CE4099D MAJOR PROJECT

ANALYSING TRAFFIC CONGESTION AT SIGNALISED INTERSECTIONS UNDER HETEROGENEOUS TRAFFIC CONDITIONS USING AI

FINAL PROJECT REPORT

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DECLARATION

"We hereby declare that this submission is our own work and that, to the best of our knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other institute of higher learning, except where due acknowledgment has been made in the text."

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CERTIFICATE

This is to certify that this major report entitled "**ANALYSING TRAFFIC CONGESTION AT SIGNALISED INTERSECTIONS UNDER HETEROGENEOUS TRAFFIC CONDITIONS USING AI**" is a bonafide record of the work carried out by

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ABSTRACT

Transportation is a critical component of modern society, but the rapid growth of the population has placed unprecedented pressure on transportation systems. The increase in the number of vehicles in cities has resulted in traffic congestion, which has become a significant challenge affecting economic growth, time management, health, and the environment. To tackle this problem, traffic management systems have been developed to enhance traffic efficiency and safety. These systems utilize a range of applications and management tools that collect information from various sources, enabling them to identify potential hazards and provide effective solutions to manage them.

When traditional traffic control measures fail, alternative measures must be implemented to control traffic. One potential solution is Artificial Intelligence (AI) techniques, which can revolutionize transportation by improving passenger safety, reducing traffic congestion and accidents, minimizing carbon emissions, and lowering overall financial expenses. This study is dedicated to exploring the effectiveness and stability of AI in transportation, providing insights into how this technology can be utilized to create a more efficient, safe, and sustainable transportation system.

The main objective of this study is to analyze the operation and maintenance of signalized intersections and explore efficient alternatives to replace the existing systems. A specific focus is given to the parameter of delay, which significantly affects efficiency. Cities like Bangalore are facing major challenges with intersection delays as urban populations continue to grow. However, there is potential for improvement using AI-based solutions. These solutions can gather real-time data from vehicles and utilize it to effectively manage traffic, offering a seamless travel experience. Integration of decision-making, traffic management, routing, and optimization tools through object detection and algorithms is implemented in this study. Simulation techniques are employed to evaluate the performance of the proposed system and further optimize it. The simulation results are compared with real-time data to enhance the accuracy and effectiveness of the system.

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CHAPTER 1
INTRODUCTION

1.1 General

The importance of transportation to human life cannot be overstated. The population is expanding at a very rapid rate. To counteract population explosion and maintain the calibre and effectiveness of transportation services, population growth needs thoughtful solutions. The last few decades have seen a rapid escalation in the number of motor vehicles in developing countries. Over the years, it has been noted that the traffic in most cities around the globe has worsened. Congestion at intersections is a challenging problem to deal with in places where the number of vehicles is growing faster than the infrastructure needed to sustain it, and it gets considerably worse in the event of car accidents. This problem affects a wide range of aspects of modern life, including time spent, economic growth, traffic accidents, an increase in greenhouse gas emissions, and health issues.

As urban areas experience a growing number of vehicles, road networks are struggling to cope with the resulting drop in capacity and Level of Service. Fixed signal timers used in traffic control systems at intersections often contribute to traffic-related issues because they repeat the same phase sequence and duration with no adjustments. Consequently, the rising demand for road capacity underscores the need for new traffic control solutions, which can be found in the domain of Intelligent Transport Systems (ITS). These advanced technologies, systems, and services can improve safety, efficiency, and sustainability across various transportation modes.

Let us take the case study of Mumbai and Bangalore. Traffic flow in Bangalore is the worst in the world while Mumbai is close behind in fourth position, according to a report detailing the traffic situation in 416 cities across 57 countries. In Bangalore, a journey during rush hour takes 71% longer. In Mumbai, it is 65% longer. There are three standard methods for traffic control that are being used currently:

1) <u>Manual Controlling</u>: As the name suggests, it requires manpower to control the traffic. The traffic police are allotted a required area to control traffic. The traffic police carry a signboard, sign light, and whistle to control the traffic.

2) Conventional traffic lights with static timers: These are controlled by fixed timers. A constant numerical value is loaded in the timer. The lights are automatically switching to red and green based on the timer value.
3) Electronic Sensors: Another advanced method is placing some loop detectors or proximity sensors on the road. This sensor gives data about the traffic on the road. According to the sensor data, the traffic signals are controlled.

In recent years, video monitoring and surveillance systems have been used extensively in traffic management for security, ramp metering, and real-time traveler information. Video monitoring systems can also be used to estimate traffic density and vehicle classification, which can be used to optimize traffic flow and reduce congestion.

The traditional methods of traffic control have their limitations. Manual control requires a significant amount of manpower, and traffic police are often overstretched and unable to cover all areas of a city or town. Static traffic control, which uses traffic lights with fixed timers, is unable to adapt to real-time traffic conditions. Electronic sensors such as proximity sensors or loop detectors are expensive and limited in their coverage.

To address these issues, we propose a traffic light controller based on computer vision. This system uses live images from CCTV cameras at traffic junctions to calculate real-time traffic density by detecting the number of vehicles at the signal and adjusting the green signal time accordingly. The system also classifies vehicles as cars, bikes, buses/trucks, or rickshaws to obtain an accurate estimate of green signal time. It uses YOLO to detect the number of vehicles and set the timer of the traffic signal according to vehicle density in the corresponding direction.

This system optimizes green signal times, allowing for faster traffic clearance and reducing delays, congestion, waiting times, fuel consumption, and pollution.

1.2 Objectives:

- To identify the factors influencing traffic congestion at signalized intersections under heterogeneous conditions.
- To analyze various parameters considered for evaluating the efficiency of signalized intersections.
- To improve the performance of signalized intersections using Artificial Intelligence.

1.3 Methodology:

- Identification of major problems at signalized intersections.
- Discussing the factors which influence traffic congestion.
- Knowing the parameters involved in evaluating the performance of signalized intersections.
- Understanding the Adaptive Signal Control Technology.
- Working with software for object detection through images and videos.
- Optimising the green signal time using an algorithm.
- Simulating the proposed system with the help of software packages and modules in Python.
- Data Collection at Nandilath Intersection

CHAPTER 2
LITERATURE REVIEW

U. Illahi, M.S. Mir:

- Researched the suitability of different options as solutions to the specific intersection Their research is intended to check the efficiency and control of the flow of traffic at "Mahjoor Chowk: Y-intersection," point out flaws (if any) in the geometric design and work out the possible solutions.
- They come up with a result of constructing a flyover that has a capacity that is much less than the volume, especially during peak hour traffic.

Li Jian, Yue ZQ, Wong S:

- Intersections are the bottlenecks that cause most of the traffic congestion. The operational and safety performance of an intersection is based on five index parameters degree of saturation, average delay, queue length, deflect ratio, and separation ratio.
- Parameters are inputted into the evaluation equations which are developed based on the Gray System theory.

B. G. Savitha1, R. Satya Murthy, H. S. Jagadeesh, H. S. Sathish, T. Sundararajan:

- Saturation flow is considered as a measure of performance due to heterogeneous motorized traffic, along with slow-moving traffic including pedestrians.
- Studies on 15 signalized intersections with varying geometric factors like width, gradient, and turning radius are considered, and concluded that introduction to these factors gives a better view to assessing the Level of Service.
- Highway Capacity Manual is used in finding Saturation Flow.

Marwah and Singh 2000:

- Did simulation studies of traffic flow on urban roads in Kanpur City, India using a two-lane one-way traffic simulation model.

- Through this study, the level of service LOS. experienced by different categories of vehicles were decided when the traffic stream contained 65% nonmotorized vehicles.

Rahul Sharma, Pinakin Patel, Nekzad Umrigar, Dr. L. B. Zala

- Compared different models (like Highway Capacity Manual (HCM 2010), Webster's delay model, and Highway Capacity Manual (HCM 2010) model) for delay estimation for homogeneous traffic conditions.
- Studied some of the existing models for heterogeneous lane conditions. It is found that an extra additional factor is added according to the specific field conditions.
- Most of the models give satisfactory results for normal cycle timings but fail at times of long cycle timings. Either overestimating or underestimating the delay is observed.

Raval and Gundaliya's (Modified Webster's) Model

- Designed based on the traffic flow conditions for Ahmedabad city. The adjustment factor is added in the mathematical form of the model.
- Adjustment factor is calculated based on Q = vehicle arrival rate (PCU/sec); C = cycle time in seconds; X = degree of Saturation; λ = effective green ratio and t_w = percentage two wheelers.
- Average delay to the vehicles, assuming uniform arrivals is calculated which cannot be true always. It has a considerable Mean error Percentage value but underestimates the delay.

Mina Ghanbarikarekani, Xiaobo Qu ,Michelle Zeibots, and Weiwei Qi

- Minimised the average delay at intersections using pre-signals and speed control.
- Several parameters like signal time, density and capacity, and speed of the vehicles is assumed as constant which is not always the same.
- Pre-signal is a signal that is installed in advance of the intersections and gives private cars a red signal to prioritize buses
- This strategy reduces buses' delay and travel time and increases their speed efficiently. However, cars are not considered in pre-signals, and they are given additional stops.

Hyunjeong Jeon1, Jincheol Lee1, Keemin Sohn:

- This study suggests an artificial intelligence that uses only video images of an intersection to represent its traffic state rather than using handcrafted features.
- In simulation experiments using a real intersection, consecutive aerial video frames fully addressed the traffic state of an independent 4-legged intersection, and an image-based RL (reinforcement learning) model outperformed both the actual operation of fixed signals and a fully actuated operation.

Khushi (2017)

- Proposed a solution using video processing where the video from the live feed is processed before being sent to the servers where a C++-based algorithm is used to generate the results.
- Hard code and Dynamic coded methodologies are compared, in which the dynamic algorithm showed an improvement of 35%.

Shenghua Zhou , S. Thomas Ng, Yifan Yang, J. Frank Xu:

- This work proposes an integrative framework that orchestrates the CV and TM to link real-world transport systems and operable virtual traffic models for signal timing optimizations of multiple intersections.
- The proposed approach has been demonstrated through the case of a real-world road network.

