AI and IoT gadgets will enhance real-time data acquisition and control together with integrating the machine learning algorithms for improving the efficiency of the flow patterns and increasing the accuracy of the traffic congestion forecasts. More intersections, urban areas should be covered and the technology must be redesigned to work for rural areas as well. Further, the subsequent implementations should incorporate better emergency response measures, with traffic conditions for emergencies in real-time. It will be also necessary to develop the base for involving the public into the process and getting their feedback to work constantly on the system improvement. The review of the ITMS based studies with focus on the environmental, economic, and social consequences of the system can help in identification of further enhancements, and facilitate search for the funding. Last but not the least, integration with urban planning programs will help to assure that ITMS will support general development trends in a city, making transportation better, safer, and more environmentally friendly. In following such directions, the ITMS can develop further and overcome the future problems of urban mobility.

Chapter 11: Identification of Complex Engineering Problems and Activities.

11.1: Identify the attribute of complex engineering problem (EP)

Table 16: Identifying the Attributes of Complex Engineering Problems (EP)

	Attributes	**Put tick (√) as appropriate**
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	√
P3	Depth of analysis required	√
P4	Familiarity of issues	√
P5	Extent of applicable codes	
P6	Extent of stakeholder involvement and needs	
P7	Interdependence	√

11.2: Provide reasoning how the project address selected attribute (EP)

P1. Depth of Knowledge Required: Common disciplines that have an interaction in the ITMS include traffic engineering, Artificial Intelligence and Data Analytics, Electrical Systems, and Renewable Energy. Real-time traffic controls, vehicle detection systems, and even sustainable power solutions will need multiple forms of expertise to address them.

P2. Range of Conflicting Requirements: The requirement of optimization in terms of traffic flow, safety, and environmental aspects creates challenges in terms of choices, for example facilitating emergency vehicles while disturbing ordinary traffic flow or integration of solar power with stable electricity supply.

P3. Depth of Analysis Required: The project requires extensive data analysis through traffic simulations and violation tracking mechanisms, and vehicle detection algorithms. The problems under analysis concern the improvement of the system performance, energy efficiency, and the localization of sensors.

P4. Familiarity of Issues: While matters such as congestion and rules have traditional traffic problems, the introduction and application of modern technologies such as AI in traffic control or systems that automatically detecting violations arise unique technological and legal questions, especially in developing countries.

P7. Interdependence: The implementation of the ITMS involves a number of interacting systems including messages and signals from traffic lights, sensors, communication channels and energy recuperation systems that calls for technological and infrastructural connection.

11.3 Identify the attribute of complex engineering activities (EA)

Table 17: Identifying the Attributes of Complex Engineering Activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	√
A2	Level of interaction	
A3	Innovation	
A4	Consequences for society and the environment	√
A5	Familiarity	√

11.4 Provide reasoning how the project address selected attribute (EA)

A1. Range of Resources: The project involves lots of resources such as hardware such as sensors and cameras, soft wares in form of AI algorithms, human resource in terms of skilled personnel, renewable energy in the form of solar systems among others besides financial capital for infrastructure and frequent replacement.

A4. Consequences for Society and the Environment: It has a social implication because it relieves congestion on the roads hence reducing accidents, improving response to emergencies. There are environmental benefits that include; Greenhouse Gas emissions reduction by integrating renewable energy into the grid.

A5. Familiarity: Although the traffic management idea is conventional, the application of artificial intelligence, real-time data, and renewable energy is novel and adds more complexity in the way the solution is deployed on the market.

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[46] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[47] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

Appendix A

FYDP Summary of Team Log Book

FYDP - P (Fall-2023)				
Date/Time/Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
27.09.2023	All Members	Discussion for group formation, mild idea sharing about what we want to do in FYDP	All	N/A
01.10.2023	All Members	A small ice breaking session, sharing detailed ideas of different projects, discussion on ongoing potential projects we can work on, will read more papers, articles about the potential ideas.	All	N/A
03.10.23	All Members	Meeting with the ATC, sharing our ideas (Weather Analyst Rover).	All	Find more papers on the topic, also look into better real life based projects.
04.10.23	Fahim, Labib, Ibrahim	Discussion on topic, New ideas	All	N/A
06.10.23	All Members	Discussion with ATC about topic confirmation	All	Rather than looking into rover or drone, look into more practical things Idea about digital traffic signals, what features can we have in the system Smart agriculture can be another approach Read more papers on these topic
07.10.23	Fahim, Sakib, Ibrahim	Detailed discussion on the literature review of the topics ATC suggested, and added a new idea from our own	All	N/A
09.10.23	All Members	Meeting with ATC member for confirmation of topic	All	Work with the traffic signals, do detailed background research, find out how you can implement the project, how others have done

