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Comparative Study of Various Road Toll Collection Systems - A Review

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ABSTRACT

ITS is an integrated system that implements a broad range of communication, control, vehicle sensing and electronics technologies to help in monitoring and managing traffic flow, reducing congestion, providing optimum routes to travelers, enhancing productivity of the system, and saving lives, time and money. ITS relies on wide range of technologies and functions such as Communications (Microwave, internet, Bluetooth), Geographical Locations, System, Data acquisition and exchange, Camera system and Artificial vision, Detection and classification, In-vehicle systems and Digital Mapping. Thinking of the Japanese and European thought leaders about- how ITS can contribute toward meeting environment goals - is very helpful to improve the environmental performance of ITS. Indian traffic can benefit from several possible ITS applications. One set of applications is for traffic management at toll plaza. ITS is not only helpful at toll plaza but also helpful at traffic signals, emergency management system in India. At toll plaza, deciding factor is the how much time a vehicle is going to be in the line of toll. More the time, more will be fuel consumption and waste of fuel. Knowing what kind of vehicles, and in what proportions, play main role in application of ITS at toll. ITS helps to reduce this Time factor. Also ITS clears the traffic at toll in less time. Long term data helps ITS to reduce traffic congestion at toll and reduce waste of fuel at toll efficiently.

Keywords: ITS, Microwave, Internet, Geographical Locations, Toll Plaza

I. INTRODUCTION

Intelligent Transportation System can be defined as the application of information technology to the field of transportation for achieving safety as well as mobility while reducing the environmental impact of transportation. Intelligent Transportation System consists of wide range of communication, control, vehicle sensing and electronics technologies that is helpful in monitoring and managing traffic flow, providing optimum routes to travelers, reducing congestion. ITS helps in saving lives, time and money.ITS is a smart technology and contains wide range of technology and functions such as communications like Microwave, Internet, Bluetooth. Also it depends on technologies like Camera System and Artificial Vision, Detection and Classification, Data Acquisition and Exchange and Geographical Locations. ITS is designed for all types of road transport organization including urban, state as well as private road transportation. The goal of ITS is to achieve enhanced safety and mobility as well as reducing the environmental impact of transportation. ITS not only covers all modes of transportation but also elements of transportation that includes the infrastructure, the vehicle, the driver, interacting together dynamically.

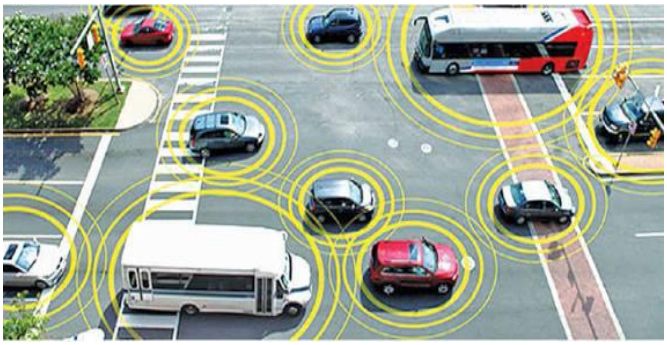

Figure 1 : Intelligent Transportation System at intersection

II. METHODS AND MATERIAL

1. Different Techniques Used in Its

A. ATIS (Advanced Traveler Information System)

As name suggests, ATIS is the advanced system of transportation that works with the help of internet, mobile, telephone, television, radio. ATIS helps as pre-trip and on-trip manager. Pre-trip info helps to plan travel. It gives easy, accessible routes as well as nearest bus stop information which helps to plan the journey and travel. On-trip information helps during the travel. It works on real time data accessed from internet and other media. On-trip info helps to travel without any frustration which avoids rash driving of traveler.

B. ATMS (Advanced Traffic Management System)
Today traffic congestion is the problem of every metro city due to rapid growth of number of vehicles. ATMS helps to reduce this congested traffic. ATMS can be used by the traffic police department as well as traffic control department. ATMS is used to control and monitor traffic flow as well as to manage the traffic flow. The best thing about ATMS is that it uses real time information and manages traffic flow according to or with the help of traffic signals.

