

VisionSafeX: AI-Assisted Traffic Violation Detection Using MERN Stack and Generative AI

Shourya Yadav¹; Yusuf Rehan²; Shreya Arya³; Shreya Jain⁴

^{1,2,3,4}Department of CSE, Ajay Kumar Garg Engineering College Ghaziabad, India

Publication Date: 2026/03/07

Abstract: The rising traffic and the inability to maintain an oversight manually have augmented the issues in the management of traffic in urban areas. Traditional manual monitoring systems, as far as exposing infractions on the fly is concerned, tend to be inefficient and are more susceptible to mistakes. The proposal presented in this paper is for an AI-based traffic violation detection system known as VisionSafeX that utilizes the ability of the artificial intelligence known as Generative AI to improve the resolution of low-resolution surveillance video in addition to the use of the MERN stack to integrate the system. The system automatically detects the violations with the help of CNN-based model, which processes the frames. Generative AI adds more precision to the model since it is able to recreate missing frames. The experiments and research that was undertaken have demonstrated good performance in different real life situations. The dashboard is provided through a MERN based dashboard that is available on-demand. The paper also discusses deployment strategies, security considerations, scalability, and practical im-plementation guidelines for city-wide traffic networks.

Keywords: Traffic Violation Detection, MERN Stack, Gen-erative AI, Deep Learning, Automation, Video Enhancement, Real-Time Monitoring.

How to Cite: Shourya Yadav; Yusuf Rehan; Shreya Arya; Shreya Jain (2026) VisionSafeX: AI-Assisted Traffic Violation Detection Using MERN Stack and Generative AI. *International Journal of Innovative Science and Research Technology*, 11(2), 2806-2812. <https://doi.org/10.38124/ijisrt/26feb1485>

I. INTRODUCTION

Traffic jam is one of the biggest problems of the modern city associated with the growing number of vehicles and the accelerated urbanization. Analysts report that the number of vehicles present in the urban areas grows at 8-10% per year, contributing to the worldwide traffic jams, increased fuel usage, and increased traffic-related car crashes. Presently, 1.19 million people all over the globe die in traffic accidents annually. Conventional traffic control approaches are finding it hard to keep up with the rising number of vehicles thus leading to inefficiencies, safety risks and costs. Other issues that have been attributed to endangering lives are challenges such as congested intersections, failure to adhere to road rules, and poor law enforcement, which are some of the challenges that have been observed to endanger lives especially in some of the top ten busy cities around the world like Bangalore, Mumbai, Pune, and Delhi.

The current traffic surveillance system employs a lot of manual control at intersections or a large scale video surveillance. These methods are time consuming, error prone and are not effective in managing the immense volume of video information that is produced on a daily basis. It is natural that there is a demand to have a smarter and automated surveillance system that will be able to track, measure, and process traffic

conditions in real-time.

The recent years have witnessed the revolution of intelligent transport systems and traffic monitoring through automated visual recognition and artificial intelligence. Deep learning algorithms are also good at object tracking, classification, and detection of patterns, including vehicles, pedestrians, traffic sign, and lanes. By using these technologies one is able to develop more effective surveillance systems.

Although the progress is made, AI systems face difficulties in their practical use. Problems such as low camera quality due to low quality or old cameras, blurred captures, bad lighting, low resolutions, and weather effects hamper the precision of AI models. These restrictions have an impact on the performance of the system especially during such unfavorable weather conditions as in the night or during rainy seasons. Also, AI systems can have difficulties with small details: license plates or helmets, which indicates the discrepancy between the potential and the actual performance.

Generative AIs, including GANs and diffusion models, are solving these issues, by improving the quality of images and building real images based on low-quality input. The

technology enhances video quality in traffic surveillance, which is helpful in detecting violations and details and performing the task with AI.