09.10.23	All members	Discussion after topic confirmation how we want act forward	All	N/A
11.10.23	All members	Individual progress and revision of the topics studied/researched.	All	N/A
12.10.23	Labib, Sakib, Fahim	The problems we might face to implement the project	All	N/A
13.10.23	All members	Finalization of title, features, desires and limitations, talked about the deadlines	All	N/A
14.10.23	All members	Starting with Draft of concept note, work division among the group members	All	N/A
15.10.23	Fahim, Ibrahim	Problems faced during doing the assigned work, how to solve or overcome them, note down details we need to share with ATC	All	N/A
17.10.23	All members	Talking about the background research on the topic, sharing what problems we are facing and trying to brainstorm through the problems	All	N/A
19.10.23	All members	Discussion with ATC about work progress	All	Design the project in such a way that it can be implemented at real traffic Signal Discussion on the features we want to add like E-challan
20.10.23	All members	Adding individual work in the draft, explaining the work of each member, cross checking if any lacking were there	All	N/A
23.10.23	All members	Finalized work of each member shown to everyone, explaining the whole work so that everyone has full idea about what we are doing	All	N/A
25.10.23	All members	Submitted first draft of concept note after final confirmation from all members	All	N/A
25.10.23	All Members	Making PPT for final presentation, and mock presentation among the group members		N/A
26.10.23	All members	Progress Presentation	All	Objectives needs to be specific about what you want to do Requirements are not done correctly, functional requirements are the ones you have to fulfill

				Citation necessary for the literature review Use block diagrams for design approaches, writing can not be the way to show us the approaches Try to be in the time limit of 8 mins in the presentation from the next time
28.10.23	All members	Discussion on the shortcomings, what we could do better and what we should do next.	All	N/A
30.10.23	All members	Preparing for the Final concept note by correcting the mistakes pointed out during the presentation.	All	N/A
03.11.23	Sakib, Labib, Ibrahim	Discussion on Mohsin sir’s lecture on thursday, how can we improve the concept of our project	All	N/A
06.11.23	All members	Meeting during midweek to sum up all the suggestions, required improvements and all the work progress.	All	N/A
10.11.23	All members	Final correction from all members and discussion on the final concept note and submission	All	N/A
15.11.23	All members	Discussion on proposal Requirements and how should we proceed, assigned tasks to individuals	All	N/A
17.11.23	All members	Showing individual work progress and cross checking	All	N/A
19.11.23	All members	Discussion on the FYDP class on engineering ethics, how ethics plays part in our project	All	N/A
21.11.23	All members	Work progress of individual, planning on showing our progress to the ATC	All	N/A
22.11.23	All members	Checking more related papers and articles which can improve our proposal on project	All	N/A
27.11.23	Fahim, Ibrahim, Sakib	Work on the final budget, specifications, and more research based requirements	All	N/A
29.11.23	All members	Meeting with ATC about our work, progress and suggestions	All	Make the block diagram a bit more specific Look into the requirements a bit more Practice the presentation

				beforehand so that u can complete in time Small tips about the presentation
02.12.23	All members	Finalizing the content of our first draft of project proposal a mock presentation how we want to present to the ATC	All	N/A
05.12.23	All members	Showing the corrected block diagram to ATC	All	It will work, practice the presentation now
13.12.23	Sakib, Fahim Ibrahim, Labib	PPT making for final presentation, mock presentation among group members	All	N/A
14.12.23	All members	Final Presentation	All	No such differences between the two approaches, could have explained the slides a bit more.
17.12.23	All members	Preparation for the final Proposal making as per the comments in the presentation	All	N/A
20.12.23	All members	Meeting with ATC about what we can improve in our proposal paper	All	Presentation was good, but you block diagram was visually identical. So try to correct that.
21.12.23	Fahim,Sakib, Ibrahim	Final work on the proposal for making a draft to show the ATC	All	N/A
22.12.23	All members	Submission of Proposal after confirmation from all group members	All	N/A

FYDP - D (Spring-2024)				
Date/Time/Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
25.01.24	All Members	Discussion on how to proceed with the Design of our Project	All	N/A
01.02.24	All Members	Meeting with Mohaimenul sir in order to fix a time for the FYDP meetings. Discussion on the subsystems we need to work on.	All	N/A
08.02.24	All Members	Meeting with the ATC, planning for the semester, explaining the points in the report and assigning work.	All	Proceed with the Design from the first week.
15.02.24	Fahim, Labib, Ibrahim	Discussion on work division, who will do which part. Labib - find the modern IT tools Ibrahim - 3D modeling Fahim - Reorganise the design approaches Sakib - Literature Survey	All	N/A
22.02.24	All Members	Individual progress in respective work and explaining what each person has done.	All	N/A
23.02.24	Fahim, Sakib, Ibrahim	Working on separate subsystems, assigning work to all the members	All	N/A
25.02.24	All Members	Discussion on the Violation detection part. Number plate detection and the traffic infrastructure	All	N/A
28.02.24	All members	Mock presentation within the group mates with the progress achieved till midterm	All	N/A
29.02.24	All members	Progress Presentation	All	Always mention the Neural networks that are used in your work You have mentioned the modern IT tools As you are using Solar, did you get your power consumption and load calculation? Lacking behind as half the semester has passed and most of the

