



NANDAN NILEKANI
CHAIRMAN

Unique Identification Authority of India (UIDAI)

28.6.2010

Dear Shri Kamal Nathji,

With an objective of paving way for a unified Electronic Toll Collection (ETC) technology for National Highways in India, the Ministry of Road Transport & Highways, vide Order No. NH-12037/33/2010-PIC dated 20.04.2010, constituted a Committee with a mandate to examine all technologies available for Electronic Toll Collection (ETC) and recommend the most suitable one for implementation throughout India.

I thank you for giving me an opportunity for Chairing this Committee. The other members of the Committee were Prof. Pankaj Jalote, Director, IIIT-Delhi, Dr. Kolin Paul, Asst. Professor, IIT-Delhi (outside experts nominated as Members), Shri. A.V. Sinha, Director General (Road Development) & Special Secretary, Ministry of Road Transport & Highways and Shri. V.L. Patankar, Member (Technical), National Highways Authority of India.

I have received excellent support and contribution of all members of the Committee in finalizing the ETC technology report.

I would particularly like to bring to your notice the valuable contribution rendered by Shri. R.C. Palekar, General Manager (Electronics), National Highways Authority of India, who provided technical inputs and coordinated with the Committee in an efficient manner.

I once again thank you and the Government of India for giving me an opportunity to head this Committee.

With regards,

Yours Sincerely,

(Nandan Nilekani)

Shri. Kamal Nath
Hon'ble Minister (RT&H)
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Executive Summary

Highway expansion has led to a focus on toll collection

The Government of India has embarked on an ambitious plan for building India's highway network through various phases of the National Highways Development Project (NHDP), which are being financed largely through user fees collected from the users of the improved highways. This underlines the need for large scale tolling of the highways.

An emerging priority is to implement an effective toll collection system

Tolling has come to be associated with delays at collection points and congestion at toll plazas. The delays negatively impact the operational efficiency of the improved network and thus neutralize the benefits of the improvement of highway infrastructure. Government has, therefore decided to adopt Electronic Toll Collection (ETC) system across India's National Highway network, which would enable toll to be collected electronically from vehicles at a toll plaza while the vehicle is in motion.

An opportunity to build an integrated Electronic Toll Collection system in India

One of the essential requirements of ETC systems is to provide an integrated solution that can work throughout the country. In advanced countries, the prevailing systems or the legacy systems reduce the design options. In India, on the other hand, there is no baggage of legacy system. And therefore, there is an opportunity to evolve a simple and robust integrated solution – one which is scalable, reliable, inter-operable and capable of use across the country.

Constitution of committee

Keeping these objectives in view, the Government constituted a Committee under Shri Nandan Nilekani, Chairman, Unique Identification Authority of India (UIDAI) with two outside experts nominated by him as Members, besides Director General (Road Development) & Special Secretary, Ministry of Road Transport & Highways and Member (Technical), National Highways Authority of India being the other Members of the Committee. The constitution of the Committee is at Appendix A.

The Committee interacted with various stakeholders, such as NHAI, the concessionaires, the ETC vendors, and the User Groups. It reviewed the various ETC technologies, such as Dedicated Short Range Communications (DSRC)-active as well as passive, Radio Frequency Identification (RFID)- active as well as passive, Communication Air-Interface, Long and Medium Range (CALM), Global Positioning System (GPS)-based Global Navigation Satellite System/ Cellular Network (GNSS/CN), Automatic Number Plate Recording (ANPR), and their applications in different parts of the world. The committee deliberated upon issues such as appropriate system architecture, initial and recurring cost of technologies, interoperability and availability of vendors.

After deliberations, the committee came to the conclusion that an appropriate ETC system should meet the following requirements with high degree of reliability:

- i. Vehicles should be uniquely identified and classified through On Board Unit (OBU), say Tag and the Road Side Unit, say Reader, once it passes through the toll gate.
- ii. Toll should be immediately charged from the vehicle once it passes through the toll gate by debiting the user.
- iii. Different toll operators should be able to realize their respective toll and should have access to the toll collection data.
- iv. Violation in toll collection should be detected.
- v. The cost to users should be low for acceptability by road users to achieve penetration.

vi. There should be multiple vendors to ensure competition.

vii. There should be a network of Tag recharge facility.

Based on the interactions, review and deliberations as discussed above, the Committee came to the following conclusions with regard to an appropriate ETC system:

Passive RFID technology for automatic vehicle identification

- Automatic vehicle identification can be effectively achieved through almost all the technologies. However, there appears to be a certain clear advantage in using passive RFID technology, especially in terms of cost of the tag and widespread use of the technology. This technology has two variants, viz, ISO18000- 6C and ISO 18000-6D. The former scores over the latter because it has been in use for the last one decade or so in various countries and has many vendors, while the latter is a more recent one and has only one vendor, as per information available with the Committee. Besides, 6C technology has also been used for a host of other purposes. This technology is maintenance-free as the passive tag does not require a battery and has a long life. It is simple to install (an RFID tag can be simply stuck on the windscreen of a vehicle), and the reliability of identification is high. Most importantly, the cost of the passive RFID tag for the vehicle owner is a fraction of the cost of the other alternatives. The Committee recommends that ISO 18000-6C standard be adopted for ETC in India.

A prepaid system for toll collection

- Going by the success of prepaid phone cards in the country, the Committee is of the opinion that a prepaid system would be preferable for toll collection, though a postpaid system could also be supported. With prepaid systems a vehicle owner can “recharge” the account for the vehicle (the account number will be the RFID tag number), and when the vehicle passes through the ETC lane of any toll plaza across the country, appropriate toll will be debited from the account.