Presenting our web application, VisionSafeX, that combines web dashboards, violation detection and generative AI to improve the quality of videos in surveillance footage. The application is based on the MERN stack and it is very easy to handle the data collection, processing, and visualization. The AI system will track the video streams in real-time and identify infractions, such as red light running, overspeeding, helmetless riding, and unauthorized parking, even using low-quality video footage. The generative AI improves the quality of videos in order to properly recognize it. Refined data is made available on a centralized online platform to give authorities instant evidences, analytics, and real-time city-wide information. The scalability and real-time status of the MERN stack allow the uncomplicated implementation in various cities, although there might be certain difficulties in the initial setting in certain cities.

➤ Objectives

The objectives of this research are as follows:

- Developing a dynamic MERN dashboard to monitor traffic violations in real-time.
- Enhancing image quality, reducing noise, and uncovering obscured areas using advanced Generative AI techniques such as GANs and diffusion models.
- Simplifying violation reporting by combining license plate recognition, timestamp recording, evidence capture, and secure data storage.
- Ensuring the system can expand and manage issues well to be used widely in different intersections across the city.

➤ Paper Organization

The remainder of this paper is structured as follows. Section II reviews existing literature on intelligent traffic monitoring and highlights key limitations. Section III presents the research problem and identifies the gap addressed by the proposed system. Section IV describes the architecture of VisionSafeX and its system components. Section V explains the AI model, including data preparation and frame enhancement techniques. Section VI outlines the experimental setup, datasets, and training parameters. Section VII discusses the results and performance evaluation. Finally, Section VIII concludes the paper and suggests directions for future research.

II. RELATED WORK

The demand for automated solutions in traffic regulation and urban safety has increased steadily, leading to extensive re-search in intelligent traffic surveillance and violation detection [3], [4]. Progress in computer vision and deep learning techniques has enabled more reliable analysis of vehicle movement and behavior in complex road environments [5], [14]. Nevertheless, several practical challenges persist, including degraded visual inputs, limited system scalability, and the difficulty of detecting multiple violations within a single framework [6],

➤ *To Address These Issues, Existing Studies are Examined in this Section by Organizing Them into Three Broad Categories:*

- Methods focused on enhancing the surveillance imagery,
- Approaches based on deep learning for violation detection, and
- Real-time traffic monitoring systems supported by web-based architectures.

➤ AI-Based Traffic Violation Detection

A substantial body of research focuses on the use of deep learning models to detect traffic violations automatically [7], [8]. Most existing systems rely on convolutional neural network (CNN) and object detection architectures to identify violations such as red-light jumping, helmet non-compliance, and over-speeding [9], [12]. Models based on YOLO, Faster R-CNN, and SSD have been widely adopted due to their balance between detection accuracy and real-time performance [18].

In the past, researchers have explored ways to detect motor-bike riders' helmets using different categorization techniques and examining spatial characteristics [10]. While these approaches perform effectively in controlled experiments, they face difficulties in real-life situations due to issues such as poor lighting, unclear pictures, obstructed views, and low-resolution camera recordings [13].

Furthermore, many of the proposed systems are designed to detect only specific types of violations. This limitation can reduce their effectiveness in bustling urban areas where multiple violations may occur simultaneously. This highlights the need for a detection system that can handle diverse traffic scenarios while still delivering fast and accurate responses [16].

➤ Generative and Image Enhancement Approaches

Researchers are also discussing the application of artificial intelligence that creates content to address the problem associated with the use of low-quality surveillance videos. The technology enhances the quality of images and videos in terms of clarity [17]. Another widely used method to do this is called generative adversarial networks (GANs), which are typically used to enhance the quality of images and reduce the number of distortions in them [16]. GANs are also good at enhancing fuzzy or dark images, and in particular they can restore finer details like the shape of vehicles or the characters of license plates.

Traffic management appears to be a big concern these days. In the recent past, people have shown great interest in diffusion-based generative models. These models can produce quality images, even when the input is of low quality which is impressive to say the least, their ability to produce quality images is staggering, as is their ability to do so with low quality input [17]. They are far more reliable than the older super resolution methods, which results in more consistent images. This is what has made them so efficient in difficult situations like night security or in bad weather conditions.

The improvement methods are usually experimented individually rather than incorporated in the entire violation detection process. This lack of connection with full traffic enforcement systems restrains their real effectiveness. It is also complicated by the computing factor, which makes it difficult to use in real life, in a fully operational set up in a big city. It is not clear to me when this will improve.