				work is still to be done.
07.03.24	All members	Discussion on the reflection at the progress presentation, shortcomings, what we could do better and what we should do next.	All	N/A
21.03.24	All members	Meeting with ATC about the progress presentation and comments of ATC members and what to do next.	All	Yes, the presentation looks nice. Work is good whatever you have done, but there is a lot more to cover. Load calculation looks fine. But do it for two cases for both real case and prototype. Work on emergency vehicle prioritization as previous other groups haven't worked on it yet. You can use image processing or even sound detection for this.
28.03.24	Sakib, Labib, Ibrahim	Fixing issues in emergency vehicle prioritization work and discussing it further with the ATC members	All	N/A
02.04.24	All members	Showing prototype load an actual load calculation	All	N/A
15.04.24	All members	Designing of multiple solutions for the final presentation	All	N/A
17.04.24	All members	Discussion with the ATC members with our final solution	All	N/A
22.04.24	All members	Showing our works to the ATC members before our final presentation	All	N/A
23.04.24	All members	Working on presentation slides and having a mock presentation within the group members	All	N/A
24.04.24	All members	Final presentation in front of all ATC panels	All	N/A
22.11.23	All members	Checking more related papers and articles which can improve our proposal on project	All	N/A
28.04.24	Labib, Ibrahim, Sakib	Work on the final report	All	N/A
05.05.24	All members	Taking feedback from our ATC before submitting our final report	All	Small tips to improve writing in some points

FYDP - C (Summer-2024)				
Date/Time/Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
10.06.24	All Members	Discussion on how to proceed with the Implementation of our Project	All	N/A
15.06.24	All Members	Meeting with Mohaimenul sir in order to fix a time for the FYDP meetings. Regarding work procedure and how to advance in the whole prototype building. We informed about our order placement and the date of receiving the product	All	N/A
30.06.24	All Members	Installing Raspberry pi	All	Proceed with the from the first week.
12.07.24	Fahim, Labib, Ibrahim	Building prototype 1 for better understanding of the main prototype	All	N/A
14.07.24	All Members	Started with the main Prototype	All	N/A
22.08.24	All Members	Emergency vehicle detection worked properly but there was a problem in rule violation detection.	All	N/A
29.08.24	All Members	Difficulties in finding red light detection	All	N/A
18.09.24	All members	Red light detection completed and implemented it in Gulshan 2 signal but failed to identify the red light in real scenario due to camera efficiency	All	N/A
29.09.24	All members	Real life implementation of detection of emergency vehicles completed near AMZ hospital	All	Attach the picture in the report and also show it in the final showcase If possible to do it more places
04.10.24	All members	Project Demonstration in front of ATC	All	Suggest to do density based traffic control
11.10.24	All members	Working on the addition and improvement suggested by ATC	All	N/A
18.10.24	All members	Added new features, Density based traffic control and manual handling. Also, developed Number plate extraction separately.	All	N/A

19.10.24	All members	Implemented Real life density based traffic control.	All	N/A
21.10.24	All members	Feedback on the final report from the ATC	All	Suggest to correct some format
24.10.24	All members	Demonstration	All	N/A

Assessment Guideline for Faculty

[The following assessment guideline is for faculty ONLY. **This portion is not applicable for students**.]

Assessment Tools and CO Assessment Guideline

	Distribution of assessment points among various COs assessed in different semesters														
PO	l	c	f	g	c	b	d	c	e	l	k	k	h	i	j
CO	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	CO 7	CO 8	CO 9	CO 10	CO 11	CO 12	CO 13	CO 14	CO 15
EEE 400C/ ECE 402C (Out of 100)							30	24	6	4	4	6	7	7	12
Project Final Report/ Project Progress Report							x	x	x	x	x	x	x		x
Demonstration of working prototype							x								x
Progress Presentation/ Final Presentation								x			x				
Peer-evaluation*													x	x	
Instructor's Assessment*													x	x	
Demonstration at FYDP Showcase								x							x

Note: The star (*) marked deliverables/skills will be evaluated at various stages of the project.

