

An overview review of a highway toll plaza

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Abstract - The effective design and management of highway toll plazas are crucial to reducing traffic congestion and guaranteeing smooth vehicle movement. This study presents a complete analysis of toll plaza systems, emphasizing their design, functioning, and influence on traffic management. It looks at several toll collecting methods, such as manual toll booths, Electronic Toll collecting (ETC), and Automatic Vehicle Identification (AVI) systems. The report emphasizes the difficulties involved with toll plaza operations, including traffic delays, environmental effect, and cost efficiency. The report provides best practices for enhancing toll plaza performance using case studies and simulation models. The findings indicate that integrating sophisticated technology and implementing dynamic toll pricing may considerably improve the efficiency and sustainability of toll plazas.

Key Words: Global Navigation Satellite System (GNSS), Automatic Number Plate Recognition (ANPR), Radio-Frequency Identification (RFID), Waiting time, Toll plaza, FASTag.

1.INTRODUCTION

Manual toll collection and delayed processing have led to traffic congestion and long queues at toll plazas, posing a significant concern in India. This leads to excessive wait times and wasted fuel during toll collection. Additionally, this leads to increased pollution and slower highway speeds, potentially affecting the quality of food, particularly milk. Several countries, including Japan, Korea, and America, are conducting research in this sector. The paper discusses how an automated toll collecting system (ATCS) might reduce processing time for moving vehicles at toll plazas. ALPR uses image processing techniques to read a car's license plate while it is moving. Indian citizens have a unique identifying card, known as Aadhaar. The Indian government mandates that individuals link their cell phone number, bank account, and automobiles to their Aadhaar card. This article proposes a method for identifying the vehicle owner, linking their bank account to the registered license plate, and automatically deducting tolls from their associated

Aadhar card. In India, every car is linked to its owner's bank account, either directly or indirectly. Many countries have applied different methods for toll collections. Like travel time estimation and prediction (TTEP) and Global System for Mobile Communications (GSM) based car tracking, automatic vehicle identification, light mirror technique etc. But here is the most famous approach is electronic toll collection (ETC). Road Network in the Country: India has about 66.71 lakh km of road network, which is the second largest in the world. The length of various categories of roads is as under: National Highways: 1,46,145 km, State Highways: 1,79,535 km, Other Roads: 63,45,403 km. India's overall toll collection has increased by nearly 2.6 times in the past five years.

Table -1: Details of India's overall toll collection

Years	India's overall toll collection
2018-19	Rs 25,154.76 cr
2019-20	Rs 27,637.64 cr
2020-21	Rs 27,923.80 cr
2021-22	Rs 33,907.72 cr
2022-23	Rs 48,028.22 cr

Automatic number plate recognition systems record real-time vehicle counts and provide precise traffic patterns. Many automatic license plate identification systems include both still and video footage. Some are intended to photograph a vehicle accelerates, runs a red light, or makes the wrong turn. The recordings are stable in a range of camera positions and perspectives, as well as indifferent weather scenarios. Traffic departments and legal counsel can

Benefit from video footage. Serial traffic violators are identified Licence plate recognition. The technology also helps with reactive security. Inspections, forensics, investigations, and legal actions are all instances of this.

However, there are some downsides. Automatic license plate identification eliminates the need to manually record digits, saving time. The registration number might be difficult to discern, especially in fast-moving traffic.

1.1 Manual Toll Collection

Manual toll collection has been a common method of collecting fees for road usage for many decades. Early Years, Toll roads date back to ancient times, with the Romans using tolls on their roads. In 19th Century, The first modern toll roads appeared in the U.S. in the early 1800s, often operated by private companies. Where in 20th Century, Growth of the Highway System: The rise of automobiles in the early 20th century led to a significant expansion of toll roads, particularly in the U.S. and Europe.

Manual Collection Methods: Tolls were typically collected at booths where drivers would stop to pay cash to an attendant. This often caused congestion at busy times. Challenges are Traffic Delays, Manual toll collection frequently led to delays and bottlenecks, especially during peak travel times, cost and Labor: Staffing toll booths required a significant labor force, contributing to operational costs.

