IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, June 2026
Impact Factor: 8.2

Design & Development of Secure Toll Access Control System

Anil Haushabal Bangar, Vishal Popatrao Hire, Rahul Shivaji Dolzake
Mahesh Navnath Landge, Prof. P. N. Wakchaure
Department of Mechanical Engineering
Vidya Niketan College of Engineering, Bota, Sangamner

Abstract: *This project focuses on the design and development of a Secure Toll Access Control System to improve toll collection efficiency and security. The system uses modern technologies such as image processing, IoT, and cloud database verification to automate toll operations. A camera captures the vehicle number plate, and Optical Character Recognition (OCR) extracts the registration number for identification. An ESP32 microcontroller controls the system, while a load cell sensor measures vehicle weight to detect overloaded vehicles. The extracted vehicle data is verified with a centralized database to check registration, insurance, PUC, and pending fines. Based on the verification results, the barrier gate automatically opens or remains closed. The proposed system reduces traffic congestion, minimizes human effort, improves accuracy, and enhances road safety. It also supports faster toll processing and provides a reliable solution for smart transportation infrastructure.*

Keywords: Secure Toll Access Control System, IoT, Image Processing, OCR, ESP32, Load Cell, Automated Toll Collection, Smart Transportation.

I. INTRODUCTION

The rapid growth in vehicle usage and highway transportation has increased the demand for efficient toll collection systems. Traditional toll booths often face problems such as long vehicle queues, traffic congestion, delays, and fuel wastage due to manual toll collection processes. These issues reduce transportation efficiency and create inconvenience for commuters and transport operators [1].

Conventional toll systems mainly focus on collecting toll fees and often lack proper mechanisms to verify vehicle-related information such as registration validity, insurance, Pollution Under Control (PUC) certification, and pending fines. This can allow unauthorized or non-compliant vehicles to use highways without proper monitoring, affecting road safety and regulatory control [2].

Recent advancements in IoT, image processing, and cloud computing have made it possible to develop intelligent toll systems with automated operations. Image processing and Optical Character Recognition (OCR) help in automatically detecting and reading vehicle number plates, eliminating the need for manual verification and improving accuracy and speed [3][4].

The integration of IoT-based sensors enables real-time monitoring and communication between system components. In addition, load cell sensors can be used to measure vehicle weight and identify overloaded vehicles, which are a major cause of road damage and accidents [5][6].

The Secure Toll Access Control System is designed to provide automated vehicle identification, weight monitoring, database verification, and gate control in a single platform. This system helps reduce congestion, improve security, minimize human errors, and support smart transportation infrastructure for future highway management [7].

II. PROBLEM STATEMENT

Conventional toll collection systems face several challenges such as traffic congestion, long waiting times, manual errors, revenue leakage, and inadequate vehicle verification. These systems often fail to efficiently check important

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, June 2026
Impact Factor: 8.2

compliance parameters like vehicle registration, insurance validity, Pollution Under Control (PUC) certification, pending fines, and overloading, which can compromise road safety and operational efficiency. The increasing number of vehicles on highways has further highlighted the need for a faster, smarter, and more secure toll management system. Therefore, there is a need to develop a Secure Toll Access Control System that uses automation, real-time monitoring, and intelligent verification to ensure efficient toll collection, improve security, reduce congestion, and enhance overall transportation management.

III. OBJECTIVES

- To design and develop a secure toll access control system for automated and efficient toll management.
- To implement automatic vehicle identification using image processing and Optical Character Recognition (OCR) for number plate detection.
- To integrate IoT-based monitoring for real-time communication between sensors, controllers, and the database.
- To detect overloaded and non-compliant vehicles by using load cell sensors and database verification.
- To reduce traffic congestion, manual errors, and toll processing time by enabling automated gate control and faster vehicle clearance.

IV. LITERATURE SURVEY

Vinodha et al. (2023) presented an IoT-based toll automation system in their study "Smart Toll Gate System Using IoT," where they integrated RFID, OCR, and cloud connectivity for automated toll collection. Their system reduced waiting time and improved transaction speed by enabling contactless toll processing. However, the system mainly focused on toll payment automation and had limited capability for advanced compliance verification such as insurance and overload detection.

