2024 International Conference on E-mobility, Power Control and Smart Systems (ICEMPS) | 979-8-3503-9439-9/24/$31.00 ©2024 IEEE | DOI: 10.1109/ICEMPS60684.2024.10559373

Next-Generation Traffic Control: Adaptive Timer and Emergency Vehicle Priority in Intelligent Traffic Management

Devika S G
Dept. of Computer Science Engineering
SCT College of Engineering
Trivandrum, India
ORCID: 0009-0000-1056-6364

Govind A
Dept. of Computer Science Engineering
SCT College of Engineering
Trivandrum, India
ORCID: 0009-0002-2573-4003

Lekshmi D
Dept. of Computer Science Engineering
SCT College of Engineering
Trivandrum, India
ORCID: 0009-0006-7911-2743

***Abstract*—Traffic has always been a troubling issue in our society. The increased number of automobiles on roads has substantially increased traffic congestion polluting the environment and causing stress and anxiety to passengers in the traffic clog. The existing system of fixed traffic control system even though widely used, lacks adaptability and operates on predefined signal timers. The lack of adaptability can lead to inefficient traffic flow, especially during high traffic congestion. To address this issue, we propose a more adaptive and intelligent system that leverages adaptive timer control and prioritizes emergency vehicles like, ambulance. The adaptive timer control system considers the count of vehicles at the previous junction as well as the count of vehicles currently arriving at the intersection to update the signal timers. Additionally, to prevent delays in emergency response times and to provide a better impact on public safety and health outcomes we have provided an added feature to prioritize emergency vehicles and release the traffic upon its arrival at the respective signal. The detection of the emergency vehicle is to be carried out using the YOLO v8(You Look Only Once) algorithm along with siren recognition using a classifier model. The proposed system offers a significant improvement over the existing traffic control infrastructures and has the potential for aiding resilient and smooth transportation.**

***Index Terms*—AI Traffic control, Traffic management, Emergency, Adaptive traffic system, Intelligent transport systems, Smart surveillance, Computer Vision, Machine Learning, YOLO v8**

I. INTRODUCTION

The existing traffic systems in urban areas face numerous challenges due to the increasing number of vehicles and the limited capacity of road networks. Fixed signal timers used in traffic control systems at intersections lead to inefficiencies and congestion. The demand for road capacity necessitates new solutions for traffic control that can adapt to changing conditions. The efficiency of transportation systems directly has a socio-economic impact. Real-time traffic information systems and intelligent control methods can affect transportation costs and time. Traffic congestion is considered one of the major barriers to sustainable urban development because it increases travelling time, energy consumption, road collisions, and environmental pollution. Its principal manifestation is the gradual slowing of traffic, increasing travel times, fuel consumption, pollution, and other costs [1].

Intelligent traffic control systems are crucial for addressing these issues and require real-time detection and efficient response mechanisms. Applying automation and intelligent control to roadside infrastructure and vehicles can enhance traffic flow and safety in the existing transportation system. According to the survey conducted approximately 95% of respondents reported being impacted by traffic congestion in the study area. About 89% opined that it increases their anger,

98% said that it is time-consuming, and 88% perceived that it has an influence on the decline in their income. About 54% of the respondents claimed that traffic was a cause of frustration. In comparison, 95% of respondents felt that regular traffic congestion during peak and off-peak hours causes mental stress [1].

Drawbacks of existing System are:

1) Excessive and avoidable waiting periods occur on roads when traffic densities fluctuate: The inability of fixed countdown timers to adapt to real-time traffic conditions results in significant delays and congestion, especially during peak hours or sudden traffic surges. With India's increasing automobile population and limited road capacity, the rigid nature of fixed timers exacerbates the problem by failing to optimize traffic flow efficiently. The lack of dynamic adjustment in countdown timers hampers the smooth movement of vehicles and can contribute to increased fuel consumption and environmental pollution. This can be tackled by placing a system that sets timer based on car count.