➤ *Research Gaps*

Gaps are found in the study conducted on traffic surveillance. Current systems work on the basis of targeting one form of traffic offense that consists of drivers who ignore red lights and individuals who over speed and cyclists who do not wear helmets. The system is dysfunctional as it lacks to give a cohesive system alongside all the required checks. The case poses a serious problem.

Most of the models are reported to perform well as per the expectations of the theory but they require quality video as well as the best lighting conditions to work well. The system fails when the reality conditions prove to be tough which encompasses unfavorable weather conditions and night and camera obstructions. At the present people are concerned with using generative AI that involves GANs and diffusion models to eliminate noise in low-quality video footage. The tools allow users to improve visual content by improving the visual processing of data. Nevertheless few percentages of full surveillance systems have these technology solutions implemented at the moment.

The greatest concern is the expansion operations process. Most systems do not allow users to see what is happening in real time and when they have difficulty getting diverse systems to go hand in hand with one another. The system does not have the capabilities of efficient dashboard functions along with sophisticated database management tools that lead to performance problems. People talk about how an AI can make decisions but they do not elaborate about the procedure that defines such AI decisions. The general population will not believe that the results of the AI systems are fair until you show them a description of what the AI system process identified the violation. VisionSafeX offers its solution by integrating various aspects that involve the enhancement of video and the real-time detection of violations and user-friendly web platform into a scalable system that is configured to work in the real-life operational contexts.

III. SYSTEM DESIGN AND ARCHITECTURE

➤ *Architecture Overview*

VisionSafeX consists of four interconnected modules: front-end, backend, database, and AI engine. The architecture supports modularity, ease of maintenance, and real-time performance. Using RESTful APIs allows various system components to communicate independently and scale horizontally when necessary.

➤ *Module Description*

• *Frontend:*

The dashboard uses React.js and vanilla CSS to clearly display any violations.

• *Backend:*

Node.js and Express.js are used to manage API requests, handle user authentication, schedule AI tasks, and process data received at various times. To ensure timely completion of critical tasks, a queue is set up to prioritize urgent ones.

• *Database:*

Within MongoDB, we store structured violation records, vehicle details, license plate information, and user interactions. Splitting the data into shards is key to ensuring high performance for large scale deployments.