1.2 FASTag-RFID Collections

The National Highways Authority of India operates FASTag, an electronic toll collecting system in India. It uses Radio Frequency Identification technology to collect toll payments directly from the prepaid or savings account linked to it, or from the toll owner. There is no need to stop at tollgates, regular travelers can convert monthly passes into FASTag passes and improves the environment by reducing the consumption of paper. FASTag was introduced in 2014 and becomes obligatory on all vehicles in December 2020.

The technology uses Radio Frequency Identification (RFID) to automatically debit toll costs from a connected prepaid account. A FASTag is attached to the vehicle's windshield. As the car nears a toll plaza, the RFID scanner reads the tag. The toll money is taken automatically from the user's associated account, with no need to stop. This has cut wait times, fuel waste, and increased transparency. Vehicle owners must get FASTags to avoid penalties when traveling on national highways.

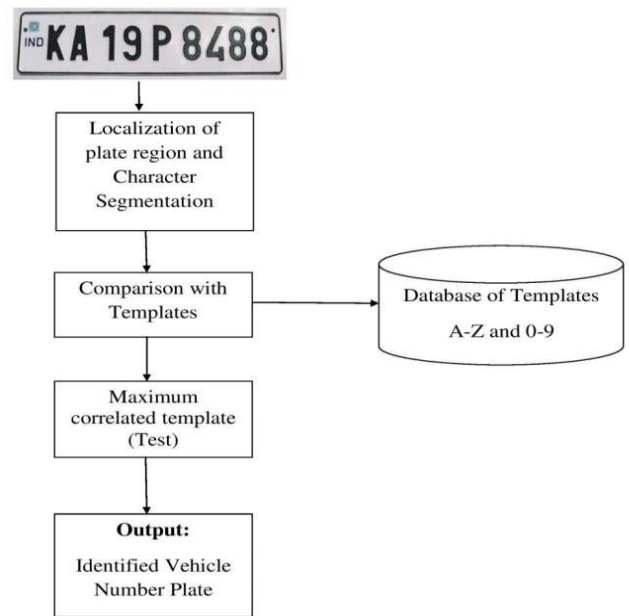


Fig -1: Smart Plate Recognition: Automated License Detection & Matching System

1.3 Global Navigation Satellite System (GNSS)

Toll collecting systems rely heavily on GNSS technology, especially with the advent of electronic toll collection (ETC) systems. Here's how GNSS is used:

- Automatic Vehicle Identification: GNSS enables the automatic identification of vehicles as they approach toll plazas. This allows for faster and more efficient toll collecting, without the need for manual involvement.
- Distance-Based Tolling: With GNSS, charges are determined based on the distance traveled on toll roads rather than fixed toll booths. This approach encourages fair pricing based on real consumption.
- Real-Time Tracking: GNSS allows for real-time vehicle tracking, which aids in traffic flow monitoring and toll point congestion management. This information may also be utilized to optimize road maintenance and planning.
- Integration with Other Systems: GNSS may be integrated with mobile applications and electronic wallets to provide smooth payment choices. Users can receive toll-charge notifications and pay immediately using mobile apps.
- Interoperability: GNSS technology facilitates interoperability among states and toll providers, allowing cars to access different toll roads without the need for numerous accounts or transponders.

- These innovations not only speed toll collecting, but also improve the overall efficiency of India's transportation system.

2. Benefits and Drawback

A detailed analysis of the advantages and disadvantages of toll collecting techniques in the past, present, and future:

Past (Manual Toll Collection)

Benefits:

Low upfront costs, Simple implementation, Personalized connection with toll collectors ,Simple to use for drivers

Demerits:

Time intensive, prone to human mistake, Security risks (theft and fraud),Limited payment choices, Congestion and lines.

Present (Electronic Toll Collection).