Ajit Gedam , Amey Shiwal, Aditya Rokade , Vishwajeet Raut , Aditya Sarwade:

- The proposed system utilizes live images from traffic junction cameras to calculate traffic density using image processing and AI.
- The resulting data is sent to an IOT device, in this case, an Arduino Board, which adds extra green light time to traffic signals when necessary.

Arpita Saha; Satish Chandra, A.M. ASCE; and Indrajit Ghosh:

- The proposed model is based on the existing HCM model and was developed using traffic data from seven signalized intersections.
- Queue length was measured over time, and Simpson's one-third rule was used to estimate the total delay in a cycle and the average delay per vehicle.
- The proposed model was validated using data from eight other intersections, and the maximum difference between the observed delay and the estimated delay was less than 5%.

2.1 Summary:

The literature review covers various studies on traffic flow and intersection management. Different parameters like degree of saturation, average stop queue length, deflect ratio, and ration ratio have been evaluated for operational and safety performance. Saturation flow is considered as a measure of performance for assessing the Level of Service. Several models have been compared for delay estimation, and adjustment factors have been added based on specific field conditions. Various strategies like pre-signals, speed control, and video processing have been proposed to minimize delay at intersections. Additionally, an integrative framework has been proposed to link real-world transport systems and operable virtual traffic models for signal timing optimizations of multiple intersections.

CHAPTER 3
METHODOLOGY

3.1 SIGNALIZED INTERSECTIONS:

Traffic intersections are complex locations on any highway. This is because vehicles moving in different directions want to occupy the same space at the same time.

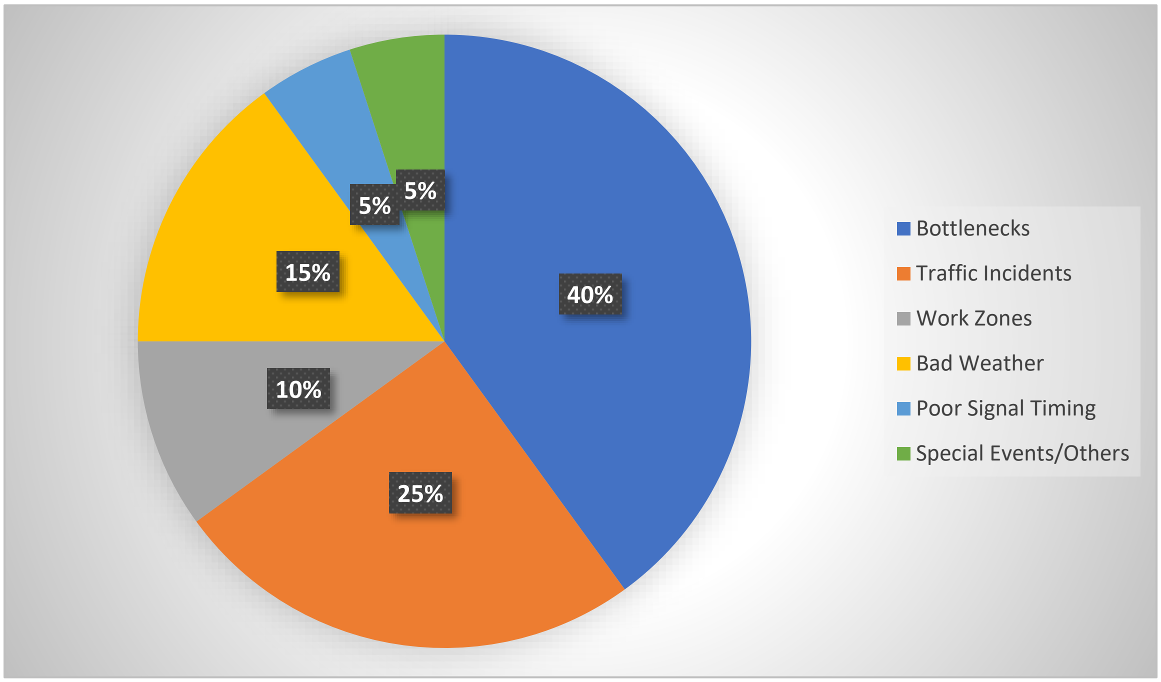

Fig 3.1 Main sources of Traffic Congestion

In addition, the also seek the same space for crossing Intersections may be signalised to address a road safety, efficiency, or operational issue or to improve crossing opportunities for pedestrians and cyclists. Signalised intersections are generally installed at intersections of major roads and, due to the temporal component, usually involve several approach lanes on each leg. These intersections function as key points in the transportation network. Therefore, it is necessary to make sure they work efficiently. The above pie chart shows the sources of congestion. Bottlenecks and Traffic Incidents contribute to the major percentage of congestion. These two are mostly at intersections. Poor signal timing also adds up to this. Therefore nearly 70% of traffic congestion occurs at Intersections.

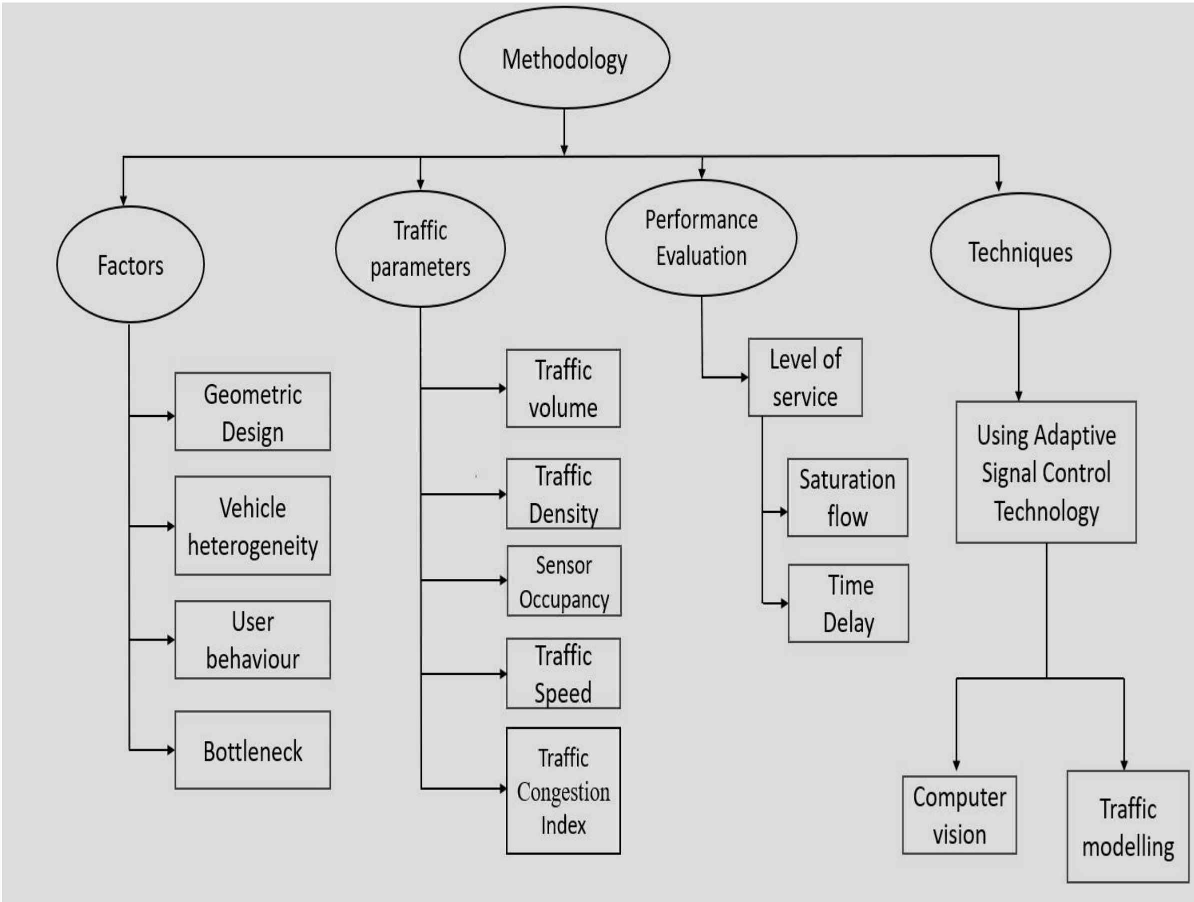

Fig 3.2. Flowchart showing the framework of traffic management

3.2 OPERATIONAL MEASURES OF EFFECTIVENESS

The efficiency of intersections contributes significantly towards the efficiency of whole urban road networks as they are the main bottlenecks in the system. Three measures of effectiveness are commonly used to evaluate signalized intersection operations:

- Capacity and volume-to-capacity ratio.
- Delay.
- Queue

3.2.1 Volume to Capacity Ratio

The v/c ratio, also referred to as the degree of saturation, represents the sufficiency of an intersection to accommodate vehicular demand. A v/c ratio less than 0.85 generally indicates that adequate capacity is available and vehicles are not expected to experience significant queues and delays. As the v/c ratio approaches 1.0, traffic flow may become unstable, and delay and queuing conditions may occur. Once the demand exceeds the capacity (a v/c ratio greater than 1.0), traffic flow is unstable and excessive delay and queuing is expected. Under these conditions, vehicles may require more than one signal cycle to pass through the intersection (known as a cycle failure).

For design purposes, a v/c ratio between 0.85 and 0.95 generally is used for the peak hour of the horizon year. Overdesigning for an intersection should be avoided due to negative impacts to pedestrians associated with wider street crossings, the potential for speeding, land use impacts, and cost.

3.2.2 Delay:

Vehicle delay is considered as one of the most important performance measures of effectiveness (PMOE) in intersection traffic operations because it allows traffic engineers to evaluate the overall performance of a traffic system. Currently, vehicle delay is used as a principal performance measure to determine the intersection level of service (LOS), estimate average speed, and calculate fuel consumption and emissions.

Delay is defined in *HCM 2000* as “the additional travel time experienced by a driver, passenger, or pedestrian.” The signalized intersection chapter (chapter 16) of the HCM provides equations for calculating control delay, “the delay a motorist experiences that is attributable to the presence of the traffic signal and conflicting traffic. This includes time spent decelerating, in the queue, and accelerating.” Control delay is used as the basis for determining the Level of Service (LOS).