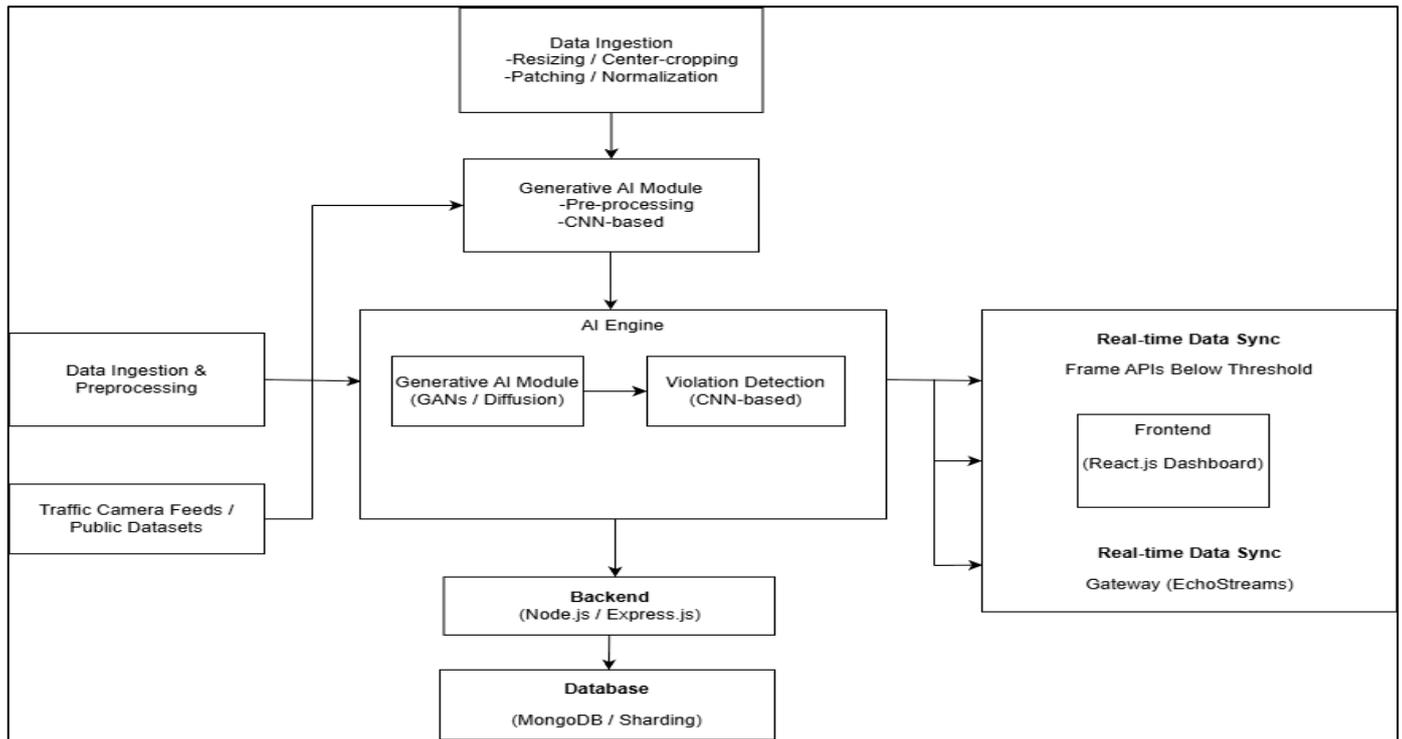


Fig 1 System Architecture of VisionSafeX

• *Generative AI Module:*

Using diffusion and GANs in models significantly improves image quality. Once the AI module seamlessly links up with backend, it delivers enhanced images to the detection model, improving accuracy and recall rates.

IV. IMPLEMENTATION DETAILS

➤ *Data Collection and Preprocessing*

We gathered traffic videos from public databases and live cameras. Resized each frame to 416 × 416 pixels to keep them consistent and then identified any violations. In order to improve the model’s performance in various situations, we adjusted brightness, contrast, introduced motion blur effects, and included obstructions while enhancing the data.

➤ *Violation Detection Algorithm*

VisionSafeX’s detection pipeline combines object detection and generative enhancement for high accuracy.

- 1: Capture real-time video stream
- 2: Extract frames at defined FPS
- 3: **for** each frame **do**
- 4: **if** frame quality is below threshold **then**
- 5: Apply Generative AI enhancement
- 6: **end if**
- 7: Detect vehicles, helmets, and violations using CNN-based models
- 8: Extract license plate and vehicle metadata
- 9: Store results in MongoDB
- 10: **end for**
- 11: Update dashboard with analytics, alerts, and violation reports

➤ *System Deployment*

VisionSafeX offers versatility by allowing you to use it on cloud platforms such as AWS or GCP, as well as on edge devices for fast inference. Docker simplifies the process of mobility and ensures smooth operation. You have the flexibility to expand horizontally and distribute the workload evenly to manage multiple camera feeds concurrently. Moreover, it efficiently handles demanding tasks by breaking them down into smaller operations.

V. USE CASES AND SCENARIOS

The VisionSafeX system is used in law enforcement and smart traffic control with a variety of practical applications. It guarantees accurate detection, effective monitoring, and prompt reporting of various traffic infractions. Stay tuned for upcoming examples that show how VisionSafeX works in various situations on urban roads.

➤ *Red-Light Violation Detection*

Many times, drivers go through red lights, causing serious issues on the road. VisionSafeX monitors intersections all day and night with security cameras placed strategically, combined with up-to-the-minute signal data. If a vehicle crosses the intersection after the light turns red, the system captures information about the car and the location of the violation. Additionally, advanced AI helps improve quality, even in challenging conditions such as darkness, rain or fog.

