Smart Toll Solutions for Indian Roads: Exploring the present & future

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Revision History

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Introduction

With the boom in infrastructure in India, Indian Government has planned to expand the existing Highway network as part of the National Highway Development Project (NHDP). Most of the stretches of these Highways are executed through a Public-Private Partnership (PPP) model and thus getting financed through Toll charges levied on the users of these Highways. Apart from National Highways, lots of city roads that provide connectivity to Highways are also being converted to Toll roads. And these Toll Roads have the Toll Plazas to check for entry and exit of vehicles and to collect toll based on the category of vehicles.

Most of the existing Toll booths currently have toll operator to collect the toll based on the vehicle type. And these toll booths are aided by sensor based vehicle classification system which help in auditing the collected toll. This way of verifying the amount collected in Toll booths is very tedious and error prone. Moreover even if the Vehicle classification data is available, it is used after the amount has been collected thus relegating to auditing purposes rather than for collecting the Toll amount. Such work flows create an opportunity for pilferage in Toll booths thus leading to huge losses to exchequer.

Since the tool booths control the economy of infrastructure companies and governments alike, there’s an implicit need to prevent pilferage in toll booths thus resulting in a need to automatically classify the vehicle before the toll gets charged for the commuter.

This paper shares some of the pitfalls of the existing Toll Solutions in the Indian market and proposes a solution that looks at automating some of the workflow in a toll booth and thereby reducing the pilferage in the Toll booths.

The following image shows the typical vehicle classification categories required by the National Highway Authority of India. The predominant vehicle classifications that are required are Cars (including Jeep and Van), LCV, HCV (Bus/Trucks) and Construction vehicles (HCM/EME). Some of the Highways (not shown in the image) do exempt two and three Wheelers and farm vehicles.

Figure 1: Notice board at a Toll Plaza
A typical Toll Solution consists of an ATCC system that classifies and counts the number of vehicles that enter the Toll booth.

1 ATCC – Traditional Systems

The traditional ATCC systems are either Induction Loop based or Piezo electric sensor based systems or a Combination of both.

1.1 Induction Loop and Weight based Systems

Induction loop [1] is a term used to describe an electromagnetic communication and detection system, relying on the fact that a moving magnet will induce an electrical current in a nearby conducting wire. Such an induction loop is installed under the road. When a vehicle moves over the loop, an electrical voltage is generated and thus adding to the count of the vehicle. The weight sensors provide the load of the vehicle thus aiding in vehicle classification.

1.2 Piezo electric sensor Based Systems

Piezo-electric sensors [2] are used to measure pressure exerted by the vehicles when they pass over the road. The sensors convert the resultant pressure into an electric voltage which is then used to count the vehicles.

For vehicle classification, Piezo electric Axle sensors are used in a permanent setup that is fixed on to the road. Dual Piezo electric sensors that are around 6ft long strips are embedded inside the road orthogonal to the direction of traffic. These sensors communicate the resultant voltage to an amplifier and an Analog to Digital Converter before sending it to micro controller which in turn classifies the vehicles based on the strength of the resultant voltage spikes. Typically a car would generate four distinct pulses i.e., one pulse/wheel. Each classifiable vehicle produces a unique set of pulses that
distinguish them from one another. Since each of the wheels produce the pulses, it’s possible to find the velocity of the vehicle based on the time difference between successive pulses

1.3 Combo Systems

There are ATCC systems available that use a combination Induction Loop, Piezo-Electric sensors and Height sensors. The following figure describes the installation done in Nelamangala, Bangalore

Figure 2: Traditional ATCC system

1.4 Challenges faced using Existing Systems

Most of the traditional ATCC systems that are based on a combination of Induction loop, Axle sensors suffer from the following inefficiencies.

- Lack of evidence
  - There are no image evidence available to back up the data collected by sensor based systems

- Difficult to achieve high degree of accuracy –
  - Over the years historically these systems are providing accuracy in the range from 85% to 90% [3]. The drop in accuracy is contributed by mainly by the following factors.
- Multi axle vehicles sometimes cause Induction Loops to generate inaccurate pulses thus dropping the accuracy.
- Single loop detectors normally cannot classify vehicles because of differences in vehicle speeds and lengths, a long vehicle moving quickly could appear the same as a shorter vehicle moving slowly.

- Post Classification
  - These systems provide vehicle classification outputs only after the vehicle has left the Toll booth. This information can be used at best for auditing and not for preventing any pilferage.

- Maintenance
  - The traditional sensors need to be cleaned and maintained on a regularly basis [4]. The typical shelf life of these sensors is around 4-5 years if maintained well. Most of the manufacturers provide only 1 year warranty [5] for these systems.

- Lack of portability
  - The biggest disadvantage of such a system is the portability. Since installing and maintaining such a system involves lot of civil work, these end up being permanent setups. These systems are time consuming to install and require sufficient man power.