Table 1: LOS CRITERIA FOR SIGNALISED INTERSECTIONS

Delay (Seconds)	Level of Service
0-10	A
10-15	B
15-25	C
25-35	D
35-50	E
>50	F

Source: Highway Capacity Manual 2000, Transportation Research Board

3.2.3 Queue:

Vehicle queuing is an important measure of effectiveness that should be evaluated as part of all analyses of signalized intersections. Estimates of vehicle queues are needed to determine the amount of storage required for turn lanes and to determine whether spillover occurs at upstream facilities (driveways, unsignalized intersections, signalized intersections, etc.). Approaches that experience extensive queues also are likely to experience an overrepresentation of rear-end collisions.

3.3 FRAMEWORK:

This study is concentrated on minimizing the delay as it is a serious problem concerning India. Concerning India, Mumbai shares second place with Bogota and Manila, with all-seeing congestion levels of 53%. (This means a trip to any of these cities would take about 53% more time than it should.) Bengaluru is at #6 (51% congestion), and New Delhi is at #8 (47% congestion) down a bit from its last appearance at #4 in 2018. The other Indian city to feature is Pune, at #16, with 42% congestion. There are many more reasons and factors associated and numerous solutions to those. One of them is due to "Traditional Traffic Signal Timings." where pre-timed control consists of a series of intervals that are fixed in duration. Collectively, the pre-set green, yellow, and red intervals result in a deterministic sequence and fixed cycle length for the intersection.

Traffic patterns and traffic density varies from day to day, region to region (i.e. varies both in space and time). Even within the four-legged intersection, traffic volume distribution changes from each leg to leg. But the signal timing (whether red or green) remains the same irrespective of the number of vehicles. Even if there are less or no vehicles on one side, the timer continues while the demand exceeds capacity on the other side, resulting in delay and congestion. If in case the signal timings are operated based on the volume, a significant amount of delay is minimized. So, we are focussing on solving this problem with the help of suitable technologies and algorithms.

3.3.1 Challenges for dynamic signal timing:

- First and foremost, the challenge is obtaining real-time traffic data (the number of vehicles present in each leg of an intersection to assess the signal time accordingly.
- Traffic Volume Count can be done by various methods depending upon various factors like manpower available, budget, technology/instrument available, and magnitude of

traffic data required or to be collected which will then determine the quality and type of vehicle classification to be adopted. Traffic counting falls into two main categories, namely: manual count and automatic count. Different methods of traffic volume count are mentioned below –

1. Manual Count: It involves a group of people recording a few vehicles passing, at a predetermined location, using tally marks in inventories. But this is not feasible for this situation as it requires the data continuously through day and night. And, there are chances of mistakes due to fatigue, etc.

2. Automatic Count: Various instruments are available for automatic counting, which have their own merits and demerits. Some of the widely used instruments are pneumatic tubes, inductive loops, weigh-in-motion Sensors, micro–millimeters wave Radar detectors, and video cameras.

- Among all these, the video camera technique is the most suitable. Video image processing systems utilize machine vision technology to detect vehicles and capture details about individual vehicles when necessary. As the traffic in India is highly heterogeneous, different types of vehicles with varying speeds and physical dimensions travel from place to place. So, the Class of Vehicles is also a factor that should be considered.
- Next important part is adjusting the green signal time based on the vehicles detected.
- Software packages like Python, OpenCV, and MATLAB are used for developing algorithms. Computer Vision is a field of study that enables computers to replicate the human visual system. As already mentioned above, It is a subset of artificial intelligence which collects information from digital images or videos and processes them to define the attributes. The entire process involves image acquiring, screening, analysing, identifying, and extracting information. This extensive processing helps computers to understand any visual content and act on it accordingly.

3.4 PROPOSED SYSTEM OVERVIEW:

A proposed system for real-time traffic density calculation utilizes CCTV cameras located at traffic junctions. The input image is analysed through image processing and object detection algorithms that detect the number of vehicles of various classes such as cars, bikes, buses, and trucks. YOLO algorithm is used to detect the vehicles in the input image. The detected number of vehicles of each class is used to determine the traffic density. A signal-switching algorithm employs this density, along with other factors, to set the green signal timer for each lane, while also updating the red signal times. To prevent starvation of a particular lane, the green signal time is limited to a maximum and minimum value. Additionally, a simulation is developed to demonstrate the efficacy of the system and compare it with the existing static system.

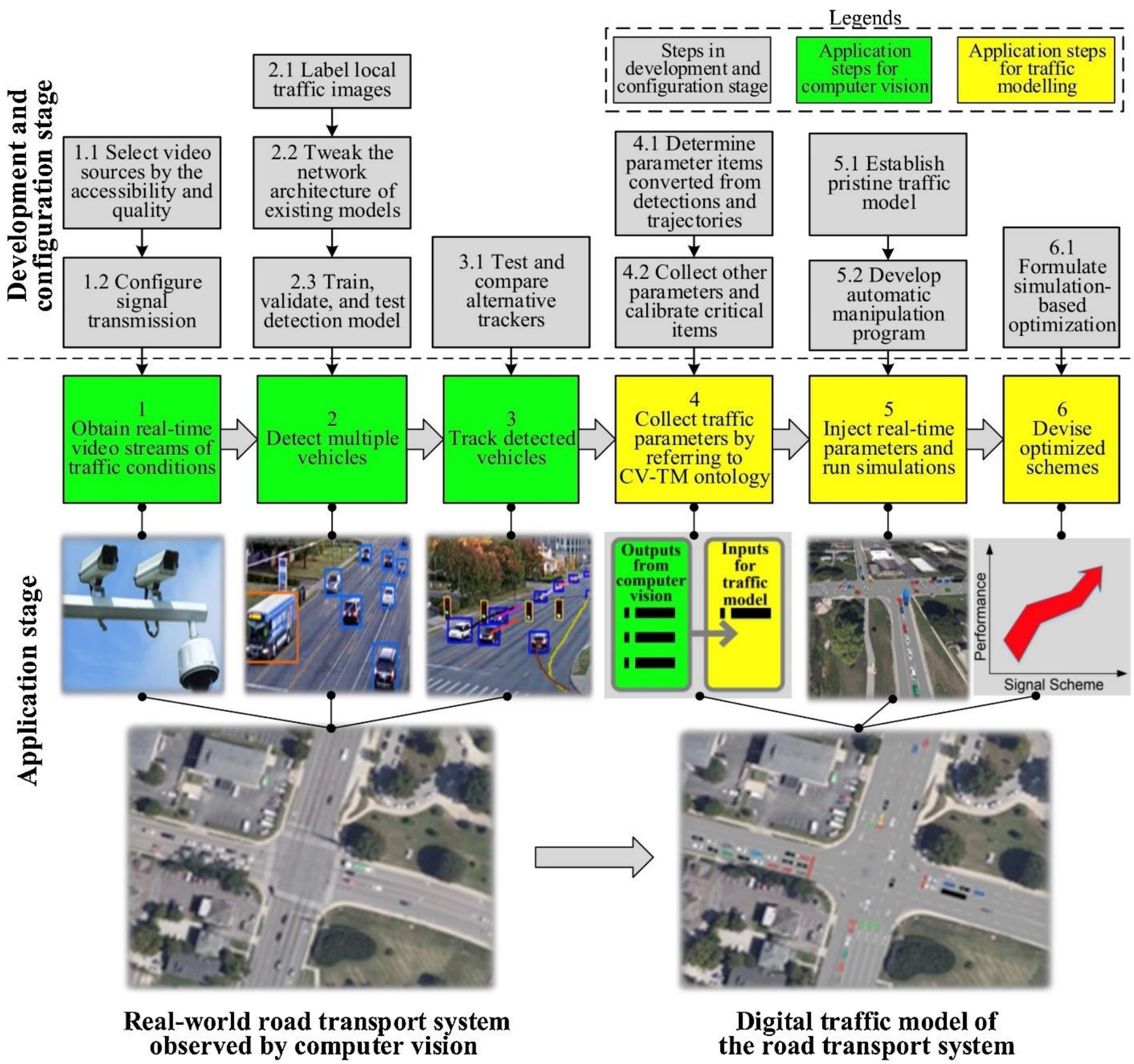

Fig.3.3. The framework for combining traffic simulation and machine vision.

Benefits and Advancements of Smart Traffic Control Systems:

A potential system that can improve traffic management and pedestrian safety is the use of CCTV cameras at intersections combined with smart traffic lights. These traffic lights can be integrated with GPS, laser radars, and sensors to detect irregular traffic flow, swerving, or stopped vehicles, and warn drivers accordingly. Tesla vehicles already use similar technology to increase safety, and it's possible for smart traffic lights to share this information to prevent potential accidents. In the event of an accident, the system could also automatically notify emergency services.

Implementing this technology can help save lives during the "golden hour" after a collision and improve traffic flow throughout a city. As more data is collected through these smart traffic lights, artificial intelligence can be utilized to determine the best options for traffic management citywide. Ultimately, integrating smart traffic lights into a city's infrastructure can contribute to create a Smart City.

Intelligent traffic lights can be a cost-effective solution for cities, as only one traffic light at each intersection needs to be equipped with smart technology. As technology advances approximately every 18 months, the computer systems in these traffic lights can process more data and make use of more sensors. For the system to work effectively, vehicles also need to have smart technology, such as GPS, driver assistance systems, and map navigation systems. Smart vehicles can send information to the traffic lights, providing them with more data to make intelligent decisions.

Tesla's self-driving technology is an example of this. The traffic lights can not only use this information to control traffic flow, but they can also send it back to the smart vehicles, creating a seamless system that works together to improve safety and efficiency throughout the city. By integrating intelligent traffic lights into a city's infrastructure and promoting the use of smart technology in vehicles, we can work towards creating a truly Smart City.

Intelligent traffic lights can communicate with each other to find the best solution for incidents such as accidents or adverse weather conditions. Major automakers, such as Volkswagen, Honda, Ford, and BMW, are also exploring technology that allows vehicles and traffic lights to work together to reduce congestion, and emissions, and increase safety.