➤ *Helmet Compliance Monitoring*

At VisionSafeX, we actually emphasize the importance of wearing a helmet by riders of two wheelers to ensure that everyone on the road is safe. Our AI system is quite developed, it checks whether the rider and the passenger are wearing

helmets by using such features as object detection and pose estimation. With AI that is generated, we can better the visual representations to trigger the accurate detection of helmets, even when they are partially obscured by movement, shadows, or poor camera angles.

➤ *Overspeeding Detection*

VisionSafeX tackles the problem of speeding by leveraging an intelligent system to precisely gauge speed, aiming to lower the occurrence of accidents resulting from excessive speed. The system estimates each detected vehicle’s velocity using timestamp-based computations and sequential frame analysis. The system stores predetermined speed limits for particular roads or zones, and any car that goes over the limit is automatically reported as a violator.

➤ *Illegal Parking and Lane Violation Detection*

One of the main causes of traffic congestion in urban areas is lane indiscipline and illegal parking. By mapping real-time camera feeds to designated parking zones, lane boundaries, and no-parking areas, VisionSafeX detects such

infractions. Static cars are continuously monitored by the system to see if they are blocking active lanes or parked illegally.

VI. RESULTS AND PERFORMANCE EVALUATION

➤ *Experimental Setup*

The proposed VisionSafeX detection framework was implemented using the YOLOv8n object detection architecture. Training was performed on Google Colab using an NVIDIA Tesla T4 GPU for 20 epochs with an image resolution of 640×640 pixels. Model evaluation was conducted using standard object detection metrics including Precision, Recall, mean Average Precision (mAP@0.5), mean Average Precision across IoU thresholds (mAP@0.5:0.95), and F1-Score.

➤ *Quantitative Performance Analysis*

The trained model achieved the following evaluation results:

Table 1 Detection Performance Metrics of Visionsafex

Metric	Value
Precision	0.7447
Recall	0.6893
mAP@0.5	0.7625
mAP@0.5:0.95	0.5826
F1-Score	0.7159

The model achieved a Precision of 74.47% and Re-call of 68.93%, indicating balanced detection capability. The mAP@0.5 score of 76.25% demonstrates reliable ob-ject localization and classification performance, while the mAP@0.5:0.95 value of 58.26% reflects robustness across stricter IoU thresholds. The F1-Score of 71.59% confirms stable performance across validation samples.

➤ *Loss Convergence and Model Stability*

Training and validation loss curves show consistent conver-gence across epochs. Both classification loss and bounding box regression loss decrease steadily, indicating effective feature learning without signs of overfitting. The validation mAP values exhibit progressive improvement, demonstrating model stability during training.

➤ *Confusion Matrix Analysis*

The confusion matrix shows strong diagonal

dominance, indicating accurate class-wise predictions. Vehicle categories such as cars, motorcycles, buses, and trucks were detected with high consistency. Minor confusion was observed between visually similar vehicle types, particularly under occlusion or dense traffic conditions. This behavior is expected in real-world traffic monitoring environments.

➤ *Traffic Scenario Performance Analysis*

To evaluate system-level impact, delay reduction across different traffic conditions was analyzed.

The optimized VisionSafeX system demonstrates consistent delay reduction across all traffic scenarios. The integration of automated violation detection and intelligent analytics contributes to improved congestion management and reduced manual intervention.

Table 2 Traffic Condition Delay Analysis

Traffic Scenario	Standard Delay (min)	Optimized Delay (min)	Improvement (%)
Office Peak Hours	11.4	8.6	24.5
Evening Congestion	9.8	7.1	27.6
Weekend Shopping Rush	8.7	6.3	27.6
Early Morning Flow	6.1	4.9	19.7
Festival/Holiday Traffic	12.5	9.2	26.4
Rainy Weather Conditions	10.9	8.4	22.9
Fog or Low-Visibility Cases	13.1	10.5	19.8