2 TollAssist - MindTree’s Vision based Toll Solution

TollAssist - A vision based Toll Assistance Solution from MindTree consists of two High Speed Megapixel cameras for every lane in the Toll booth. The first camera is an ATCC camera that classifies and counts every vehicle that enters the Toll booth. The second Megapixel camera is an ANPR camera that captures the vehicle’s License Plates of the Vehicles that enter the Toll Booth.

These cameras are housed in vandal proof, IP66 housing that is suitable for the outdoor environment and are designed to withstand stringent environment conditions such as dust, rain, fog and.

MindTree uses its patent pending algorithm to classify and count vehicles. Predominantly the ATCC camera relies on the vehicle’s signatures that are seen from the profile view. These include but not limited to Vehicle Contour, Number of Tires and Tire Size. Once the vehicle is classified it signals the high speed ANPR camera to capture the License Plate of the vehicle that’s inside the Toll booth. The ANPR camera captures and recognizes the License Plate of the vehicle and stores the image of the vehicle along with the image of the License Plate. In case where the ANPR camera fails to recognize the License Plate correctly it stores the image and prompts for a manual entry. This helps the Toll Operators for all the cases where the vehicle has License Plates which are non-standard viz., non-reflective.

The following images show the setup of MindTree’s Toll Solution.

Figure 3: MindTree’s Toll booth Solution – Network Setup
Figure 4: MindTree’s Toll booth Solution – Block Diagram
The following steps describe a typical workflow in any Toll booth.

- Vehicle comes and halts at the boom barrier
- TollAssist application continuously receives the video from both cameras.
- ATCC module recognizes the vehicle that's entered the toll booth and signals the ANPR camera.
- The ANPR camera captures and recognizes the License Plate of the vehicle
- The recognized license plate and the vehicle image and the classification are displayed to the Toll booth operator to verify. After verification, the information is entered into a secure database.
- MindTree provides an application to view the live video and to configure, search and audit the vehicle entries for the operator.

To achieve the accuracy MindTree’s solution uses the optimized camera placements that are shown below.

**Figure 5: MindTree’s Toll booth Solution – Top view**
2.1 Advantages of Vision based ATCC System

- The counting accuracy is 100% and classification accuracy is higher (93% to 95%). The classified categories are Car, LCV and HCV during pre-classification and MAV as post classification.
- The Vehicle License Plate Recognition accuracy is around 75% for Indian License Plates.
- Each of the vehicles that is classified and counted has a corresponding image as an evidence.
The classification information is available pre toll collection. Since the data cannot be altered or modified, Integrity of vehicle count and classification is assured and hence pilferage is reduced to a large extent.

For the special category of vehicles which don’t slow down (Ambulances, Exempted Govt Vehicles), the system works without any issues as the system is capable to classify the vehicles even when the vehicles move at 30 kmph.

Detects vehicles and classify vehicles even when they tailgate. This is particularly useful when we want to detect serial offenders.

Provides “Watch list/Black list” feature: that automatically alerts if a stolen vehicle or a routine offender enters the Toll booth.

The collected data can further be analysed for trending and predicting future road requirements.

The Toll Assist Solution comes with an SDK and is easy to integrate with any third party Toll Management MIS system.

Provides flexible deployment options since it is easy to install and commission

2.2 Challenges in Indian Conditions

Indian conditions pose unique challenges in Toll Applications. Some of the older Toll booths when they were built (late 90’s) weren’t really planned keeping future automation in mind. Hence deploying the camera based Toll Assist system in some of the older Toll booths in India can really offer challenging conditions. Following are some of the challenges faced in one of the Toll booths at Khed-Shivpur Toll Plaza located near Pune.

2.2.1 Lack of planning

- As shown in Figure 6, the distance between the vehicle driver and the Toll booth operator is about 8 ft. This requires one more person to collect the money from the driver & he hands it over to the toll booth operator and collects the change & gives it to the driver.
- Since the driver doesn’t have to pay the toll operator directly he/she stops the vehicle where the amount collector is standing. This results in people stopping their vehicles at different places.

Figure 7: Image of a Toll Plaza
The vehicles don’t stop necessarily at the same place as shown in Figure 7.
• So for ANPR, the range that it has to cater is too large. Hence most times the characters are either too large or too small, thus making the accuracy numbers look bad.

2.2.2 People Movement

• The people moving around also affects the accuracy of ATCC and ANPR system as they sometimes tend to block the vehicle or the number plates either partially or fully.

• When it rains, people seem to use the Toll Plaza as cover to protect them from rain. Since Toll booths are located at the edge of the cities, the people movements in such cases are higher during rain thus sometimes blocking the ATCC camera. To avoid this situation, the both the cameras (& the housing) are placed inside grilled fencing thus making it secure and inaccessible to the public.

