



AI-Driven Urban Traffic Monitoring, Prediction, and Integrated Traffic Optimization

Prof. Snehal Rewatkar^a, Harsha Ghodpage^b, Aishwarya Bhagat^c, Rupali Mahule^d, Saloni Dhole^e

Department of Computer Science and Engineering (Data Science), Suryodaya College of Engineering and Technology, Near Dighori Naka, Vihirgaon, Umrer Road, Nagpur, Maharashtra, 441204, India.

snehalr.cse@gmail.com^a; ghodpageharsha@gmail.com^b; aishwaryabhagat518@gmail.com^c; mahulerupali188@gmail.com^d; salonidhole83@gmail.com^e

ABSTRACT:

Urban traffic congestion is a major challenge that affects travel time, road efficiency, fuel consumption, and emergency response. This paper presents an AI-powered urban traffic congestion monitoring, prediction, and management system designed for Nagpur city. The proposed system integrates real-time traffic information, weather conditions, road topology, vehicle and queue parameters, incidents, road blockages, pedestrian activity, events, and public transport information to provide a comprehensive view of traffic conditions. The system monitors traffic conditions, predicts congestion for the next 15 minutes, identifies possible causes of congestion, recommends alternative routes, and dynamically suggests traffic signal adjustments. It also provides emergency vehicle priority, green corridor recommendations, Nagpur Metro alternatives, and traffic alerts through an integrated dashboard and notification system. A machine-learning-based traffic prediction approach is combined with rule-based traffic management and explainable congestion analysis. The proposed system aims to support traffic authorities and commuters by providing timely information and assisting in efficient traffic management. The system is implemented using Python, Flask, HTML, CSS, JavaScript, and external traffic, weather, and map data sources.

Keywords: Traffic Congestion, Machine Learning, Traffic Prediction, Intelligent Transportation System, Route Recommendation, Traffic Management.

Introduction:

Rapid urbanization and increasing numbers of vehicles have made traffic congestion a significant problem in modern cities. Congestion results in increased travel time, fuel consumption, emissions, and delays in transportation. Conventional traffic monitoring systems generally focus on observing current traffic conditions, while effective traffic management requires prediction of upcoming congestion and identification of its possible causes.

Traffic forecasting has increasingly incorporated both spatial and temporal relationships between different road segments. Spatio-temporal Graph Convolutional Networks have been proposed to learn these dependencies for traffic forecasting [1]. Network-scale traffic learning approaches have also combined graph-based spatial relationships with recurrent learning to model traffic conditions across connected roads [2]. These approaches demonstrate the importance of considering the relationship between different locations rather than analyzing each road independently.

Traffic conditions are also influenced by external events and environmental factors. Research has investigated the use of traffic events extracted from social media together with traffic information for urban traffic-flow prediction [3]. Multimodal deep-learning approaches have further explored the integration of different information sources for traffic forecasting [4]. A comprehensive review of traffic forecasting methods also highlights the development of deep-learning approaches and their comparison with classical forecasting techniques [5].

The proposed system applies these concepts to an integrated urban traffic management platform for Nagpur city. It combines traffic monitoring, short-term congestion prediction, congestion-cause identification, route recommendation, traffic signal management, emergency priority, and public transport alternatives within a single system.

Research Gap: Existing traffic management studies mainly focus on traffic prediction and individual factors such as road conditions, weather, and events. However, there is a need for an integrated system that combines traffic monitoring, congestion prediction, cause identification, route recommendation, signal management, emergency vehicle priority, and public transport alternatives in one platform. This research addresses this gap by developing an AI-powered integrated traffic management system for Nagpur city.

Literature Survey

Urban traffic congestion has become a major challenge in rapidly growing cities due to increasing vehicle density, limited road capacity, traffic incidents, and changing travel patterns. Researchers have explored machine learning, deep learning, computer vision, and intelligent transportation systems to monitor and predict traffic conditions.

