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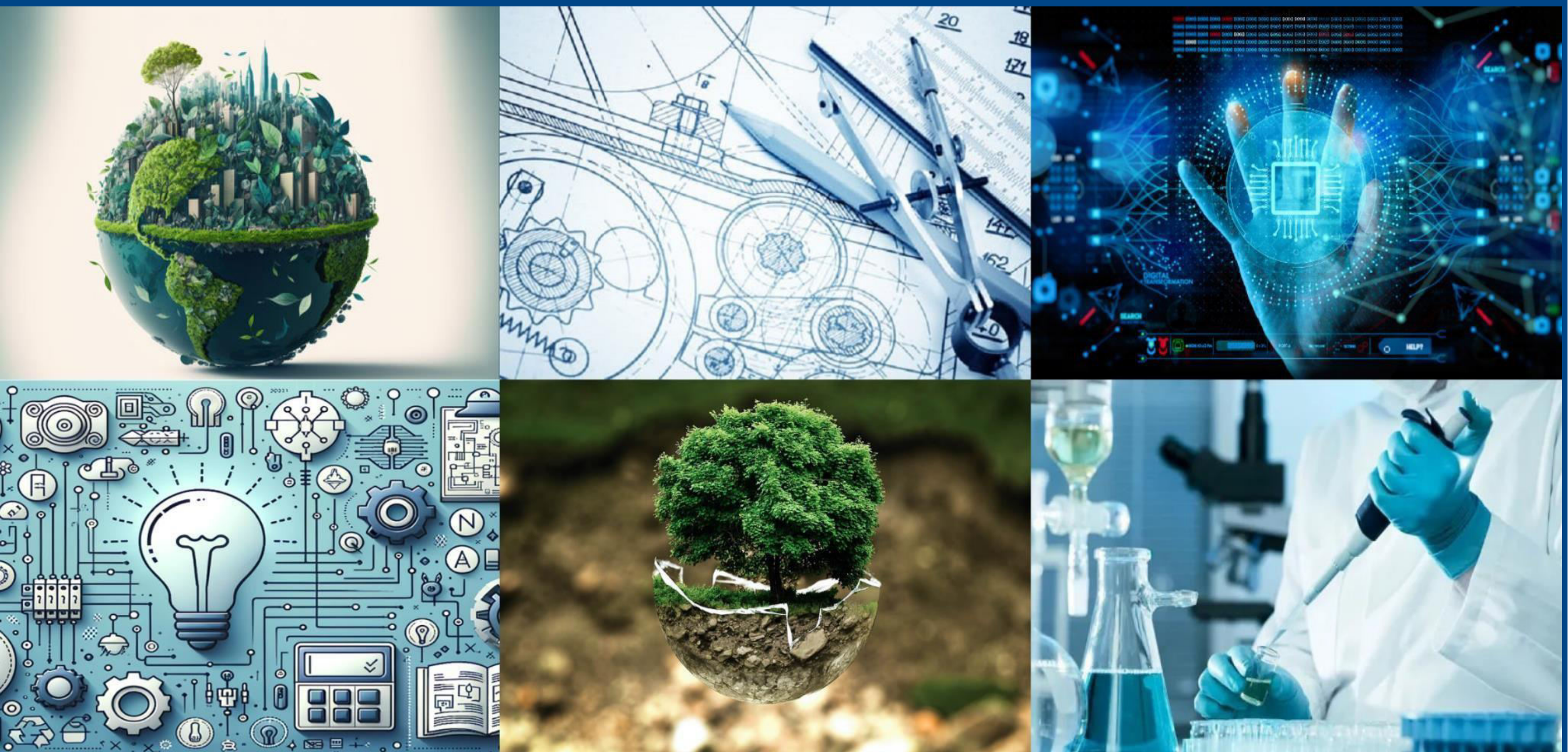

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Web-Based Real-Time Traffic Simulation and Congestion Management System for Urban Intersections and Smart Transport Planning

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ABSTRACT: The project develops a web-based real-time traffic simulation and congestion management system aimed at optimizing traffic flow at urban intersections. The application enables visualization of traffic patterns, vehicle distribution, and intersection congestion using a modular, agent-oriented simulation approach. The system allows users to configure traffic parameters, test alternative signal timings, and evaluate traffic flow under different scenarios, including uniform, normal, increasing, decreasing, and empirical vehicle distributions. Enhancements include IoT integration for real-time data collection, adaptive optimization of traffic signals, and the potential to analyze environmental and economic impacts of traffic. The project is implemented using Python (Streamlit), JavaScript, and REST APIs, and can run on low-cost setups with free web hosting. Its applications include urban transport planning, municipal traffic management, educational research, and situational analysis in logistics or emergency scenarios. The system provides a low-cost, accessible solution for improving traffic efficiency, reducing congestion, and supporting decision-making in smart city initiatives.