A central system to manage financial transactions

- A Central Toll Clearing House (CTCH) is essential to manage all the financial transactions relating to toll collection (e.g., recharging, toll debiting, payment to the toll concessionaires, etc.). A suitable software client will run at all toll plazas, which will be connected to the Clearing House through a WAN.

The Clearing House will retain toll records and will perform transactions on request from the client at the toll plazas. In many ways, this system will be like the existing credit/debit card system, which uses a central clearing house. The Central Clearing House for Tolling provides many benefits; most important being that it simplifies the system that has to run at toll plazas. It provides a modern, simple, and scalable solution for toll collection and settlement.

A legal framework that will allow violator handling

- For the ETC to be operationally successful, it is imperative that a proper legal framework be evolved that will allow suitable handling of violators. While this is outside the scope of this document, the legal approach must be carefully considered. Violator handling in particular is an integral part of the ETC system and suitable laws are needed to manage and enforce this. Without such laws in place, no ETC system will work, as leakages due to violators will force toll plaza operators to minimize the use of ETC.

Hiring of a System Integrator for ETC implementation

- The design and implementation of an ETC system is a complex task, and it is recommended that an experienced System Integrator be employed for it. Furthermore, as the task of developing a proper RFP and selecting vendors and system integrator itself is complex, a consultant should be employed for this purpose by the NHAI.

Based on the above conclusions, the committee recommends that the appropriate ETC technology would be passive RFID conforming to ISO 18000-6C, which uses Tags that can be stuck on the windscreen of the vehicles (and can even be provided at the time of manufacture by regulation). The Tags will have the unique identification of the vehicle, and all tolling transaction and settlement can be accomplished by the reader, the software client, and a Central Toll Clearing House.

Introduction

Tolled highways are a critical part of road infrastructure

Toll operations are primarily manual, increasing wait times

Electronic payments using OBU/Tags and smart cards for toll transactions

Electronic Toll Collection (ETC) can enable scalable, convenient electronic payments

Clear, automatic vehicle identification is essential

2.1 The expanding highway network in India makes toll infrastructure a priority

Across the world, tolled highways have emerged as a means to effectively manage the use of road infrastructure, and also fund its expansion. In tolled highways, a vehicle plying on a tolled road has to pay an amount of money – a toll – for its use. The common method of toll collection is by having the vehicle pass through a toll plaza, where it pays the toll. The amount of toll paid depends on various factors, including the type of the vehicle.

Presently, in toll plazas toll operations are primarily manual, where the receipt and collection of money is done manually and the receipts are issued with the help of computers. The cash collection method forces road users to stop & pay at the toll plazas sometimes resulting in long queues.

In the coming years India is going to have an extensive and fast-growing national highway network. As the volume of traffic increases, this method of toll payment becomes cumbersome – payment necessarily requires users to stop for payment, and users generally have to wait at toll plazas for their turn to come. This results in wastage of time and fuel, and also reduces the overall throughput of the highway.

2.2 Electronic payments for toll collection

Electronic payments, a popular mode of toll collection worldwide, process financial transactions without human intervention at toll plazas.

Electronic Payments may be achieved with :

- (a) Electronic Toll Collection (ETC) using On Board Units (OBU)/Tags
- (b) Smart Cards

2.3 Electronic Toll Collection (ETC) systems

Electronic Toll Collection (ETC) systems enable the electronic payment of highway tolls. ETC systems use vehicle-to-roadside communication technologies to perform an electronic monetary transaction between a vehicle passing through a toll plaza and the toll collection agency. ETC equipment can take the place of a human toll collector who manually collects tolls at tollbooths. Such a system can work across toll plazas run by different operators. In addition, it allows such transactions to be performed while vehicles travel at near highway cruising speed.

Any ETC system must address the following four aspects for functioning properly:

- (i) Vehicle identification

Automatic Vehicle Identification generally involves the use of Transponders installed in the vehicle, which communicate with roadside readers to identify the vehicle.

Toll charges depend on vehicle class, and require clear classification mechanisms

(ii) Vehicle classification

Vehicle classification is needed, as toll charges levied on a vehicle depend not only on the toll route being used, but on the class of the vehicle – Car /Jeep/Van, LCV, Truck, Bus, Multi Axle Vehicles etc.

Toll charges must be processed clearly and securely

(iii) Transaction processing for collecting the toll

Once the vehicle is identified, the toll charges need to be billed to the user and the toll collected passed to the toll concessionaire. The ETC system has to handle this financial transaction in a reliable and secure manner.

Violators must be managed effectively for system to function

(iv) Violation handling

The system needs to detect and manage cases of a vehicles passes through an ETC lane without a valid Tag or insufficient funds in its account. Violator detection and handling is essential for the success of an ETC system – without policies and systems in place for this, an ETC system will simply not work.

2.4 Advantages of ETC systems

Some of the distinct advantages of implementing Electronic Toll Collection Systems include:

ETC systems lower traffic congestion and increase convenience for road users

For Road Users :

- (i) Increases user convenience from payment without stops at toll plazas
- (ii) Less traffic congestion and reduced commute times
- (iii) Toll statements which can be mailed or made available online – the road user no longer has to request a receipt

Lowers operating costs with clearer audits, and operators can easily expand capacity

For Toll Operators :

- (i) Less operating costs for toll operators
- (ii) Better audit control through centralized user accounts
- (iii) Expanded capacity without being required to build more infrastructure

Brings transparency in toll transactions, and savings on car emissions

For Govt. / Society:

- (i) Savings on fuel and reduction of emissions from idling and repeated stops for vehicles
- (ii) Improves transparency of toll transactions
- (iv) Reduces revenue leakages

Current Scenario of Electronic Tolling in India

Developed countries have faced legacy constraints in implementing ETC

In most advanced countries, ETC systems have evolved from older systems where many of the existing technologies did not exist. Due to backward compatibility constraints, implementing ETC models across the country has proved to be a challenge, and sometimes complicated solutions have evolved to ensure interoperability between systems of different toll vendors.