Gobinath et al. (2018) proposed an automated toll collection model in "Automatic Toll Collection System Using OpenCV," where OpenCV and OCR techniques were used for vehicle number plate recognition. Their approach improved toll efficiency by eliminating manual toll operations and reducing operational costs. However, the system performance decreased under poor lighting and unclear number plate conditions.

Chaouki Tadjine et al. (2025) discussed computer vision applications in automation in their paper "Computer Vision in Warehouse Management Automation." They highlighted the importance of AI-based image recognition and real-time object detection for automated systems. Their work demonstrated high processing efficiency but required powerful hardware, increasing implementation cost for real-time applications.

Anusha et al. (2021) developed a smart transportation monitoring system using IoT sensors and embedded controllers for real-time vehicle tracking and traffic management. Their research showed that IoT improves communication between devices and enables efficient remote monitoring. However, system performance depended heavily on stable internet connectivity and cloud availability.

Kumar and Sharma (2022) proposed a vehicle overload detection system using load cell sensors and microcontroller-based processing for highway monitoring. Their system successfully identified overweight vehicles and helped reduce road damage and accident risks. However, calibration and sensor accuracy remained challenging under varying road conditions.

Patel et al. (2023) introduced a cloud-based vehicle verification system for intelligent transportation applications. Their system enabled real-time verification of registration, insurance, and traffic violation records using centralized databases. Although the approach improved transparency and security, concerns related to data privacy and server downtime remained significant.

Comparison Table

Author & Year	Method Used	Advantages	Limitations
Vinodha et al. (2023)	IoT + RFID + OCR	Fast toll processing, less	Limited compliance

		waiting time	verification
Gobinath et al. (2018)	OpenCV + OCR	Automatic number plate detection	Poor performance in low light
ChaoukiTadjine et al. (2025)	Computer Vision + AI	High detection accuracy	High hardware cost
Anusha et al. (2021)	IoT Sensors + Embedded System	Real-time monitoring	Depends on internet connectivity
Kumar & Sharma (2022)	Load Cell + Microcontroller	Detects overloaded vehicles	Sensor calibration issues
Patel et al. (2023)	Cloud Database Verification	Better security and transparency	Privacy and server issues

V. WORKING OF SYSTEM

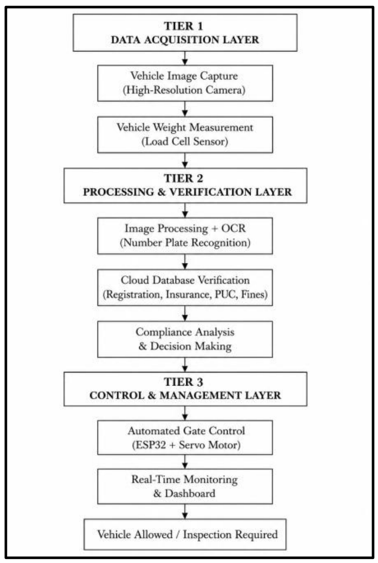

Fig 1: System Architecture

1. Data Acquisition Layer

This is the first stage of the system where vehicle-related data is collected using sensors and imaging devices. It gathers the necessary inputs for further processing.

2. Vehicle Image Capture (High-Resolution Camera)

A high-resolution camera is placed near the toll gate to capture the image of the approaching vehicle.

3. Vehicle Weight Measurement (Load Cell Sensor)

As the vehicle passes over the sensing platform, the load cell sensor measures its weight. This helps in identifying overloaded vehicles that may violate road safety regulations.

4. Processing and Verification Layer

In this stage, the collected image and weight data are processed and analyzed. The system verifies whether the vehicle satisfies all compliance requirements.

5. Image Processing and OCR (Number Plate Recognition)

The captured vehicle image undergoes image processing to improve clarity and remove noise.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 11, June 2026 Impact Factor: 8.2

6. Cloud Database Verification
The extracted registration number is matched with records stored in the cloud database. The system checks important vehicle details such as registration validity, insurance status, PUC certificate, and pending fines.

7. Compliance Analysis and Decision Making
After verification, the system analyzes all collected information including vehicle identity, weight, and legal compliance.

8. Control and Management Layer
This layer controls the overall operation of the toll system and manages communication between hardware and software components.

