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AI Powered Eco Traffic System

[1]V.M.Heralge, [2]A.K.Sherkhane, [3]H.S.Omanna, [4]S.M.Madnaik, [5]T.A.Patil

[1,2,3,4,5]Electrical Engineering, D.K.T.E's Yashwantrao Chavan Polytechnic, Ichalkarnji, Maharashtra, India
E-mail: [1]Vipulheralge1992@gmail.com, [2]aryansherkhane29@gmail.com, [3]omannaharsh@gmail.com, [4]Shravanimadnaik@gmail.com, [5]tejashripatil0222@gmail.com

***Abstract* - Growing urbanization and the rapid increase in vehicles have made traffic congestion, air pollution, and delayed emergency response serious problems in today's cities. Most existing traffic control systems still depend on fixed or partially adaptive signal timings, which are not capable of handling real-time traffic variations, environmental impacts, or emergency situations effectively. To overcome these limitations, this project presents an AI-Powered Eco Traffic Management and Simulation System that brings together artificial intelligence, IoT, wireless communication, and renewable energy into a single, practical solution.**

The proposed system is designed around four key components. First, an AI-based traffic signal control module uses reinforcement learning to adjust signal timings dynamically according to real- time traffic density, queue length, and past traffic patterns, helping to reduce congestion and vehicle waiting time. Second, an ESP-NOW-based ambulance detection system using ESP32 controllers provides instant, low-latency communication within a 15-meter range, allowing traffic signals to automatically give priority to emergency vehicles. Third, a CO_2 and pollution filtration duct system, equipped with activated carbon and HEPA filters, actively removes harmful vehicular emissions at busy intersections, improving local air quality. Finally, the entire system is powered by solar energy, ensuring reliable operation while reducing dependence on conventional grid power.

The system is evaluated using traffic simulations in SUMO combined with Python-based AI models, followed by prototype-level testing. A centralized dashboard enables real-time monitoring of traffic flow, pollution levels, and emergency vehicle movement. Results from simulations and experiments show smoother traffic flow, reduced congestion and emissions, and faster ambulance response times.

In summary, this project offers a practical, scalable, and environmentally friendly approach to smart traffic management. By combining AI-driven decision making, IoT-based sensing, and renewable energy, the system effectively connects academic research with real-world application and contributes toward building safer, cleaner, and more efficient smart cities.

Keywords: Smart Traffic Management, Artificial Intelligence (AI), Internet of Things (IoT), Reinforcement Learning, ESP-NOW Communication, Emergency Vehicle Priority, CO_2 Filtration System, Traffic Signal Optimization, Solar-Powered Infrastructure, Smart Cities, Sustainable Transportation, Traffic Simulation (SUMO).

I. INTRODUCTION

Traffic congestion and environmental pollution are two of the most critical challenges faced by modern urban societies. Rapid urbanization, exponential growth in the number of vehicles, and limited road infrastructure have contributed to long travel times, wasted fuel, and severe air quality deterioration. According to the World Health Organization (WHO), air pollution is now considered one of the leading environmental risks to health, contributing to respiratory illnesses, cardiovascular problems, and premature deaths. Vehicular emissions, especially carbon dioxide (CO_2), nitrogen oxides (NOx), and particulate matter (PM2.5 and PM10), are primary contributors to this crisis.

Traditional traffic management systems rely primarily on static traffic signals with fixed timings or basic sensor-driven adaptive controls. While these systems provide some level of traffic flow regulation, they fall short in addressing real-time complexities such as dynamic congestion patterns, emergency vehicle prioritization, and energy sustainability. This is where the integration of modern technologies like the Internet of Things (IoT), Artificial Intelligence (Al), wireless communication, and renewable energy can create transformative solutions.

The proposed project, Smart Traffic Management and Simulation Model,seeks to combine multiple innovative components into a holistic system:

1. CO_2: Filtration with Duct System - Incorporating ducts alongside traffic junctions with embedded CO: filters to actively absorb vehicular emissions while reducing environmental pollution.

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2. ESP-NOW based Ambulance Detection - Leveraging ESP-NOW communication protocol on ESP32 microcontrollers to automatically detect ambulances within a 15-meter range and provide instant green signal priority for emergency response efficiency.
3. Al-Powered Traffic Signal Optimization - Using machine learning algorithms to dynamically adjust signal timings based on traffic density, queue lengths, and historical patterns, thereby minimizing congestion.
4. Solar-Powered Smart Infrastructure - Reducing dependency on grid power by equipping traffic lights and control systems with solar panels and storage batteries, ensuring sustainability and reliability.

This project not only addresses traffic flow but also simultaneously tackles environmental sustainability, energy efficiency, and public safety. By creating a simulation model and later al real-world prototype, the work aims to contribute significantly to the development of smart city infrastructure.