India is largely free from legacy infrastructure in toll collection

India has an advantage as there are no legacy systems in place, and highway expansion has begun to take off mainly over the last decade. Consequently, there is an opportunity to build a simple and robust ETC system that leverages modern information and communication technologies. This proposal aims to create a framework for building an integrated and uniform system across the country.

Presently, Electronic Toll Collection is used at few toll plazas on National Highways like:

- (i) Delhi – Gurgaon Highway
- (ii) Bangalore – Electronic City Elevated Highway

4

Constitution of The Committee

Committee constituted to recommend technologies for ETC systems

The Ministry of Road Transport & Highways, vide Order No. NH-12037/33/2010 –PIC dated 20.04.2010 has constituted a Committee to examine all technologies available for Electronic Toll Collection and recommend the most suitable one for implementation throughout India. The members of the Committee are:

- | | | |
|---|---|------------------|
| (i) Shri Nandan Nilekani, Chairman, UIDAI | - | Chairman |
| (ii) Prof. Pankaj Jalote, Director, IIIT, Delhi | - | Member |
| (iii) Dr. Kolin Paul, Asst. Professor, IIT, Delhi | - | Member |
| (iv) Shri A. V. Sinha, DG (RD), MoRTH | - | Member |
| (v) Shri V. L. Patankar, Member (Tech), NHAI | - | Member-Secretary |

Copy of the Order placed as Appendix – A.

ETC Technologies

Different Automatic Vehicle Identification technologies determine the choice of ETC

DSRC is bidirectional, and may be active or passive

Used in European countries, and has no internal power source

Used in Japan; has an internal power source, and is used for a long-read distance

RFID tags come in three types – active, passive, and assisted passive.

World-wide, the following ETC Systems are used which are based on different Automatic Vehicle Identification (AVI) technologies. The AVI technology forms the basis of the ETC system, since it enables the automatic identification of a moving vehicle. A good summary of ETC technologies and their adoption is available at http://www.calccit.org/itsdecision/serv_and_tech/Electronic_toll_collection/electron_toll_collection_report.html.

5.1 Dedicated Short Range Communications (DSRC)

Dedicated Short Range Communications is bidirectional communication between an On Board Unit (OBU) and the Road Side Unit (RSE). The system works within the 5.8 GHz band with 20-30 MHz

5.1.1 5.8 GHz Microwave (Passive)

In this case, the OBU does not have an internal power source, like a battery. Instead, it gets power from the Reader. The Reader sends out electromagnetic waves to the OBU and the antenna induces the energy to power the ICs.

Most of the European countries use 5.8 GHz microwave (Passive) technology based on CEN 278 standards.

5.1.2 5.8 GHz Microwave (Active)

In this case, two way communications between OBUs and Road Side Units / Infrastructure is possible. Active OBU has an internal power source, usually a battery. The OBU use the power to work the IC and broadcasts a signal to the reader continuously. It is normally used for a long read distance.

This technology also supports integration of smart cards, and is presently being used in Japan.

5.2 RFID (Radio Frequency Identification)

Generally, RFID tags are used for the purpose of identification and tracking using radio waves.

There are generally three types of RFID tags: active RFID tags, which contain a battery and can transmit signals autonomously, passive RFID tags, which have no battery and require an external source to provoke signal transmission, and battery assisted passive (BAP) RFID tags, which require an external source to 'wake up' but have significantly higher read range.

In Passive RFID, two standards exist i.e ISO 18000-6C and ISO 18000-6D. The protocols for communication between the Tag and the Reader are different between the two standards. 6C uses "Reader talk first" approach in which Reader initiates the communication with the tag, while 6D uses "Tag talks first" approach.

The Use of CALM is limited since the ISO standard only exists for the Infrared medium

Uses the GSM network, eliminating need for toll plazas. Managing violations is a challenge

Images of license plates are captured, which are compared to a license plate database.

Requires a centralized database of vehicle registration, which is absent in India.

5.3 CALM (Communication Air-interface, Long and Medium range) ISO /TC204

This technology supports multiple communication media including Cellular, Microwave, and Infrared. However, the ISO has till date, published the CALM Standard only for the Infrared medium.

5.4 GNSS/CN (Global Navigational Satellite System/ Cellular Network) systems

GNSS/CN is being used in Germany for commercial vehicle tolling. The location of the vehicle is tracked using GPS receivers which transmit the information to the control centre using GSM networks for calculation of toll.

This type of tolling system eliminates the need of toll plaza infrastructure along highways. However, enforcement of violated vehicles is a great challenge in India.

5.5 Automatic Number Plate Recording (Vehicle Identification using number plates)

Vehicles wishing to use toll roads pay for passes in advance or have a central account from which monthly deductions are made. In the free flow lane at the toll area, images of the license plates of all vehicles are captured. These are compared with the database of the license plate of the subscribers. Those not in the list are issued a notice to pay the toll with penalty.

This system requires a robust and centralized database of vehicle registration throughout the country. India is yet to have such a countrywide linked system. Therefore, enforcement and identification of defaulted vehicles would be a major problem.

This method of tolling is presently being used in London Road Pricing.