9. Automated Gate Control (ESP32 + Servo Motor)
The ESP32 microcontroller sends signals to the servo motor to control the gate barrier.

10. Real-Time Monitoring and Dashboard
All vehicle and system data are displayed on a monitoring dashboard in real time. This allows toll operators or authorities to monitor traffic flow and system performance efficiently.

11. Final Output: Vehicle Allowed / Inspection Required
Finally, the system provides the output decision. Compliant vehicles are allowed to pass through the toll gate, while non-compliant or overloaded vehicles are redirected for further inspection.

V. SYSTEM DESIGN

1. System Overview
The system begins when a vehicle approaches the toll plaza. A high-resolution camera captures the vehicle image, while a load cell sensor measures its weight. The captured image is processed using image processing techniques and OCR to extract the vehicle registration number. This extracted data is then sent to a cloud database where important vehicle details such as registration status, insurance validity, PUC certificate, and pending fines are verified. Simultaneously, vehicle weight is checked against permissible limits. After analyzing all collected information, the system makes a decision. If the vehicle satisfies all requirements, the ESP32 microcontroller activates the servo motor to open the barrier gate. Otherwise, the vehicle is stopped for inspection. All system activities are monitored in real time through a dashboard.

2. Components of the System
1. High-Resolution Camera

Fig 2: High-Resolution Camera

The camera captures images of vehicles entering the toll lane. It provides clear images for number plate detection and vehicle identification.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, June 2026
Impact Factor: 8.2

2. Load Cell Sensor

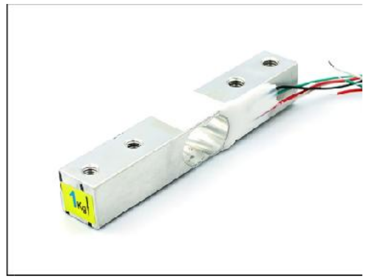

Fig 3: Load Cell Sensor

The load cell sensor measures the weight of the vehicle. It helps identify overloaded vehicles that may damage roads or violate regulations.

3. ESP32 Microcontroller

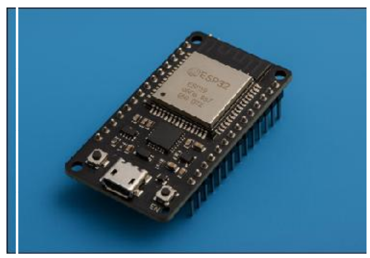

Fig 4: ESP32 Microcontroller

ESP32 acts as the central controller of the system. It receives sensor data, processes commands, and controls gate operation.

4. OCR Module

The OCR module converts the captured number plate image into machine-readable text, enabling automatic vehicle identification.

5. Cloud Database

The cloud database stores vehicle-related records such as registration details, insurance status, PUC validity, and fine history for verification.

6. Servo Motor and Barrier Gate

Fig5: Servo Motor

The servo motor controls the opening and closing of the toll barrier gate based on system decisions.

DOI: 10.48175/568

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, June 2026
Impact Factor: 8.2

7. Monitoring Dashboard

The dashboard displays real-time vehicle data, verification status, toll activity, and overall system performance for monitoring and management.

8. Power Supply Unit

Fig 6: Power Supply Unit

The power supply provides stable electrical power to all hardware components for continuous operation.

Overall, the system design ensures secure access control, fast toll processing, reduced congestion, and improved traffic management.

VII. RESULTS

The experimental evaluation of the proposed Secure Toll Access Control System was carried out to analyze its performance in real-time toll management applications. The system was tested based on key parameters such as number plate recognition accuracy, vehicle weight detection, automated gate operation, system response time, and overall reliability. The obtained results demonstrate the efficiency, accuracy, and practical feasibility of the developed system.

OCR Performance Analysis

The performance of the Optical Character Recognition (OCR) module was evaluated using multiple vehicle number plates under different environmental conditions, including variations in lighting and plate orientation. The results shown in Fig. 7 indicate that OCR accuracy ranged from 94% to 97% for all test cases. The highest accuracy of 97% was observed for Vehicle 4, while the lowest accuracy of 94% was recorded for Vehicle 3. Minor variations in accuracy were mainly caused by poor illumination and slight misalignment of number plates. Despite these variations, the OCR module demonstrated consistently high recognition performance, making it suitable for reliable vehicle identification in real-time toll operations.

