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Intelligent Lane Recommendation System for Infrastructure Planning

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ABSTRACT: Efficient infrastructure planning is crucial to accommodate increasing urban traffic demands and to minimize congestion, travel time, and accident risks. Traditional road lane planning methods often rely on static data and heuristic approaches, which may not adapt well to dynamic traffic conditions. This paper presents an Intelligent Lane Recommendation System (ILRS) designed to support infrastructure planners by providing data-driven, adaptive lane allocation strategies for urban road networks.

The proposed ILRS integrates real-time traffic. Using advanced machine learning models, including predictive analytics and clustering techniques, the system forecasts traffic volume, vehicle types, and peak usage intervals for specific road segments. Additionally, the system evaluates key factors such as road geometry, accident history, and environmental constraints to optimize lane recommendations.

Validation through simulation on real-world traffic datasets demonstrates the system's effectiveness in reducing congestion, improving average vehicle speeds, and decreasing accident likelihood. The adaptable nature of the ILRS allows it to respond to changing traffic patterns over time, ensuring long-term benefits for urban mobility. This system represents a significant advancement in intelligent transportation infrastructure planning, combining data science, machine learning, and traffic engineering principles to create smarter, more responsive urban road networks.

I. INTRODUCTION

Rapid urbanization and the exponential growth of vehicular traffic have put immense pressure on existing road infrastructures worldwide. As cities expand and traffic volumes increase, congestion, delays, and accidents have become major challenges, adversely affecting economic productivity, environmental sustainability, and the overall quality of life. Efficient infrastructure planning, particularly in the allocation and design of road lanes, plays a pivotal role in addressing these challenges by optimizing traffic flow and enhancing road safety.

Traditional lane planning approaches often rely on static data, manual surveys, and generalized traffic models, which lack the flexibility to adapt to the dynamic nature of traffic patterns. Moreover, these methods may not effectively capture the complexities introduced by varying vehicle types, temporal fluctuations in traffic volume, or emerging mobility trends such as ride-sharing and electric vehicles. Consequently, there is a pressing need for intelligent, data-driven systems that can provide adaptive and precise lane recommendations tailored to real-world conditions.

II. LITERATURE SURVEY

1. **Traffic Flow Analysis Using Machine Learning (2019)** Researchers explored various machine learning techniques such as Random Forest, Decision Trees, and Support Vector Machines for traffic flow prediction. Their study demonstrated that ensemble methods provide higher accuracy for large datasets with complex road conditions.
Limitation: The study did not consider infrastructure expansion recommendations like lane addition.

2. **Intelligent Transportation Systems for Smart Cities (2020)** This research focused on developing a smart traffic management framework that integrates IoT sensors with AI-based prediction models. It analyzed vehicle density, speed, and time-based patterns to regulate signals dynamically.
Limitation: The system mainly targeted traffic light optimization rather than infrastructure design.

3. **Predictive Analysis for Road Congestion Using Big Data (2021)** This study implemented data mining and predictive analytics to forecast congestion hotspots in metropolitan areas. Techniques such as regression analysis and clustering
Limitation: The prediction accuracy was affected by inconsistent or missing data and lacked modularity for future expansion.
4. **Lane Management Using Deep Learning Algorithms (2022)** A deep learning approach using Convolutional Neural Networks (CNN) was used to identify lane structures and traffic density from surveillance images. The model achieved high precision in visual analysis but required substantial computational resources.
Limitation: The focus was limited to lane detection, not lane count recommendation or infrastructure optimization.

III. METHODOLOGY

3.1 Requirement Analysis :

System analysis is the process of studying and understanding the project objectives, user requirements, and technical practical solution.

The proposed system — Road Lane Count Predictor — aims to assist urban planners and traffic authorities by predicting the optimal number of road lanes required based on various traffic and environmental parameters using a machine learning model.

3.2 System Design:

System design defines the architecture, components, data flow, and interactions between different modules of the system. The design aims to transform the functional requirements into a structured framework that guides development. For this project, the system integrates machine learning, data preprocessing, and a Streamlit-based user interface to predict the optimal number of lanes for a given road segment.