A comparison between some of the technologies:

	ETC Technology	Cost	Suppliers	In use	Comments
DSRC	Active Microwave 5.8 GHz	About Rs 2000 per OBU About Rs 5 Lac per Reader	Limited	Yes (Japan)	Due to higher bandwidth and data speed, supports many ITS applications
	Passive Microwave 5.8 GHz	~ Rs 1000 for OBU ~ Rs 2L for Reader	Multiple	Yes (Europe)	Very Simple OBU
	Infrared ISO-CALM	Rs 1000 for OBU ~ Rs 2L for Reader	Limited	Yes (Austria and Malaysia)	Can be easily extended to a contactless card and useful for other ITS applications
RFID	Passive RFID	About Rs 100 per Tag About Rs 2 Lac per Reader	Multiple	Yes (South America, Georgia, US)	Allows tamper resistant "stickers" Small, light, very cheap, almost unlimited life
	Active RFID	About Rs 1000 per On Board Unit (OBU)	Limited	Yes (Florida)	On-board transmitter, higher range, expensive Finite life as the battery has to be replaced
	GNSS/CN	About Rs 2 Lac per Reader About Rs 2000 per OBU	Limited	Yes (in Germany)	Too sophisticated and due to absence of toll plazas, enforcement on violations is very difficult in India.

DSRC more suitable for high data rate requirements, and is expensive

Many European countries have deployed passive microwave DSRC based systems while some US states and Japan have deployed active microwave DSRC. The exclusive advantage of Active systems as compared to Passive systems is with respect to very high data rates. The domain of ETC in India will not (in our opinion) require more than 2.5 Mbps data rates in the foreseeable future. Clearly this means that the DSRC Active systems are expensive (and in some sense, powerful) products to be used exclusively for tolling. Even in the developed countries (USA for example) it will take time for adoption despite the fact that ETC in some form is already in place. Further, there are some questions regarding the interoperability of such systems.

RFID may be more suitable in India

On the other hand, the RFID based ETC is going to be technology of choice in the coming days even in countries where passive and active DSRC systems are in place. There are many instances in the US where toll operators have moved from the microwave based systems to RFID based systems. The RFID (6C) technology offers all the advantages over conventional 915 MHz active and 5.9GHz (active and passive) systems except data rates as mentioned above. Also the ranges and accuracy levels of RFID (6C) based systems are adequate from the tolling perspective.

RFID tags are an inexpensive technology, and can minimize cost to consumer

As mentioned above, 256 kbps data rates are adequate for the intended use in India. Most importantly, the over arching reason for adoption of RFID as the technology of choice for ETC in India is the very low cost of the Tags that would go into each vehicle. Tags are available today for under Rs 100 which we anticipate will go down in the future may even enable the toll operator to absorb the cost and provide the tag for free.

The other advantage is that these systems do away with the need for a recurring cost of changing batteries once in every five years or so this also adds to the price point advantage. The successful adoption and the high degree of penetration levels of RFID based ETC in Puerto Rico (where a high percentage of the population do not have a bank account) shows that if the investment on the part of the consumer is minimal, the uptake of technology is likely to be widespread.

6

Interoperability on National Highways

A unified ETC system would enable interoperability across toll agencies

A unified ETC technology across the nation is mandatory for the interoperability of toll operations.

Interoperability in Toll Collection Systems is essential as different Highway sections are tolled by different agencies. Such interoperability has both technical and administrative components. Technical interoperability requires the ability for any Transponder from any supplier to communicate with any Reader from any supplier.

Administrative interoperability (or procedural and contractual interoperability) means multiple toll operating agencies share toll transaction data and revenue reconciliation.

Central Toll Clearing House (CTCH)

A central system to manage toll transactions is necessary for a nationwide ETC

A common electronic payment mechanism that can be used across toll plazas

A centralized back office operation or Central Toll Clearing House is mandatory for the operation of nation-wide ETC systems.

The Central Clearing House concept is a transaction management system which will enable multiple Toll Collection Agencies to share toll transaction data and revenue reconciliation.

Today, if one has to travel from Mumbai to Delhi on the NH-8, he/she will have to pay tolls at about 24 toll plazas. In such conditions, it is convenient and easy for a road user to use a common payment mechanism which can be accepted at all toll plazas. Irrespective of the toll plazas being operated by NHAI or BOT concessionaires, the reader system at each toll plaza debits the applicable amount from the OBU / Smart Card of road users.

