SEMINAR REPORT
On
WEIGH-IN-MOTION SENSOR BASED ELECTRONIC TOLL COLLECTION SYSTEM

Submitted to Jawaharlal Nehru Technological University Hyderabad

In partial fulfilment of the requirements for the
Award of the degree of
BACHELOR OF TECHNOLOGY
IN
ELECTRONICS & COMMUNICATION ENGINEERING

Submitted
by
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Under the supervision of

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Certified that Seminar work entitled "**DEEP LEARNING**" is a bonafide work carried out in the IV Year I Semester by **"B.Ajay Reddy (20E11A0448)"** in partial fulfilment for the award of **Bachelor of Technology** in **ELECTRONICS & COMMUNICATION ENGINEERING** from **Jawaharlal Nehru Technological University Hyderabad** during the academic year **2023-2024.**

By

B.Ajay Reddy

In the Department of Electronics And Communication Engineering, ***BHARAT INSTITUTE OF ENGINEERING AND TECHNOLOGY****, Ibrahimpatnam is submitted to Jawaharlal Nehru Technological University, Hyderabad in partial fulfillment of the requirements for the award of B.Tech degree in Electronics And Communication Engineering during 2023-2024.*

Seminar Presentation held on……

SEMINAR SUPERVISOR **SENIOR FACULTY MEMBER** **HEAD OF THE DEPARTMENT**

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ABSTRACT

The proposed method is a novel way to calculate the toll price for vehicles based on their weight at the time of toll collection. The proposal is based on the research that the road damage caused by a fully loaded vehicle is significantly higher than the road damage caused by an empty loaded vehicle.

The implementation of this approach using Weigh in Motion (WIM) sensors to calculate the weight of the vehicle dynamically is discussed. In addition, this model also uses computer vision principles and Optical Character Recognition (OCR) to extract the registration number from an image of the vehicle captured using a camera. This registration number is then used to query the vehicles database for vehicle registration and insurance details using Structured Query Language (SQL).

These details are used to make the toll decision and determine the toll price for the vehicle. This model ensures that only vehicles which are registered, insured and loaded within maximum capacity are allowed to travel on the highway. The model can be integrated with the existing FASTag infrastructure used for electronic toll collection and the impact of this model on the toll price for different vehicle classes is evaluated.

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LIST OF SYMBOLS & ABBREVIATIONS

WIM	Weigh in Motion
OCR	Optical Character Recognition
SQL	Structured Query Language
NHAI	National Highway Authority of India
NETC	National Electronic Toll Collection
EMI	Electro-Magnetic Interference
RTO	Regional Transport Office
GVWR	Gross Vehicle Weight Rating
ETR	Express Toll Route
RFID	Radio Frequency Identification
GSM	Global System for Mobile Communication

CHAPTER 1

INTRODUCTON

Electronic toll collection (ETC) is a wireless system to automatically collect the usage fee or toll charged to vehicles using toll roads, HOV lanes, toll bridges, and toll tunnels. It is a faster alternative which is replacing toll booths, where vehicles must stop and the driver manually pays the toll with cash or a card. In most systems, vehicles using the system are equipped with an automated radio transponder device. When the vehicle passes a roadside toll reader device, a radio signal from the reader triggers the transponder, which transmits back an identifying number which registers the vehicle's use of the road, and an electronic payment system charges the user the toll. A major advantage is the driver does not have to stop, reducing traffic delays. Electronic tolling is cheaper than a staffed toll booth, reducing transaction costs for government or private road owners. The ease of varying the amount of the toll makes it easy to implement road congestion pricing, including for high-occupancy lanes, toll lanes that bypass congestion, and city-wide congestion charges. The payment system usually requires users to sign up in advance and load money into a declining-balance account, which is debited each time they pass a toll point.

1.1 Background

The Indian Road Industry Report by Indian Brand Equity Foundation, states that India has one of the world's largest road networks across the world, spanning over 5.89 million km. Road transportation has been increasing over the years providing better connectivity between villages, towns and cities in the country. The construction of highways for each financial year from 2014 is shown below in the Fig 1.1.1:

Fig.1.1.1 Highway Construction in India (km) from Financial Year 2014 This road network caters to 64.5% of all goods transportation and 90% of India's passenger

transportation. The maintenance of this road network is supported by the revenue generated from the toll taxes collected for commuting on these roads. With an increasing number of vehicles commuting on highways, the National Highway Authority of India (NHAI) has taken optimistic measures to control and curb the congestion that occurs at the bottlenecks of the toll plazas.