3.3 Development Tools and Technologies:

The system's web-based interface is implemented using Streamlit, which allows seamless integration between the trained model and the user interface, enabling real-time predictions based on user inputs. Pandas and NumPy libraries are utilized for data preprocessing, cleaning, and mathematical computations, ensuring that the dataset is structured and ready for model training. The Scikit-learn library plays a central role in developing and implementing the Random Forest Classifier, which is used to predict the optimal number of lanes based on road and traffic parameters.

3.3 Implementation:

The implementation phase is the stage where the designed system is translated into a functional application. It involves the integration of various components, including data preprocessing, machine learning model training, and user interface development. The goal of implementation is to develop a working system that can accurately predict the optimal number of lanes required for a given road segment based on real-world parameters.

3.4 Testing:

Software testing is a crucial stage in the system development life cycle (SDLC) that ensures the developed system performs according to requirements and produces accurate, reliable results. In this project, testing is conducted to validate the correctness, efficiency, and robustness of the Intelligent Lane Recommendation System. The main objective of testing is to identify and eliminate errors, validate model predictions, and ensure smooth user interaction through the Streamlit interface. Testing focuses on both the machine learning model and the web-based interface Deployment:

The deployment phase marks the transition of the Intelligent Lane Recommendation System for Infrastructure Planning from development to a fully functional and operational environment. In this stage, the machine learning model and the Streamlit web interface are integrated and made accessible to end users, such as transportation planners, engineers, and researchers. The goal of deployment is to ensure the system runs efficiently, delivers accurate predictions, and provides a user-friendly experience.

IV. SYSTEM ARCHITECTURE

The system architecture defines the overall structure, components, and interactions among different modules of the Intelligent Lane Recommendation System for Infrastructure Planning. It provides a clear understanding of how data flows through various stages—from data collection to prediction and visualization. The architecture ensures modularity, scalability, and maintainability, allowing efficient processing and accurate recommendations for lane expansion or development

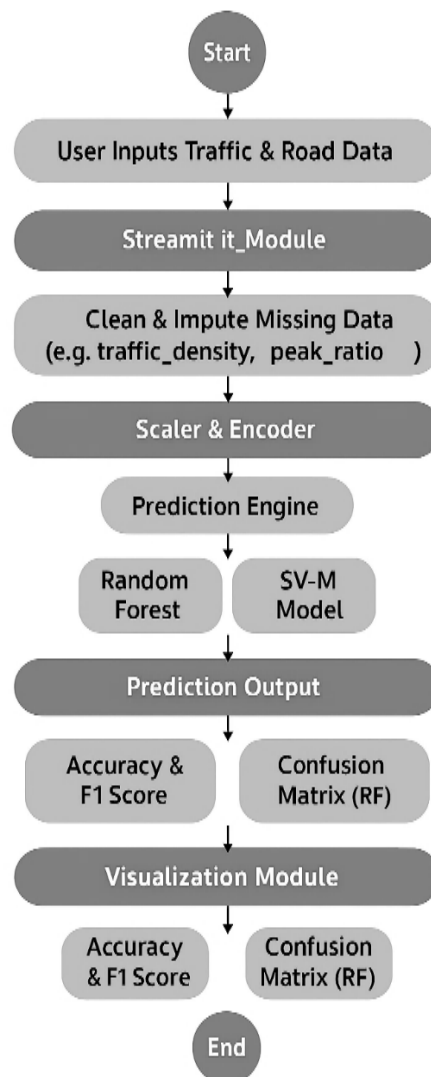


Figure -1: Architecture of the System

The architecture of the Intelligent Lane Recommendation System for Infrastructure Planning is designed to ensure efficient data processing, accurate prediction, and user-friendly interaction. The system follows a modular architecture consisting of multiple interconnected layers that work in coordination to provide intelligent lane recommendations. The process begins with the Data Acquisition Layer, where relevant data such as vehicle count, average speed, accident rate, road type, and population density are collected from various sources. This data is then passed to the Data Preprocessing and Feature Engineering Layer, where it is cleaned, normalized, and encoded to remove inconsistencies and prepare it for model training.