2.2.3 Technological Challenges

Since MindTree’s TollAssist solution is broadly based on looking at vehicle tires as the first signature for vehicle classification, the following vehicles categories pose serious challenges

- Two wheelers in India come with all different sized tires ranging from small scooters to bigger sized bikes. So classifying them purely based on wheel size is impractical.

- Bus and Truck generally use same sized tires and hence separating an HCV category into either a Bus or Truck requires further processing using other signatures offered by individual vehicles.

- Categorizing Multi Axle Vehicles (MAVs) also pose a challenge as the ATCC camera sees only a small portion of the vehicle before the transaction is complete. However the TollAssist classifies the MAV once the vehicle has left the Toll booth. Thus MAVs are provided as a Post Classification Information.

2.3 TollAssist - Examples from Live Installations

We deployed MindTree’s TollAssist solution in 3 different Toll booths to measure the effectiveness of our system. Our first pilot installation was at Jas Toll booth on Bangalore Pune Highway (NH4) at Nelamangala and subsequently we installed at NICE Road Madavara Toll Plaza (Nandi Infrastructure Corridor Enterprises) and at Khed-Shivapur Toll Plaza near Pune. At each of these locations we had left our solutions for a longer period (over 3 months) to collect data and to refine the accuracy. By working with the Toll Plaza team we were able to improve our accuracy to 92%-95% for vehicle classification and 100% for vehicle counting. Following are some of the images from the installations.

Figure 9: MindTree’s Toll booth Solution
2.4 MindTree Advantage

MindTree offers the best in class, video based TollAssist solution that's tailor made for Indian market. Apart from some of the advantages described in section 2.1, MindTree also offers the following advantages in TollAssist solution.

- The database that gets continuously updated during the course of the toll collection, is encrypted and archived and hence is tamper proof.

- MindTree provides a simple, easy to use Windows based application. Using this application the user can configure Camera; update Highway information including GPS location.

- The application also provides comprehensive reports (daily, weekly and monthly reports) that are easy to access from a central location. This would aid the Central agencies to take a look at the current day's report whenever they want.

- The reports can be used to generate the trending information such as traffic density; peak and lean hour traffic periods.

2.5 Insight into Future

Ministry of Road Transport & Highways has come out with a White paper on Electronic Toll Collection in India [6]. The report recommends usage of passive RFID tags with RFID readers for the Electronic Toll collection. The report recommends an RFID reader for every lane in the Toll Plaza and every road user to be given a passive RFID tag. The RFID tags would have all the vehicle information including the Number Plate, Make, Model, Driver Name, License Details, Insurance details; this appears to be
the cheapest option for vehicle classification. Since the passive RFID tags are fairly cheap, the burden on the Road user is very minimal. A prepaid system for Toll collection is envisaged where the user charges his/her account much ahead in advance and when he/she uses the Toll road appropriate amount is debited from the account.

This model also requires a Central Toll Clearing House that manages all the financial transactions related to the Toll Collection. These include Toll debiting, recharging the prepaid card and payment to toll operators.

MoRTH recommended ETC report stresses also on pilferage. For instance, a vehicle fleet owner can potentially chose to have a small number of RFID tags that are obtained for cars and use them with Trucks and Large Multi Axle vehicles thus paying a small amount of Toll than the actual recommended Toll. This obviously creates a window of pilferage opportunity.

Thus ETC report recommends having another complimentary ATCC system [6] to audit the daily traffic movement and Toll collection. The secondary ATCC system would count and classify the vehicles and will be integrated with ETC system. So at the end of the day when the Toll booth operator does an audit, he can easily find out cases where there have been misuses. Among all the available ATCC solutions in the market, MindTree’s TollAssist stands out with the advantages as mentioned in section 2.1

3 Conclusion

Camera based ATCC system when used in Toll Plazas provides numerous advantages over the traditional sensor based systems. Mind Tree’s Vision based ATCC provides accurate data on vehicle count and classification before the actual transaction. The pre classification information helps Toll Plazas to reduce the toll pilferage thus increasing the revenue for the Toll operators.

The report generated by the solution can be used by the government authorities who are involved in infrastructure development for planning the State and National Highways. These reports provide a great insight for the financial institutions who are involved in financing Road and Highway projects.

Also in a larger context of an ETC deployment, MindTree’s camera based ATCC system serves well as an audit tool thus minimizing the pilferage opportunities.

4 Definitions, Abbreviation and Acronyms

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<td>AVCC</td>
<td>Automatic Vehicle Counting and Classification</td>
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<tr>
<td>PCU</td>
<td>Passenger Car Unit</td>
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<td>FoV</td>
<td>Field Of View</td>
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<td>LCV</td>
<td>Light Commercial Vehicle</td>
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<td>Heavy Construction Machinery/Earth Moving Equipments</td>
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