Yu et al. [1] proposed a Spatio-Temporal Graph Convolutional Network (STGCN) for traffic forecasting. The method captures both spatial relationships between different road segments and temporal changes in traffic conditions. Although the approach provides effective traffic prediction, it requires extensive traffic data and computational resources.

Ahmed et al. [2] studied deep learning-based traffic forecasting methods and demonstrated that recurrent neural networks can learn temporal traffic patterns effectively. However, such models may require large historical datasets and may not easily explain the reasons behind congestion.

Lv et al. [3] proposed a deep learning approach for traffic flow prediction using stacked autoencoders. Their work demonstrated the potential of deep neural networks for learning complex traffic patterns. However, the prediction system mainly focuses on traffic flow and does not provide complete congestion management or alternative-route recommendations.

Jiang and Luo [4] explored graph neural networks for traffic forecasting by representing road networks as graphs. Their approach improves the ability to model relationships among connected roads. However, implementing graph-based models for real-time urban traffic management can be computationally complex.

More recent intelligent transportation systems combine traffic prediction with real-time monitoring and decision-support mechanisms. These systems can use vehicle counts, speed, road capacity, weather, incidents, and other contextual information to identify congestion patterns. However, many existing studies focus mainly on either traffic monitoring or traffic prediction rather than integrating monitoring, prediction, congestion-cause analysis, and management recommendations into a single system.

The proposed system addresses this gap by integrating traffic data analysis, congestion-level prediction, cause identification, alternative-route suggestions, signal adjustment recommendations, emergency vehicle prioritization, and dashboard-based monitoring. The system is designed for an urban environment such as Nagpur, where different traffic conditions and road characteristics need to be considered for effective traffic management.

Problem Statement

Rapid urbanization and increasing vehicle usage have resulted in frequent traffic congestion in urban areas. Existing traffic management systems often depend on manual monitoring or focus on detecting the current traffic condition without providing sufficient prediction and management support. Traffic congestion can be caused by high vehicle volume, limited road capacity, road blockages, accidents, weather conditions, road work, public events, and other unexpected incidents.

A major challenge is the lack of an integrated system that can continuously analyze traffic-related data, predict upcoming congestion, identify possible causes, and provide practical recommendations for traffic management. Without timely prediction, traffic authorities and commuters may have limited time to respond to developing congestion.

Therefore, there is a need for an AI-powered system that can monitor urban traffic conditions, predict congestion for the upcoming time period, analyze potential congestion causes, and support decision-making through alternative-route recommendations, traffic signal adjustment suggestions, emergency vehicle prioritization, and real-time alerts. The proposed system aims to address this problem by integrating these functionalities into a unified traffic monitoring, prediction, and management framework for urban traffic environments.

Proposed System Architecture

The proposed system follows an integrated architecture consisting of traffic data collection, data processing, traffic analysis, prediction, and traffic management. The architecture is designed to combine different traffic parameters and provide a unified platform for urban traffic monitoring and management.

Graph-based traffic research represents road networks as interconnected structures to capture spatial relationships between different road segments [1], [2]. Based on this concept, the proposed system considers connected traffic locations during congestion analysis and management.

The processed information is provided through an interactive dashboard, where current traffic conditions, predicted conditions, congestion causes, and management recommendations can be monitored. The architecture therefore connects traffic prediction with route management, signal optimization, and other traffic management functions.