1.2 Motivation

Under the National Electronic Toll Collection (NETC) program launched by NHAI, toll collection is done using FASTag, an RFID tag that can be used for making toll payments directly from the customer's linked bank accounts. This program allows customers to travel without stopping at the toll plaza using FASTag and thus reduce congestion at the plaza, save fuel and reduce travel time.

However, the pricing of these tolls in India depends on the class of the vehicle, categorized into different types, namely cars, light weight commercial vehicles, mini-bus, buses, trucks, earth moving machinery etc. But, the inadequacy in this pricing model is that a partially or empty loaded vehicle pay the same toll price as a fully-loaded vehicle of a particular vehicle class. Arguably, this method of pricing is inconsistent because it does not accommodate for the difference in damage caused by a fully-loaded vehicle and an empty load vehicle. Research has shown that the weight of the vehicle is a crucial factor when determining the extent of damage caused to the roads.

Fig.1.2.1 Overloaded Indian Truck on road

Another major concern is the lack of governance on the overloaded vehicles on road as shown in the Fig.1.2.1. The threats posed by these overloaded vehicles on the roads are mainly tire blowouts due to excessive strain and improperly secured load that could be fatal to other

vehicles. The presence of such vehicles on roads exposes other travellers to high risks of accidents and causes excessive damage to the road infrastructure.

1.3 Objective

The objective of this paper is to propose a model that tackles the problems in road maintenance with the following solutions:

- Fair toll pricing based on the weights of the vehicle at the time of travel.
- Prevent the commute of overloaded vehicles on the highway.
- Tracking of unregistered and uninsured vehicles.

The model requires minimal infrastructure to be installed at the toll plaza. The integration of this model with the existing electronic toll collection system is convenient and it offers potent feature upgrades to the current system.

CHAPTER 2

LITERATURE SURVEY

Recent advancements have made it possible to measure the weight of an automobile while it is in motion. This is achieved using Weight-In-Motion (WIM) sensors. The earliest research in this area involved the use of embedded concrete strain sensors on the highways to calculate the weight of a vehicle, especially trucks. A Wheatstone bridge is used to calculate the weight based on the relative resistance of the strain gauges under the weight of the vehicle. Another approach towards measuring the weight of a vehicle dynamically is using the Fibre Optic micro-bend sensors. This system is also immune to Electro-Magnetic Interference (EMI). The principle of this model is to use the loss of intensity in output light from the sensor to measure the weight of the vehicle. These methods have shown to have less than 5% measurement error for speeds under 15km/h.

Overloaded trucks affect the lifespan of the roads by causing excessive damage. Performs a comprehensive study to observe the relationship between truck overloading and damage accumulation. From the fatigue damage estimation, it can be observed that for 50% of weight overloading on a truck, the damage caused to the asphalt tarred road is increased by nearly 80%. Another investigation backed by the American Society of Civil Engineers reveals that the overloaded vehicles damage the roads by more than 100% than the vehicles whose weights are commuting in the permissible limits. These studies have laid the foundation for the need to monitor the damage caused by overweight vehicles.

Electronic Toll collection systems have been implemented in India using the FASTag methods. This method reduces the waiting time and congestion at the bottleneck of the toll booth. It involves the use of RFID tags, to uniquely identify the vehicles and determine toll price. The amount is automatically deducted from an Electronic Wallet linked to the customer bank account.

With the advancements in computer vision and deep learning, the extraction of license plates from a vehicle image to determine the registration number can be achieved. Different computer vision techniques and algorithms have been reviewed and discussed in to accomplish this task. More recently, a deep learning approach using YOLO V3 algorithm has proven robust with recognition accuracy of 91% for a custom dataset of 6500 images under different light illumination and camera angles of the vehicle.