Mapping of CO-PO-Taxonomy Domain & Level- Delivery-Assessment Tool

Sl.	CO Description	PO	Bloom's Taxonomy Domain/Level	Assessment Tools
CO7	**Evaluate** the performance of the developed solution with respect to the given specifications, requirements and standards	d	Cognitive/ Evaluate	• Demonstration of working prototype • Project Progress Report on working prototype
CO8	**Complete** the final design and development of the solution with necessary adjustment based on performance evaluation	c	Cognitive/ Create	• Project Final Report • Final Presentation • Demonstration at FYDP Showcase
CO9	**Use** modern engineering and IT tools to design, develop and validate the solution	e	Cognitive/ Understand, Psychomotor/ Precision	• Project Final Report
CO10	**Conduct** independent research, literature survey and learning of new technologies and concepts as appropriate to design, develop and validate the solution	l	Cognitive/ Apply	• Project Final Report
CO11**	**Demonstrate** project management skill in various stages of developing the solution of engineering design project	k	Cognitive/ Apply Affective/ Valuing	• Project Final Report • Project Progress presentation at various stages
CO12	**Perform** cost-benefit and economic analysis of the solution	k	Cognitive/ Apply	• Project Final Report
CO13	**Apply** ethical considerations and professional responsibilities in designing the solution and throughout the project development phases	h	Cognitive/ Apply Affective/ Valuing	• Peer-evaluation, • Instructor's Assessment • Final Report
CO14**	**Perform** effectively as an individual and as a team member for successfully completion of the project	i	Affective/ Characterization	• Peer-evaluation • Instructor's Assessment

CO15**	**Communicate** effectively through writings, journals, technical reports, deliverables, presentations and verbal communication as appropriate at various stages of project development	j	Cognitive/ Understand Psychomotor/ Precision Affective/ Valuing	• Project Final Report • Progress Presentations, • Final Presentation • Demonstration at FYDP Showcase

Note: The double star (**) marked CO will be assessed at various stages of the project through indirect deliverables.

Appendix B

Codes:

Emergency Vehicle Detection Code:

```
import argparse
import os
from pathlib import Path

import torch
import RPi.GPIO as GPIO
from yolov5.models.common import DetectMultiBackend
from yolov5.utils.dataloaders import LoadImages, LoadStreams
from yolov5.utils.general import (LOGGER, check_img_size, check_imshow, cv2,
increment_path, non_max_suppression, scale_boxes)
from yolov5.utils.plots import Annotator, colors
from yolov5.utils.torch_utils import select_device, smart_inference_mode

# GPIO setup for triggering signals
GPIO.setmode(GPIO.BCM)
GPIO.setup(23, GPIO.OUT)
GPIO.output(23, False)

@smart_inference_mode()
def run(
        weights='yolov5s.pt',  # model path
        source='data/images',  # input source
        imgsz=640,  # image size
        conf_thres=0.25,  # confidence threshold
        iou_thres=0.45,  # NMS IOU threshold
        device='',  # cuda or cpu
        view_img=False,  # show results
        save_img=True,  # save images with detections
        max_det=1000,  # max detections per image
):
    # Convert source to string and check type (file, webcam, stream)
    source = str(source)
    is_webcam = source.isnumeric()

    # Set up directories
    save_dir = increment_path(Path('runs/detect') / 'exp', exist_ok=True)  # save results to
runs/detect/exp
    save_dir.mkdir(parents=True, exist_ok=True)  # create save directory if not exists
```

```
# Load model
device = select_device(device)
model = DetectMultiBackend(weights, device=device)
stride, names = model.stride, model.names
imgsz = check_img_size(imgsz, s=stride)  # check image size

# Data loader
if is_webcam:
    view_img = check_imshow()
    dataset = LoadStreams(source, img_size=imgsz, stride=stride)
else:
    dataset = LoadImages(source, img_size=imgsz, stride=stride)

# Warmup the model
model.warmup(imgsz=(1, 3, *imgsz))

for path, im, im0s, vid_cap, _ in dataset:
    im = torch.from_numpy(im).to(model.device).float() / 255.0  # normalize
    if im.ndimension() == 3:
        im = im.unsqueeze(0)

    # Inference
    pred = model(im)

    # NMS (Non-Maximum Suppression)
    pred = non_max_suppression(pred, conf_thres, iou_thres, max_det=max_det)

    for det in pred:
        if len(det):
            det[:, :4] = scale_boxes(im.shape[2:], det[:, :4], im0s.shape).round()

            # Annotate detections
            annotator = Annotator(im0s, line_width=3)
            for *xyxy, conf, cls in det:
                label = f'{names[int(cls)]} {conf:.2f}'
                annotator.box_label(xyxy, label, color=colors(int(cls)))

                # Trigger GPIO for emergency vehicle detection
                if names[int(cls)] in ["fire truck", "ambulance"]:
                    print(f"Emergency Vehicle Detected: {names[int(cls)]}")
                    GPIO.output(23, True)
                else:
                    GPIO.output(23, False)
```

```
        # Display and save results
        im0s = annotator.result()
        if view_img:
            cv2.imshow(str(path), im0s)
            cv2.waitKey(1)
        if save_img:
            cv2.imwrite(str(Path(save_dir) / Path(path).name), im0s)

    LOGGER.info(f"Results saved to {save_dir}")

def parse_opt():
    parser = argparse.ArgumentParser()
    parser.add_argument('--weights', type=str, default='yolov5s.pt', help='model path')
    parser.add_argument('--source', type=str, default='data/images', help='input source (file,
dir, stream)')
    parser.add_argument('--imgsz', type=int, default=640, help='image size')
    parser.add_argument('--conf-thres', type=float, default=0.25, help='confidence threshold')
    parser.add_argument('--iou-thres', type=float, default=0.45, help='NMS IOU threshold')
    parser.add_argument('--device', default='', help='cuda or cpu')
    parser.add_argument('--view-img', action='store_true', help='display results')
    parser.add_argument('--save-img', action='store_true', help='save images with detections')
    return parser.parse_args()

def main():
    opt = parse_opt()
    run(**vars(opt))

if __name__ == "__main__":
    main()
```

