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Smart Toll Collection: Study of AI-Driven Approaches

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Abstract
Smart Toll Collection systems are transforming conventional toll operations by addressing challenges such as traffic congestion, long queues, manual errors, and high operational costs. This survey paper reviews AI-Driven approaches that integrate real-time license plate detection using deep learning models like YOLO, Optical Character Recognition (OCR) techniques such as Tesseract and EasyOCR for vehicle identification, and IoT-based automation for seamless toll processing. These systems leverage edge computing platforms such as Raspberry-Pi to enable real-time image processing, database verification, automated payment deduction, and intelligent gate control using sensors and actuators. By minimizing human intervention and enhancing accuracy under varying environmental conditions, AI-Driven toll collection frameworks significantly improve efficiency, transparency, and scalability within modern intelligent transportation systems.

Keywords: *AI-Driven Toll Collection System; Automatic Number Plate Recognition (ANPR); YOLO Object Detection; OCR (Optical Character Recognition); Raspberry-Pi; Vehicle Detection; Ultrasonic Sensor; DC Motor Gate Automation; IoT-Based Toll Collection*

1. Introduction
The rapid growth of vehicular traffic has increased the demand for efficient, secure, and automated toll collection systems. Toll collection systems in India and many other countries still rely heavily on manual operations or semi-automated RFID-based systems, which often lead to long queues, delays, human errors, and operational inefficiencies. With the rapid growth of vehicles on roads, the need for a fast, intelligent, and fully automated toll management system has become essential. An AI-Driven vehicle toll collection system that replaces manual toll booths with a smart, contactless, and automated solution using advanced computer vision and IoT technologies.The system uses a camera to capture images of incoming vehicles and employs a YOLO based object detection model to accurately identify and extract number plates from the captured frames. The detected number plate is then processed using OCR (Optical Character Recognition) to convert the image into machine-readable alphanumeric text. The extracted number is matched with a vehicle database, and toll deduction is carried out automatically through a pre-linked digital account. In addition, IoT hardware components such as ultrasonic sensors, DC motors, LCD display, and buzzer work in coordination with the Raspberry-Pi to detect vehicle presence, automate gate operation, display system status, and trigger alerts. The system also sends automated email notifications to vehicle owners after each toll transaction, ensuring transparency and digital record-keeping. By integrating AI algorithms, OCR technology, embedded automation, and cloud communication, it demonstrates a modern, efficient, and scalable approach to smart toll collection.

2. Literature Survey
Wiput Puisamlee Andrathachaichawuthai's Vehicle Make Model Recognition (VMMR) is widely used in Intelligent Transportation Systems (ITS), free-flow image-based toll systems, and enforcement systems. Front-end car photographs need to be processed and examined in order for these technologies to be utilized as evidence. Convolutional Neural Networks (CNN) are widely used for image classification and VMMR applications. More internal parameters and intricate model architectures are needed to improve classification accuracy with many classes. Among the issues were larger models and longer processing times. Investigating and creating a smaller CNN