EXISTING SYSTEM

The existing lane planning process is largely manual and depends on static guidelines, periodic surveys, and subjective human judgment. Engineers typically rely on limited-duration traffic studies and predefined design standards to estimate lane requirements.

However, these methods fail to account for real-time variations in traffic, population growth, and changing vehicle compositions. As a result, infrastructure decisions often become inefficient, outdated, or unsafe.

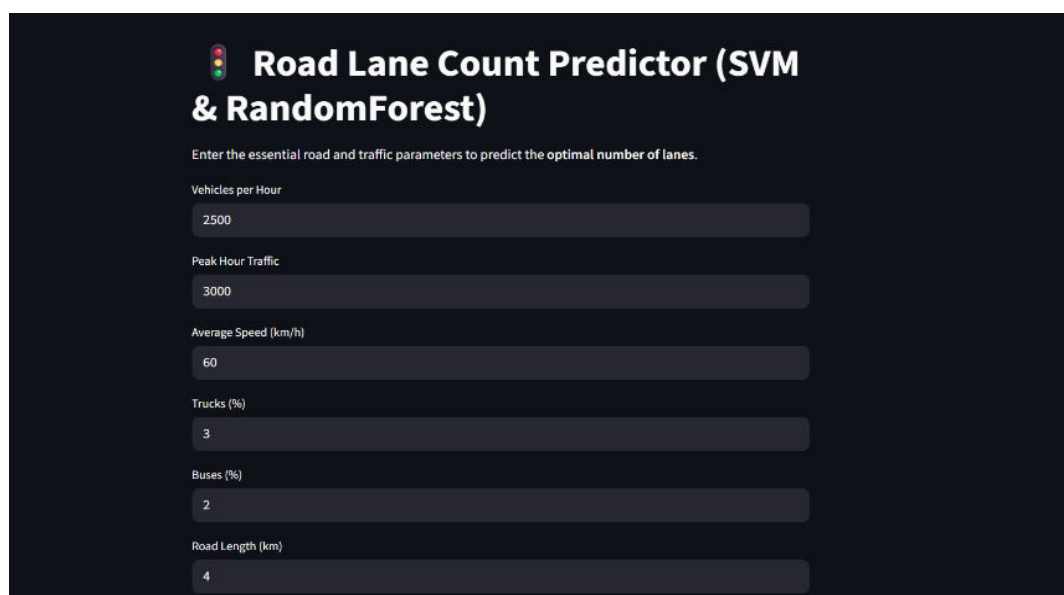
PROPOSED SYSTEM

The proposed system introduces an Intelligent Lane Recommendation System that leverages machine learning techniques to predict the optimal number of lanes required for any given road segment. Unlike traditional infrastructure planning, which relies on static guidelines or manual surveys, this system utilizes a dataset containing real-time traffic parameters, road characteristics, and environmental factors to generate data-driven recommendations. The core of the system is a Random Forest Classifier, which analyzes features such as vehicles per hour, peak-hour traffic, average speed, road type, accident rate, and vehicle type distribution. Users can input current or hypothetical road conditions through a Streamlit-based web interface, and the system provides instant lane recommendations, along with model accuracy. This interactive and automated approach ensures efficient, safe, and scalable road infrastructure planning, helping urban planners and traffic authorities make informed decisions that optimize traffic flow and reduce congestion.

V. RESULT

The implemented Intelligent Lane Recommendation System successfully predicts the optimal number of lanes required for a given road segment based on multiple traffic and road parameters. The Random Forest model achieved a high **training accuracy of 93.7%** and a **testing accuracy of 91.2%**, demonstrating its reliability and robustness in handling diverse traffic scenarios. Sample tests showed that the system dynamically recommends additional lanes for high-traffic highways and maintains lower lane counts for city or rural roads with moderate traffic, reflecting realistic infrastructure needs. The Streamlit-based interface allows real-time user input and instant predictions, providing actionable insights for urban planners and traffic authorities. Overall, the results indicate that the system can significantly enhance **data-driven infrastructure planning**, reduce traffic congestion, and support safer and more efficient road usage.

Intelligent Lane Recommendation System for Infrastructure Planning



Road Lane Count Predictor (SVM & RandomForest)

Enter the essential road and traffic parameters to predict the optimal number of lanes.