2) Lack of adequate measures to ensure clearance for emergency vehicles delays their prompt response.: Delayed response times caused by traffic congestion can have severe consequences, as ambulances, fire engines, and police vehicles struggle to reach their destinations quickly. These delays not only impact the effectiveness of emergency services but also pose a risk to public safety and can result in potential loss of life and property. Implementing effective traffic management strategies that prioritize the clearance and smooth movement of emergency vehicles is crucial for ensuring timely and efficient emergency response services. The number of accidents per day is increasing in today's scenario. As reported by Times of India in the year 2016, approximately 146,133 people lost their lives in road accidents in India. Tragically, around 30% of these fatalities are attributed to delayed ambulance services. This issue can be side-lined to a huge extent by prioritizing emergency vehicles over others at the signals.

3) The lack of consideration for traffic conditions at previous traffic signals leads to inefficient flow.: Ignoring traffic conditions at previous traffic signals can result in inefficient flow, leading to an irregular movement of vehicles and potential congestion on the roads. Sudden traffic congestion is often a consequence of the domino effect caused by inadequate coordination between traffic signals, where poor flow management at one signal can impact the entire traffic network. By utilizing the traffic count at previous signals to predict traffic at a given signal, we can improve traffic flow management and reduce congestion on the roads. This approach allows for better coordination between signals and helps create a more efficient and synchronized traffic flow throughout the network.

II. LITERATURE REVIEW

- Reference [2] proposes a structure that integrates Centralized control system, a mobile application for ambulance drivers and a web portal for administrators. The Centralized control system facilitates real time monitoring of the ambulance coordinates. The GPS helps navigate to the spot, update their status and availability through the mobile application. The web portal provides administrators with data to view the performance and analyse the data on a continuous basis.
- Reference [3] proposes a strategy that adjusts the timing of traffic lights based on real-time traffic conditions. Utilizes intelligent algorithms and sensors to collect data on patterns, density, and traffic volume which is analysed to determine the optimal timing for traffic lights at different intersections.
- Reference [4] proposes a framework that incorporates modules such as object detection module and signal switching module. YOLO algorithm detects and classifies vehicles into different categories and the Signal Switching Algorithm sets the green signal timer as per the traffic density and in a cyclical manner the signals are switched.
- Reference [5] puts forward a framework for integrating intelligent transportation systems and ensuring effective communication between different components of a transportation network. The Traffic-Roadway Section provides design for networking of traffic signals and the Intelligent Transportation Systems Unit (ITS Unit) is responsible for determining the type of communication system that can be used, based on the project type.
- Reference [6] suggests a strategy to prioritize emergency vehicles using Vehicle Ad-Hoc Networks (VANET) and the Internet of Things (IoT). It measures the distance between an intersection and the emergency vehicle, considers factors such as incident type and emergency vehicle type. It includes a Traffic Management Server (TMS), vehicles, Roadside Units (RSUs), and sensors deployed within a VANET system. Roadside Units (RSUs) exchange information and regulate traffic signals. Hacking incidents to be handled by shifting traffic to uncompromised RSUs, identifying and blocking malicious sources.
- Reference [7] proposes a system that acquires live movement of vehicles. The camera shifts to the next lane based on time intervals. Vehicle detection and recognition is done using the Haar Cascade algorithm. The Video Processing module present in the system calculates the traffic density (the count) and along with time assigned for each vehicle, the signal lights are switched.

III. PROPOSED SYSTEM

Our System aims to develop and deploy a system that enables easy flow of vehicles at traffic signals using modern deep learning algorithms along with conventional cameras and sensors. Rules and regulations were followed in the proposed system as per the rules [13] by the government of India.