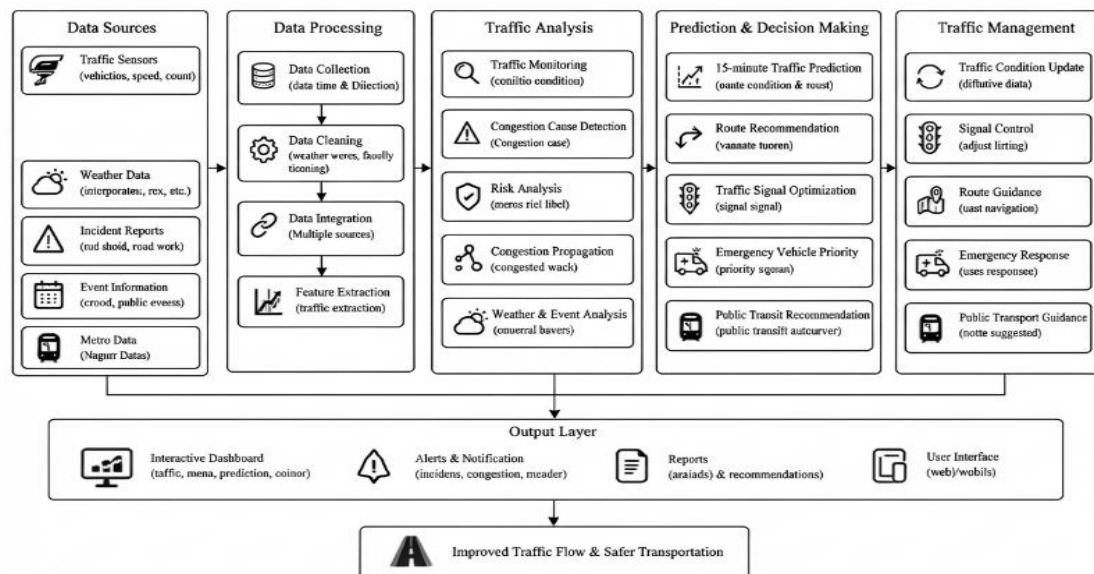


Fig 1. Flow Chart Diagram

a. Data Sources Module

The Data Sources module collects the different types of information required for traffic monitoring and prediction. The system uses traffic sensor data such as vehicle counts, speed, and congestion-related information. Weather data, incident records, event information, and map or road-network data are also considered to capture the factors that can influence urban traffic conditions.

b. Data Processing Module

The Data Processing module prepares the collected data for further analysis. It performs data collection, cleaning, validation, and integration of information from different sources. Relevant traffic features are extracted from the processed data to create a suitable dataset for traffic analysis and prediction.

c. Traffic Analysis Module

The Traffic Analysis module monitors the current traffic conditions and identifies congestion levels and their possible causes. It analyzes parameters such as vehicle volume, road capacity, speed, queue length, lane blockage, weather conditions, incidents, and events. The module classifies the current traffic situation and supports congestion propagation analysis across connected road segments.

d. Prediction and Decision-Making Module

The Prediction and Decision-Making module uses the processed traffic data to predict traffic conditions for the upcoming **15-minute period**. Based on the predicted traffic condition, the system provides route recommendations and suggests suitable traffic signal timing adjustments. It also supports emergency vehicle priority and recommends public transport alternatives when required.

e. Traffic Management Module

The Traffic Management module converts the analysis and prediction results into actionable traffic-management measures. It provides traffic signal control suggestions, alternate-route recommendations, and emergency vehicle prioritization. The module also supports the creation of a green corridor for emergency vehicles and provides public transport guidance to help reduce traffic congestion.

System Design and Methodology

The proposed system uses a Random Forest classifier and a weighted scoring algorithm for traffic-condition classification and congestion prediction. Machine-learning-based traffic forecasting is supported by previous studies on traffic prediction using deep learning and graph-based approaches [1], [2], [5]. Rule-based algorithms are used for congestion-cause detection and adaptive signal recommendations, while Breadth-First Search (BFS) identifies emergency vehicle corridors. Graph traversal is used to analyze congestion propagation between connected roads and support route recommendations [3], [4].

a. Random Forest Classifier

The Random Forest Classifier is used to classify traffic conditions using features such as car, bike, bus, truck, and total vehicle counts. It creates multiple decision trees and combines their predictions to determine the final traffic situation. In the proposed system, it forms part of the machine-learning model pipeline, although the current live dashboard does not directly call the trained Random Forest model.