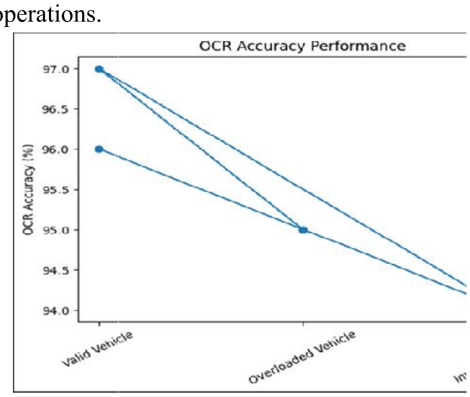

Fig 7: OCR Performance Analysis

DOI: 10.48175/568

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, June 2026
Impact Factor: 8.2

Vehicle Weight Detection Analysis

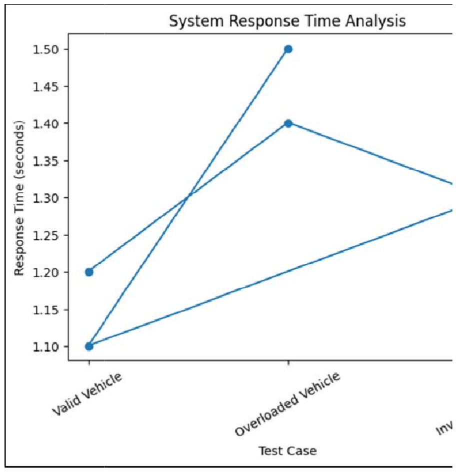

Fig 8: System Response Time Analysis

The vehicle weight detection subsystem was tested to evaluate its capability to oaded vehicles.

Gate Control Performance

The automeasure vehicle load and identify overloaded vehicles accurately. The measured weights were compared with the predefined permissible limit of 1000 kg, as shown in Fig. 8. Vehicles A, C, and E recorded weights below the permissible threshold and were classified as normal vehicles. Vehicles B and D exceeded the limit and were identified as overloaded vehicles. The load cell sensor provided stable and accurate measurements during repeated testing. These results confirm the effectiveness of the weight detection module in improving safety and reducing road damage caused by overlmated barrier gate mechanism was analyzed based on verification and compliance results. Gate operation depended on the combined output of OCR recognition, database verification, and weight analysisthe barrier gate opened only for valid and compliant vehicles, while it remained closed for overloaded vehicles or vehicles with invalid documentation. The servo motor-controlled gate operated smoothly without any mechanical delay or operational failure. This demonstrates the reliability and effectiveness of the automated access control mechanism.

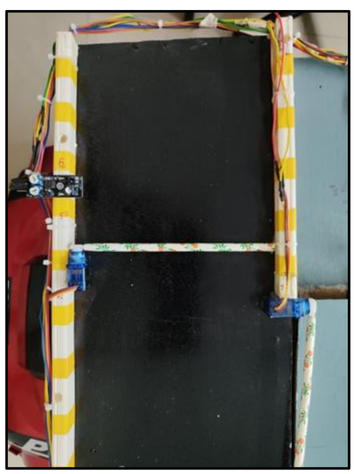

Fig 9: Model View 1

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Volume 6, Issue 11, June 2026
ISSN: 2581-9429
Impact Factor: 8.2