C. APTS (Advanced Public Transportation System)
APTS focuses mainly on public transport. APTS helps to improve public transportation with the advance technologies. APTS works on technologies like RFID (Radio Frequency Identification) as well as UHF tag (Ultra High Frequency).

D. EMS (Emergency Management System)
EMS is the combination of different ITS techniques and it is used in emergency conditions like road accidents. EMS is very helpful and it has reduced the fatality rate in the accidents. GIS technique is the most used technique in EMS as it gives the easy and accessible route in emergency condition.

E. APMS (Advanced Parking Management System)
Parking is also the problem of every metro city in the world. And with the help of APMS, parking problem is very much solved in cities like Delhi. User can get the information about vacant parking space without even entering the parking complex. APMS uses sensors as well as sign boards to notify the parking situation. Sensors look for how much vacant parking space is in parking area and display this information on the sign boards.

Figure 2 : Intelligent Transportation System (Animated)

2. Applications of Its

ITS is developing very fast with new technologies every year. ITS is developing to increase the comfort while driving and improving accessibility.

Figure 3 : Applications of ITS

Following are the applications of ITS to improve the transportation system:

1) Alco-lock: In alco-lock driver has to take breath test before starting the car, if BAC is too high, car will not start.
2) Seatbelt Lock: If seatbelt is not fastened, car will not start.
3) Electronic Stability Control: Electronic Stability Control gives stability to cars at edges and controls carsfrom skidding at edges.

4) Lane Departure Warning System: Lane Departure Warning System warns during unsafe overtaking.
5) Intelligent Speed Adaption: Intelligent Speed Adaption system warns the driver when he/she is driving at the speed that exceeding the limit.
6) Electronic Vehicle Identification: Electronic Vehicle Identification system is mainly used by police department as it can locate and follows a car in a network.
7) Electronic Data Recorder: Registers all sorts of driving behavior. It can be used both for punishing as well as for rewarding.
8) Collision Avoidance System: Collision Avoidance System warns when a moving object is detected in front of the vehicle.
9) Vehicle Detection at Intersections: Vehicle Detection at Intersections warns when crossing and gives information of vehicles avoiding collision.
10) Night Time Vision System: Improves night time vision and thus timely detection of pedestrians/cyclists. Night Time Vision System is very helpful on the platforms like national highways because there is no lamps provided on national highways, also in urban area where there is low light on road.
11) Fatigue Warning System: Fatigue Warning System is truly advance as well as smart system as it detects deviations from normal brain activity, eye movements or driving behavior and warns.
12) Forward Collision Warning System: Volvo company developed 'Forward Collision Warning System' to reduce rear crashes by giving warning on screen. This system is helping in reducing road accidents.
13) Vehicle Lane Departure Prevention System: In Japan, Nissan motor company developed 'Vehicle Lane Departure System' to keep vehicles in lane which avoid traffic congestion. This system has shown great results.

3. Literature Review

B Singh and A Gupta, (2015) carried out recent trends in Intelligent Transportation System. Author explained 4 modules of ITS i.e. Advance Traveler Information System (ATIS), Advance Traffic Management System (ATMS), Advance Public Transportation System (APTS) and Emergency Management System (EMS). All four modules are explained in detail. Objective of the paper is to study various ITS architecture and model and review such models to get in-depth of their architecture.

C S Rao et al., (2011) carried out survey of ITS in Delhi. Authors collected data related to current scenario of vehicle users in Delhi. Authors highlighted parking problem in Delhi. Authors collected data information and age of user and divided the data into groups according to age to solve the problem. Authors succeeded to find the solution.

Dr. P Kumar et al., carried out utilization of ITS using Geographical Information System (GIS) in Hydrabad. Module used by Authors is ATIS(Advance Traveller Information System). They applied ITS for giving bus routes, bus number and important places in Hydrabad which is used by public as user. Software used by authors is Geographical Information System (GIS).