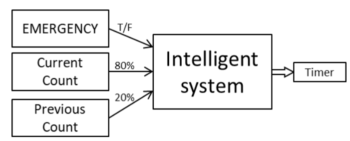

Fig. 1. Proposed system flowchart

The proposed system consists of the following:

1) Vehicle detection and Counting Module: The proposed system leverages the YOLO (You Only Look Once) algorithm for accurate and efficient vehicle detection. YOLO v8's fast processing time and high accuracy makes it a suitable choice for this purpose. To enhance vehicle detection capabilities, a custom YOLO v8 model was fine-tuned specifically for identifying various vehicle classes such as cars, bikes, trucks, buses and emergency vehicles. The advantages of using YOLO v8 for vehicle detection include real-time performance, enabling the system to process a continuous stream of video received from the camera and instantly identify vehicles. Additionally, YOLO's ability to detect multiple objects in a single pass improves efficiency and reduces processing time compared to traditional detection methods. This allows the proposed system to provide timely and reliable vehicle detection for effective traffic control and management. The dataset to train the model was obtained from two different sources. The labelled dataset was obtained from VehicleID (PKU VehicleID) . The dataset contained images of 26,267 vehicles . Then the model was trained using the pre- trained weights downloaded from the YOLO website. The trained model of the output was stored according to Darknet format. The ".cfg" file holds the network architecture configuration and hyperparameters of the YOLO v8 model, defining its structure. The ". weights" file contains the learned weights and parameters of the trained YOLOv8 model, representing the knowledge gained during the training process. The confidence level was set to 80% in order for more successful detection. OpenCV module was used to capture the video from camera and passed to identify the presence of vehicles and also count the number of vehicles.

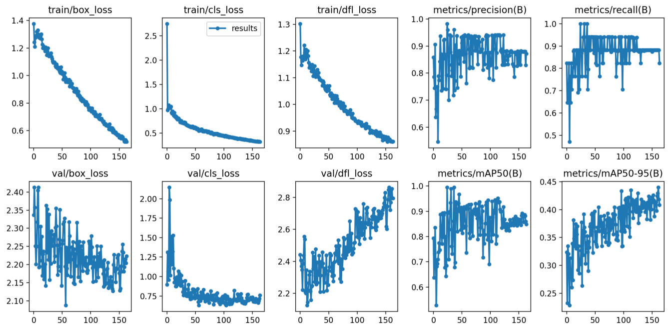

Fig. 2. YOLOv8 Model was fine-tuned with 160 epochs on image size 512.

The survey highlighted the prevalence of RCNN (Recurrent Convolutional Neural Network) and YOLO architectures in existing methods, suggesting that future research should focus on developing a vehicle detection method based on the YOLOv8 architecture. However, the survey also mentions the need for improvements in tracking methods as existing approaches heavily rely on manual intervention and camera views. Moreover, the similarities between different classes of vehicles and the small size of vehicles in satellite images pose challenges that require fine-tuning of network parameters for desired results. Overall, the advantages of using YOLO for vehicle detection include real-time performance, efficient object detection, and the ability to identify multiple vehicle classes. However, addressing limitations in tracking methods and fine-tuning network parameters are areas that need further attention and improvement [8].

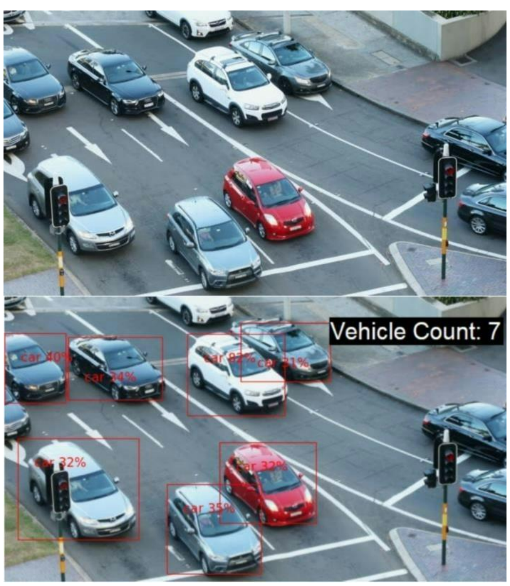

Fig. 3. Showcases test images that were subjected to our vehicle detection model. On the top, the original image is displayed, while on the bottom, the output is presented, demonstrating the application of the vehicle detection model. The output includes bounding boxes around the detected vehicles and their confidence score and label.