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model that can be utilized on low-resource devices, like embedded computers and computer cameras, to identify the type of car from a front view image is the aim of this work [1]. To solve the problem of the inability to fully and accurately recognize number plate information in bad weather, Zilu Wang proposes an algorithm based on environmental perception and enhanced recognition of number plate information. We developed an Enhanced Transformer Block (ETB) and a histogram YOLO (H-YOLO) detector based on the YOLOv11 framework to improve the extraction of regional properties of the number plates in complex situations. Meanwhile, a Real Time Weather Aware Image Enhancement Module is developed that uses real-time environment awareness technology to improve image quality and dynamically adjust the image enhancement technique in response to changing weather conditions. The detection architecture was optimized using thresholding and distinct image enhancement of the plate region [2]. S. Hemalatha studied the application of Number Plate Recognition (NPR) in a Dynamic Toll Collection System, a ground-breaking advancement in charge collection and toll booth management. The main elements of this system include automatic payment gates, secure payment processing techniques, strategically positioned high-resolution cameras at toll booths, a large database containing vehicle and toll rate data, and NPR software that precisely scans license plates. As a car approaches the toll booth, its license plate is captured by the system's cameras. The quality of the camera can be used to measure distance. License plate photos can be taken both during the day and at night, and the data can be analyzed as an image [3]. One of the primary causes of catastrophic injuries in motorcycle accidents, according to Chunduru Anilkumar, is not wearing a helmet, highlighting the need for effective measures to encourage helmet use. To stop these frequent violations of business regulations, regular inspection is necessary. The proposed technology is meant to detect motorbike riding without a helmet violations in India. YOLO and OCR non-helmet riders for object detection and license plate number extraction using learning [4]. Twana Mustafa's research indicates that the advancement of deep learning has revolutionized computer vision and enabled real-time analysis, which is crucial for traffic control and vehicle identification. In order to obtain a record-breaking 97.5% accuracy rate, this study provides a system that combines Automatic Number Plate Recognition (ANPR) with vehicle make and model detection. This study integrates both components into a single, cohesive system, providing a more complete and efficient solution for vehicle identification and ensuring dependable performance even in bad weather, in contrast to traditional methods that focus on either make and model detection or ANPR separately [5]. In the context of increasing automation and intelligence in rail transportation, Xiaofeng Huang claims that accurate identification and detection of Overhead Contact System (OCS) mast number plates are crucial for ensuring train safety. Due to problems including scale variations, motion blur, and lighting variations, which have shown flaws in the precision and processing speed of current techniques, feature extraction has grown increasingly difficult. To solve these challenges, we developed a YOLO-M4ST algorithm especially for railway applications. This system enhances detection and recognition capabilities by utilizing the VTR architecture and upgrading YOLOv8 [6]. The Smart GPS-based Toll Collection System that Dr. A. Naveena suggested is a big step in the right direction toward meeting this pressing requirement. By combining GPS technology with an Arduino board, this innovative approach revolutionizes toll collection processes. On highways, users can be charged exactly for the distance they travel, preventing overpaying and offering a more equitable tolling experience. In order to precisely compute the distance and toll fees and display the results on an LCD, this system uses a GPS-based distance algorithm to identify entry and departure coordinates. Toll computations are transparent and reliable thanks to real-time computing on an Arduino board [7]. In response to the accuracy and speed issues with the traditional license plate identification method, Hengliang Shi reviewed an end-to-end deep learning model for license plate location and recognition in natural circumstances. First, we improved the You Only Look Once (YOLOv5) down sampling process's channel attention mechanism. Additionally,

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position information is supplied to lessen the information loss from sampling [8]. A clever automated toll collection system built on Internet of Things (IoT) technology was presented by Dr. Rupali A. Zamare. The technology automates vehicle identification and toll collection by combining IoT connectivity with image processing algorithms. The technology facilitates smooth data flow between central servers and toll infrastructure by combining sensors and communication modules. The suggested approach minimizes traffic congestion at toll booths while lowering labor requirements. It is transparent, economical, and efficient. [9]. Shan Luo demonstrated a deep learning-based automobile license plate identification system. The suggested approach creates a comprehensive end-to-end deep learning framework by combining an enhanced YOLOv5m model for license plate identification with LPRNet for character recognition. Intelligent transportation systems and automated vehicle monitoring can benefit from this integrated architecture's excellent identification accuracy and performance, which removes the need for numerous intermediate processing stages [10]. An intelligent toll collection system for moving cars in India was proposed by Rajeev Kumar Chauhan. To detect cars going through toll booths, the system combines license plate localization techniques with an Automatic Toll Collection prototype. A vehicle database is connected to the detected license plate data, allowing for automatic toll deduction from the corresponding account. This method shows that automated toll debiting is feasible while guaranteeing precise vehicle identification and minimizing operator intervention [11]. For vehicle access control applications, Muhammad Usman presented an Automatic Number Plate Recognition (ANPR) pipeline based on deep learning. In order to increase dependability, the system uses front and rear vehicle recognition algorithms in addition to YOLOv4 object identification to identify cars and license plates. Deep learning models like AlexNet and R-CNN are used for character recognition. The pipeline successfully detects and recognizes license plates, especially in restricted spaces like parking lots and locked building doors [12]. Using information from Automatic License Plates, Xinyi Qi suggested a technique for reconstructing vehicle trajectories in urban traffic networks systems for recognition (ALPR). The study examined vehicle movement patterns throughout the network using ALPR data gathered from several traffic monitoring locations. The author used an enhanced K-Shortest Path (KSP) method, which calculates the most likely paths followed by vehicles between observation points, to reconstruct incomplete vehicle trajectories. In order to promote improved traffic analysis, urban planning, and intelligent transportation system applications, our method greatly improves the accuracy of reconstructing incomplete vehicle trajectories [13].