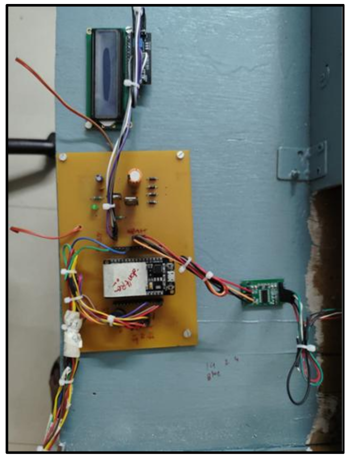

Fig 10: Model View 2

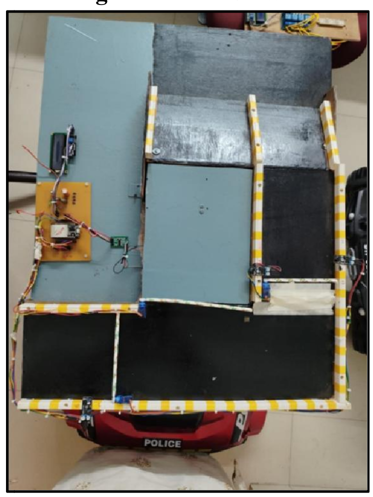

Fig 11: Model View 3

Overall Discussion

The experimental results confirm that the proposed Secure Toll Access Control System successfully achieved its intended objectives. The system demonstrated high OCR accuracy, reliable overload detection, fast response time, and stable communication among all integrated components. By combining image processing, IoT communication, cloud-based verification, and automated gate control, the developed system significantly improves toll collection efficiency, enhances security, reduces manual intervention, and supports modern smart transportation infrastructure.

VIII. CONCLUSION

The Secure Toll Access Control System developed in this study successfully demonstrated an efficient and intelligent approach for modern toll management. By integrating image processing, Optical Character Recognition (OCR), IoT communication, cloud-based verification, and automated gate control, the system enabled accurate vehicle identification, overload detection, and real-time compliance verification. The experimental results showed high OCR accuracy, reliable weight measurement, fast response time, and stable communication among all system components. The proposed system effectively reduces traffic congestion, minimizes human intervention, improves security, and enhances operational efficiency at toll plazas.

DOI: 10.48175/568

ISSN 2581-9429 IJARSCT

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, June 2026
Impact Factor: 8.2

IX. FUTURE SCOPE

The proposed Secure Toll Access Control System can be further enhanced by integrating advanced technologies to improve accuracy, security, and scalability. In the future, Artificial Intelligence (AI) and Machine Learning (ML) algorithms can be incorporated to achieve more accurate vehicle recognition and predictive traffic analysis. The system can also be integrated with blockchain-based payment systems to ensure secure and transparent financial transactions. Additional features such as facial recognition, thermal cameras, GPS tracking, and automatic e-payment gateways can strengthen security and user convenience. Integration with smart city infrastructure and intelligent traffic management systems can enable centralized monitoring and better traffic flow control. Furthermore, cloud analytics and big data techniques can be used to analyze traffic patterns and support infrastructure planning, making the system more efficient and suitable for large-scale highway deployment.

REFERENCES

1. Digital Image Processing — Rafael C. Gonzalez, Richard E. Woods, 4th Edition, Pearson, 2018.
2. Computer Vision: Algorithms and Applications — Richard Szeliski, Springer, 2022.
3. Internet of Things: A Hands-On Approach — ArshdeepBahga, Vijay Madisetti, Universities Press, 2015.
4. Embedded Systems with ARM Cortex-M Microcontrollers — Yifeng Zhu, E-Man Press, 2017.
5. Vinodha D., Keerthana A.P., Sangeetha T., Surekha N., “Smart Toll Gate System Using IoT,” Special Issue on Computer Applications, 2023.
6. Gobinath S., Prakash A., Aravindan S., Bavadharani N., Karthika I., “Automatic Toll Collection System Using OpenCV,” JETIR, Vol. 5, Issue 3, 2018.
7. ChaoukiTadjine et al., “Computer Vision in Warehouse Management Automation,” Engineering Applications of Artificial Intelligence, Elsevier, 2025.
8. Institute of Electrical and Electronics Engineers, “IoT in Intelligent Transportation Systems,” IEEE Access, 2021.
9. Patel R., Sharma K., “Cloud-Based Vehicle Verification System,” International Journal of Smart Transportation, 2023.
10. Kumar S., Sharma P., “Vehicle Overload Detection Using Load Cell Sensors,” International Journal of Engineering Research, 2022.
11. OpenCV Documentation.
12. Tesseract OCR Documentation.
13. ESP32 Documentation
14. Arduino IDE Documentation
15. Firebase Documentation
16. International Organization for Standardization Standards for Intelligent Transportation Systems.
17. Ministry of Road Transport and Highways Toll Management Reports.
18. National Highways Authority of India (NHAI)
19. Intelligent Transportation Systems Research Papers, Elsevier.
20. Society of Automotive Engineers Technical Papers on Smart Mobility