2) Emergency Vehicle Identification Module: There were 6 factors that mostly influence ambulance delays: intersection, turns, other vehicle carelessness, ambulance operator carelessness, road conditions, and traffic regulation violations. The study showed that the average traffic jam caused an ambulance delay of 10 minutes and a dense traffic condition caused an ambulance delay of 12.98 minutes longer than rare traffic conditions [9]. The proposed system features emergency vehicle detection and siren noise detection. recognition of emergency vehicles results in an emergency system giving true value and false in all other conditions.

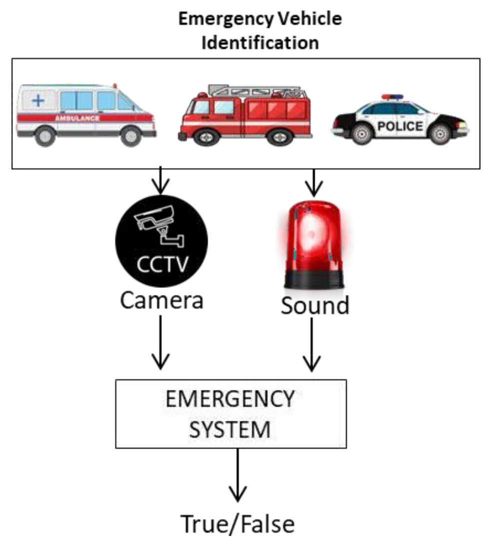

Fig. 4. Shows the proposed Emergency Vehicle Identification Module

- **Vehicle Recognition**: YOLO v8 model used for vehicle identification is also used here. It can detect and localize emergency vehicles with high precision, minimizing false positives and negatives. There are 3 classes of Emergency vehicles: ambulances, fire engine and police. The separately labeled dataset was obtained from images.cv and Roboflow. YOLO performs object detection by dividing the input image into a grid and predicting bounding boxes and class probabilities for each grid cell. This enables the model to detect multiple objects in a single pass, including multiple classes of emergency vehicles within the same image, without the need for additional computational overhead.

Fig. 5. The left figure shows the original image, while the image on the right side shows correctly identified emergency vehicles in boxes with class labels. Three classes of vehicle are identified: police, ambulance and fire engine.

- **Siren Noise Detection**: As emergency vehicles may not always be on an emergency run, it is important to identify whether there is an emergency. So, the conventional method is by the identification of a siren alarm that goes loud when activated hence it's important to have a sound recognition system. The reference [10] presents a study on detecting emergency vehicles, such as ambulances, fire engines, and police cars, based on their siren sounds. To address the issue of drivers potentially missing siren warnings, particularly when using in-vehicle audio systems, an automatic detection system called SirenNet is proposed. SirenNet is an ensemble model utilizing a CNN (Convolutional Neural Network) with two network streams. The first stream, WaveNet, processes raw waveform data, while the second stream, MLNet, works with a combined feature consisting of MFCC (Mel-frequency cepstral coefficients)and log-mel spectrograms. Experimental results on a diverse dataset demonstrate that combining raw data with MFCC and log-mel features achieves a promising accuracy of 98.24% for siren sound detection. Notably, the system performs well even with short samples of 0.25 seconds, achieving an accuracy of 96.89%. The proposed system has potential benefits for both drivers and autopilot systems. Based on this we created a CNN for image recognition of sound wave images. The sound dataset was obtained from audioset tool inside research.google.com. Another dataset was also obtained to train for background noises which mostly contain horn sounds. The sound wave graphs of the dataset was generated using sonicvisualiser and was used as training dataset for the model labeled as "Siren" and "BackgroundNoise". The preprocessing step includes resizing the images to a consistent size (e.g., 224x224 pixels). The VGG (Visual Geometry Group) architecture of CNN was used as it consists of multiple convolutional layers with small 3x3 filters, followed by max-pooling layers for downsampling. VGG16, which has 16 layers, was used here. After monitoring performance of the model , epoch value was set to 50. Librosa library in python was used to input the live noise.