In Helmond, a city in the southern Netherlands, Dynniq and KPN introduced an innovative Green Flow for Blue Lights system in June 2019. This invention automatically switches traffic lights to green for emergency service vehicles, reducing the risk of accidents and casualties that occur at junctions featuring traffic lights within built-up areas.

Smart technologies can improve traffic safety, flow, and efficiency, which is especially crucial during emergency situations when normal traffic rules may not apply. Computer model simulations can be used to test, analyse, improve, and predict traffic conditions in different scenarios without leaving a room. Smart traffic lights gather information on factors such as vehicle volume, weather conditions, and traffic patterns to identify areas that require improvements in traffic flow. Computer programs analyse this information and suggest changes like adjusting traffic signal timing or installing traffic islands. These measures promote traffic flow and pedestrian safety.

Front distance headway is the distance between vehicles in a lane, while lateral distance headway refers to the space between adjacent vehicles. Variations in these distances impact traffic flow. During congestion, headway is typically small-, and the time headway represents the time needed to cover the front distance headway. There are simulators that help determine the best traffic light design for specific locations based on factors like visibility and height. However, using wireless connections for smart traffic lights may lead to signal interference if a building blocks the Wi-Fi signal. To overcome this, more Wi-Fi receivers in the streets, smart vehicles with Wi-Fi signals, or satellite communication can be used.

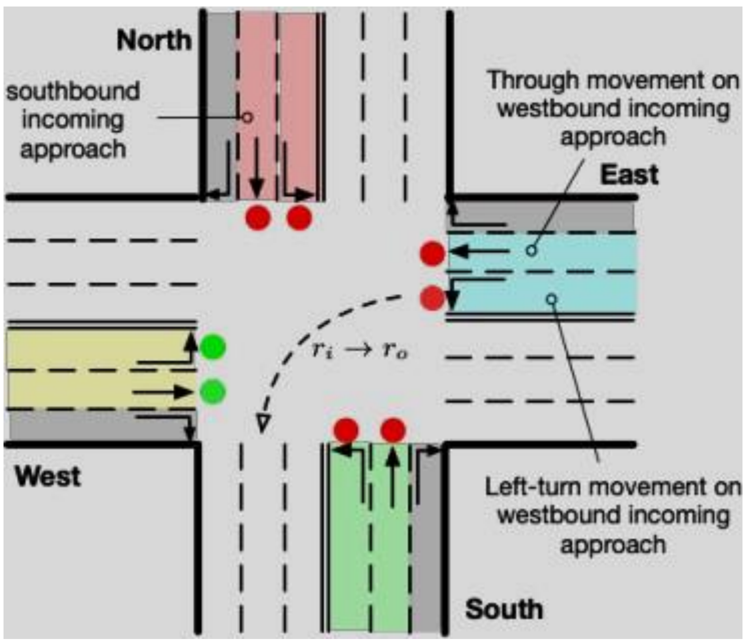

Fig 3.4 Signalized intersection

Smart traffic lights can improve road safety and traffic flow by using technology to gather information about the number of vehicles, weather conditions, and speed. Computer programs can then use this information to identify problem areas and suggest changes such as adjusting the signal time or adding traffic islands. This can help to direct traffic flow and increase pedestrian safety. The distance between adjacent vehicles is known as the front distance headway, and the lateral distance between vehicles is known as the lateral distance headway. These distances can affect traffic flow, with smaller headway in congested areas. Simulators can be used to design traffic lights, considering location, height, and visibility.

Smart traffic lights can also detect and respond to situations such as a vehicle driving too slowly or stopping longer than necessary to prevent accidents. In the future, smart traffic lights may even apply brakes to prevent accidents or improve traffic flow. However, there are concerns about security and privacy, as these systems can be hacked or used to monitor people's movements.

Governments are working to protect infrastructure from these risks. In practice, traffic light systems have vulnerabilities that can be exploited by attackers. For example, attackers may be able to acquire the same radio model as the controllers through social engineering the manufacturer to sell one, as they can see the service set identifier of the network.

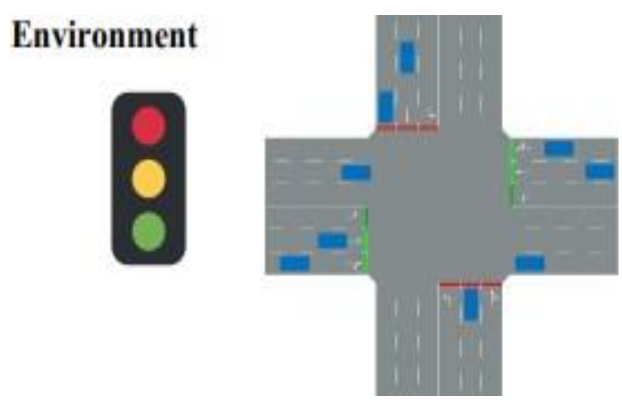

Fig 3.5 Setup environment

The use of facial recognition technology has raised concerns over privacy and civil liberties, as seen in the case of Ed Bridges in London. However, despite these concerns, technology continues to advance and we must adapt to these changes as they can improve our daily lives and road safety. For example, smart traffic lights have the potential to reduce CO_2 emissions and encourage the use of public transportation by giving them priority on the road. One potential barrier to implementing these technologies is the generational gap in the acceptance of change. However, we can learn from past successes and failures to find new solutions that address these concerns. It is also important for governments and cities to support the implementation of smart traffic lights, as it will require lengthy consultations, land purchases, and access agreements.

In conclusion, while there may be drawbacks to the use of smart technology such as facial recognition and smart traffic lights, we must embrace these changes and work towards finding solutions that address concerns while still reaping the benefits.

Smart traffic management offers several benefits that can enhance the safety and efficiency of our roads:

- Firstly, the system can detect traffic congestion and take appropriate actions to reduce it. Sensors and peripherals provide the traffic control unit with real-time information, allowing the system to make informed decisions to improve traffic flow.
- Secondly, the system can adjust traffic light timings in real time, responding to changing traffic conditions automatically. This helps to avoid unnecessary delays and reduce traffic congestion.
- Thirdly, the deployment of smart traffic management systems can help to increase road safety and reduce the likelihood of accidents occurring.
- Lastly, by managing traffic flow more effectively, the system can help to reduce pollution levels. This is achieved by minimizing fuel consumption and improving the overall efficiency of the transportation network. As a result, smart traffic management can help to create a more sustainable and environmentally-friendly transportation system.

3.4.1. Vehicle Detection:

The proposed system uses YOLO, a CNN algorithm for object detection, for real-time vehicle detection. A custom YOLO model was trained to detect various classes of vehicles, such as cars, bikes, heavy vehicles, and rickshaws. YOLO applies a single neural network to the entire image, dividing it into regions and predicting bounding boxes and probabilities for each region, which are weighted by the predicted probabilities.

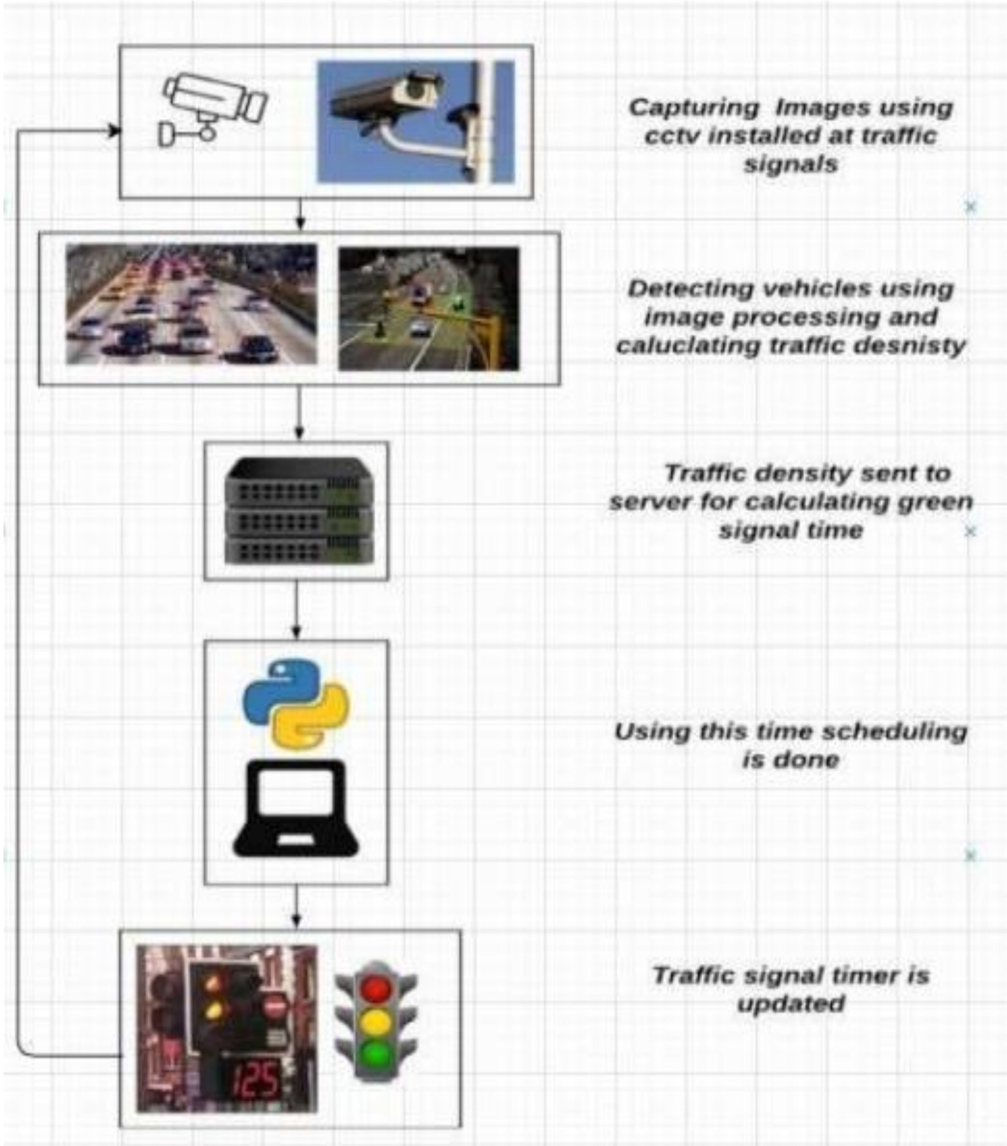

Fig 3.6 Flowchart of the proposed Adaptive Signal Control System

The dataset for training was created by scraping images from Google and manually labelling them using Label IMG. The pre-trained weights downloaded from the YOLO website were used for training, and the configuration file was modified to suit the model's requirements. The number of output neurons in the last layer was set to the number of classes the model was supposed to detect, which was four in this case - Car, Bike, Bus/Truck, and Rickshaw. The number of filters was also adjusted based on the formula 5*(5+number of classes), resulting in 45 filters for this model. Training continued until the loss was significantly reduced and seemed to stabilize.

