Enhanced Traffic Management System using YOLO v7

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***Abstract*— The exponential growth in global vehicle numbers has escalated concerns regarding traffic management and road congestion. Traditional traffic signal systems have struggled to keep pace with the dynamic nature of modern traffic patterns, necessitating innovative solutions. The proposed system integrates state-of-the-art Artificial Intelligence and Machine Learning (AIML) technologies into traditional traffic signals, offering a dynamic and adaptive approach to optimize urban traffic flow. Leveraging real-time image processing, computer vision (CV), and You Only Look Once (YOLO) algorithms, the system accurately detects traffic density in each lane within a junction, autonomously adjusting signal timings based on comprehensive training datasets. Salient features include real-time traffic information collection, adaptive signal control, prioritization for public transit and emergency vehicles, queue detection systems, efficient pedestrian crossings, emergency vehicle signal control, and the utilization of specialized optimization software. This holistic solution aims to minimize congestion, enhance transportation efficiency, and provide valuable insights to traffic authorities and commuters. The proposed Intelligent Traffic Monitoring System signifies more than just a technological upgrade; it represents a model shift in traffic management. By adopting pioneering technology, this holistic solution aims to mitigate crowding and improve transportation proficiency. The inclusion of specialized optimization software underscores the commitment to continuous improvement, ensuring the system remains adaptable to evolving traffic patterns. In essence, this forward-thinking approach revolutionizes traditional traffic signal systems to meet the challenges of the modern era, heralding a new era in urban transportation management.**

Keywords—YOLO, AIML, Computer Vision, Traffic, Real-time, Vehicle.

I. INTRODUCTION

Traffic control plays a crucial role in modern society, managing the millions of vehicles traversing roads worldwide. It establishes necessary regulations to ensure the safe movement of goods, services, and people. With India boasting a vehicle count of 34 crores, cities like Bangalore stand out as major traffic hubs, ranking among the world's most congested. Bangalore, leading in India, grapples with a traffic index where travelling 10 kilometres consumes an average of 30 minutes and 30 seconds, compounded by around 150 daily traffic jams. This congestion exacts a toll on citizens, with an average of 2 hours wasted in traffic in congested cities. In response, traffic signal optimization is a critical strategy to alleviate congestion and enhance commuting efficiency. By leveraging technologies like YOLO for vehicle detection and employing advanced data analytics, traffic signal optimization aims to synchronize traffic signals, facilitating smoother traffic flow based on real-time volume and behavioural patterns. This approach promises to mitigate congestion challenges as urban centres expand, ensuring more streamlined and time-efficient travel experiences for commuters.

Traditional traffic signal systems have struggled to keep pace with today’s dynamic traffic, requiring innovative solutions. The proposed system integrates state-of-the-art Artificial Intelligence and Machine Learning (AIML) technologies with traditional traffic signals to provide a dynamic and adaptive approach to urban traffic has been successfully leveraging real-time image processing and computer vision (CV). You Only Look Once (YOLO) algorithms precisely search and autonomously adjust signal timings based on comprehensive training datasets Highlights include real-time traffic information collection, adaptive signal control, public transport and emergency vehicle prioritization, queue detection systems, efficient pedestrian crossing, emergency traffic signal management, and use of specialized optimization software Can provide authorities and travellers alike have gained valuable insights. Utilizing state-of-the-art technology, all solutions aim to reduce congestion and increase efficiency. The addition of specialized optimization software underscores the promise of continuous improvement, ensuring that the system adapts to changing traffic patterns. In essence, this forward-thinking approach revolutionizes traditional traffic signal systems to meet the challenges of the modern era, heralding a new era in urban transportation management.

II. LITERATURE REVIEW

Abhijeet Choudhary et al.[1] have proposed a system which processes traffic using real-time video processing utilizing the Gaussian mixture model algorithm and shortest job first algorithm for scheduling the timer.

Ratan Kumar.[2] has analyzed various machine learning algorithms for traffic control like Decision Tree, Linear Regression, Random Forest, and Support Vector Regression and found that Random Forest and Support Vector Regression performed well compared to other algorithms.

Krish Meshram et al.[3] have put forward a DTES algorithm for a junctionto detect emergency vehicles like ambulances and give priority to that lane whereas this has some limitations of goodvideo footage and length.

R. Roopa Chandrika et al. [4] have used various image-processing algorithms to detect various vehicles at speed to classify and help in the detection of any accidents and traffic rule violators.