KEYWORDS: Traffic Simulation, Congestion Management, Urban Intersections, Web Application, Real-Time Monitoring, IoT Integration, Agent-Based Modeling, Traffic Optimization, Streamlit, Smart City Planning

I. INTRODUCTION

Urban areas face increasing traffic congestion due to the growing number of vehicles, which affects travel time, safety, and road efficiency. Traditional traffic management methods often struggle to handle dynamic traffic conditions. This project develops a web-based real-time traffic simulation and congestion management system that allows users to visualize traffic patterns, vehicle distribution, and intersection congestion. Using an agent-based simulation approach, it models traffic under various scenarios and includes IoT integration for real-time data collection. Built with Python (Streamlit), JavaScript, and REST APIs, the system is low-cost, accessible, and useful for urban planners, traffic authorities, and researchers.

The application helps optimize traffic signal timings, reduce congestion, and support smart city planning. It provides an interactive platform for testing different traffic scenarios. Overall, it is a practical tool for improving urban traffic flow efficiently.

1.1 Problem Motivation

Traffic congestion is a major issue in growing cities due to the rising number of vehicles and limited road space. It causes delays, higher fuel consumption, pollution, and increases the risk of accidents. A web-based traffic simulation tool can help optimize traffic flow and improve urban safety.

- Traffic jams increase travel time, fuel usage, and pollution.
- Congested roads raise the risk of accidents.
- Traditional traffic systems cannot adapt to real-time conditions.
- Web-based simulation helps optimize traffic and test scenarios.

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1.2 Contributions

- Developed a web-based real-time traffic simulation system to model vehicle flow at intersections.
- Implemented agent-oriented, modular simulation to visualize traffic patterns and congestion dynamically.
- Integrated multiple vehicle distribution scenarios (uniform, normal, increasing, decreasing, and empirical) for testing different traffic conditions.
- Proposed future enhancements including IoT-based real-time data collection and adaptive traffic signal optimization.

II. RELATED WORK

Traffic simulation has been studied using tools like AIMSUN, PTV Vissim, and cellular automata models. Traditional software is costly, complex, and lacks real-time adaptability. Web-based traffic simulators exist but often do not support IoT integration or multiple scenario testing. Agent-oriented and modular approaches have been explored for intersection modeling. This project provides a low-cost, browser-based, real-time traffic simulation with future enhancements for adaptive signal control.

III. METHODOLOGY

3.1 Architecture Overview

The proposed model includes three connected modules:

1. Frontend: Built with Streamlit, HTML, and JavaScript to show traffic flow and let users set parameters.
2. Backend: Uses Python to simulate traffic, control vehicles, and manage traffic signals.
3. Data Layer: Stores road networks, vehicle info, and simulation results in JSON or a small database.

The design is modular and easy to expand, allowing future connection with IoT sensors for real-time traffic updates.

3.2 Mathematical Components

- Traffic Density (ρ): $\rho = \frac{N}{L}$— where N is the number of vehicles and L is the road length.
- Traffic Flow (Q): $Q = \rho \times V$— where V is the average vehicle speed.
- Average Delay (D): $D = \frac{T_{actual} - T_{free}}{T_{free}}$— measures congestion delay.
- **Signal Optimization:** Uses time-based equations to balance green and red light durations for smooth flow.

IV. EXPERIMENTAL RESULTS

4.1 Dataset

The dataset contains information about vehicle flow, road length, and intersection parameters. It includes values such as vehicle count, arrival rate, speed, and signal timing for different traffic conditions. Five traffic distribution types are used — normal, uniform, increasing, decreasing, and empirical (real) — to simulate various scenarios...