Table 1 Literature Review Summary

Author & Year	SUMMARY TABLE		
	Purpose	***Technology Used***	***Accuracy***
Wiput Piusamlee Andratheachaikna wuth (2025) [1]	Vehicle make recognition from frontal vehicle images with reduced model size	1) Convolutional Neural Network (CNN) 2) Model optimization for embedded systems	Reduced model size with efficient performance suitable for resource-limited devices
Zilu Wang (2025) [2]	License plate information recognition under varying environme ntal conditions	1) Histogram YOLO (H-YOLO) 2) YOLOv11-based Deep Learning framework	Improved recognition accuracy compared to standard YOLO Models
S. Hemalatha (2024) [3]	Dynamic toll collection using automatic number plate recognition	ANPR system Optical Character Recognition (OCR) Secure payment with OTP verification	Accurate number plate recognitio n and secure automated toll collection
Chunduru Anilkumar (2024) [4]	Detection of non- helmeted motor riders and license plate recognition	YOLO for object detection OCR for license plate extraction	Higher efficiency and accuracy in violation detection
Xiaofeng Huang (2024) [6]	Automated recognition of OCS mast number plates in railway scenarios	1)YOLOv8 framework 2)YOLO-M4ST algorithm 3)MobileNet V 4 backbone 4)C2f-Star module	Improved inference speed and feature extraction while maintaini ng

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		5)VTR integration	high detection accuracy
Dr. A. Naveena (2024) [7]	Smart GPS-based electronic toll collection system	GPS distance algorithm Arduino-based ETC system LCD display	Enables real-time toll calculation with improved efficiency
Hengliang Shi (2023) [8]	License plate detection and recognition in natural scenes	1)Improved YOLOv5 2)Channel attention mechanism GRU	Enhanced accuracy and speed in complex environments
Dr. Rupali Zamare (2023) [9]	Smart automated toll collection	1) IoT-based system Image processing techniques	Low-cost, efficient system ensuring transparency and reduced manpower
Shan Luo (2022) [10]	Car license plate recognition system	1) Improved YOLOv5m LPRNet End-to- end deep learning	High recognition on Performance with end to end processing
Rajeev Kumar Chauhan (2021) [11]	Intelligent toll collection system for moving vehicles in India	1) Automatic Toll Collection prototype 2) License plate localization 3) Vehicle database linkage	Successfully identifies vehicles and supports automated toll debiting
Muhammad Usman (2022) [12]	Deep learning-based ANPR pipeline for vehicle access control	1)YOLOv4 object detection 2) Front/ rear vehicle detection 3) AlexNet / 0R-CNN for recognition	Effective license plate detection and recognition under access-control scenarios
Xinyi Qi (2021) [13]	Vehicle trajectory reconstruction in urban traffic networks	1)Automatic License Plate Recognition data 2) Improved K-Shortest Path (KSP)	Improves reconstruction of incomplete vehicle trajectories

3. Conclusion And Future Work

Smart Toll Collection Systems have emerged as a significant advancement in Intelligent Transportation Systems (ITS), offering an effective solution to challenges associated with conventional toll collection methods such as traffic congestion, long waiting times, manual errors, and operational inefficiencies. This survey reviewed recent research on AI-driven toll collection technologies, including Automatic Number Plate Recognition (ANPR), YOLO-based object detection models, Optical Character Recognition (OCR), deep learning frameworks, IoT-enabled automation, and embedded computing platforms. The literature demonstrates that modern AI techniques have substantially improved vehicle detection and license plate recognition accuracy, even under challenging conditions such as poor lighting, adverse weather, and high-speed vehicle movement. Advanced models such as YOLOv5, YOLOv8, YOLOv11, CNN-based recognition systems, LPRNet, and GRU-based architectures have enabled reliable real-time identification of vehicles while maintaining high computational efficiency. Furthermore, the integration of IoT devices, sensors, GPS technology, and cloud-based communication has facilitated automated toll deduction, intelligent gate control, and transparent transaction management. The surveyed studies collectively indicate that AI-driven toll collection systems can significantly reduce human intervention, improve operational efficiency, enhance security, and support scalable deployment in smart city infrastructures. However, challenges remain in terms of handling varying environmental conditions, ensuring data privacy and cyber security, managing large-scale databases, and optimizing computational requirements for edge devices. Future research should focus on developing more robust and lightweight deep learning models, integrating edge AI and 5G communication technologies, strengthening security mechanisms, and enabling fully barrier-free tolling systems. The convergence of artificial intelligence, IoT, cloud computing, and intelligent transportation technologies is expected to play a vital role in building next-generation toll collection systems that are efficient, reliable, cost-effective, and user-friendly.

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