Density Detection Code:

```
import cv2
import numpy as np
import torch  # PyTorch for YOLOv5
import RPi.GPIO as GPIO
import time

# Set up GPIO
GPIO.setmode(GPIO.BCM)
GPIO.setwarnings(False)
PIN_ROI1 = 23  # Pin to signal when ROI 1 exceeds vehicle count
GPIO.setup(PIN_ROI1, GPIO.OUT)
GPIO.output(PIN_ROI1, GPIO.LOW)

roi1_points = []
roi2_points = []
is_drawing = False
current_roi = 1
drawing_complete = False

model = torch.hub.load('ultralytics/yolov5', 'yolov5s', pretrained=True)

def draw_polygon(event, x, y, flags, param):
    global roi1_points, roi2_points, is_drawing, current_roi, drawing_complete
    if event == cv2.EVENT_LBUTTONDOWN and not drawing_complete:
        if current_roi == 1:
            roi1_points.append((x, y))
        else:
            roi2_points.append((x, y))
        is_drawing = True
    elif event == cv2.EVENT_RBUTTONDOWN and is_drawing and not drawing_complete:
        if current_roi == 1:
            current_roi = 2
        else:
            drawing_complete = True
        is_drawing = False

def point_in_roi(point, roi_vertices):
    if len(roi_vertices) > 0:
        roi_vertices = np.array(roi_vertices, dtype=np.int32)
        return cv2.pointPolygonTest(roi_vertices, point, False) >= 0
    return False
```

```
def static_roi_selection(frame):
    global roi1_points, roi2_points, drawing_complete
    cv2.namedWindow('Select ROIs')
    cv2.setMouseCallback('Select ROIs', draw_polygon)
    while not drawing_complete:
        display_frame = frame.copy()
        if len(roi1_points) > 0:
            cv2.polylines(display_frame, [np.array(roi1_points)], isClosed=False, color=(0, 255,
0), thickness=2)
        if len(roi2_points) > 0:
            cv2.polylines(display_frame, [np.array(roi2_points)], isClosed=False, color=(0, 0,
255), thickness=2)
        cv2.imshow('Select ROIs', display_frame)
        if cv2.waitKey(1) & 0xFF == ord('q'):
            break
    cv2.destroyWindow('Select ROIs')

def detect_vehicles_with_rois():
    global roi1_points, roi2_points
    try:
        choice = input("Would you like to use a video file or live feed? (Enter 'video' for file or
'live' for live feed): ").strip().lower()
        if choice == 'video':
            video_path = input("Please provide the full path to the video file: ").strip()
            cap = cv2.VideoCapture(video_path)
            if not cap.isOpened():
                return
            ret, frame = cap.read()
            if not ret:
                return
            static_roi_selection(frame)
            cap.set(cv2.CAP_PROP_POS_FRAMES, 0)
        elif choice == 'live':
            cap = cv2.VideoCapture(0)
            if not cap.isOpened():
                return
            cap.set(cv2.CAP_PROP_FRAME_WIDTH, 640)
            cap.set(cv2.CAP_PROP_FRAME_HEIGHT, 480)
            ret, frame = cap.read()
            if not ret:
                return
            static_roi_selection(frame)
        else:
            return
```

```
    roi1_vertices = np.array(roi1_points, dtype=np.int32) if len(roi1_points) > 0 else
np.array([])
    frame_count = 0
    while cap.isOpened():
        ret, frame = cap.read()
        if not ret:
            break
        frame_count += 1
        if frame_count % 2 != 0:
            continue

        results = model(frame)
        vehicles_in_roi1 = 0

        for result in results.xyxy[0]:
            x1, y1, x2, y2, conf, cls = result[:6]
            center_x = (x1 + x2) / 2
            center_y = (y1 + y2) / 2
            center_point = (int(center_x), int(center_y))

            if point_in_roi(center_point, roi1_vertices):
                vehicles_in_roi1 += 1

        GPIO.output(PIN_ROI1, GPIO.LOW)

        if vehicles_in_roi1 > 5:
            GPIO.output(PIN_ROI1, GPIO.HIGH)
            time.sleep(10)
            GPIO.output(PIN_ROI1, GPIO.LOW)

        for box in results.xyxy[0]:
            x1, y1, x2, y2, conf, cls = box[:6]
            cv2.rectangle(frame, (int(x1), int(y1)), (int(x2), int(y2)), (0, 255, 255), 2)

        if len(roi1_vertices) > 0:
            cv2.polylines(frame, [roi1_vertices], isClosed=True, color=(0, 255, 0),
thickness=2)

        text_roi1 = f'Vehicles in ROI 1: {vehicles_in_roi1}'
        cv2.putText(frame, text_roi1, (10, 30), cv2.FONT_HERSHEY_SIMPLEX, 1, (0, 255,
0), 2)

        cv2.imshow('Processed Frame', frame)
```

```
            if cv2.waitKey(1) & 0xFF == ord('q'):
                break

        cap.release()
        cv2.destroyAllWindows()

    except KeyboardInterrupt:
        pass

    finally:
        GPIO.output(PIN_ROI1, GPIO.LOW)
        GPIO.cleanup()

detect_vehicles_with_rois()
```