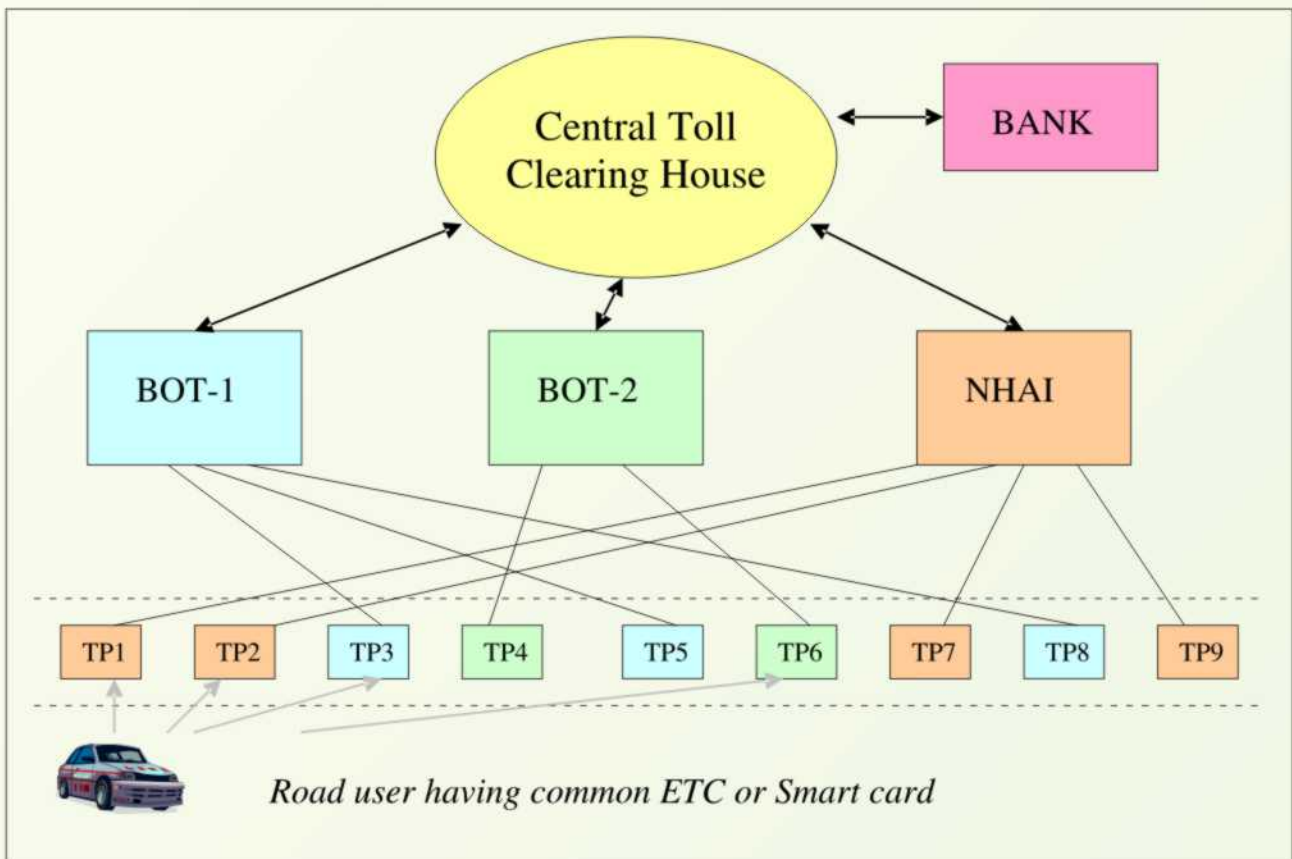


Fig 1: The ETC ecosystem

Every toll plaza shall have the facility to account for ETC based payments, and all such transactions for the day are sent to the Central Toll Clearing House (CTCH) as claims. The CTCH runs an end of day settlement and sends files to every toll plaza and point of sales outlet for their receivables for that particular day. Such files are then sent to the bank for conducting financial settlements to the particular bank accounts of all the toll collecting agencies.

Meetings of The Committee

The Committee has met with ETC vendors and BOT concessionaries

Pursuant to the communication vide DO letter ref. RW/NH/12027/5/2009 dated 14.01.2010 of Hon'ble Minister (RT&H) to Chairman, UIDAI, advance action has been initiated and as part of that exercise, an interactive meeting / presentation was held with the following ETC vendors and BOT Concessionaires on 15.04.2010 at UIDAI office, Jeevan Bharti Building, Connaught Circus, New Delhi.

Sl. No.	Participating firm / Organisation	ETC Technology
01	IRDSA, New Delhi, IBI Group, Gurgaon	RFID
02	Kapsch / Metro Road System, New Delhi	5.8 GHz Microwave (Passive)
03	Mitsubishi, Mumbai	5.8 GHz Microwave (Active)
04	Efkon India, Mumbai	ISO CALM
05	Siemens, New Delhi	GPS/GSM
06	DS Constructions	
07	DND Toll Agency	
08	L&T	
09	GMR	
10	All India Motor Transport Congress (AIMTC)	

Further, meetings of the Committee were held on 06.05.2010, 08.06.2010 and 16.06.2010.

Factors Considered for Finalising The ETC Technology

The system must be interoperable nationwide, and affordable

Technologies should be tried and tested

Multiple suppliers should be available for each component

The system should be easy to use

The ETC should be scalable to other applications

Payments should be possible through credit cards and mobile phones

NHAI/MoRTH should be overall regulatory authority for central transaction management

While deliberating upon various technologies and their possible adoption/application in India, the following factors were considered:

- (i) The proposed system should be interoperable throughout India. Any vehicle should be able to go through any toll plaza.
- (ii) The system should be affordable to road users.
- (iii) The technologies to be used should have been proven in the field. This is a deployment and operational project, not an R&D one. Hence, while the latest technology is desirable, this project should not be the "pilot".
- (iv) There should be multiple suppliers and manufacturers for each major component of the technology to be used, and different vehicle owners, as well as different plaza operators, should have a choice of suppliers.
- (v) The system should be easy to use, deploy, manage, etc, particularly at the user end. The education levels prevailing in the country, particularly for the driver segment, necessitates that the solution should be simple requiring minimal intervention / actions from the driver.
- (vi) The system can primarily be used for Toll Collection, but could also be subsequently used for other applications like Vehicle Identification / Tracking, Registration, Traffic Enforcement, Parking etc.
- (vii) Due to common availability of Credit Cards and Mobile Phones among the general public in India, these channels may be used as the preferred mode of payments for ETC.
- (viii) Regarding distribution / recharging of Tags, a model similar to Mobile Phone network may be considered.
- (ix) Banks / Financial Institutions / Depositories may be involved for Central Toll Clearing House / Back office operations. However, NHAI / MoRTH should be the regulatory / controlling authority for this purpose.

Based on the above factors, the Committee's recommendations focus on four aspects.