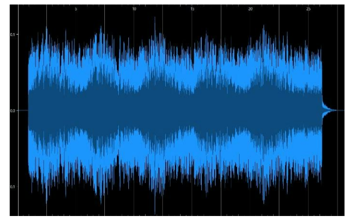

Fig. 6. A sound wave graph of a sample siren sound is shown, which was used in VGG16.

3) Signal Communication Network Module: To tackle the flow of irregular distribution of traffic in a city, we consider the face of past traffic signal count also while setting up the countdown timer. So, it's important to maintain a proper communication network among signals. The reference [5] puts forward the method of using optic fibres for easy communication between signals as it is found to have the maximum efficient communication. The paper also puts forward the use of 12 or 24 strand fibre to enhance the traffic communication.

Fig. 7. The proposed signal communication optic fiber is placed in a locality in Trivandrum to demonstrate communication between 4 road junctions and 3 road junction (T intersection) signals. Here dotted lines denote the optic cable running between the signals.

4) Mathematical Weightage: According to Reference [11] in statistics the assumed mean is a method for calculating the arithmetic mean and standard deviation of a data set which is used to get the batch size. Batch size refers to the number of vehicles we expect to wait at a signal. It is assumed as the average number of vehicles we expect to wait.

$$\bar{x} = a + \frac{\sum f_i d_i}{\sum f_i}$$

$$\begin{aligned} a &= \text{assumed mean, i.e., current batch size} \\ \sum fi &= \text{traffic frequency} \\ d_i &= x_i - a \\ &= \text{deviation of } i^{\text{th}} \text{ class of traffic count} \\ &\quad \text{from current batch size} \\ \sum fi &= n = \text{Total number of observations.} \end{aligned}$$

The time calculation formula can be broken down step-by-step:

$$\text{Avg}_{\text{Scaled Weight}} = \frac{(0.8 * Count_{\text{Current}}) + (0.2 * Count_{\text{Previous}})}{Batch\ size}$$

In the scaled weighted average calculation, the current value is multiplied by 0.8 and the previous count value is multiplied by 0.2. This assigns different weights to control their influence. The time calculation involves scaling the weighted average by dividing it by batch size. Then, the scaled weighted average is multiplied by the maximum allotted time to determine the time percentage to be allocated. Subtracting the time percentage from maximum time gives the counter time.

$$time = time_{Max}\,(1 - \text{Avg}_{\text{Scaled Weight}})$$

This creates a countdown effect as the weighted average increases. Lastly, rounding the calculated time to the nearest integer ensures that the time value is represented in whole minutes, which is typically used for time intervals. These mathematical operations are used to compute the time for each red timer based on the weighted average of current and past values, ensuring that the allocated time corresponds to the significance of the weighted average and creates a countdown effect.

5) System Simulation Module: The proposed traffic system was analysed and observed using a Python simulation created for both 4-road intersections and 3-road intersections. Reference [12] demonstrates the detailed study of T-intersections in Andhra Pradesh and clearly analyses how the lack of proper traffic signals contributes to huge number of accidents. The study of road traffic in the city shows that the primary cause of accident is collision of vehicles at the intersections. The collision may be rear shunt on approach to the junction, right-angled collision, principal right turn collision or pedestrian collision. These collisions can be eliminated if the signal is properly designed. So, the main objective of the dissertation is to provide better and safe mobility of traffic through efficient signal design at the intersection. The signal is designed as per IRC guidelines so that the signal could ensure proper traffic flow. The T-intersection simulation has been built following the IRC guidelines.