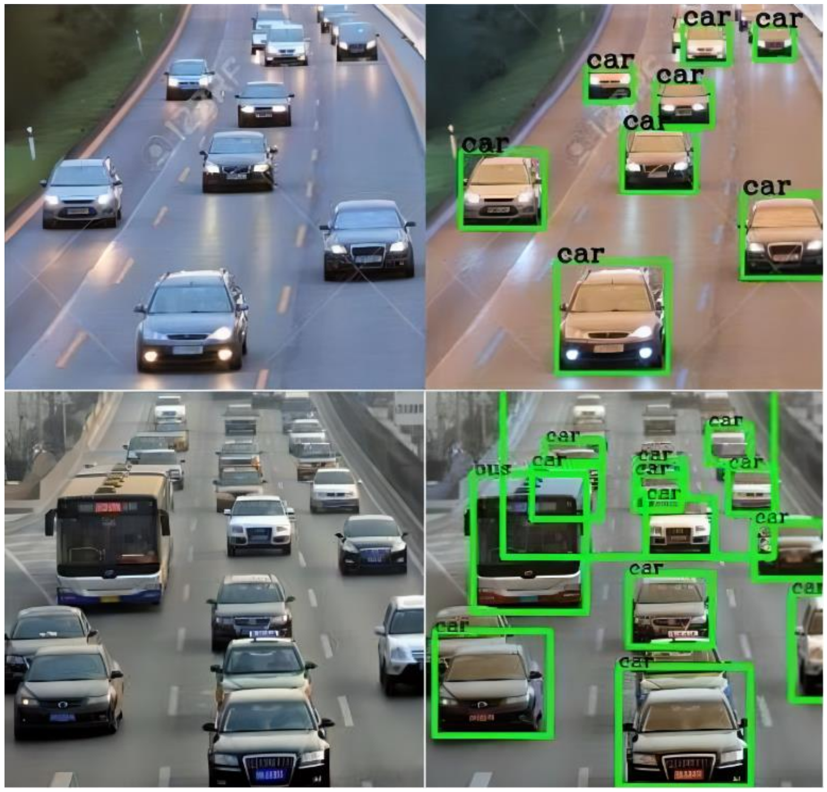

Fig.3.7. Shows the detection of multiple cars

- Test images on which the vehicle detection model was applied. The left side of the image shows the original image and the right side is the output after the vehicle detection model is applied to the image, with bounding boxes and corresponding labels.
- This marked the end of the training, and the weights were now updated according to the requirements. A threshold seats the minimum confidence required for successful detection. After the model is loaded and an image is fed to the model, it gives the result in a JSON format i.e., in the form of key-value pairs, in which labels are keys, and their confidence and coordinates are values. Again, OpenCV can be used to draw the bounding boxes on the images from the labels and coordinates received.
- It achieves high accuracy and runs in real-time by only requiring one forward propagation pass through the network. The algorithm outputs recognized objects and their bounding boxes after non-max suppression to avoid detecting objects multiple times. Test images were used to demonstrate the effectiveness of the model.

3.4.2. Signal Switching Module:

- Input: The Signal Switching Algorithm takes as input the information about the vehicles that were detected from the vehicle detection module. This input is in JSON format, with the label of the object detected as the key and the confidence and coordinates as the values.

- Factors considered: The algorithm considers several factors when setting the green signal timer and adjusting the red signal timers of other signals. These factors include the number of lanes, total count of vehicles of each class, traffic density, time added due to lag each vehicle suffers during start-up, the average speed of each class of vehicle when the green light starts, and the minimum and maximum time limit for the green light duration.

- Processing time: The processing time of the algorithm to calculate traffic density and green light duration is important in deciding at what time the image needs to be acquired.
- Scaling: The algorithm can be scaled up or down to any number of signals at an intersection.

- Initialization: When the algorithm is first run, the default time is set for the first signal of the first cycle, and the times for all other signals of the first cycle and all signals of the subsequent cycles are set by the algorithm.

- Threads: A separate thread is started to handle the detection of vehicles for each direction, while the main thread handles the timer of the current signal.

- Green signal timer: The green signal time for the signal is calculated based on the number of vehicles of each class, using the average speeds of vehicles at startup and their acceleration times. The minimum and maximum time limit for the green light duration is also considered.

- Seamless switching: Once the green timer of the current signal becomes zero, the next signal becomes green for the time set by the algorithm. The image is captured when the time of the signal that is to turn green next is 5 seconds, allowing the system a total of 10 seconds to process the image, detect the number of vehicles of each class, calculate the green signal time, and set the times of this signal as well as the red signal time of the next signal. This allows for seamless switching between signals and prevents any lag.

To find the optimum green signal time based on the number of vehicles of each class at a signal, the average speeds of vehicles at startup and their acceleration times were used, from which an estimate of the average time each class of vehicle takes to cross an intersection was found.

The green signal time is then calculated using:

$$GST = \frac{\sum_{vehicleClass} (NoOfVehicles_{vehicleClass} * AverageTime_{vehicleClass})}{(NoOfLanes + 1)}$$

Where,

- GST is green signal time
- No of Vehicles of Class is the number of vehicles of each class of vehicle at the signal as detected by the vehicle detection module,
- Average Time of Class is the average time the vehicles of that class take to cross an intersection, and
- No. of lanes are the number of lanes at the intersection.

The average time each class of vehicle takes to cross an intersection can be set according to the location, i.e., region-wise, city-wise, locality-wise, or even intersection-wise based on the characteristics of the intersection, to make traffic management more effective. Data from the respective transport authorities can be analysed for this.

The signals switch in a cyclic fashion and not according to the densest direction first. This is in accordance with the current system where the signals turn green one after the other in a fixed pattern and do not need the people to alter their ways or cause any confusion. The order of signals is also the same as the current system, and the yellow signals have also been accounted for.

Order of signals: Red →Green →Yellow →Red

3.4.3 Simulation Module:

A simulation was developed from scratch using Pygame to simulate real-life traffic. It assists in visualizing the system and comparing it with the existing static system. It contains a 4-way intersection with 4 traffic signals. Each signal has a timer on top, showing the time remaining for the signal to switch from green to yellow, yellow to red, or red to green.

Each signal also has the number of vehicles that have crossed the intersection displayed beside it. Vehicles such as cars, bikes, buses, trucks, and rickshaws come in from all directions. In order to make the simulation more realistic, some of the vehicles in the rightmost lane turn to cross the intersection. Whether a vehicle will turn or not is also set using random numbers when the vehicle is generated. It also contains a timer that displays the time elapsed since the start of the simulation and shows a snapshot of the final output of the simulation.

Fig.3.8. Shows a sample simulation image

Pygame is a cross-platform set of Python modules designed for writing video games. It includes computer graphics and sound libraries designed to be used with the Python programming language. Pygame adds functionality on top of the excellent SDL library.

3.5 WHY SIMULATE TRAFFIC FLOW:

The main reason behind simulating traffic is generating data without the real world. Instead of testing new ideas on how to manage traffic systems in the real world or collecting data using sensors, you can use a model run on software to predict traffic flow. This helps accelerate the optimization and data gathering of traffic systems. Simulation is a much cheaper and faster alternative to real-world testing.

Training machine learning models require huge datasets that can be difficult and costly to gather and process. Generating data procedurally by simulating traffic can be easily adapted to the exact type of data needed.

3.5.1. Modelling:

A traffic model is a mathematical model of real-world traffic, usually, but not restricted to, road traffic. Traffic modelling draws heavily on theoretical foundations. To analyse and optimize traffic systems, we first must model a traffic system mathematically. Such a model should realistically represent traffic flow based on input parameters (road network geometry, vehicles per minute, vehicle speed. Models can teach researchers and engineers how to ensure an optimal flow with a minimum number of traffic jams.

Traffic system models are generally classified into three categories, depending on what level they are operating on:

• **Microscopic models**: represent every vehicle separately and attempt to replicate driver behavior.

• **Macroscopic models**: describe the movement of vehicles in terms of traffic density (vehicle per km) and traffic flow (vehicles per minute). They are usually analogous to fluid flow.

• **Mesoscopic models**: hybrid models that combine the features of microscopic and macroscopic models; They model flow as “packets” of vehicles.

Development of green interval time and signal-switching algorithm:

This algorithm updates the red, green, and yellow times of all signals. These timers are set based on the count of vehicles of each class received from the vehicle detection module and several other factors such as the number of lanes, average speed of each class of vehicle, etc.

- **Cycle:** A signal cycle is one complete rotation through all the indications provided.

- **Cycle length:** Cycle length is the time in seconds that it takes a signal to complete one full cycle of indications. It indicates the time interval between the starting off the green for one approach till the next time the green starts. It is denoted by C.

- **<u>Interval:</u>** Thus, it indicates the change from one stage to another. There are two types of intervals- change interval and clearance interval. Change interval also called the yellow time indicates the interval between the green and red signal indications for an approach. Clearance interval also called all red is included after each yellow interval indicating a period during which all signal faces show red and is used for clearing off the vehicles in the intersection.

- **<u>Green interval:</u>** It is the green indication for a particular movement or set of movements and is denoted by Gi. This is the actual duration the green light of a traffic signal is turned on.

- **<u>Red interval</u>**: It is the red indication for a particular movement or set of movements and is denoted by Ri. This is the actual duration the red light of a traffic signal is turned on.