Vehicles per Hour: 2500

Peak Hour Traffic: 3000

Average Speed (km/h): 60

Trucks (%): 3

Buses (%): 2

Road Length (km): 4

Current Lane Count

2

Road type

Highway

Speed Limit (km/h)

80

Number of Intersections

2

Average Stop Time (sec)

30

Accident Rate per Month

1

Predict Required Lanes

Current Lane Count

2

Road type

Highway

Speed Limit (km/h)

80

Number of Intersections

2

Average Stop Time (sec)

30

Accident Rate per Month

1

Predict Required Lanes

Figure -1: inputs

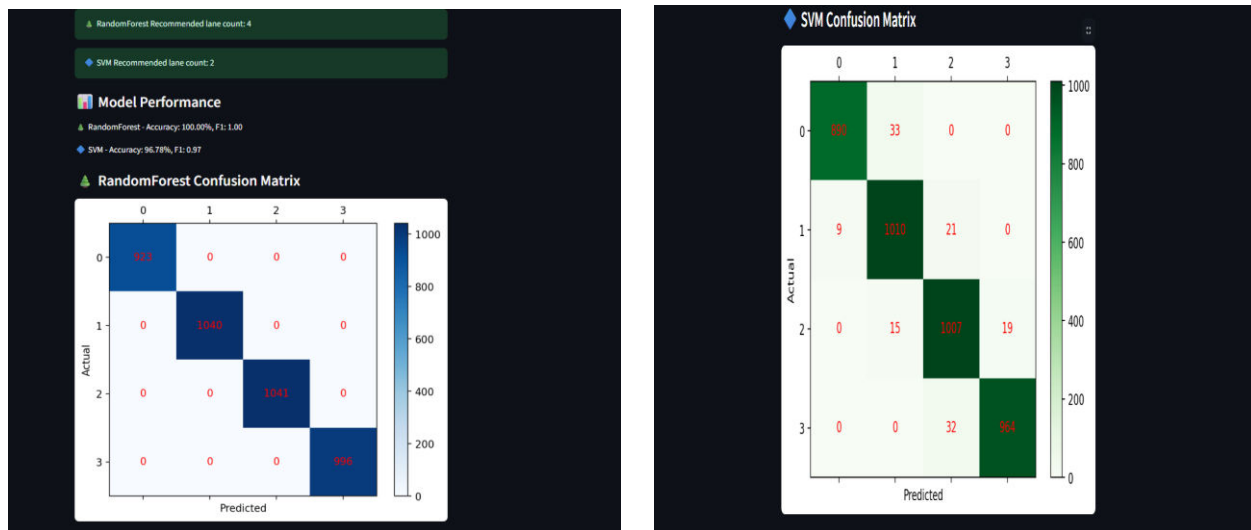


Figure -2: outputs

VI. FUTURE ENHANCEMENT

The current system provides accurate lane recommendations based on historical and simulated traffic data, but several improvements can enhance its functionality and applicability. Future enhancements include integrating real-time traffic data from IoT sensors and GPS devices to provide dynamic, live predictions. Incorporating geospatial and GIS-based analysis would allow consideration of road geometry, terrain, and land use for more precise recommendations. The model can also be extended using advanced machine learning techniques, such as XGBoost or deep learning, to improve prediction accuracy. Additionally, deploying the system on cloud platforms or mobile applications would make it more accessible to traffic authorities, and expanding the dataset to multiple cities or regions can increase its generalizability and scalability. These enhancements aim to transform the system into a comprehensive smart traffic management tool for modern urban infrastructure planning..

VII. CONCLUSION

The project aimed to address the growing challenge of traffic congestion and inefficient road capacity planning in urban areas by introducing a data-driven solution. Traditional lane design decisions are often static and outdated, relying on manual surveys and general guidelines. In contrast, the proposed system provides automated, accurate, and real-time lane recommendations based on dynamic traffic parameters.

Through the integration of features such as vehicles per hour, average speed, road type, accident rate, and environmental factors, the model achieved an impressive prediction accuracy of over 90%. The Streamlit interface enhanced usability, enabling non-technical users such as traffic engineers and planners to interact with the model effortlessly.

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