Automated toll based collection system has helped a lot in reducing heavy congestion which has caused in front of the bridges of busy cities of the world. It is also the easiest method to control heavy flow of traffic. Digitally it captures the radio frequency by means of RFID technology.

In this method a RF tag along with a unique code will be attached to the vehicle which emits RF signals. Every owner has to have an account with RFID tag attached to their vehicle. Whenever the vehicle reaches nearer to the entrance toll gate the signals will be detected and passed to the controlling device. If the vehicle owners are found with sufficient amount of balance in their account, only then they will be allowed to pass. Again digital toll based collection system has also been found in developed countries like Canada which is known as Canada 407 Express toll route (ETR). In this system they introduced optical camera with Optical Character Recognition (OCR) which captures images and recognizes license plates without any tag. In Gujrat, a state of India there is electronic toll collection system using radio frequency and tag operates commercially on expressway where all needed equipment were supplied by Mitsubishi Heavy Industries. Again India has got its first interoperable RFID based electronic toll system in Ahmadabad Mumbai National Highway which enables automobiles having electronic tags operates at frequency of (850-950 MHz) with distance up to 90 feet where response time is 10 milliseconds.

This system can be considered as cost efficient but the driver has to get the receipt and pass through the gate. Furthermore, an institution named Active wave Inc. has come up with a system which monitors active tagged vehicles. These automobiles have active wave ranging 30 meters operating (916-917 MHz) for operation transmit and (433MHz) for receiving the link. Here, in form of blinking LEDS and beeping sounds the signals are observed. Moreover, the user interface has been designed using Microsoft .NET Framework. The tag uses car battery for power and two modules through RF modem transfer signals among themselves over the ISM frequency range of about (902-928) MHz. Another proposed model of digital toll collection has been developed in Poland which has got a combination of GSM and satellite based global positioning system. Here the system has got sensors and camera which captures and detects number plate. In addition, it captures the distance, evaluates the fees and rates transmitting them to the System Centre.

CHAPTER 3

EXISTING TOLL COLLECTION SYSTEM

3.1 National Electronic Toll Collection System

National Payments Corporation of India (NPCI) has developed the National Electronic Toll Collection (NETC) program to meet the electronic tolling requirements of the Indian market. It offers an interoperable nationwide toll payment solution including clearing house services for settlement and dispute management. Interoperability, as it applies to National Electronic Toll Collection (NETC) system, encompasses a common set of processes, business rules and technical specifications which enable a customer to use their FASTag as payment mode on any of the toll plazas irrespective of who has acquired the toll plaza.

FASTag is a device that employs Radio Frequency Identification (RFID) technology for making toll payments directly while the vehicle is in motion. FASTag (RFID Tag) is affixed on the windscreen of the vehicle and enables a customer to make the toll payments directly from the account which is linked to FASTag.

FASTag offers the convenience of cashless payment along with benefits like - savings on fuel and time as the customer does not has to stop at the toll plaza.

Fig 3.1.1: Toll collection system in India

3.2 What is FASTag?

FASTag is a RFID passive tag used for making toll payments directly from the customers linked prepaid or savings/current account. It is affixed on the windscreen of the vehicle and enables the customer to drive through toll plazas, without stopping for any toll payments. The toll fare is directly deducted from the linked account of the customer. FASTag is also vehicle specific and once it is affixed to a vehicle, it cannot be transferred to another vehicle. FASTag can be purchased from any of the NETC Member Banks. If a FASTag is linked to the prepaid account, then it needs to be recharged/ topped-up as per the usage of the customer. If adequate balance is not maintained by the customer, the FASTag gets blacklisted at the toll plaza. In such a scenario if the customer travels through a toll plaza without recharging then he won't be able to avail the NETC services and would be required to pay the toll fare through cash.

3.3 NETC FASTag Transaction Process Flow

Fig 3.3.1: NETC FASTag transaction process flow

The above Fig 3.3.1 illustrates transaction flow of the NETC system. The Transaction from the Toll Plaza is sent to the acquiring system. The Acquiring System validates these transactions and send it to NETC Switch. NPCI route these transactions to the respective Issuer Bank which in turn debit the tag holder account.