- **<u>Phase:</u>** A phase is a green interval plus the change and clearance intervals that follow it. Thus, during the green interval, non-conflicting movements are assigned to each phase. It allows a set of movements to flow and safely halts the flow before the phase of another set of movements starts.
- There is no precise methodology for the design of phases. This is often guided by the geometry of the intersection, the flow pattern especially the turning movements, and the relative magnitudes of flow. Therefore, a trial-and-error procedure is often adopted. However, phase design is very important because it affects further design steps. Further, it is easier to change the cycle time and green time when the flow pattern changes, whereas a drastic change in the flow pattern may cause considerable confusion to the drivers.
- To illustrate various phase plan options, consider a four-legged intersection with through traffic and right turns. The left turn is ignored. The first issue is to decide how many phases are required. It is possible to have two, three, four, or several phases.
- There are two intervals, namely the change interval and clearance interval, normally provided in a traffic signal. The change interval or yellow time is provided after green time for movement. The purpose is to warn a driver approaching the intersection during the end of a green time about the coming of a red signal. They normally have a value of 3 to 6 seconds.

- The design consideration is that a driver approaching the intersection with design speed should be able to stop at the stop line of the intersection before the start of red time. The Institute of transportation engineers (ITE) has recommended a methodology for computing the appropriate length of change interval.
- Cycle time is the time taken by a signal to complete one full cycle of iterations. i.e., one complete rotation through all signal indications. It is denoted by C. The way in which the vehicles depart from an intersection when the green signal is initiated will be discussed now. Illustrates a group of N vehicles at a signalized intersection, waiting for the green signal. As the signal is initiated, the time interval between two vehicles, referred to as headway, crossing the curb line is noted. The first headway is the time interval between the initiation of the green signal and the instant vehicle crosses the curb line.
- In order to determine the green light interval time in different traffic states and greatly improve the traffic capacity at the intersection, a calculation method that replaced speed with traffic flow into a kinematical equation was put forward. Greenshields model, Greenberg model, and Underwood model were used to analyse the relationship between green light interval time and traffic according to different conditions of traffic volumes. A green light interval time calculation method was established under different traffic conditions and volumes.
- The second headway is the time interval between the first and the second vehicle crossing the curb line. Successive headways are then plotted. The first headway will be relatively longer since it includes the reaction time of the driver and the time necessary to accelerate. The second headway will be comparatively lower because the second driver can overlap his/her reaction time with that of the first driver.
- After a few vehicles, the headway will become constant. The results show that the new model can significantly improve the passing vehicle numbers, enhance the average velocity and reduce the block percentage at intersections. So, the method can optimize the green light interval time and improve the traffic capacity of the intersection. This constant headway which characterizes all headways beginning with the fourth or fifth vehicle is defined as the saturation headway and is denoted as h.

3.6 OBJECT DETECTION IN AN IMAGE USING YOLO:

Object detection in an image was carried out using YOLOv4. For the purpose of the YOLOv4 object detection, its pre-trained model weights were used. The pre-trained model was trained on the MS-COCO dataset, a dataset of 80 classes containing day-to-day objects. This large dataset comprises annotated photos of everyday scenes of common objects in their natural contexts and is labelled using predefined classes. Therefore, this dataset is widely used to establish a benchmark for the purposes of detection and classification. An image of a traffic intersection was used for object detection. YOLOv4 was able to detect pedestrians, cars, motorbikes, and traffic signals. The image containing the detected objects is shown in the figure.

Fig.3.9. Vehicles detected using YOLO Test Case 1

In the previous Figure, the numbers (0.99, 0.85, etc) indicate the probability of correctly classifying the objects in the image. It is seen that the pre-trained model can identify vehicles with high precision.

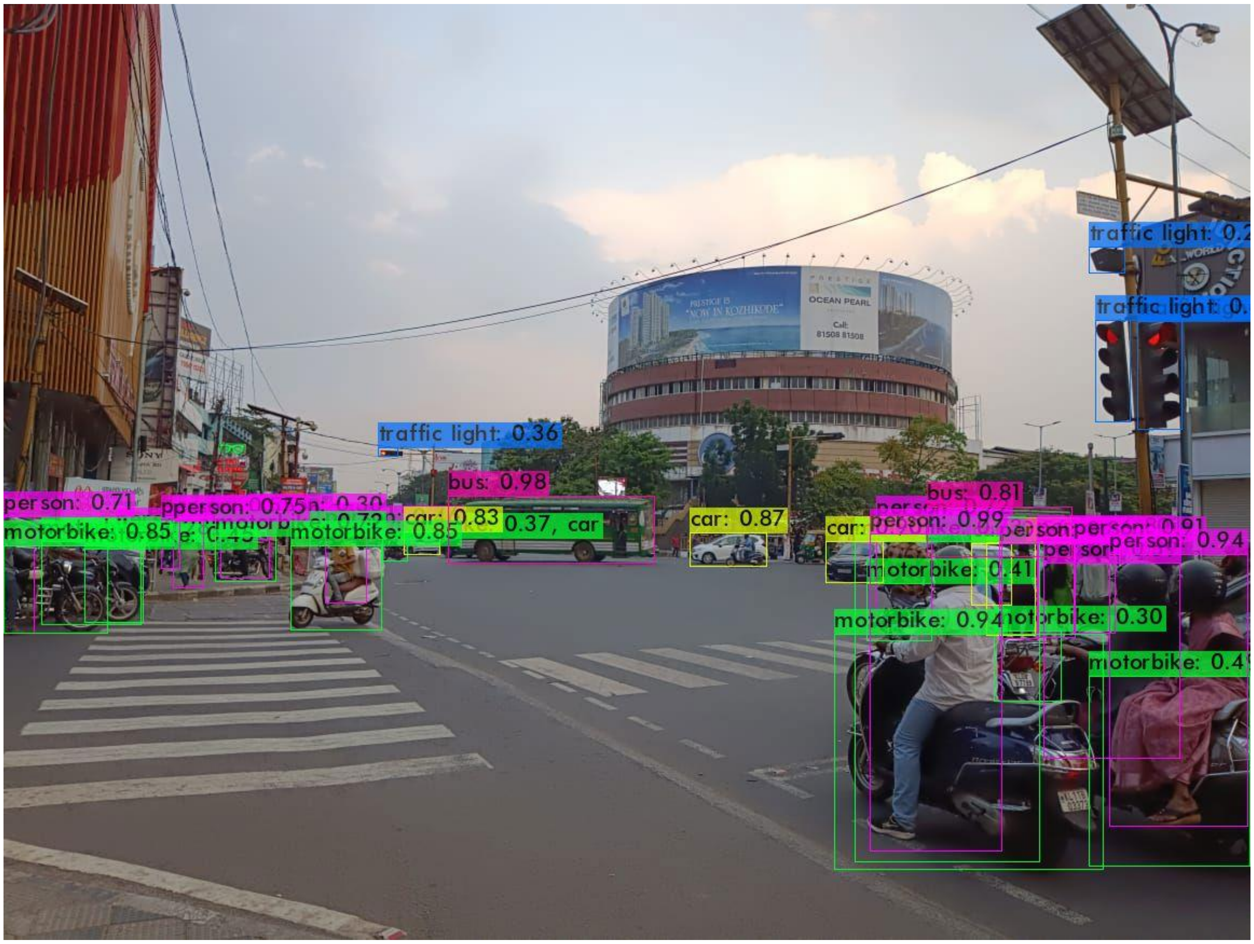

Fig.3.10. Vehicles detected using YOLO Test Case 2

Similarly, vehicles are detected through the images taken by the CCTV cameras installed at the intersection using YOLO. These include several vehicles of each type like motorbikes, cars, buses, etc. These data are further processed in later stages.

SNAPSHOTS OF THE SIMULATION:

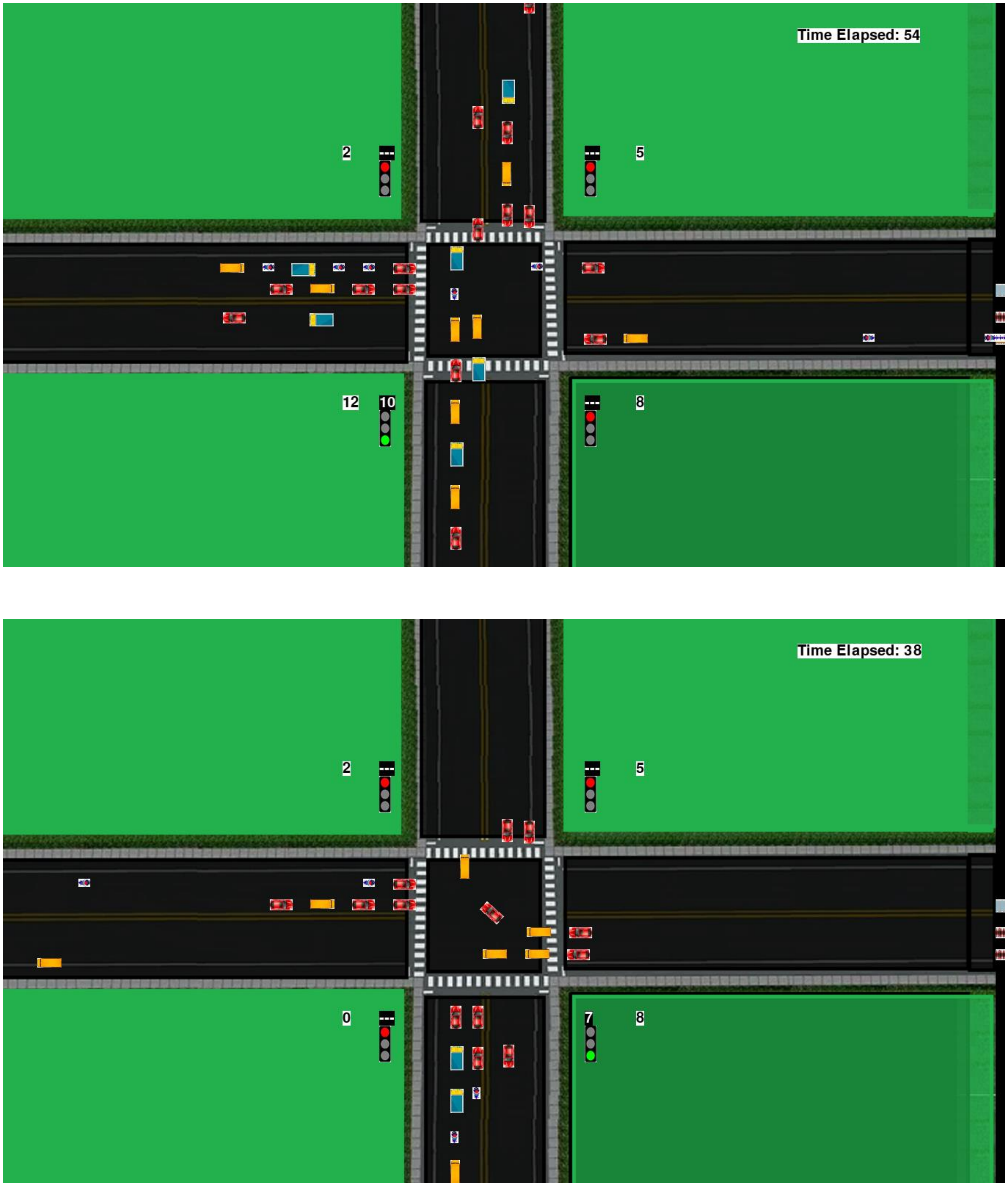

Fig.3.11. Snapshots of the simulation

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Evaluation of Vehicle Detection Module:

The accuracy of the vehicle detection module has been tested on multiple test images, which contained different numbers of vehicles. The results have shown that the detection accuracy ranges from 75% to 80%. Although this level of accuracy is acceptable, it is not optimal. The primary reason for the low accuracy is attributed to the inadequacy of the dataset used to train the model.

To enhance the accuracy of the vehicle detection module, it is suggested to use real-life footage from traffic cameras to train the model. By doing so, the model can learn from a more comprehensive and diverse dataset, which can significantly improve its ability to accurately detect vehicles in various situations. Therefore, incorporating real-life footage from traffic cameras can be a highly effective method to enhance the accuracy of the vehicle detection module.

4.2 Evaluation of the proposed adaptive system:

To evaluate the effectiveness of the proposed adaptive system in comparison to the existing static system, a series of 15 simulations were conducted for both systems over a 5-minute duration. The simulations were conducted using various traffic distributions across the four directions.

The performance of each system was measured by calculating the number of vehicles that were able to pass through the intersection per unit of time. The measurement was based on the idle time of the signal, which refers to the duration during which the signal is green, but no vehicles pass through the intersection. The objective was to compare the idle time of each signal between the adaptive and static systems.

The results of this comparison have an impact on the waiting time of the vehicles and the queue lengths of the other signals. Therefore, by analysing the performance of both systems under different traffic distributions, it is possible to determine which system is more effective in optimizing the flow of traffic through the intersection.

The distribution [a,b,c,d] means that the probability of a vehicle being in lane 1, lane 2, lane 3, and lane 4 is a/d, (b-a)/d, (c-b)/d, and (d-c)/d, respectively. For example, in simulation 1, the distribution is [300,600,800,1000] which means probabilities of 0.3, 0.3, 0.2, and 0.2. The results obtained were tabulated in the form of the number of vehicles passed lane-wise and the total number of vehicles passed.

Table 2. Simulation results of the current static system

S.no	Distribution	Lane 1	Lane 2	Lane 3	Lane 4	Total
1.	[300,600,800,1000]	70	52	52	65	239
2.	[500,700,900,1000]	112	49	48	31	240
3.	[250,500,750,1000]	73	53	63	62	251
4.	[300,500,800,1000]	74	44	65	71	254
5.	[700,800,900,1000]	90	32	25	41	188
6.	[500,900,950,1000]	95	71	15	14	195
7.	[300,600,900,1000]	73	63	69	24	229
8.	[200,700,750,1000]	54	89	10	67	220
9.	[940,960,980,1000]	100	10	8	4	122
10.	[400,500,900,1000]	81	29	88	37	235
11.	[200,400,600,1000]	42	47	54	86	229
12.	[250,500,950,1000]	39	52	93	22	206
13.	[850,900,950,1000]	74	10	13	17	114
14.	[350,500,850,1000]	49	46	69	50	214
15.	[350,700,850,1000]	51	64	37	43	195

Table 3. Simulation results of the proposed adaptive system

S.no	Distribution	Lane 1	Lane 2	Lane 3	Lane 4	Total
1.	[300,600,800,1000]	87	109	41	50	287
2.	[500,700,900,1000]	128	55	49	25	257
3.	[250,500,750,1000]	94	50	60	58	262
4.	[300,500,800,1000]	89	46	69	59	263
5.	[700,800,900,1000]	185	25	23	28	261
6.	[500,900,950,1000]	94	118	11	16	239
7.	[300,600,900,1000]	87	68	70	33	258
8.	[200,700,750,1000]	56	108	19	78	261
9.	[940,960,980,1000]	193	6	5	7	211
10.	[400,500,900,1000]	97	29	100	34	260
11.	[200,400,600,1000]	26	52	67	99	244
12.	[250,500,950,1000]	52	75	101	7	235
13.	[850,900,950,1000]	154	17	12	18	201
14.	[350,500,850,1000]	64	53	80	47	244
15.	[350,700,850,1000]	66	82	40	48	236

According to the data presented in Figure, the proposed adaptive system consistently outperforms the current static system, regardless of the traffic distribution. The level of improvement in performance, however, is contingent on the degree of traffic distribution skewness across the lanes. Specifically, the greater the skewness of the traffic distribution, the more pronounced the improvement in performance observed with the adaptive system.

Based on the simulation data presented, when the traffic is evenly or nearly evenly distributed among the four lanes, the proposed adaptive system shows only a slight performance improvement over the current static system. This can be observed in simulation scenarios 1, 2, 3, and 4. In these cases, the performance improvement with the adaptive system is approximately 9%.

According to the simulation data presented, when the traffic distribution is moderately skewed, the proposed adaptive system performs significantly better than the current static system. This is evident in simulation scenarios 5, 6, 7, 8, 14, and 15, where the performance improvement with the adaptive system is approximately 22%. It is worth noting that this type of traffic distribution is typically observed in real-life scenarios.

Based on the simulation data presented, when the traffic distribution is sharply skewed, the proposed adaptive system exhibits a significant improvement in performance compared to the current static system. This is demonstrated in simulation scenarios 9 and 13, where the red line drops sharply and there is a considerable gap between the red and green lines. The performance improvement in these scenarios is approximately 36 %.

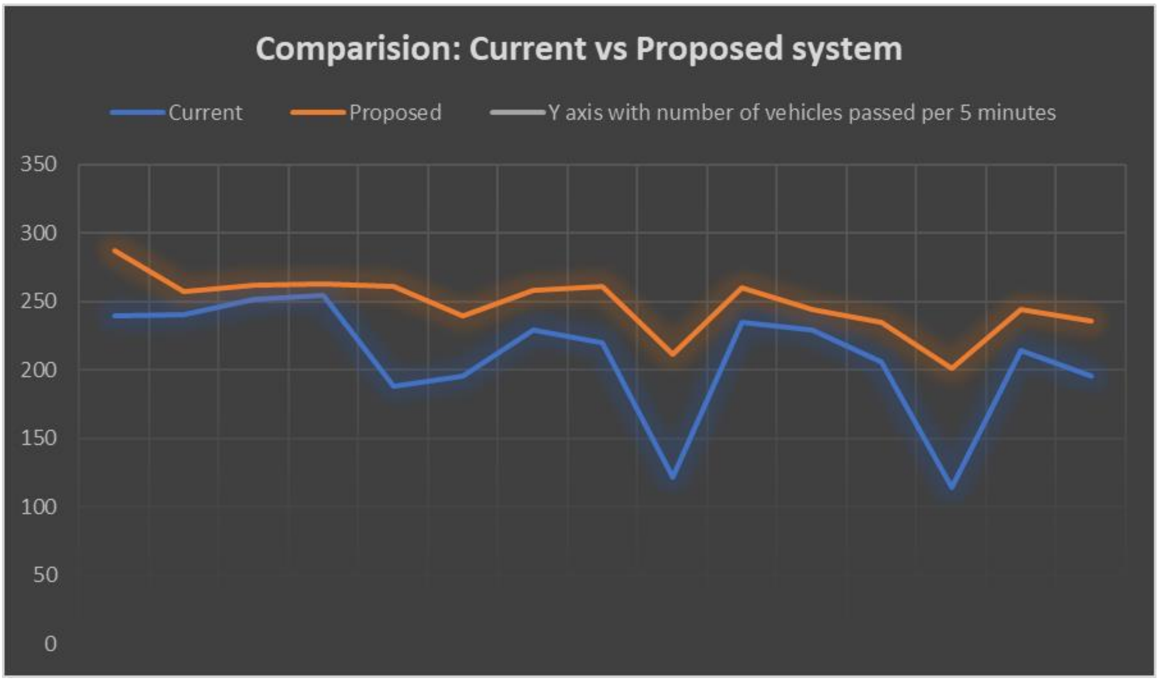

Fig.4.1. Comparison of the current static system and proposed adaptive system

As per the simulation results with consistent traffic distribution, vehicle speeds, and other factors, the simulations were run for a total duration of 1 hour and 15 minutes with 300 seconds (5 minutes) for each distribution. It was observed that the proposed system, on average, improved the performance by about 23% as compared to the current static system with fixed timings. This improvement suggests a reduction in idle green signal time and waiting time for vehicles, resulting in a more efficient and effective traffic flow management system.

4.3 Case Study of Nandilath Intersection:

The study conducted an analysis of a 4-way intersection in Calicut, which involved observing the traffic patterns during peak hours. The intersection was managed by traffic signals that were set to a fixed time. Among the four roads that met at the intersection, one road had considerably less traffic than the other three, even during the busiest times of the day. This road was located next to Nandilath G mart.

The other three roads had similar amounts of traffic during peak hours, with Indira Gandhi Road having slightly more traffic compared to the other two. It is worth noting that the traffic volume on Indira Gandhi Road was significantly higher than the traffic on the road next to G mart. This information could be useful in determining how to optimize traffic flow at the intersection, potentially by adjusting the timing of the traffic signals or exploring alternative traffic management solutions.