Benefits:

Reduced congestion, Increased efficiency, Improved safety, Enhanced user experience, Automated Payment Processing

Demerits:

Significant upfront expenses, Technical concerns and upkeep, Interoperability Concerns, Privacy Concerns (Data Collection),Dependence on Technology

Future (Automatic and Electronic Toll Collection)

Benefits:

Increased efficiency, Increased security, Better user experience , Automated payment processing, Real-time Traffic Management, Reduced congestion, Increased revenue collections

Demerits:

Significant upfront expenses, Technical concerns and upkeep, Cyber security risks, Dependence on sophisticated technologies, Potential for faults (system glitches)

3. Comparative Analysis

Evolution of Toll Collection Benefits

- Increased efficiency.
- Improved safety.
- Improved User Experience
- Automated Payment Processing
- Real-time Traffic Management

Evolution of Toll Collection Demerits

- Significant upfront expenses
- Technical concerns and upkeep.
- Security issues (theft, fraud, and cyber security)
- Dependence on technology
- Possibility of faults (human, system malfunctions)

Future Directions

- Integration of Intelligent Transportation Systems (ITS)
- Application of AI and Machine Learning (ML)
- Implementation of Block chain Technology
- Increased attention on cyber security.
- Developing more efficient and sustainable toll collecting mechanisms.

This comparative analysis focuses on the progress of toll collection methods, from manual to automated and computerized systems. While each approach has advantages and disadvantages, the future of toll collecting offers more efficiency, security, and automation.

Table -2: Comparative Analysis of Toll Collection

Years	Waiting Time	Source Used
1950 – 20's	14 -16 Min	Manual Collection
2014 Launched (2020 December Implemented) - 2025	47 Sec-5 Min (Approximate)	RFID (Radio Frequency Identification)
2025 - Future	10 Sec (Expected)	GSNSS (Global Satellite Navigation Systems And Services)

Key observations:

1. Significant decrease in wait time: from 14-16 minutes in the 1950s to 10 seconds in the future.
2. Technological developments increase efficiency: RFID cut waiting time by 75%, while GSNSS is predicted to lower it by 90% compared with RFID.

4. Auto Gate Toll System (Smart Vehicle Identification & Payment Flow):

The Smart Toll Pass system automates and streamlines toll collecting, employing vehicle recognition technology and real-time account management to enhance traffic flow and payment efficiency at toll gates. Traditional toll collecting techniques, which frequently rely on manual payments, can create substantial delays, contributing to traffic congestion and inefficiency. In contrast, the Smart Toll Pass technology

streamlines the procedure by identifying cars, validating registration status, checking account balances, and enabling automated payments. The flowchart that is being shown here shows the Smart Toll Pass system's intricate process flow. It describes how the system manages cars that are registered or unregistered, performs balance sufficiency checks, and opens toll gates in accordance with those operations. Toll collection may be completed smoothly with the help of an automated system, which even permits cars with low balances to pass while recording the status of their accounts for a future resolution. This guarantees a more effective, user-friendly passenger experience in addition to reducing congestion.

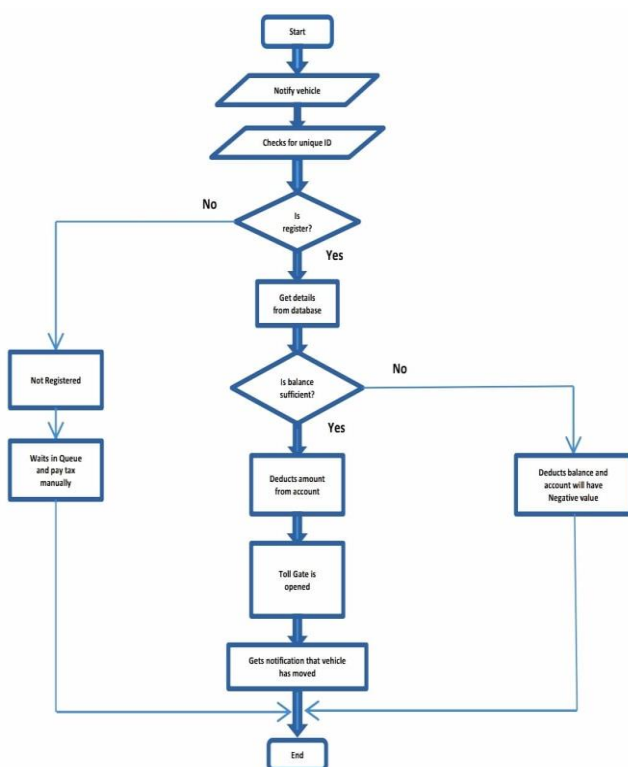


Fig -2: Auto Gate Toll System: Smart Vehicle Identification & Payment Flow

Working: This is a schematic that shows how a car goes through a toll gate. It demonstrates the procedures for determining whether the car is registered, making sure there is enough money in the account, and taking the toll out of the account. The gate opens and signals that the car has moved, marking the conclusion of the procedure. a flow diagram showing how the electronic toll collection method works. The procedure starts by alerting the car and then looks for a special ID. In the event that the ID is not registered, the flow leads to a manual payment queue. When a user registers, the system obtains information from a database. The chart determines whether the balance is adequate. If not, money is taken out of the account, leaving a negative balance. If there is enough balance.