Red Light Violation:

```
import os
import numpy as np
import cv2
from ultralytics import YOLO
from datetime import datetime

drawing_light = False
drawing_vehicle = False
point1_light, point2_light = (), ()
point1_vehicle, point2_vehicle = (), ()
currentframe = 0

image_folder = input("Enter the folder path where violation images will be saved: ")

if not os.path.exists(image_folder):
    os.makedirs(image_folder)

model = YOLO('yolov8n.pt')
selecting_light = True

def mouse_drawing(event, x, y, flags, params):
    global point1_light, point2_light, drawing_light
    global point1_vehicle, point2_vehicle, drawing_vehicle
```

```
    global selecting_light

    if selecting_light:
        if event == cv2.EVENT_LBUTTONDOWN:
            drawing_light = True
            point1_light = (x, y)
        elif event == cv2.EVENT_MOUSEMOVE and drawing_light:
            point2_light = (x, y)
        elif event == cv2.EVENT_LBUTTONUP:
            drawing_light = False
            point2_light = (x, y)
            selecting_light = False
    else:
        if event == cv2.EVENT_LBUTTONDOWN:
            drawing_vehicle = True
            point1_vehicle = (x, y)
        elif event == cv2.EVENT_MOUSEMOVE and drawing_vehicle:
            point2_vehicle = (x, y)
        elif event == cv2.EVENT_LBUTTONUP:
            drawing_vehicle = False
            point2_vehicle = (x, y)

cap = cv2.VideoCapture(0)
cv2.namedWindow("Detection")
cv2.setMouseCallback("Detection", mouse_drawing)

while True:
    ret, img = cap.read()
    if not ret:
        break

    red_light_detected = False
    yellow_light_detected = False

    if point1_light and point2_light:
        cv2.rectangle(img, point1_light, point2_light, (0, 255, 0), 2)
        frame_light_ROI = img[point1_light[1]:point2_light[1], point1_light[0]:point2_light[0]]
        if frame_light_ROI.size != 0:
            hsv = cv2.cvtColor(frame_light_ROI, cv2.COLOR_BGR2HSV)
            lower_red = np.array([0, 100, 100])
            upper_red = np.array([10, 255, 255])
            lower_yellow = np.array([20, 150, 150])
            upper_yellow = np.array([30, 255, 255])
```

```
            maskr = cv2.inRange(hsv, lower_red, upper_red)
            masky = cv2.inRange(hsv, lower_yellow, upper_yellow)

            r_circles = cv2.HoughCircles(maskr, cv2.HOUGH_GRADIENT, 1, 80, param1=50,
param2=10, minRadius=0, maxRadius=30)
            y_circles = cv2.HoughCircles(masky, cv2.HOUGH_GRADIENT, 1, 30, param1=50,
param2=5, minRadius=0, maxRadius=30)

            if r_circles is not None:
                r_circles = np.uint16(np.around(r_circles))
                red_light_detected = True
                for i in r_circles[0, :]:
                    center = (int(i[0]), int(i[1]))
                    radius = int(i[2])
                    cv2.circle(frame_light_ROI, center, radius, (0, 0, 255), 2)

            if y_circles is not None:
                y_circles = np.uint16(np.around(y_circles))
                yellow_light_detected = True
                for i in y_circles[0, :]:
                    center = (int(i[0]), int(i[1]))
                    radius = int(i[2])
                    cv2.circle(frame_light_ROI, center, radius, (0, 255, 255), 2)

    if point1_vehicle and point2_vehicle:
        cv2.rectangle(img, point1_vehicle, point2_vehicle, (255, 0, 0), 2)
        frame_vehicle_ROI = img[point1_vehicle[1]:point2_vehicle[1],
point1_vehicle[0]:point2_vehicle[0]]

        if frame_vehicle_ROI.size != 0:
            results = model(frame_vehicle_ROI)
            vehicle_detected = False
            for result in results[0].boxes:
                class_id = int(result.cls)
                if class_id == 2:
                    vehicle_detected = True
                    x1, y1, x2, y2 = map(int, result.xyxy[0])
                    cv2.rectangle(frame_vehicle_ROI, (x1, y1), (x2, y2), (0, 255, 0), 2)
                    cv2.putText(frame_vehicle_ROI, 'Car Detected', (x1, y1 - 10),
cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 255, 0), 2)

            if vehicle_detected and (red_light_detected or yellow_light_detected):
                timestamp = datetime.now().strftime('%Y-%m-%d %H:%M:%S')
                cv2.putText(img, timestamp, (10, img.shape[0] - 10),
```

```
cv2.FONT_HERSHEY_SIMPLEX, 1, (0, 255, 255), 2, cv2.LINE_AA)
            name = f'{image_folder}/violation_{currentframe}_{timestamp.replace(":", "-")}.jpg'
            cv2.imwrite(name, img)
            print(f'Violation captured: {name}')
            currentframe += 1

   cv2.imshow("Detection", img)

   if cv2.waitKey(33) == 27:
      break

cap.release()
cv2.destroyAllWindows()
```