Gudala Lavanya et al.[5] have employed YOLO which is the most advanced real-time object detection algorithm using convolution neural networks (CNN). It detects objects in one pass making it a vital tool in computer applications.

Tausif Diwan et al.[6] have explored the evolution of object detection in computer vision, highlighting the shift from two-stage to single-stage detectors, with a focus on the advancements and performance of YOLO and its successors.

N Murali Krishna et al.[7] have studied the pivotal role of deep learning, particularly in real-time object recognition and trailing. Whereas algorithms like RCNN (Region-based Convolutional Neural Networks) offer superior accuracy, the YOLO (You Only Look Once) approach prioritizes speed without compromising much on accuracy, making it a preferred choice for real-time applications.

Ninad Lanke et al.[8] have explained that traffic congestion is a pressing issue in Indian cities due to limited infrastructure expansion and various management challenges. The introduction of (RFID) Radio Frequency Identification technology offers an affordable and efficient resolution for real-time traffic management, enabling early bottleneck detection and mitigation to alleviate congestion.

Pranav Aadarsh et al.[9] have provided an overview of object detection algorithms with two classes and two-stage detectors focusing on speed & accuracy and introduced an improved version which is YOLO v3-Tiny.

P. Sindhu et al.[10] have used copious Machine learning techniques to explore their use in software defect prediction.

S. Javaid et al.[11] have integrated RFID technology into their traffic management system to prioritize emergency vehicles and also incorporated fire & smoke sensors to detect emergencies for real-time alerts.

Yash Modi et al.[12] came up with a methodology for a traffic managing system, which is composed of various tools and technologies from diverse sources for smart signal traffic flow prediction, management, and traffic congestion identification.

III. Overview of Technologies

A. *YOLO*

This module utilizes YOLO, a real-time object recognition algorithm, to identify and locate vehicles within the camera's coverage field. YOLO is a deep Convolutional Neural Network (CNN) that processes video frames and identifies objects within them, including vehicles. It can provide real-time object recognition, making it reliable for traffic management applications. YOLO is crucial for understanding the current state of traffic at the intersection, as it provides information about vehicle positions and counts.

B. *OpenCV(cv2)*

OpenCV is a widely used computer vision library that facilitates copious image and video processing functions. Thus, this context is likely utilized for image manipulation, frame processing, and drawing bounding boxes around detected vehicles. This is a fundamental tool for handling image data, extracting features, and visualizing object detection results.

C. *Tensorflow(tf)*

TensorFlow is a popular deep-learning framework utilized for building and training neural networks. Our system uses it fordeep learning tasks, possibly in conjunction with YOLO for object detection. This allows for the implementation of deeplearning models and facilitates the integration of YOLO intothe overall traffic light control system.

D. *Torch*

PyTorch is a machine-learning framework used to accomplish neural networks and other machine-learning algorithm tasks. In our model ‘torch’ is used for loading and running the deep learning model which is ‘YOLOv7’ for the completion of tasks such as object detection and processing the video data.

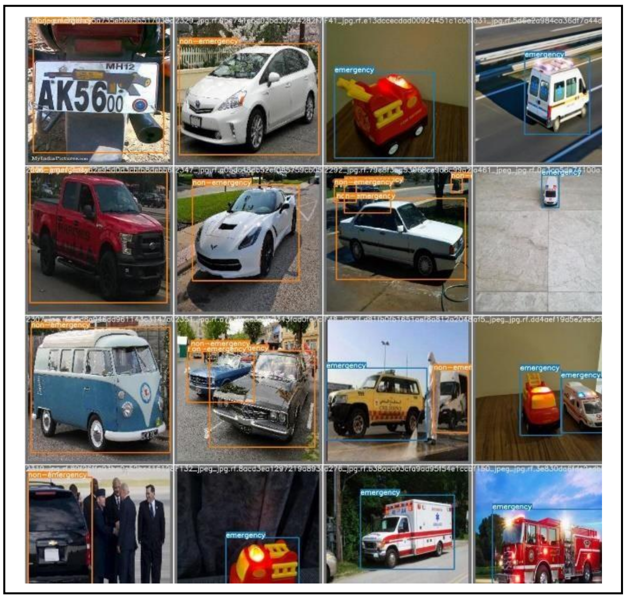
IV. Novelty

Our system being AIML-based, has been trained using the latest model training platform "Roboflow" which enhances accuracy and precision. The model is trained to detect emergency vehicles and act accordingly. Using the latest version of YOLO (V7), we have leveraged the latest function called "Focal loss" which can detect the tiniest Objects with enhanced accuracy.