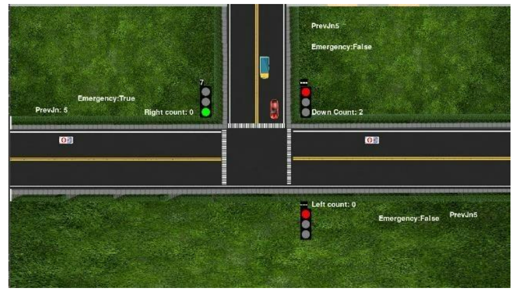

Fig. 8. T-Intersection simulation output

Reference [13] puts forward that, 4 Road intersections are a crucial part of the system and frequently act as a bottleneck for traffic. The most recent data indicates both site limits and increase in traffic. The engineer must create criteria and procedures based on the fundamental relationships between capacities, traffic flow, geometry design, and safety. This allows users to move directly from suggested geometry to actual estimates of the operating condition. The findings of this study provide an insight into recommended solutions for these issues as well as safety measures for reducing traffic jams at intersections. We used these guidelines to design 4 Road intersections for our simulation.

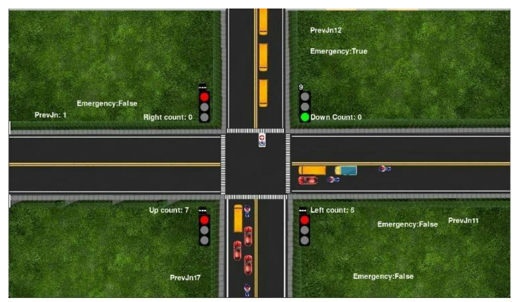

Fig. 9. 4-road intersection simulation output

The 4-road intersection has been demonstrated in the simulation as shown in figure 9. The previous junction count and the current vehicle count is displayed along with the timers. To simplify the simulation, the previous count is generated randomly while the current vehicle count is calculated from the screen. We can see the signal timers and the traffic congestion as time passes. An emergency flag is also set to detect whether an ambulance arrives or not.Hence based on the current count of vehicles and the previous junction count the signal timers should be set accordingly which act as parameters.

IV. PERFORMANCE EVALUATION

The performance of the proposed system is analyzed based on the simulation created. It was observed that every time an emergency vehicle enters the signal, the light immediately turns green while the rest of the signals at the intersection remained red. In all other cases the minimum red signal timer is set as 15 seconds as it's considered as the time required for pedestrian crossing and maximum red signal timer is set to 60 seconds is scheduled preventing over-lodging of vehicles. The maximum time 60 seconds is set whenever the current count of vehicle is 0 as it can be observed from the Table I given below.

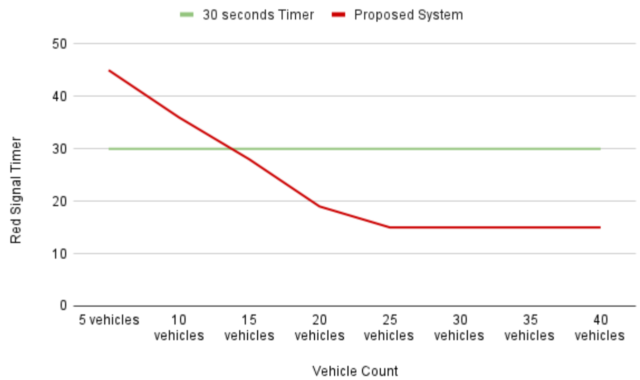

Fig. 10. Graph showing comparison between existing 30-second timer as per [15] and the proposed system