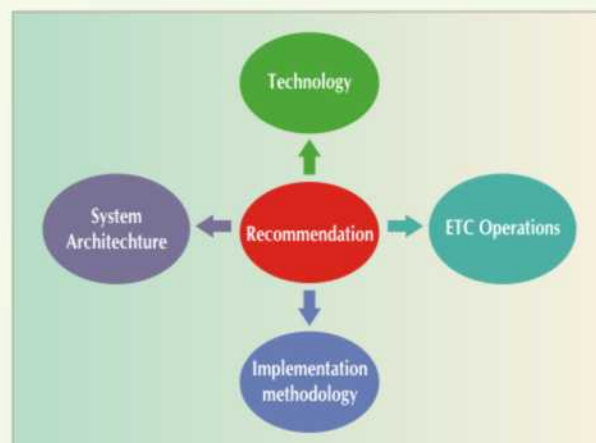


Fig 2: Committee recommendations for an ETC system in India

Technology Recommendations of The Committee

Passive RFID is the cheapest solution; it is also reliable and widely tested

After detailed analysis, the Committee has taken up individual technologies for further consideration.

10.1 RFID (Passive) - Based on the above it is clear that passive RFID, besides satisfying functional requirements, is the cheapest solution available. It is also a reliable, tested solution, despite being a relatively new technology. It is extremely simple to use and administer, requiring no actions on the part of the user (the sticker itself can be stuck on the vehicle by the auto vendor or the manufacturer). It should be emphasized that the most persuasive reason in favor of passive tags is the cost and low maintenance - it can cost 10% or lesser than the cost of alternatives, and requires no battery replacement or any other action on part of the user.

Tags complying with ISO 18000-6C have been in existence for over a decade and have been widely used, including in many ETC systems. In fact, most of the passive RFID based ETC systems that are deployed use ISO 18000-6C Standards. ISO 18000-6D is a newer standard, which allows higher bandwidth communication with less interference. Although 18000-6D is also an open standard in ISO, as far as the Committee could find out, there is only one microchip manufacturer as on date for this kind of application.

Also the widespread use of ISO 18000-6C Standard in transportation as well as supply chain management systems mandates that we use RFID based on ISO 18000-6C for ETC in India as it will fulfill our functional requirements.

The higher cost of DSRC approaches compared to RFID removes them from consideration

10.2 Microwave 5.8 GHz Passive – Undoubtedly this technology is being used widely world-over, and has multiple vendors. But due to its higher cost of OBU in comparison with RFID tags, the committee has not recommended ETC based on 5.8 GHz Passive technology for further consideration.

10.3 Microwav 5.8 GHz Active – The ETC based on this technology is successfully operational in Japan. This is a moderately new technology supports most of the high speed / high bandwidth ITS applications. Again, due to the higher cost of OBU in comparison with RFID tags, the committee has not recommended ETC based on 5.8 GHz Active technology for further consideration.

The higher cost of DSRC approaches compared to RFID removes them from consideration

10.4 GNSS / CN – This ETC technology is presently being used in Germany for commercial vehicles.

The Committee has not considered this ETC technology for the following reasons:

- (I) GPS /GSM tolling is a kind of Open Road Tolling (ORT) wherein the vehicles are tracked and tolled based on the distance traveled. In this case, there is no need for setting up of toll plazas.

As there is no toll plaza, all vehicles must compulsorily install OBUs. The other possibilities of alternate toll payments are through Internet pre-booking and Manual Vending Machines.

The GNSS/CN technology requires a central vehicle registration database

OBU component is expensive; system cannot be implemented in phases

CALM-based implementation globally has been limited. Expensive OBU

Number plates not standardized in India, which limits ANPR implementation

In case of toll violations or absence of OBU, enforcement cameras will capture the image of the number plate and transmit to control centre for matching with the central vehicle registration database and initiate action for penalty. However, there is no Central Vehicle Registration Database in India to enable tracking of vehicle / ownership details for dispatching toll bills / Penalty notices.

(ii) Expensive OBU

(iii) The GPS/GSM tolling system cannot be implemented in phased manner. The implementation would have to be nation-wide.

10.5 CALM - The ETC based on this technology is operational in select few countries only. Also, due to its higher cost of OBU in comparison with RFID tags and limited vendors, the committee has not recommended ETC based on CALM technology for further consideration.

10.6 ANPR (Automatic Number Plate Reader) – The ETC based on this technology is presently being used for London Road Pricing. Since this type of ETC technology solely relies upon the number plates of the vehicles, the standardization of number plates is a prerequisite.

In the absence of standardized number plates in India and issues related to enforcement of toll violations, the Committee has not recommended ETC based on ANPR technology for further consideration.

Finalisation of ETC Technology

RFID (passive) would be the most suitable technology for ETC in India

RFID (passive) would be the most suitable technology for ETC in India

The Committee is of the opinion that RFID (Passive) based on ISO 18000-6C standard is adequate for ETC in India. The advantages of this technology in terms of cost and simplicity make it suitable for the Indian environment.

Within passive RFID there are multiple standards. To ensure that multiple suppliers can provide the tags as well as readers, and that tags produced by one producer can be read by all the readers, the standards have to be fixed. For selecting which of the passive RFID standards should be used, the **Committee recommends adopting RFID based on EPC, Gen-2, ISO 18000-6C Standards for Electronic Toll Collection on National Highways in India.**

Recommendations on System Architecture

A central system to manage toll transactions, which will be the repository of vehicle data

Local client software for each stakeholder

Stakeholders connected to central system through a WAN link

12.1 A central transaction management system - It is proposed that a Central Toll Clearing House (CTCH) be established by the NHAI. The CTCH will be on the internet (or the "cloud") and will handle all financial aspects of tolling (e.g. debiting toll from the users account, crediting the amount due to the different operators, managing recharging, etc.). It will also be the repository of the master data about vehicles and their IDs, related information about vehicle owner, the usage of toll systems, etc. (With this centralized information, the CTCH can, in future, offer many more services.)