Smart Traffic Light Control utilizes reinforcement learning or machine learning algorithms to dynamically adjust signal timings based on real-time traffic density. For example, if one lane experiences heavy congestion while the crossroad is empty, the system intelligently allocates more green light time to the busier road, optimizing overall traffic flow. Additionally, the system offers **Eco-Route Suggestions**, providing drivers with routes that minimize congestion, travel time, and fuel consumption—similar to how Google Maps predicts traffic, but tailored to localized deployment. To tackle environmental concerns, the system includes a **CO_2 and Pollution Estimation** module, which calculates emissions based on vehicle counts and average idling times. A live dashboard can display pollution levels and highlight the emission reductions achieved through the system's optimizations. Lastly, **Emergency Vehicle Priority** is enabled through AI-powered sensors and cameras that detect sirens or flashing lights from ambulances or fire trucks. Upon detection, traffic signals are automatically adjusted in real time to clear the path, ensuring faster emergency response and enhancing public safety.

II. LITERATURE REVIEW

Shi *et al.* [1] examine the energy impact of autonomous vehicles using nine real-world traffic datasets. Their study shows that autonomous driving strategies can reduce energy consumption by smoothing acceleration and braking patterns. They highlight the dependence of energy savings on traffic conditions, providing insights for practical AV energy optimization. This research supports AI's role in enhancing eco-friendly autonomous driving.

Treiber *et al*. [2] proposes a deep reinforcement learning (DRL) based adaptive traffic light control system. Their approach optimizes signal timings to improve traffic flow and reduce vehicle energy consumption simultaneously. Results demonstrate significant reductions in idling time and emissions compared to traditional traffic control. This work illustrates AI's effectiveness in eco-friendly urban traffic management.

Goswami *et al.* [3] develops an AI-powered routing protocol to minimize fuel consumption in intelligent transportation systems. By leveraging machine learning and real-time traffic data, their system guides vehicles to avoid congested routes and reduce stop-and-go driving. Simulations reveal considerable energy savings and improved travel times. This study emphasizes AI's potential to enable sustainable routing decisions.

Jiang *et al.* [4] present a reinforcement learning eco-driving model for electric connected vehicles at signalized intersections. Their approach uses vehicle-to-infrastructure communication to adapt driving behavior based on real-time signal data, reducing energy usage. Simulations confirm that the method outperforms conventional driving techniques in energy efficiency. This highlights the benefits of AI-driven eco-driving in connected vehicle environments.

Bai *et al.* [5] introduces a hybrid reinforcement learning eco-driving strategy for automated vehicles at intersections. Combining model-based and model-free learning, the method optimizes energy use, travel time, and safety. Their results show improved performance over traditional eco-driving approaches, reducing energy consumption significantly. This work demonstrates advanced AI techniques for practical eco-driving solutions.

III. OBJECTIVES

Main objectives:

1. Develop a traffic management prototype capable of simulating real-world scenarios with multiple lanes, signals, and vehicles.
2. Design and implement ESP-NOW-based communication for ambulance detection within a 15-meter radius, ensuring automatic green signal priority.
3. Integrate a duct-based CO: filtration system at traffic junctions to reduce vehicular emissions in high-density zones.

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Sub objectives:

1. Apply Al algorithms for traffic signal optimization, using reinforcement learning and pattern recognition for real-time adjustments.
2. Incorporate solar panels to power the system sustainably, reducing dependency on grid electricity.
3. Simulate and test scenarios such as peak-hour congestion, emergency response, and pollution reduction.
4. Publish findings and design documentation, contributing to smart city and environmental engineering research.

IV. RELEVANCE

The relevance of this project lies in its multidisciplinary approach, intersecting the fields of transportation engineering, computer science, IoT, artificial intelligence, renewable energy, and environmental engineering

Urban Mobility Challenges: Cities worldwide are struggling with increasing vehicular population. In India alone, the number of registered motor vehicles surpassed 300 million in 2022, leading to daily congestion across urban centers. A smarter traffic management model is no longer optional-it is essential.

Emergency Response Delays: Ambulances often lose critical minutes in traffic, jeopardizing lives. Studies indicate that nearly 30% of patient fatalities in urban areas can be attributed to delayed medical assistance. ESP-NOW's low-latency, Wi-Fi-based communication provides a cost-effective, scalable solution for emergency vehicle prioritization.

Environmental Urgency: With CO: emissions and PM levels rising alarmingly, any traffic solution must also incorporate an environmental dimension. The duct-based CO filtering system ensures that while traffic moves, the surrounding air quality improves.