Arduino Code for Traffic Logic:

```
// Traffic Light System for Arduino Uno with Four Lanes
// Corrected priority handling when A1 goes low and A0 remains high

const int LANE1_RED = 2;
const int LANE1_YELLOW = 3;
const int LANE1_GREEN = 4;

const int LANE2_RED = 5;
const int LANE2_YELLOW = 6;
const int LANE2_GREEN = 7;

const int LANE3_RED = 8;
const int LANE3_YELLOW = 9;
const int LANE3_GREEN = 10;

const int LANE4_RED = 11;
const int LANE4_YELLOW = 12;
const int LANE4_GREEN = 13;

const int A0_PIN = A0;
const int A1_PIN = A1;

unsigned long previousMillis = 0;
const unsigned long greenDuration = 5000;
const unsigned long yellowDuration = 2000;

enum State {
```

```
  NORMAL_GREEN,
  NORMAL_YELLOW,
  PRIORITY_LANE1,
  PRIORITY_LANE2
};

State currentState = NORMAL_GREEN;
int currentLane = 1;

int prevA1State = LOW;
int prevA0State = LOW;

void setup() {
  pinMode(LANE1_RED, OUTPUT);
  pinMode(LANE1_YELLOW, OUTPUT);
  pinMode(LANE1_GREEN, OUTPUT);

  pinMode(LANE2_RED, OUTPUT);
  pinMode(LANE2_YELLOW, OUTPUT);
  pinMode(LANE2_GREEN, OUTPUT);

  pinMode(LANE3_RED, OUTPUT);
  pinMode(LANE3_YELLOW, OUTPUT);
  pinMode(LANE3_GREEN, OUTPUT);

  pinMode(LANE4_RED, OUTPUT);
  pinMode(LANE4_YELLOW, OUTPUT);
  pinMode(LANE4_GREEN, OUTPUT);

  pinMode(A0_PIN, INPUT);
  pinMode(A1_PIN, INPUT);

  setAllRed();
  previousMillis = millis();

  prevA1State = digitalRead(A1_PIN);
  prevA0State = digitalRead(A0_PIN);
}

void loop() {
  int a1_state = digitalRead(A1_PIN);
  int a0_state = digitalRead(A0_PIN);

  if (a1_state != prevA1State || a0_state != prevA0State) {
```

```
  prevA1State = a1_state;
  prevA0State = a0_state;

  if (a1_state == HIGH) {
    currentState = PRIORITY_LANE1;
    setAllRed();
    setLaneGreen(1);
  } else if (a0_state == HIGH) {
    currentState = PRIORITY_LANE2;
    setAllRed();
    setLaneGreen(2);
  } else {
    if (currentState == PRIORITY_LANE1 || currentState == PRIORITY_LANE2) {
      currentState = NORMAL_GREEN;
      currentLane = (currentLane % 4) + 1;
      setAllRed();
      setLaneGreen(currentLane);
      previousMillis = millis();
    }
  }
}

if (currentState == NORMAL_GREEN || currentState == NORMAL_YELLOW) {
  unsigned long currentMillis = millis();

  switch (currentState) {
    case NORMAL_GREEN:
      if (currentMillis - previousMillis >= greenDuration) {
        setLaneYellow(currentLane);
        currentState = NORMAL_YELLOW;
        previousMillis = currentMillis;
      }
      break;
    case NORMAL_YELLOW:
      if (currentMillis - previousMillis >= yellowDuration) {
        currentLane = (currentLane % 4) + 1;
        setAllRed();
        setLaneGreen(currentLane);
        currentState = NORMAL_GREEN;
        previousMillis = currentMillis;
      }
      break;
  }
}
```

```
}

void setAllRed() {
  digitalWrite(LANE1_RED, HIGH);
  digitalWrite(LANE1_YELLOW, LOW);
  digitalWrite(LANE1_GREEN, LOW);
  digitalWrite(LANE2_RED, HIGH);
  digitalWrite(LANE2_YELLOW, LOW);
  digitalWrite(LANE2_GREEN, LOW);
  digitalWrite(LANE3_RED, HIGH);
  digitalWrite(LANE3_YELLOW, LOW);
  digitalWrite(LANE3_GREEN, LOW);
  digitalWrite(LANE4_RED, HIGH);
  digitalWrite(LANE4_YELLOW, LOW);
  digitalWrite(LANE4_GREEN, LOW);
}

void setLaneGreen(int laneNumber) {
  switch (laneNumber) {
    case 1:
      digitalWrite(LANE1_RED, LOW);
      digitalWrite(LANE1_YELLOW, LOW);
      digitalWrite(LANE1_GREEN, HIGH);
      break;
    case 2:
      digitalWrite(LANE2_RED, LOW);
      digitalWrite(LANE2_YELLOW, LOW);
      digitalWrite(LANE2_GREEN, HIGH);
      break;
    case 3:
      digitalWrite(LANE3_RED, LOW);
      digitalWrite(LANE3_YELLOW, LOW);
      digitalWrite(LANE3_GREEN, HIGH);
      break;
    case 4:
      digitalWrite(LANE4_RED, LOW);
      digitalWrite(LANE4_YELLOW, LOW);
      digitalWrite(LANE4_GREEN, HIGH);
      break;
  }
}

void setLaneYellow(int laneNumber) {
  switch (laneNumber) {
```

```
    case 1:
      digitalWrite(LANE1_RED, LOW);
      digitalWrite(LANE1_YELLOW, HIGH);
      digitalWrite(LANE1_GREEN, LOW);
      break;
    case 2:
      digitalWrite(LANE2_RED, LOW);
      digitalWrite(LANE2_YELLOW, HIGH);
      digitalWrite(LANE2_GREEN, LOW);
      break;
    case 3:
      digitalWrite(LANE3_RED, LOW);
      digitalWrite(LANE3_YELLOW, HIGH);
      digitalWrite(LANE3_GREEN, LOW);
      break;
    case 4:
      digitalWrite(LANE4_RED, LOW);
      digitalWrite(LANE4_YELLOW, HIGH);
      digitalWrite(LANE4_GREEN, LOW);
      break;
  }
}
```