P Chakroborty (2011), carried out roll of ITS in sustainable transportation system for Indian cities. Author focused on need of sustainable transportation system in India. Author also highlighted sustainability and efficiency of ITS in Indian cities. Author included the challenges in application of ITS.

R Sen and B Raman, carried out research on ITS for Indian Cities. They gave different ideas that give overview of problem and available solution. It helps to outline a set of questions to answer. Research includes major Indian cities having ITS.

Sathya V and Abdul S J (2013) carried out survey on vehicles and toll plaza for National Highways(NH) in India. They covered all toll techniques used for NH in India. This data is very useful for application of ITS on NH. Authors considered all types of vehicles. Data includes all the NHs in states of India.

S Malik, 2014 carried out application of ITS for bus system. ITS used here is designed for urban/state/private road transport organization. Author gave all information about technology used in ITS (including GPS, Wi-Fi). Ultimate aim of author was to improve the bus transportation system using ITS.

S Mulay et al., carried out use of ITS to control traffic congestion and regulating traffic flow. Android application and SMS service are main components used here in ITS. The application created is user friendly and easy to understand by person of any age group. SMS service is also provided.

V E NethajiMariappan et al., 2013 carried out GIS enabled traffic assessment system for social service planning for Porur Municipality. System is based on use of GIS(Geographical Information System)-GPS(Global Positioning System) software. The system helps to improve emergency management system.

V Kumar, et al., carried out wireless sensor network based ITS application. Author focused on requirement challenges and issues in the system. Weight in motion is the highlight of the system. The system helps to give the information about overloading of trucks. Author explained every detail about wireless sensor network based ITS.

4. Toll Plaza

Toll System is used to collect toll tax that recovers the total capital expenditure which includes the cost of construction, repairs, maintenance, expenses on toll operation and interest on the expenditure. The new facility then constructed should provide less travel time and increased level of service. In India almost all of the highway projects are given on PPP basis, i.e. Public Private Partnership. In this system, the private organization constructs the facility with their own finance and recovers the capital from the users in the form of toll tax. This tax is collected for a reasonable period of time and after which that facility is surrendered to the public. Of late, toll tax is being levied on parking of vehicles in the urban centers for the purpose to reduce congestion on the streets and to reduce the pollution levels. This method is known as Congestion Pricing.

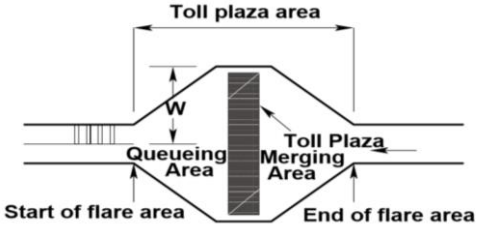

Figure 4 : General Layout of Toll Plaza Source

5. Types of Toll Collection

There are two types of toll collection systems available. These systems are (i) Open Toll System, and (ii) Closed Toll System.

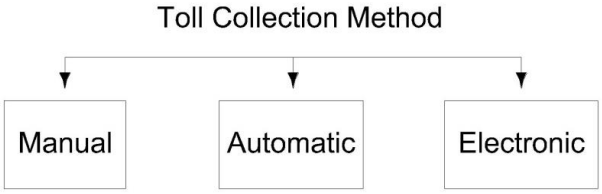

Figure 5 : Toll Collection Methods

A. Open toll System

In an open toll system, not all vehicle users are charged a toll. In this system, the toll plaza is generally located at the edge of the urban area, where a majority of long distance travelers are using this facility, with a minimum likelihood of switching to the parallel free route, or at the busiest section of the toll way. Vehicle users are identified by their category of vehicle . Toll price is base on the category of vehicle. And user pays a fixed toll according to his/her type of vehicle. The local traffic around the plaza either gets rebate or can use a service lane.

B. Closed toll System

In a closed toll system, price of toll is based on miles of travel on the facility and the category of vehicle. There are no free-rides. In a closed toll system, toll plazas are provided at all the entry and exit points, with the users receiving a ticket upon entering this system. When exiting, users give their ticket to the collector and ischarged a fee based on category of vehicle and distance travelled by the users. This system contains only two stops for the vehicles on the other hand open system contains multiple stops. But the drawback of the closed system is that it is expensive to construct than open system.