12.2 Local client software - Each stakeholder interacting and transacting with the CTCH will be provided with local client software. These stakeholders include the NHAI, Concessionaires, Toll Operators, Operators recharging the Tags, Vendors selling the Tags etc.

12.3 Proposed architecture - The proposed architecture has a CTCH and one client for each toll plaza operator, and other stake holders like banks, recharge operators, Tag sellers, etc. Each client is connected to the CTCH through WAN link.

The proposed architecture is shown below:

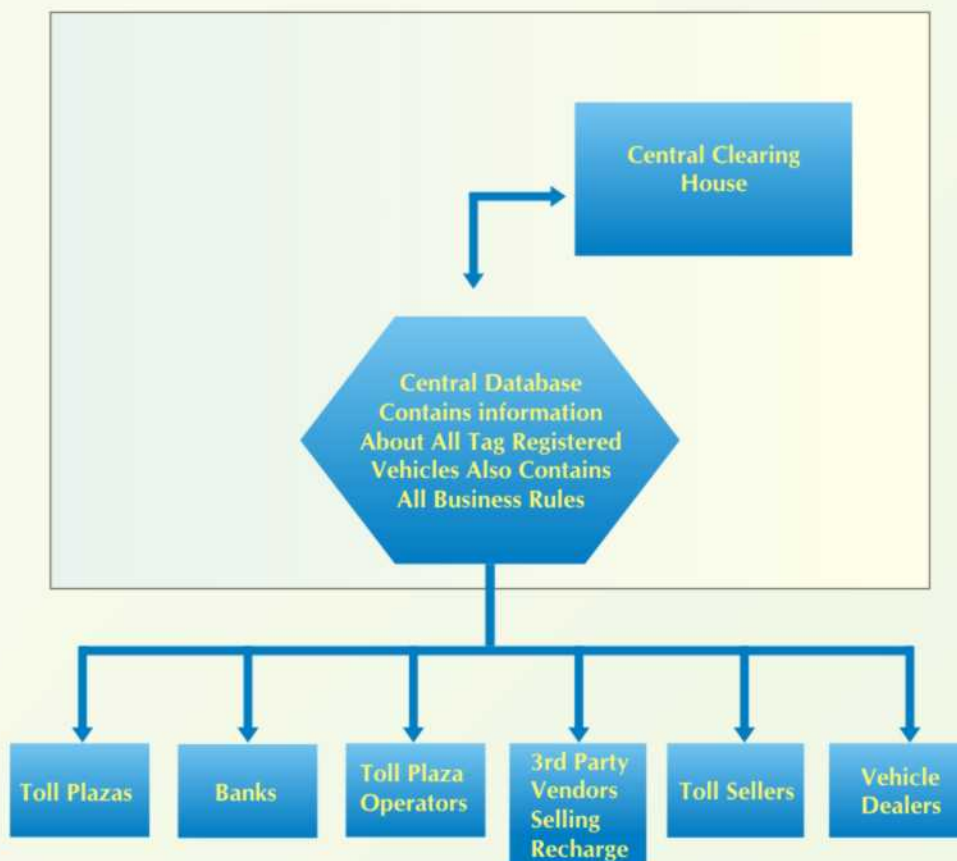


Fig 3: Overall Architecture for an ETC system in India

Reconciliation can be done periodically

Classification based on RFID tag data

Local data storage for ease in detecting violations, and periodic updation

Data updates when connectivity is available

Integrity requirements lower since risk of misuse is limited

Intelligent updates are possible, based on locality and geography

Transactions can be recorded locally and later updated to the central system

To prevent duplicate tags, unique ID should be installed into tags at factory time

12.4 Periodic reconciliation - To transfer the toll due to the toll operators, a reconciliation be done periodically (say every night), similar to the credit card system, when the amount is credited to the account of the toll operator by the CTCH (this will be done by the clearing house component). This can also be cross checked by the Toll Plaza System keeping track of total toll collection.

12.5 Vehicle classification - With this architecture and the type of RFID tags recommended, vehicle classification is done based on the classification data in the RFID tag which is read by the reader.

12.6 Local data storage and updation - While the CTCH will retain all the data and perform the transactions, it is essential that the system at the toll plaza has suitable mechanisms to quickly detect violations, and not have to contact the CTCH for this verification. One approach is to provide each client data in the local cache consisting of the ID, the amount in the user account, and some other information. This data need not be always in synch with the data at CTCH as it is only for violator detection and not for transactions, and as changes in the values for a vehicle do not happen very fast. Consequently, it will only require updation periodically.

It can be seen that this caching is feasible. Even with 100 million vehicles with ETC tags, and 32 bytes of data for each tag, the size of the total database to be maintained at the client is less than 4 GB. This can easily be downloaded, when a toll plaza “goes online”. For hourly updates, only the changes need to be transferred from the CTCH to the clients. As this is likely to be less than 0.1%, about 40 MB. This can be downloaded easily every hour (or even more frequently) by each client to update its records.

One suggested approach is a light weight method, as the integrity requirements are lower here compared to banking, with a limited risk of “misuse” (e.g. some vehicle doing two transactions in a short time without enough money, since the low caching frequency can allow an older balance which does not incorporate the fact that the vehicle has already passed one toll, to be used when the vehicle passes the second toll plaza).

Under such an approach, updating local caches can be done “intelligently” by using locality information – when the balance of a vehicle is reduced after crossing a toll plaza, this update need not be done throughout the country but only among clients that are within some vicinity (say within 250 kms). Country-wide synchronization can be done less frequently (say once a day).

12.7 Recording toll transactions - It is possible to have the transaction recorded locally, and then “pushed” to the CTCH later in a batch mode, as the chances of the vehicle doing another transaction in the near future is very low. This allows an easy way to handle the situation when the connection between the client and CTCH is down.