Customer Experience: In today's fast-paced environment, customers expect speedy responses, therefore shorter wait times can dramatically increase customer satisfaction. **Operational Efficiency:** Shorter processing times can contribute to cost savings and improved resource allocation. **Future systems** are anticipated to use various technologies (RFID, GSNSS, and IoT) to provide even more efficient operations and increased analytical capabilities.

The investigation of the financial sustainability, cost-effectiveness, and revenue generation of toll systems is the focus of the Highway Toll Plazas Economic Analysis study. **Impact on Traffic Flow:** Evaluation of the effects of toll plazas on travel times, congestion levels, and traffic patterns. **Technological Integration:** Examining how improvements in electronic toll collection systems affect productivity and user satisfaction. **Environmental Considerations:** Examining possible sustainable practices and the ecological effects of tolling on the use of highways. **User Experience:** Research on how drivers feel, how satisfied they are, and how tolling affects various demographic groups socioeconomically. **Policy and Regulation:** Synopsis of the legal frameworks controlling tolling, incorporating equity considerations and pricing tactics. **Comparative Studies:** Assessment of toll systems across various nations or areas to find best practices and lessons discovered.



Fig -3: Automated Toll Management Systems: Case Study of FASTag Integration on Chennai Outer Ring Road

The image depicts a toll plaza, likely part of a highway in India, with multiple lanes of vehicles passing through. Prominent signage above the toll lanes indicates the operator, "Tamilnadu Road Development Company Limited" (TNRDC), and it specifies the location as "Chennai Outer Ring Road, Phase 1, Kolappanchery Toll Plaza." The toll plaza is equipped to handle vehicles of various sizes, from large trucks and freight carriers to smaller vehicles like jeeps and vans. The signage also displays technology systems like FASTag, indicating an automated toll collection system. Vehicles are seen queuing up for toll payment, with some

passing through lanes equipped for RFID-based tolling, denoted by FASTag/CASH signage, facilitating both automated and manual payments. The infrastructure appears modern, supporting a seamless toll-collection process, contributing to traffic management and reducing wait times.

3. CONCLUSIONS

Through the use of cutting-edge technology including Automatic Vehicle Identification (AVI) systems and Electronic Toll Collection (ETC), the research successfully emphasizes the need of enhancing toll plaza administration. The results show that integrating the Global Navigation Satellite System (GNSS), Radio Frequency Identification (RFID), and FASTag technologies may greatly reduce traffic congestion, increase fuel efficiency, and improve overall toll-collection efficiency.

In order to minimize environmental effect and provide a scalable and sustainable solution for toll plaza operations, the paper promotes the use of automated vehicle identification and dynamic toll pricing. Future developments in toll management, like as blockchain technology for secure transactions, artificial intelligence (AI)-driven traffic optimization, and satellite-based real-time tracking systems, have the potential to significantly improve the effectiveness, security, and usability of toll collecting systems.

Toll systems may provide a more efficient and sustainable highway infrastructure by adopting these technology advancements, which will enable them to handle both present and future traffic difficulties.

In conclusion, the analysis of the highway toll plaza reveals its critical role in managing traffic flow, generating revenue for infrastructure maintenance, and enhancing road safety. By examining operational efficiency, technological integration, and user experience, it becomes clear that ongoing improvements are necessary to address congestion and optimize service. Future initiatives should focus on adopting innovative payment systems, enhancing data analytics for traffic management, and ensuring user accessibility to create a more effective and user-friendly tolling experience. Ultimately, a well-managed toll plaza can contribute significantly to the overall efficiency of highway systems and the satisfaction of motorists.

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