C. Number of Toll lanes

As mentioned previously, toll plazas are installed to collect the tax from the road users. The number of toll plazas depends on the flow of vehicles on the facility.

Following guidelines are generally followed while deciding the number of toll lanes at a toll plaza:

1) Peak Hour Factor: It is the percentage of vehicles travelling during the peak hour to the average daily traffic.
2) Number of toll lanes should be corresponding to the forecast traffic for at least 5 years.
3) Forecast traffic in terms of veh/day for all the tollable categories. Non-tollable vehicles (e.g. VIP vehicles, ambulances, etc) are exempted from the toll tax and flow through a separate lane.
4) If the queue becomes so long that the waiting time exceeds three minutes then the number of tollbooths need to be increased.

D. Tollbooth

A tollbooth is the location at the toll plaza where the tax is actually collected. . Following guidelines are generally followed during construction of tollbooth:

1) Toll booths should be made from prefabricated materials or of brick masonry.
2) Toll booth should have space for seating for toll collector, computer system, printer and cash.

E. Toll Pricing

Toll is a tax collected for the use of the road, bridge, tunnel, etc. to recover the total expenditure which includes interest on expenditure, cost of repairs, maintenance and also expenses on collection of toll. It is important that the amount of toll should not exceed the benefits which the user receive while using the that facility. The benefits are provided to reduce travel time, travel cost, increase in comfort and convenience. The toll structure should be fixed in such a way that investments and expenses are recovered within a reasonable period of time. The product of optimum toll rate and traffic volume finally determines the gross toll revenue.

F. Factors Affecting Toll Rates

Two important factors determine the toll rates. They are:

1) Traffic Volume: Traffic volume that will be using the facility is the most important factor. There for traffic volume is determined. Success of any toll depends on the accurate estimation and forecasting of toll traffic at facility and its composition.
2) Willingness to pay: Users will be willing to pay a realizable portion of their savings to use the improved facility.

III. RESULTS AND DISCUSSION

1. Indian Scenario

Construction and maintenance of toll plaza on national highways comes under authority of NHAI. NHAI (The National Highway Authority of India) was constituted by an Act of Parliament, the National Highways Authority of India Act, 1988. It is responsible for the development, maintenance and management of National Highways entrusted to it and for matters connected or incidental there to. The Authority was operationalized in Feb, 1995.

A. Scope of ETC: India

There are 377 toll plaza in India and out of which 70% of toll plaza will be having ETC system soon. According to report given by National Highway Authority of India (NHAI) carry 40% of road traffic, due to this traffic congestion is very high and to reduce it ETC can be implemented.

NH lane wise distribution can be classified as –
4 lane – 22.3%
2 lane – 52.3%
Single lane – 25.4%

By viewing all above data the ministry has decided to implement an ETC system with RFID based technology which offers compatibility for seamless movement of

vehicles on tolled national highway.

Figure 6: Network of National Highway (India)

Roads having toll plazas (India):

A. Maharashtra
1) Mumbai-Pune Expressway, Mumbai
2) Western Expressway, Mumbai
3) Eastern Expressway, Mumbai
4) SionPanvel Expressway, Mumbai
5) Western Freeway, Mumbai
6) Eastern Freeway, Mumbai
7) Mumbai–Vadodara Expressway, Mumbai to Gujarat
8) Mumbai Nashik Expressway, Mumbai to Nashik
9) Pune to Satara
10) Satara to Karad to Kolhapur
11) Pune to Solapur
12) Airoli to Mulund

B. Delhi
1) DND Flyway
2) Delhi-Gurgaon Expressway
3) Noida-Greater Noida Expressway
4) Taj Expressway
5) Ganga Expressway
6) Delhi Faridabad Skyway

C. Uttar Pradesh
1) Taj Expressway (Under Construction)
2) Ganga Expressway (proposed)
3) Kanpur Metropolitan Expressway (Under Construction)