Appendix C

C.1 Permission from Gulshan Police Commissioner

To,

The Commissioner of Police

Gulshan Division, Dhaka, Bangladesh

Subject: Application for Permission to Implement Intelligent Traffic Management System at Gulshan-2 Signal

Dear Sir,

I am writing to seek your permission and support for implementing an Intelligent Traffic Management System (ITMS) at the Gulshan-2 signal intersection. This initiative aims to improve traffic flow and enhance road safety in one of Dhaka's busiest commercial areas.

Project Details:

1. Location: Gulshan-2 Circle Traffic Signal

2. Implementation Period: 20/10/2024 to 21/10/2024

3. System Components:

   - AI-powered traffic signal optimization

   - Real-time traffic monitoring cameras

   - Smart sensors for vehicle detection

   - Emergency vehicle priority system

   - Central control room integration

Expected Benefits:

- 30-40% reduction in traffic congestion

- Improved emergency response times

- Real-time traffic data collection and analysis

- Enhanced pedestrian safety

- Reduced carbon emissions through optimized traffic flow

We assure you that all installations will comply with municipal regulations and safety standards. Our technical team will work closely with your department throughout the implementation process.

We would greatly appreciate the opportunity to present this project in detail to you and your team at your convenience.

Thank you for considering our application. We look forward to your positive response.

Yours sincerely,

Labib Rokoni

Current Student of BRAC University