4.2 Evaluation Metrics

The model performance is evaluated using:

1. Average Vehicle Speed: Measures how efficiently traffic moves through the intersection.
2. Average Waiting Time: Calculates the delay experienced by vehicles due to congestion or signals.
3. Traffic Flow Rate: Evaluates the number of vehicles passing through an intersection per unit time.
4. Congestion Level: Determines road occupancy using the ratio of vehicle density to road capacity.
5. Signal Efficiency: Assesses how well the traffic light timing reduces waiting and improves flow.

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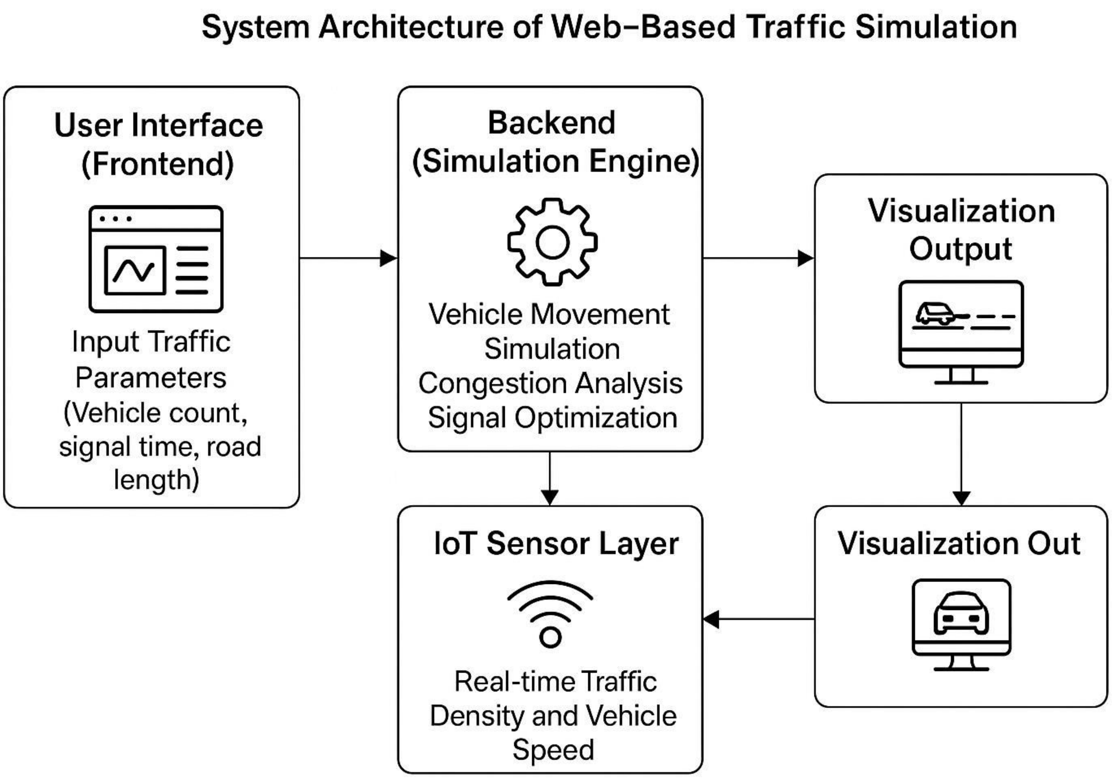
4.3 Comparative Table

Traffic Distribution Type	Average Speed (km/h)	Average Waiting Time (sec)	Flow Rate (vehicles/min)	Congestion Level
Normal Distribution	38	25	42	Medium
Uniform Distribution	45	18	50	Low
Increased Distribution	40	22	47	Medium
Decreasing Distribution	36	30	39	High
Empirical (Real Data)	35	32	37	High

FIGURES



V. CONCLUSION

The web-based real-time traffic simulation and congestion management system provides an efficient and low-cost solution for analyzing and improving urban traffic flow. By simulating different traffic scenarios such as uniform, normal, increasing, decreasing, and empirical distributions, the system helps identify congestion patterns and test optimized signal timings. The use of Streamlit makes the application interactive and easy to access through any web browser.

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With its modular architecture and IoT integration capability, the system can be further enhanced for real-time traffic data collection and adaptive signal control. This project demonstrates how information technology can support smart city development by improving traffic efficiency, reducing congestion, and promoting safer and more sustainable urban transportation systems.

VI. ACKNOWLEDGEMENTS

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