D. Karnataka
1) NH 4 from Nelamangala till Maharashtra border
2) NH 4 from K.R Puram till Tamil Nadu
3) NH 48 from Nelamangala till Hassan
4) NH 13 from [Vijapur] till Koppal
5) Bangalore - Electronic City Expressway
6) Bangalore - Nelamangala Expressway
7) Bangalore - Kempegowda International Airport(KIA) Expressway

E. Tamil Nadu
1) East Coast Road (ECR) from Chennai to Pondicherry
2) Chennai Bye Pass Road from Irumbuliyur, Chennai to NH4Madhavaram, Chennai
3) ChennaiECR - Sholinganallur Road from ECR, Chennai to Sholinganallur, Chennai
4) ChennaiOMR - Medavakkam Road from Sholinganallur, Chennai to Medavakkam, Chennai
5) NH 47Salem to Coimbatore Expressway / Industrial Corridor
6) NH 67Coimbatore to Trichy
7) NH 7Hosur to Krishnagiri
8) NH 4Krishnagiri to Chennai
9) NH 45Chennai to Villupuram
10) NH 7Krishnagiri to Salem
11) NH 45BMadurai to Tuticorin (Nearing completion)
12) NH 45Dindigul to Trichy
13) NH 45Villupuram to Trichy
14) NH 7Salem to Madurai (Nearing completion)
15) NH 7ATirunelveli to Tuticorin
16) Chennai to Ennore Express Way (Inner Ring Road &Manali Oil Refinery Rd.)
17) NH 45BMadurai to Trichy
18) NH 67 (Trichy) to (thanjavur)
19) NH 7 (Dindigual) to (karur) TNDK toll plaza

F. Telangana
1) Hyderabad Outer Ring Road Expressway
2) Hyderabad to Mancherial
3) Adilabad to Kurnool (AP) (NH 7, New NH 44)
4) Hyderabad to Raigiri (NH 202, New NH 163 towards Warangal)
5) Sangareddy (Hyderabad) to Vijayawada (AP) (NH 9, New NH 65)
6) Hyderabad to Damarcharla

G. Andhra Pradesh

1) National Highway 5 (New NH65) (Tada to Srikakulam)
2) Kurnool to Bangalore (KA) (NH 7, New NH 44)
3) Kurnool to Kadapa (Rayalaseema Expressway)
4) Kodad (TG) to Vijayawada (NH 9, New NH 65)
5) Eluru NH5 (New NH65)
6) Tanuku NH5 (New NH65)

2. Toll Collection Methods

A. Manual Toll Collection

Manual toll collection is the conventional method of toll collection. In India, all toll plazas are having this method for toll collection. This method requires man-power. It requires toll attendant. Base on the type of vehicle, toll is collected by the attendant. Then attendant gives the ticket to vehicle user. Operation time is high for this method. At the peak hour of traffic, there can be long queues of vehicles may happen.

Figure 7: Manual Toll Collection

B. Electronic Toll Collection

Electronic toll collection is advance version of manual method of toll collection. It relies on technologies like RFID (Radio Frequency Identification Technology), Android, Bluetooth, Sensors, GPS etc This system doesn't require any man-power as it automatically collects toll from vehicle user. When vehicle approaches toll plaza, sensors detects the type of vehicle by sensing the tag on the vehicle provided to user by the authority of toll plaza. Then the amount of toll is deducted from user's account and then user receives a SMS of amount deduction from bank. Then gate opens and user is ready to go. Operation time is less as compared to manual method of toll collection.