V. Model Training

Dataset management plays a critical role in machine learning projects, especially for computer vision-based projects. Our system’s object detection model is trained using a powerful online tool called ‘Roboflow’ for YOLOv7 algorithm for detecting emergency vehicles like fire trucks, police vehicles, and ambulances.

Fig. 1.1. Bounding boxes for object detection using YOLO v7



Roboflow serves as a comprehensive platform aiding developers in the management, preprocessing, augmentation, and annotation of datasets for machine learning endeavours, particularly those centred around computer vision tasks. It provides a suite of tools meticulously crafted to simplify the intricate process of data preparation for training neural networks, effectively reducing the burden on developers in terms of time and effort.

Making good use of the function called “Focal loss” of the latest version of YOLO v7, the vehicle detection accuracy has increased. In addition, it has an enhanced ability to recognize articles in images or video frames with high accuracy and efficiency, making it well-suited for tasks like detecting vehicles on roads in real time.

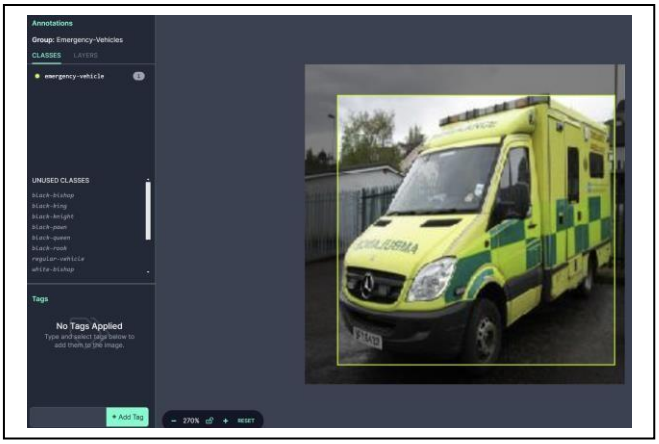


Fig. 1.2. Picture showing model getting trained with an emergency vehicle

Two classes are used for labelling datasets, which are the emergency class and the non-emergency class. The dataset labelling allows the model to distinguish between different types of vehicles, with a focus on vehicles like fire trucks, ambulances, and police vehicles. By specifically training the model to detect these emergency vehicles, the system can prioritize them in scenarios where quick detection is crucial such as in emergency response situations.

The model outputs confidence values ranging from 0.5 to 1.0 for detection. These values indicate the model's confidence in its predictions. Higher confidence values suggest greater certainty in the detected objects. By analyzing these confidence values, you can set thresholds for decision-making, such as considering detections with confidence above a certain threshold as reliable detections.

Our system combines state-of-the-art techniques and tools to train an object detection model specifically custom-made for detecting emergency vehicles. The model has the potential to significantly improve safety and efficiency on the roads by accurately identifying these critical vehicles in various environmental conditions and scenarios.

VI. System Methodology

1. Start: The process begins here.
2. Initiate Timer: This step involves initializing a timer for the traffic signal.
3. Inputs from Lanes 1, 2, 3, and 4: This represents data inputs from multiple lanes at a traffic intersection.
4. Capture Video: The system captures real-time video footage from surveillance cameras positioned at the traffic intersection.
5. Video Preprocessing: The captured video data undergoes preprocessing, which may include tasks like noise reduction, frame stabilization, or image enhancement to prepare it for analysis.
6. YOLO Object Recognition: You Only Look Once is a widely used algorithm for object detection. In this step, YOLO is used to detect and identify objects (vehicles) in the video frames.
7. Count Density: The system enumerates the vehicle count in each lane, which helps determine the intensity of traffic in each direction of the intersection.
8. If Density < Threshold: This is a conditional check. If the traffic density is below a certain threshold level, it means that the traffic is not congested. In this case, the system goes back to the "Capture Video" step to continue monitoring and collecting data.
9. If Density > Threshold: If the traffic density exceeds the threshold, indicating congestion, the system proceeds to the next step.
10. Priorities: This step involves checking for specific priorities:

11. If an Emergency Vehicle is perceived: If an emergency vehicle is spotted, the system will prioritize its movement. It sets the green signal to the lane where the emergency vehicle is present and stops other traffic to permit the emergency vehicle to move quickly.
12. If no Emergency Vehicle is detected: If there is no emergency vehicle, the system proceeds to the next step.