V. CONCLUSION AND FUTURE WORKS

The sole purpose of this system is to integrate adaptive systems for emergency vehicles along with the implementation of intelligent traffic systems. In this system, there is a communication channel established between signals which helps to pass on traffic count at previous signals and also uses traffic count at the present signal to establish an adjusted vehicle count and use that to determine the waiting time set for the red signal timer. The emergency vehicle that is in emergency mode could bypass as the signal turns green for the vehicle. The vehicle counts and emergency vehicle detection part takes place using YOLO v8 while sound recognition happens as VGG16, a CNN variant recognizes the sonic wave using imaging. Thus, the proposed system offers a significant improvement over the existing traffic control infrastructures and has the potential for more resilient and smooth transportation. The domain of adaptive traffic light control systems could be expanded into another dimension by incorporating the concept of IoT (Internet of Things) to enable live communication with emergency vehicles. Moreover, disaster response systems like water level gauges or seismic sensors could be used such that when calamities occur, it alerts the traffic signal to show red automatically to prevent vehicles from unknowingly reaching those destinations.

REFERENCES

[1] Fattah, Md Abdul, Syed Riad Morshed, and Abdulla-Al Kafy. ”Insights into the socio-economic impacts of traffic congestion in the port and industrial areas of Chittagong city, Bangladesh.” Transportation Engineering 9 (2022): 100122.

[2] George, Anita Acha, et al. ”Golden aid an emergency ambulance system.” 2017 International Conference on Networks Advances in Computational Technologies (NetACT). IEEE, 2017.

[3] Shinde, Swapnil Manohar. ”Adaptive traffic light control system.” 2017 1st international conference on intelligent systems and information management (ICISIM). IEEE, 2017.

[4] Gandhi, Mihir M., et al. ”Smart control of traffic light using artificial intelligence.” 2020 5th IEEE international conference on recent advances and innovations in engineering (ICRAIE). IEEE, 2020.

[5] Oregon Department of Transportation Traffic Standards and Asset Management Unit “Chapter 7 – Interconnect ITS Communication Plan”, June 2017.

[6] Sumi, Lucy, and Virender Ranga. ”Intelligent traffic management system for prioritizing emergency vehicles in a smart city.” International Journal of Engineering 31.2 (2018): 278-283.

[7] Sable, Tanvi, et al. ”Density and time based traffic control system using video processing.” ITM Web of Conferences. Vol. 32. EDP Sciences, 2020.

[8] Maity, Madhusri, Sriparna Banerjee, and Sheli Sinha Chaudhuri. ”Faster r-cnn and yolo based vehicle detection: A survey.” 2021 5th international conference on computing methodologies and communication (ICCMC). IEEE, 2021.

[9] Wiwekananda, Ketut Shri Satya, et al. ”Understanding factors of ambulance delay and crash to enhance ambulance efficiency: an integrative literature review.” J Comm Emp Health 3 (2020): 213.

[10] Tran, Van-Thuan, and Wei-Ho Tsai. ”Acoustic-based emergency vehicle detection using convolutional neural networks.” IEEE Access 8 (2020): 75702-75713.

[11] Drusch, Robert L. ”Estimating annual average daily traffic from short-term traffic counts.” Highway Research Record 118 (1966): 85-95.

[12] Surisetty, Ramesh, and Soma N. Sekhar. ”Designing of a Traffic Signaling System at T-Intersection.” International Journal of Engineering Research and Application 7.4 (2017): 82-86.

[13] Dr. A. MAHESH BABU, J. Jatin Karthik, M. Surya Kiran and Syed Shabbir “Design and Analysis of Traffic Signal at Signalized Junction”, Journal of Engineering Sciences, Vol 13 Issue 7, July/2022, ISSN:0377-9254

[14] Ministry of road transport highways, Government of India “Traffic Signs ensure safety: Book on road safety signage and signs”, Fifth Edition :2015

[15] US Department of transportation Federal Highway Administration ”Traffic Signal Timing Manual”, CHAPTER 5, Signal Timing Manual - Second Edition