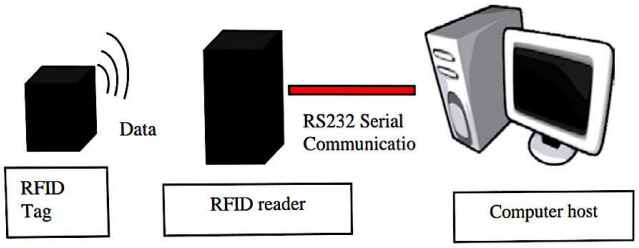

Figure 8: Toll Collection using RFID Technology Source

Figure 9: Barcode Laser Technology

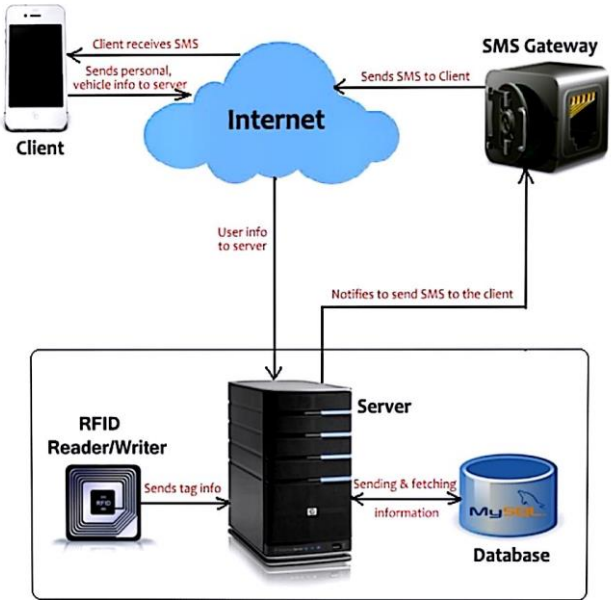

Figure 10: ETC Using NFC and Android Application

C. Open Road Toll Collection

Open Road Toll collection method is the method where there is no toll plaza is required. In this method neither man-power nor gates are provided. User doesn't require slowing down his speed when approaching this system. User need not to stop at this system and can retain his speed. Hence there is no queue problem or traffic congestion at this system. This is the most advance method of toll collection and efficient method as it provides maximum vehicles per hour through the facility. Only disadvantage of this method is the possibility of violators who do not pay. This leakage may either be written off as an expense by the toll operator or offset in part or whole by fees and fines collected against violators.

D. Infrastructure Elements of ORT

- ✓ Gantries- Overhead structure to hang antennae to read RFID or EZ pass or tags on vehicles,
- ✓ A pre-fabricated utility building with HVAC-provided at each gantry to install. This building function as communication hub,
- ✓ Generator- located outside and adjacent to each utility building,
- ✓ Junction boxes and conduits
- ✓ Signings

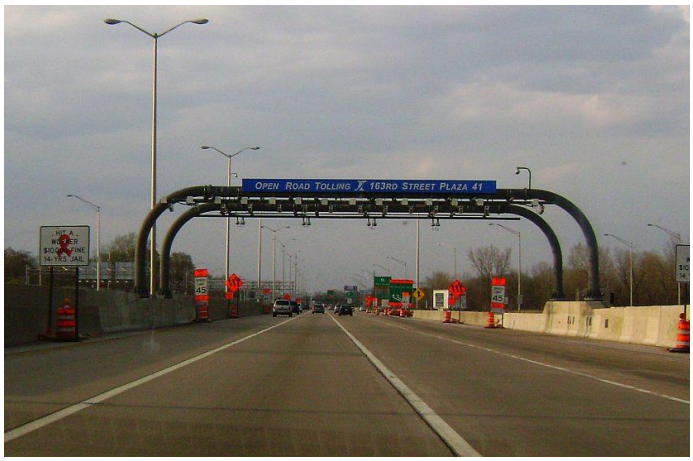

Figure 11: Open Road Tolling

In this method the total operation is divided in stages. For Manual method, the stages are Deceleration, Service and Acceleration stage. For ETC, stages are same as manual method. But for ORT there is no requirement of division of stages as this method eliminates barriers altogether and allow vehicles to travel through toll collection points without deceleration, thereby maintaining their speed.

IV. CONCLUSION

The proposed payment system combines the Iris recognition with the visual cryptography by which customer data privacy can be obtained and prevents theft through phishing attack [8]. This method provides best for legitimate user identification. This method can also be implemented in computers using external iris recognition devices.

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