CHAPTER 4

WEIGH-IN-MOTION TECHNOLOGY

Weigh-in-motion devices are designed to capture and record the axle weights and gross vehicle weights as vehicles drive over a measurement site. Unlike static scales, WIM systems are capable of measuring vehicles traveling at a reduced or normal traffic speed and do not require the vehicle to come to a stop. This makes the weighing process more efficient, and, in the case of commercial vehicles, allows for trucks under the weight limit to bypass static scales or inspection.

4.1 Introduction

Weigh-in-motion is a technology that can be used for various private and public purposes (i.e. applications) related to the weights and axle loads of road and rail vehicles. WIM systems are installed on the road or rail track or on a vehicle and measure, store and provide data from the traffic flow and/or the specific vehicle. For WIM systems certain specific conditions apply. These conditions have an impact on the quality and reliability of the data measured by the WIM system and of the durability of the sensors and WIM system itself.

WIM systems measure the dynamic axle loads of the vehicles and try to calculate the best possible estimate of the related static values. The WIM systems have to perform unattended, under harsh traffic and environmental conditions, often without any control over the way the vehicle is moving, or the driver is behaving. As a result of these specific measurement conditions, a successful implementation of a WIM system requires specific knowledge and experience.

The weight information consists of the gross vehicle weight and axle (group) loads combined with other parameters like: date and time, location, speed and vehicle class. For on-board WIM systems this pertains to the specific vehicle only. For in-road WIM systems this applies to the entire vehicle traffic flow.

This weight information provides the user with detailed knowledge of the loading of heavy goods vehicles. This information is better than with older technologies, so, for example, it is easier to match heavy goods vehicles and the road/rail infrastructure.

4.2 Accuracy

The accuracy of weigh-in-motion data is generally much less than for static weigh scales where the environment is better controlled. The European COST 323 group developed

an accuracy classification framework in the 1990s. They also coordinated three independently controlled road tests of commercially available and prototype WIM systems, one in Switzerland, one in France (Continental Motorway Test) and one in Northern Sweden (Cold Environment Test). Better accuracy can be achieved with multiple-sensor WIM systems and careful compensation for the effects of temperature. The Federal Highway Administration in the United States has published quality assurance criteria for WIM systems whose data is included in the Long Term Pavement Performance project.

CHAPTER 5

PROPOSED METHODOLOGY

5.1 Block Diagram

The block diagram for the proposed solution is represented in Fig.5.1.1. The blocks represent each system with its corresponding input and output.