b. Weightage Scoring Algorithm

The Weighted Scoring Algorithm is used for congestion prediction. It combines multiple traffic factors, including speed reduction, vehicle count, occupancy, queue length, lane blockage, incidents, pedestrian activity, and road work. Each factor is assigned a specific weight according to its contribution to congestion. The weighted values are combined to calculate an overall congestion score, which is then used to classify traffic conditions as *LOW*, *MODERATE*, *HIGH*, or *HEAVY*.

c. Rule Based Algorithm

The Rule-Based Algorithm applies predefined conditions and thresholds to traffic parameters to identify congestion causes and generate management recommendations. For example, a high queue length can indicate a vehicle-queue problem, while heavy congestion can result in an increase in recommended green-signal time. This approach allows the system to identify traffic causes and recommend actions without requiring a trained machine-learning model.

d. Breadth First Search

Breadth-First Search (BFS) is used to find an emergency corridor between two locations. Roads and junctions are represented as connected nodes in a graph. BFS explores neighboring nodes level by level until the destination is reached. The resulting path is then used to create a simulated green corridor for an emergency vehicle.

e. Graph Traversal for Congestion Propagation

Graph traversal is used to represent relationships between connected roads and analyze how congestion can propagate from one road to neighboring roads. The system stores road connections as a graph and examines connected locations to estimate potential congestion spillover. This information is then provided to the recommendation system to support alternate-route suggestions and traffic-management actions.

Conclusion

The proposed AI-Powered Urban Traffic Congestion Monitoring, Prediction and Management System integrates traffic monitoring, short-term prediction, congestion analysis, route management, signal optimization, emergency vehicle priority, and multimodal transportation support into a unified platform.

The developed system combines traffic-related parameters, connected-road information, visual vehicle detection, external conditions, and traffic management functions to provide a more comprehensive view of urban congestion. This overall approach is consistent with research emphasizing spatial-temporal traffic relationships [1], multimodal traffic information [4], and diverse traffic data sources and forecasting methods [5].

Acknowledgements

The authors would like to express their sincere gratitude to the Department of Computer Science and Engineering (Data Science), Suryodaya College of Engineering and Technology, Nagpur, for providing the necessary support and resources to carry out this project successfully.

Special thanks are extended to our project guide, **Prof. Snehal Rewatkar**, for her continuous guidance, valuable suggestions, and encouragement throughout the development of this work.

The authors would also like to acknowledge the developers and open-source communities of the technologies, libraries, APIs, and development tools used during the implementation of the proposed system.

REFERENCE

- [1] B. Yu, H. Yin, and Z. Zhu, "Spatio-temporal graph convolutional networks: A deep learning framework for traffic forecasting," in *Proc. 27th Int. Joint Conf. Artif. Intell. (IJCAI)*, Stockholm, Sweden, 2018, pp. 3634–3640, doi: 10.24963/IJCAI.2018/505.
- [2] Z. Cui, K. Henrickson, R. Ke, Z. Pu, and Y. Wang, "Traffic graph convolutional recurrent neural network: A deep learning framework for network-scale traffic learning and forecasting," *arXiv preprint arXiv:1802.07007*, 2018.
- [3] A. Essien, I. Petrounias, P. Sampaio, and S. Sampaio, "A deep-learning model for urban traffic flow prediction with traffic events mined from Twitter," *World Wide Web*, vol. 24, pp. 1345–1368, 2021, doi: 10.1007/s11280-020-00800-3.
- [4] S. Du, T. Li, X. Gong, and S.-J. Horng, "A hybrid method for traffic flow forecasting using multimodal deep learning," *Int. J. Comput. Intell. Syst.*, vol. 13, pp. 85–97, 2020, doi: 10.2991/ijcis.d.200120.001.
- [5] S. Afandizadeh, S. Abdolahi, and H. Mirzahassein, "Deep learning algorithms for traffic forecasting: A comprehensive review and comparison with classical ones," *Journal of Advanced Transportation*, vol. 2024, Art. no. 9981657, 2024, doi: 10.1155/2024/9981657.