Sustainability Goals: Governments worldwide are pushing for renewable energy adoption to reduce dependency on fossil fuels. Integrating solar panels into the traffic management ecosystem supports UN Sustainable Development Goals (SDGs) related to affordable and clean energy, sustainable cities, and climate action.

Al Adoption: The rise of Al in traffic simulation and prediction is gaining momer However; most existing models remain confined to academic research. This pro bridges theory and practice by implementing Al-driven decision-making in a phy model.

In conclusion, the project is relevant not only for academic value but also as a real-world prototype with the potential for industrial adoption.

V. THE PROPOSED WORK

Problem Statement

- Modern urban traffic faces inefficiencies such as congestion, pollution, and poor emergency response.
- Conventional traffic lights use fixed timing cycles, lacking real-time adaptability to changing vehicle densities.
- Emergency medical services, especially ambulances, often face delays at traffic junctions due to unresponsive traffic control systems, leading to preventable fatalities.
- Rising vehicle emissions contribute to environmental pollution, yet most traffic infrastructures do not address eco-friendly design.
- There is a need for a comprehensive intelligent traffic management system that includes:
- AI-based optimization for dynamic traffic signal control.
- IoT-driven ambulance detection to prioritize emergency vehicles.
- CO filtration ducts to reduce vehicular pollution.
- Solar-powered infrastructure to ensure sustainable and energy-efficient operation.
- The system aims to achieve smoother traffic flow, reduced pollution, faster emergency response, and sustainable urban transportation.

VI. METHODOLOGY

The methodology consists of five interconnected modules:

CO, Filtration Duct System

Design: Install ducts with high-capacity air filters at the roadside of traffic junctions.

Filter Technology: Activated carbon filters for CO: adsorption, HEPA filters for particulate matter.

Operation: Small suction fans draw polluted air into the ducts, filters remove toxins; purified air is released back.

IoT Sensors: Air quality sensors (MQ-135, CO: sensors) monitor pollution levels before and after filtration.

ESP-NOW Ambulance Detection

Hardware: ESP32 microcontrollers installed in ambulances and traffic lights. Protocol: ESP-NOW allows direct peer-to-peer communication without routers Range: Effective communication within 15 meters of the junction.

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Functionality: On detection, the system overrides normal signal cycles, immediately turning green in the ambulance lane.

Al-Based Traffic Optimization

Input Data: Camera feeds, IR sensors, or ultrasonic vehicle counters.

Algorithm: Reinforcement leaming model trained to minimize queue length and maximize throughput.

Features:

- Dynamic adjustment of green/red times.
- Prediction of congestion based on historical patterns.
- Adaptive learning to improve over time.
- Simulation Tools: SUMO (Simulation of Urban Mobility) integrated with Python Al libraries

Solar-Powered Smart Signals

Design: Solar panels with charge controllers, connected to battery packs.

Energy Storage: Lithium-ion or lead-acid batteries for nighttime operation.

Integration: Power both traffic signals and lot sensors, ensuring uninterrupted service even during grid failures.

Centralized Monitoring & Simulation

Dashboard: Real-time monitoring using a web dashboard.

Data Analytics: Collect statistics on traffic density, ambulance priority activations, and CO levels.

Simulation Environment: Parallel testing in a digital twin model for optimization before field deployment.

Proposed Block Diagram

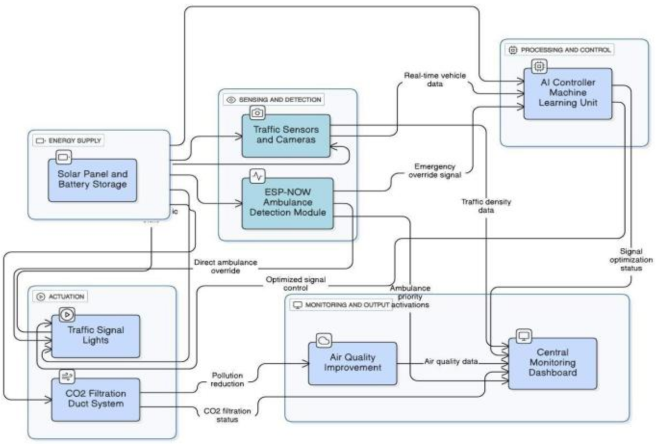

Figure No: 1

Realistic diagram:

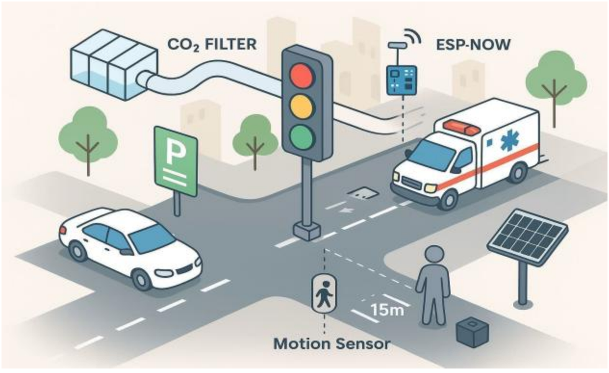

Figure No: 2

System Flow:

1. Traffic Sensors & Cameras Data Collection
2. Al Controller Processes data, predicts congestion, optimizes signals
3. ESP-NOW Module Detects ambulances and overrides signal cycle
4. CO: Duct Filters Actively filter vehicular emissions at junctions
5. Solar Panels & Batteries Supply renewable power to system
6. Central Dashboard Monitoring and analytics

VII. FACILITIES REQUIRED

To implement and test the proposed system, the following facilities are required:

Hardware

1. ESP32 microcontrollers (for ambulance detection and signal control)
2. Air quality sensors (MQ-135, CO: sensors)
3. Cameras/IR sensors (for vehicle detection)
4. Suction fans and ducting system with filters
5. Solar panels (small-scale, e.g., 50W for prototype)
6. Batteries and charge controllers
7. LEDs for traffic signal simulation (Red, Yellow, Green)
8. Power supply components
9. Prototype roads, junction models, and ambulance miniatures

Software

1. Arduino IDE (for ESP32 programming)
2. Python (for Al model development)
3. SUMO (for traffic simulation)
4. TensorFlow/PyTorch (for machine learning)
5. Node.js/React (for dashboard interface)
6. MySQL/Firebase (for data storage)

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Human & Institutional Support

1. Faculty guide and lab facilities
2. Access to lot and embedded systems laboratory
3. Internet and cloud storage services
4. Access to Al computing resources (GPU if needed)

VIII. APPROX. EXPENDITURE

Table No: 1

Item	Quantity	Cost per Unit (INR)	Total (INR)
ESP32 Boards	2	700	3,500
Sensors (CO_2, MQ-135, IR)	8	500	4,000
Solar Panel (50W)	2	3000	6,000
Batteries & Controllers	2	2500	5,000
Suction Fans + Ducts	2	2000	4,000
LED Traffic Lights	4	500	1,000
Miscellaneous (wires, PCB, casing)			500
Total Estimated Cost			**25,000 INR**

Time Schedule:

Table No: 2

Month	Work Schedule
August 2025	Conduct a comprehensive literature review on smart traffic management, ESP-NOW communication, AI in traffic optimization, CO_2 filtration technologies, and solar-powered infrastructure. Identify research gaps.
September 2025	Finalize the problem statement and research objectives. Develop tentative block diagrams and system architecture. Begin procurement of basic components (ESP32, sensors, LEDs).
October 2025	Develop initial prototype of ESP-NOW ambulance detection module. Test communication range (15m) and signal override functionality. Document results.
November 2025	Build and test small-scale CO_2 duct filtration system. Integrate sensors (MQ-135, CO_2) for before/after air quality measurement. Validate pollution reduction efficiency.
December 2026	Train AI model using SUMO traffic simulations. Implement reinforcement learning algorithms to optimize signal timings based on density and queue length.
January 2026	Begin hardware-software integration: connect AI model with ESP32 controllers for real-time signal control. Prototype dashboard for monitoring.
February 2026	Expand prototype with solar panels and batteries. Test solar charging efficiency and nighttime operation. Ensure traffic signals run independently of grid power.
February 2026	Conduct combined system testing: ambulance priority + AI optimization + CO_2 filtration + solar operation. Debug integration issues.
March 2026	Field-like simulation with multiple intersections in a lab model. Collect traffic flow data, response times, and CO_2 levels. Validate improvements over baseline.

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March 2026	Analyze results, refine AI model for better predictions. Optimize filter design and ambulance detection reliability. Prepare graphs and evaluation metrics.
April 2026	Write and submit technical paper to an international IEEE conference. Draft project documentation with detailed methodology and results.
April 2026	Finalize complete project report. Publish paper and compile necessary documentation. Submit project and prepare for viva/presentation.

IX. CONCLUSION

The AI Powered Eco Traffic System mega project delivers an innovative, multidisciplinary solution to urban congestion, pollution, and emergency response delays by integrating artificial intelligence, IoT, and renewable energy. Its core components—CO_2 filtration ducts, AI-optimized traffic signals, ambulance priority detection, and solar-powered infrastructure—work together to reduce emissions, enhance traffic flow, and improve safety at busy intersections. The project's real- world prototype demonstrates how smart technology can create more sustainable, efficient, and safe cities in India and beyond, bridging the gap between academic research and practical application for future smart city infrastructure.

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