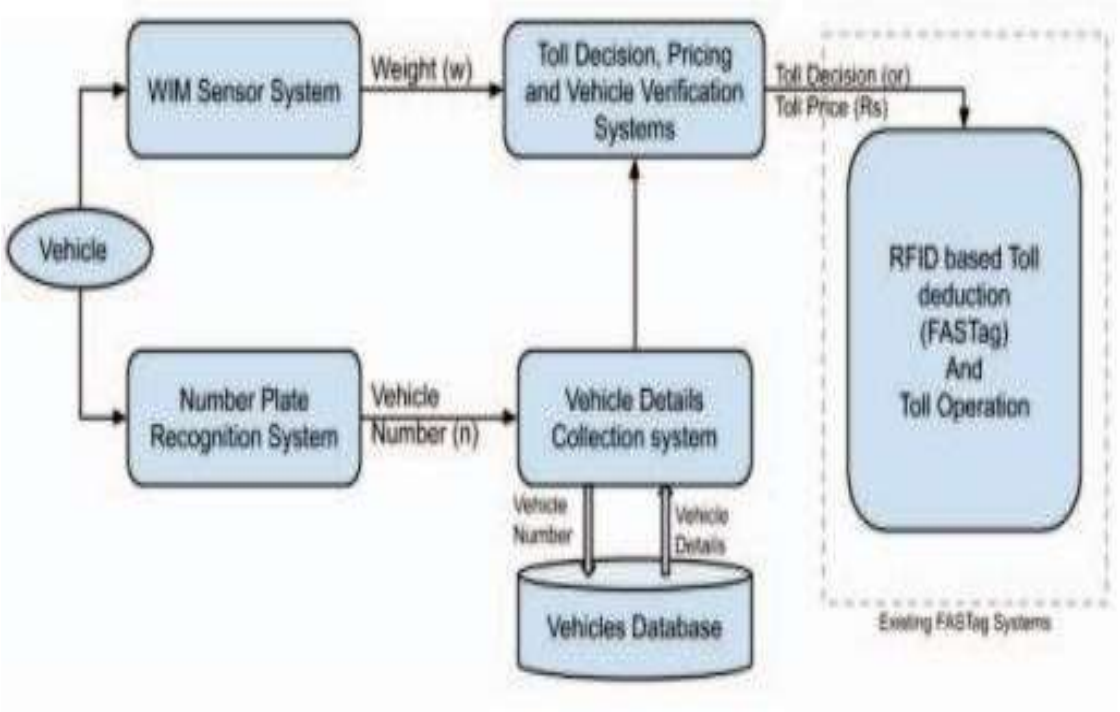

Fig.5.1.1 Block Diagram of the proposed model

The block diagram is based on the existing FASTag Electronic Toll collection system, with the following additional systems:

- Weigh-In-Motion (WIM) sensor system: To measure the weight of the vehicle dynamically at the toll plaza.
- Number Plate Recognition system: To recognize the registration number and fetch the vehicle details.

- Vehicle overload, registration, insurance validity tracking systems.

The following sections will brief the functions and implementation of each system.

Weigh-In-Motion System

Weigh-In-Motion sensor is used for the calculation of the weight of the vehicle in motion at the time of toll collection. This sensor is embedded in the road/pavement at the entrance of the toll plaza as shown in Fig.5.1.2.

Fig.5.1.2 WIM sensor embedded in road near a toll plaza

A WIM sensor contains quartz crystal, which is sensitive to the strain caused due to the weight of the vehicle as shown in Fig.5.1.3. When a vehicle passes over an installed WIM sensor, the gross vehicle weight and the axle weight of the vehicle is recorded by the sensor. This dynamic weight of the vehicle is used for determining the toll price in the next stage.

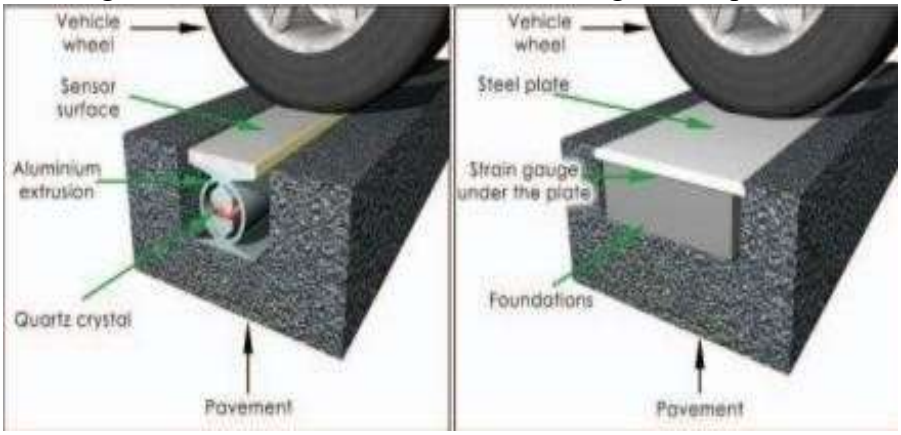

Fig.5.1.3 Weigh-In-Motion (WIM) sensor structure

Number Plate Recognition System

In the proposed approach, a camera is used to capture the image of the vehicle. This system processes the image of the vehicle to localize and detect the number plate using computer vision principles. The vehicle image is converted to gray scale image with two channels. This conversion ensures reduced complexity and increased speed in processing the image. The gray scale image is filtered using bilateral filters to remove noise in the image. The filtered image is used for edge detection and contour detection. Finally, contour approximation is used to extract the number plate from the vehicle image. The image of the vehicle at different stages of processing is shown in the Fig.5.1.4.

Fig.5.1.4 Number plate extraction from vehicle image

Then, the extracted number plate from the vehicle image is passed to an Optical-Character-Recognition (OCR) framework. This framework recognizes the characters in the number plate image and returns the registration number of the vehicle as a string.