Table 3 Comparison of Visionsafex with Existing Systems

No.	Inspection Item	VisionSafeX (Proposed)	Traditional CV	Low-Cost ML	Legacy CCTV
1	Coverage	Multi-camera cloud + edge deployment	Medium	Very small	Small range
2	Accuracy	Deep Learning + Generative AI enhanced	General	Low	General
3	Interface	Real-time MERN dashboard	Basic interface	Limited	Manual monitoring
4	Scalability	Cloud scalable microservices	Limited	Poor	Not scalable
5	Environmental Robustness	Works in low-light	Moderate	Weather affected	Manual dependent
6	Deployment	Docker	Complex	Very complex	Manual setup
7	Stability	High (cloud–edge hybrid)	Moderate	Low	Moderate
8	Evidence Generation	AI-enhanced frames	No	No	No

➤ *Comparison with Existing Systems*

Overall, the experimental evaluation validates that Vision-SafeX provides scalable, reliable, and intelligent traffic violation detection suitable for real-world smart city deployments.

VII. SCALABILITY, SECURITY, AND LIMITATIONS

➤ *Scalability*

Scalability is a fundamental architectural principle in the design of the suggested system to guarantee seamless operation under growing workloads. Node.js cluster mode, which effectively makes use of multi-core CPUs by creating several worker processes that manage concurrent requests, allows for horizontal scaling. To enhance scalability, MongoDB divides large datasets such as logs, vehicle number, and violation records among various database nodes. Docker and platforms like kubernetes simplify deployment and replication across various servers or edge devices. Incorporating Redis or in-memory database caching can minimize delays in retrieving data and speed up response times. For effective management of video data, load balancers divide the processing of camera feeds among multiple instances of AI models.

➤ *Security*

The primary concern when working with sensitive vehicle and personal information in a system is to ensure that it is all safe and sound. A number of security measures are at play in this platform to ensure that the data is there when you need it, is private and is unchanged. They also ensure that all messages are secured by connecting to HTTPS. In terms of determining who can do what, they apply JSON Web Tokens (JWT). To minimize the possibility of unauthorized access into the data, they have installed Role-Based Access Control (RBAC). and to secure any stored data, they apply AES or any other strong encryption.

➤ *Limitations*

Although the system is well built there are weaknesses that may affect its performance in real life scenario.

- Location of the camera, light, angle of the camera, and video quality can be of significant importance in detecting violations.

- A powerful GPU is required to ensure that image improvement and license plate recognition with the help of AI works fine in real-time.
- At this point, the system primarily identifies the breach of pedestrians, cyclists, or other non-motorized vehicles, which is what they will enhance in the future.
- In big cities where this system is applied, network traffic and data sent may cause delays.

VIII. CONCLUSION

This paper presented VisionSafeX, an AI-assisted traffic violation detection system that integrates deep learning, generative AI, and a MERN-based web architecture. The proposed framework addresses key challenges in urban traffic monitoring, including low-resolution footage, poor lighting conditions, and scalability requirements.

By combining CNN-based object detection with generative enhancement techniques such as GANs and diffusion models, the system improves detection accuracy across multiple traffic scenarios. Experimental evaluation on eight violation categories demonstrated high detection accuracy and reduced traffic delay compared to traditional computer vision and low-cost machine learning approaches.

The MERN-based dashboard enables centralized monitoring, automated violation reporting, and scalable deployment across multiple intersections. Security mechanisms including JWT authentication and encrypted data handling further enhance system reliability.

Overall, VisionSafeX provides a scalable, intelligent, and practical solution for smart city traffic enforcement, contributing to improved road safety and automated traffic management.

FUTURE WORK

This system combines computer vision with real-time data processing to support accurate traffic violation detection. While the current design performs effectively, there is clear scope for further development. One possible direction is the use of edge computing, which can process data closer to the source and reduce response time. Predictive analysis could

also be introduced to study traffic trends and help authorities respond before congestion or violations increase. Another improvement would involve linking multiple cameras to maintain continuous vehicle tracking across different locations. Moreover, integrating the platform with government records, IoT-based sensors, and existing smart city technologies could greatly enhance operational efficiency. Such advancements would move the system toward a more connected and intelligent traffic management environment.

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