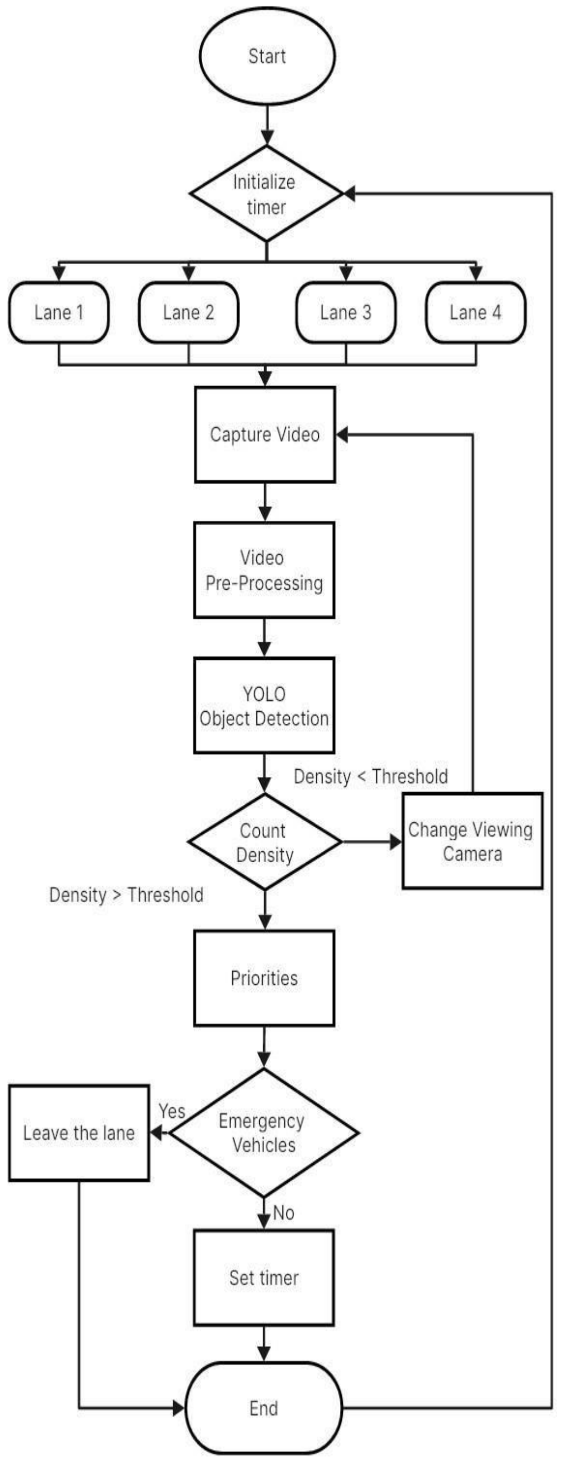


Fig. 2. Flow chart representing System Overview

13. Set Timer: Based on the traffic density and priorities determined in the previous steps, the system adjusts the timer for the traffic signal. The timer is set to enhance traffic flow and reduce congestion.
14. Stop: This indicates the end of the process or a pause in the flowchart.
15. Repeat from Capture Video Again: After adjusting the timer, the system goes back to capturing real-time video from the intersection to continuously monitor and adapt to changing traffic conditions.
16. The flowchart represents a continuous loop where traffic conditions are constantly monitored, and traffic signal timings are dynamically adjusted based on instantaneous data to improve traffic flow and respond to emergencies efficiently.

VII. RESULT

CASE 1: WITHOUT EMERGENCY VEHICLES

Lane 1:

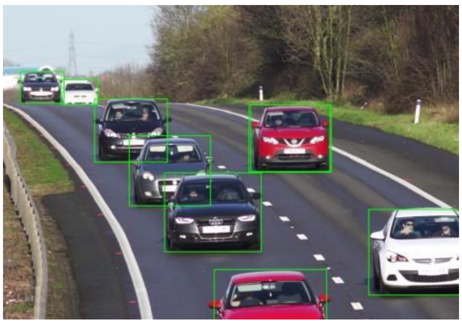


Fig. 2.1. Vehicle detection in lane 1

Lane 2:

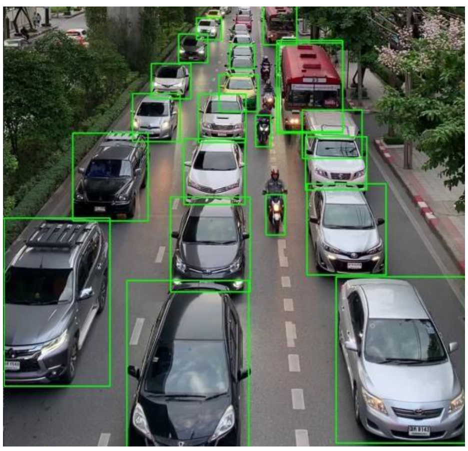


Fig. 2.2. Vehicle detection in lane 2

Lane 3:

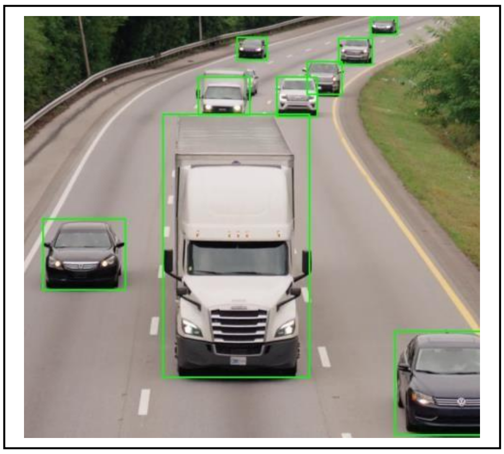


Fig. 2.3. Vehicle detection in lane 3

Lane 4:

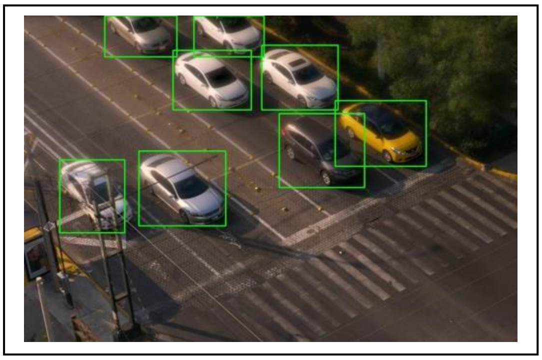


Fig. 2.4. Vehicle detection in lane 4

The system is equipped with images to simulate real-life scenarios at a four-lane intersection, accurately detecting and quantifying the count of vehicles present in each lane. This information is then utilized to determine the vehicle distribution across the intersection. Additionally, the system provides precise counts of vehicles on each side of the intersection. Furthermore, it assigns appropriate green signal timings to each lane, ensuring optimal traffic management and a smooth flow of vehicles through the intersection.

Output:

Lane 1 count: 8
Lane 2 count: 20
Lane 3 count: 9
Lane 4 count: 8

Green signal time for Lane 1: 16 sec
Green signal time for Lane 2: 40 sec
Green signal time for Lane 3: 18 sec
Green signal time for Lane 4: 16 sec

CASE 2: WITH EMERGENCY VEHICLES

Lane 1:

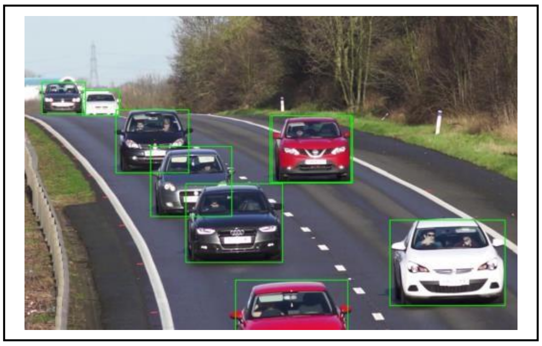


Fig. 3.1. Vehicle detection in lane 1

Lane 2:

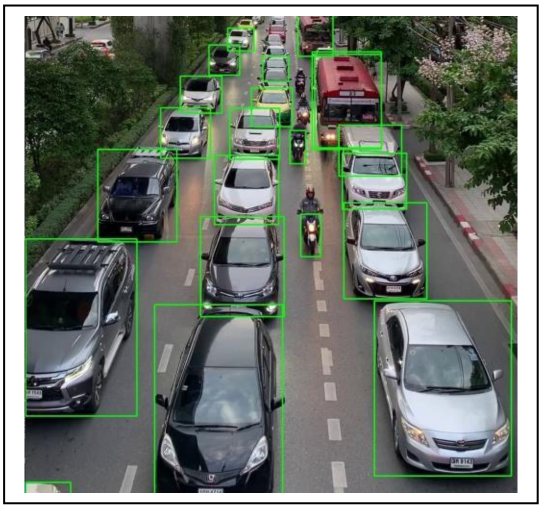


Fig. 3.2. Vehicle detection in lane 2

Lane 3:

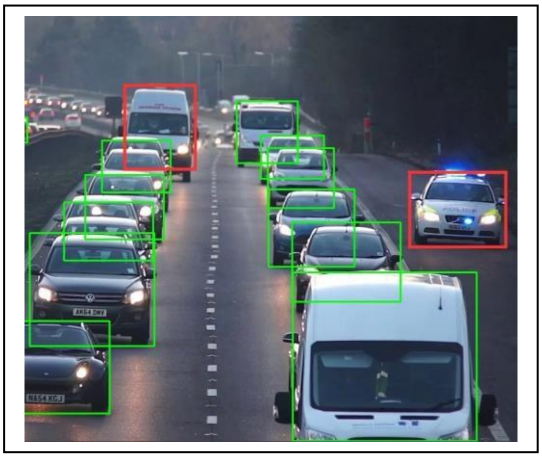


Fig. 3.3. Vehicle detection in lane 3 (Emergency vehicles detected)

Lane 4:

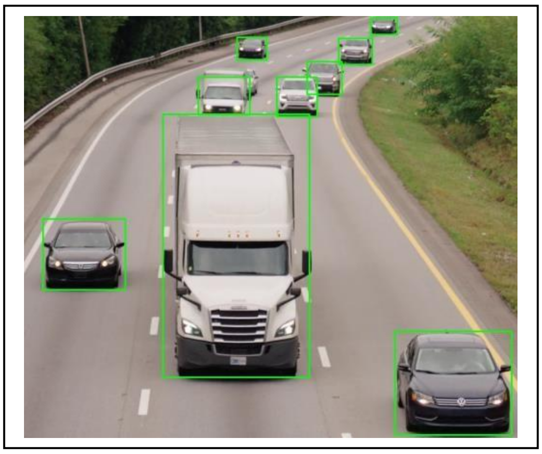


Fig. 3.4. Vehicle detection in lane 4

In a controlled test scenario aimed at evaluating emergency vehicle detection capabilities, an image depicting one of the lanes at the intersection showcased the presence of a police car and an ambulance. Leveraging an extensive training dataset comprising thousands of images, the system successfully identified and classified these emergency vehicles. Subsequently, the lane featuring the emergency vehicles was appropriately prioritized in the system's output, by predefined protocols and operational guidelines.

Output:

Lane 1 count: 8
Lane 2 count: 20
Lane 3 count: EMERGENCY VEHICLES DETECTED
Lane 4 count: 9

Green signal time for Lane 1: 0 sec
Green signal time for Lane 2: 0 sec
Green signal time for Lane 3: 30 sec
Green signal time for Lane 4: 0 sec

VIII. CONCLUSION AND FUTURE WORK

In conclusion, harnessing high-tech advancements in Artificial Intelligence and Machine Learning to drive innovation with traditional traffic signal systems represent a substantial leap towards overcoming prevailing challenges. of urban congestion. By harnessing real-time data analytics, computer vision algorithms, and adaptive signal control mechanisms, this innovative approach promises to improve traffic flow, lessen commuting times, and improve overall transportation proficiency.

Furthermore, the success of such intelligent traffic management systems underscores the importance of continual evolution and improvement. Future advancements may include further refinement of AI algorithms for more precise detection and prediction of traffic patterns, integration with smart infrastructure and vehicles for seamless connectivity, and the development of predictive modelling techniques to anticipate and proactively manage traffic bottlenecks.

Moreover, the scope extends beyond mere technological innovation. It encompasses a paradigm shift in how we approach urban transportation management, emphasizing the importance of sustainability, accessibility, and user-centric design. As cities continue to grow and evolve, intelligent traffic management systems are poised to assume a progressively essential role in determining the future of urban movement, ensuring that our cities remain vibrant, efficient, and livable spaces for all residents. In essence, the future of traffic signal optimization lies in its ability to adapt, innovate, and collaborate across disciplines, ultimately paving the way for safer, smoother, and more sustainable transportation networks in the years to come.

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