Vehicle Registration Details Database

The registration number obtained from the previous stage will be used to query the details of the vehicle from the Regional Transport Office (RTO) Database. In India, the Ministry of Road Transport & Highways offers 'VAHAN', a database of vehicles containing registration details of over 286 million vehicles. However, this database is not available for free to the public (to prevent the misuse of data), but is available to business firms/companies operating in India and academic research institutes at a nominal cost. Upon request and security approvals, the Ministry of Road Transport and Highways will share the bulk data in an encrypted format with these institutions at their respective data centres in India.

The important data points about the vehicle available in this database are: Registration Date, Registration Expiry Date, Registration Certificate Status, Insurance Expiry Date, Model of the vehicle, Vehicle class, owner name etc.

Toll Pricing and Vehicle Verification Systems

After obtaining the vehicles database, it is queried for the data points related to the registration details of the vehicle. Using the current weight (obtained from WIM sensor system) and the vehicle registration details (queried from the vehicles database), the following tasks are achieved:

- Overload detection: If the current weight of vehicle is greater than the Gross Vehicle Weight Rating (GVWR), then the vehicle is overloaded. Such vehicles should not be allowed to commute.
- Vehicle registration and insurance verification: Only the vehicles with valid insurance and registration certificates should be allowed to travel on roads.
- Toll Pricing: The weight of the vehicle is used to calculate toll price for the vehicle.

Toll Decision and Price Deduction

After successfully verifying the details about the vehicle, the calculated toll price for the vehicle based on its weight is sent to the FASTag systems for deduction of the amount from the customer bank accounts linked to the existing FASTag RFID of the vehicle. In the other case, if the vehicle is overloaded or not successfully verified, the officials at the Toll Plaza are informed about the shortcomings in verification of the vehicle, in which case the toll gate is not opened until after a manual inspection from a Toll Inspector.

CHAPTER 6

APPLICATIONS

Road Applications

Especially for trucks, gross vehicle and axle weight monitoring is useful in an array of applications including:

- ➢ Pavement design, monitoring, and research
- ➢ Bridge design, monitoring, and research
- ➢ To inform weight overload enforcement policies and to directly facilitate enforcement
- ➢ Planning and freight movement studies
- ➢ Toll by weight
- ➢ Data to facilitate legislation and regulation

Rail Applications

Weighing in motion is also a common application in rail transport. Known applications are:

- ➢ Asset protection (imbalances, overloading)
- ➢ Asset management
- ➢ Maintenance planning
- ➢ Legislation and regulation ➢ Administration and planning

Airport Applications

Some airports use airplane weighing, whereby the plane taxis across the scale bed, and its weight is measured. The weight may then be used to correlate with the pilot's log entry, to ensure there is just enough fuel, with a little margin for safety. This has been used for some time to conserve jet fuel.

Also, the main difference in these platforms, which are basically a "transmission of weight" application, there are check weighers also known as dynamic scales or in-motion scales.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 Conclusion

The proposed model for toll collection and toll pricing is novel and efficient because of its benefits to the Highway authorities and goods transportation industry. For the highway authorities, this model can be easily integrated with the existing FASTag system with minor additional infrastructure for WIM sensors and cameras. This model also proves advantageous to the goods transportation industry, as the toll price is justified based on the weight of the vehicle at the time of toll collection and the toll price for empty loaded vehicles will be significantly lesser than that of a fully loaded vehicle. All the systems of this model, namely toll pricing, number plate recognition and vehicle details verification together operate within the scope of an autonomous toll collection system without the need for manual toll operators, which reduces the traffic density occurring at the bottlenecks of the toll plazas. The method also enables the highway authorities to track overloaded, unregistered and uninsured vehicles using the details from the vehicles database fetched using the registration number of the vehicle. In these special cases, after a manual inspection from the toll official, informed toll decision can be made and legal fines can be levied on such vehicles.

7.2 Future Scope

Moreover, in future, additional features such as over speed detection and prevention, overload indication and prevention in bridge, tracking vehicle which is stolen or involved in any accident etc. can be added in the system which will make the transportation system smarter and more secured. Thus, the proposed model can contribute to build a digital and smart road transportation system.

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