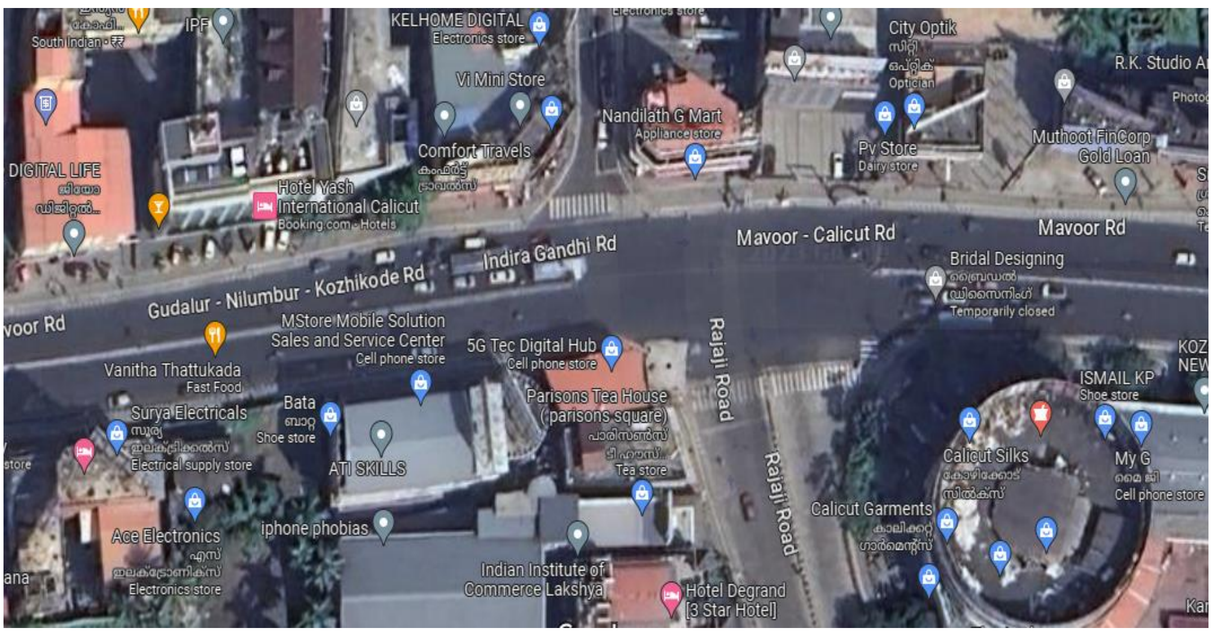

Fig.4.2. Satellite view of Selected Intersection

To provide further information on the traffic management of the intersection under analysis, the durations of the red and green traffic signals have been recorded for each of the four ways that meet at the intersection. For the sake of clarity, we have assigned a label to each of the four ways: Way 1 corresponds to Mavoor-Calicut Road, Way 2 to Rajaji Road, Way 3 to Indira Gandhi Road, and Way 4 is located beside Nandilath G-mart.

Table 4: Signal Timings of Nandilath intersection

Way	Red Signal Time	Green Signal Time
1	93	45
2	101	36
3	112	26
4	100	20

Based on the above information, it appears that Way 3 (Indira Gandhi Road) has the highest traffic volume among the four ways, but the green signal time given to this way is the shortest. This has resulted in long queues of vehicles in that direction, especially during peak hours. It is worth noting that the duration of green and red signals at an intersection is usually calculated based on the peak hour flows and lost time.

To address this issue, an adaptive signal timing algorithm can be used to adjust the signal timings based on real-time data on vehicular volume. By doing so, more green time can be allotted to Way 3 when it has heavy traffic, which can help alleviate traffic congestion and improve the overall efficiency of the intersection.

Current System				
Lane 1	**Lane 2**	**Lane 3**	**Lane 4**	**Total**
67	74	51	18	210
78	73	47	19	217
80	73	33	29	215
76	71	39	27	213
77	66	44	26	213
74	72	37	21	204
65	73	36	18	192
60	68	33	28	189
49	83	36	28	196
57	70	46	25	198
53	70	39	34	196
55	70	29	38	192
				2435

Proposed Adaptive System					
Simulation No.	**Lane 1**	**Lane 2**	**Lane 3**	**Lane 4**	**Total**
1	111	86	42	31	270
2	105	83	38	28	254
3	100	96	36	20	252
4	96	75	56	22	249
5	93	89	42	24	248
6	77	97	37	30	241
7	76	82	48	30	236
8	71	92	48	30	241
9	85	98	48	31	262
10	79	92	37	30	238
11	110	105	24	17	256
12	76	87	43	44	250
					2997

Table 5: Shows the Number of vehicles passed in 1 hour of 5 minutes intervals in the Current and Proposed Adaptive system respectively.

To compare the effectiveness of the current static traffic management system with a proposed adaptive system, the total number of vehicles that crossed the intersection over a 5-minute period was recorded for both systems. The simulations were conducted over a total period of 1 hour, with 12 simulations of 5 minutes each and different distributions of traffic, but with the same overall distribution.

The results of the simulations were tabulated to show the number of vehicles passing through each lane, as well as the total number of vehicles passed by each system. It was found that, under the same conditions, the adaptive system was able to pass 2997 vehicles in one hour, while the current static system only passed 2435 vehicles - a difference of 562 vehicles. This means that the proposed adaptive system improved performance by over 23%.

On average, the adaptive system allowed 48 more vehicles to pass every 5 minutes compared to the static system. This implies a reduction in idle green signal time (the signal is green but no vehicle passes) as well as the waiting time of the vehicles. In summary, the adaptive system is more efficient at managing traffic flow at the intersection, leading to less congestion and reduced waiting times for drivers.

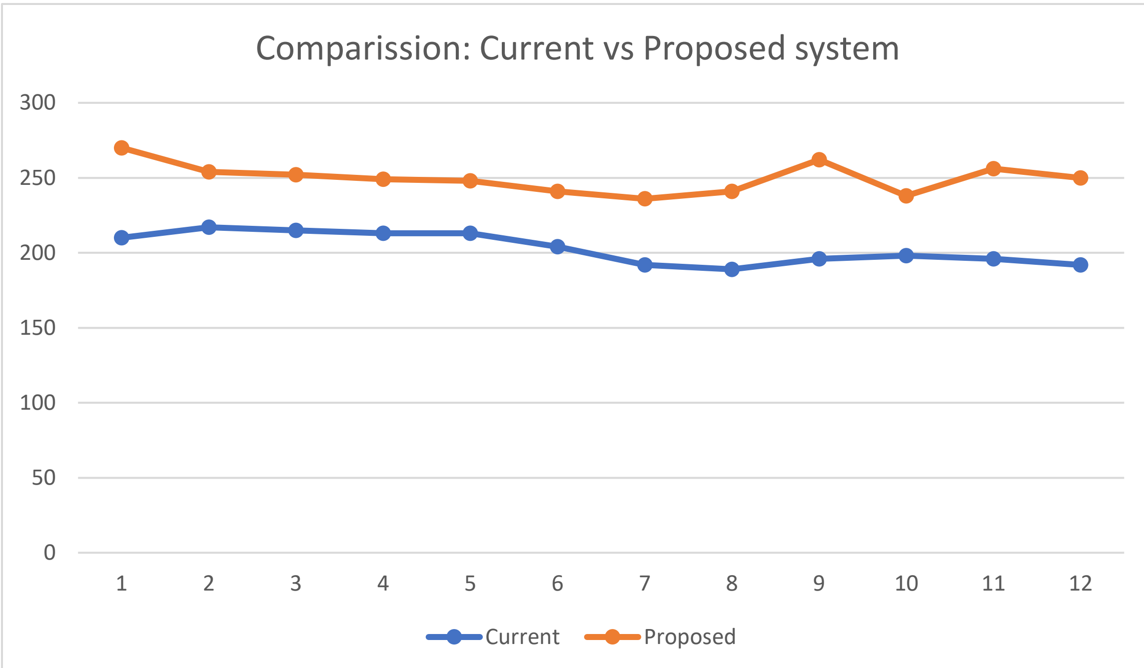

Fig.4.3. Comparison of the current static system and proposed adaptive system

CHAPTER 5
CONCLUSION

In short, the focus of the project is to identify the problems that cause traffic congestion at intersections and to find the solutions to overcome these problems. For this purpose, we have studied different research papers, and the performance and mechanisms of signalized intersections were observed. Conflicts and Delays resulting in congestion are identified as major problems. As far as Delay time is concerned, one efficient method is “Adaptive Traffic Signal Controlling.” Studies have been showing that travel time improved by an average of more than 10%.

To sum up, the proposed system adapts the green signal time based on the traffic density at the signal and allocates a longer green signal time for the direction with more traffic and a shorter green signal time for the direction with less traffic. This approach helps to reduce delays and congestion, resulting in reduced waiting times for vehicles. Additionally, this system can contribute to lower fuel consumption and pollution by optimizing traffic flow. Overall, the proposed system has the potential to improve traffic management and reduce the negative impact of transportation on the environment.

Based on the simulation results, the proposed system exhibits a significant improvement of approximately 23% over the current static system in terms of the number of vehicles crossing the intersection. This improvement suggests that the proposed system has the potential to enhance traffic flow management and reduce congestion on roads. Moreover, further calibration of the system using real-life CCTV data for training the model can lead to even better performance.

In addition to its benefits in optimizing traffic flow, the proposed adaptive traffic management system offers advantages over existing intelligent traffic control systems such as Pressure Mats and Infrared Sensors. The cost of deploying the system is minimal as it uses footage from CCTV cameras already installed at most intersections with heavy traffic, without requiring additional hardware in most cases. Only minor alignment may be necessary. Furthermore, the proposed system has lower maintenance costs compared to other traffic monitoring systems such as pressure mats, which are subject to wear and tear due to their placement on roads under constant pressure. Therefore, the proposed system has the potential to be integrated with existing CCTV cameras in major cities to facilitate more efficient traffic management.

CHAPTER 6

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