12.8 Ensuring uniqueness of tags - The tags to be used for ETC should have the unique ID burnt in the tag at factory time, in a manner that it is tamper proof. Furthermore, the ID should also contain details on the type of vehicle. The vehicle types will be defined by NHAI (e.g. two wheeler, three wheeler, car, mini truck, medium sized truck, bus, large truck, etc.) and these will have to be encoded in the tag ID. This requires different types of tags for different

types of vehicles, and the manufacturer of the tags will have to label the tag suitably, specifying the vehicle type it is for. A vehicle owner has to buy and stick the suitable Tag into his/her vehicle.

Each toll plaza lane should have AVC systems

Tag code should be used for vehicle classification; additional mechanisms may also be necessary

12.9 Automatic Vehicle Classification (AVC) systems - Each lane in the toll plaza shall be equipped with independent AVC Systems for cross checking the class of vehicles read by the ETC Reader.

Vehicle classification can be done easily by the use of classification code in the Tag. However, to detect misuse of tags (e.g. tag of lower class used in higher class vehicles), it is recommended that alternative means also be used for vehicle classification. There are a number of AVC systems available based on the following Sensors.

- (i) Fiber-optic treadles
- (ii) Laser classifiers
- (iii) Optical height sensors
- (iv) Optical axle counters
- (v) Infrared Light curtains
- (vi) Magnetic Sensors

The method for verifying the Vehicle classification may be left to the toll plaza operator.

Recommendations on Implementation Methodology

ETC systems in toll lanes

13.1 Use of ETC systems in toll plazas - To begin with, NHAI may implement ETC systems in 1/2 lanes of Toll Plazas being operated by BOT (Toll) Operators where the Toll Management System (compatible to ETC) is in operation.

Hiring of System Integrator for ETC design and implementation

13.2 Hiring of System Integrator - For design and implementation of an ETC system, it is recommended that an experienced System Integrator be employed. Furthermore, as the task of developing a proper RFP and selecting vendors and system integrator itself is a complex exercise, NHAI may engage a consultant for this purpose. Following are the broad TOR of the Consultancy Services

Hiring of Consultant for RFP and vendor selection

- (i) To prepare System Architecture (National level & Plaza level), Technical Specifications (Hardware & Software)
- (ii) Assist NHAI in implementing ETC at Toll Plazas.
- (iii) Networking and data communication between toll plazas and CTCH
- (iv) Assist in setting up of CTCH
- (v) Point of Sales (POS) for Tags

As operational issues are very important for the success of ETC, it is recommended that the Consultant shall take the working models from some countries where ETC is being used with passive RFID and integrated payment system. Two good examples to study would be Puerto Rico, and Georgia, USA.

Prepaid system may be used for toll collection

13.3 Prepaid system for toll collection - For collecting toll, a pre-paid system is recommended. With this, the vehicle owner will credit some money ("recharge") in the system against the Tag ID. For toll payment, when a vehicle passes through the toll plaza, the system at the toll plaza will determine the amount of toll to be deducted, and request the CTCH for an online transaction to deduct the toll for the particular ID.

Single Authority to set up and operate central system

13.4 Single Authority to operate central system - There should be one Authority established that will set up and operate the CTCH. It is recommended that the task of setting up the CTCH (including the servers, software, etc) and the task of operating the CTCH be given to one organization. The CTCH organization should be responsible for not only providing all support for the CTCH, but providing the local client for each stake holder. This will ensure that clients work properly with the CTCH.

We need a clear system to handle vehicles violating toll conditions

13.5 Violation Handling - The normal flow, i.e. when a vehicle with a tag and enough money in the account goes through the toll plaza is generally handled easily. Violations occur when a vehicle which does not have enough money in its account, or does not have a valid tag, tries to go through the ETC lane. Method for dealing with violations is perhaps the

most important aspect of ETC – its an aspect that will determine the long-term viability of the system.

Option to handle violators after vehicle leaves the toll plaza

First, it should be understood that an approach that will identify and stop the violating vehicle before the toll plaza, will reduce the benefits of ETC, as that vehicle will block the traffic for others behind it. Hence, despite the desire to disallow a violator to proceed, violators are often not stopped before the toll plaza. And most countries adopt the approach of letting the vehicle pass, so the traffic behind is not held up, but identify the violator and handle it after the toll plaza.

One way to handle violators is, that when the toll plaza identifies that the vehicle with ID does not have enough funds in its balance (or does not have a valid tag), it raises an alarm or turns a red light on immediately after the toll plaza for handling of the violator. Some ways of handling violators after the toll plaza are:

- (i) A red light goes on if a violating vehicle passes. The enforcement agency stops the vehicle on the side, and collects toll manually.
- (ii) Vehicle is identified and a bill is sent to the owner of the vehicle.

Difficult to handle vehicle in India once it crosses plaza

However, as Indian conditions are very different, this kind of enforcement may have difficulties – once the violators are allowed to cross the plaza, it is very difficult to handle / manage them.

Vehicle may be diverted to manual toll collection lane. NHAI may also consider additional penalty

To handle this, an alternative arrangement may be an automatic barrier before reaching the ETC lane that remains open if the vehicle has a valid tag and sufficient funds, but closes otherwise. This enables the non-tag vehicles to exit from the ETC lane and go to manual lane without disturbing vehicles with valid tags. This approach, however, will slow down traffic. Also, without any penalty imposed on the vehicle which came to ETC lane and then moved to the cash lane, no learning will ever take place and this situation of potential violators will continue. Hence, even for this, a penalty system has to be in place.

NHAI could implement pilots with different approaches toward violators before final decision

Other approaches of dealing with violators are also possible. However, they deal with operational issues and it is suggested that NHAI do a comprehensive analysis of what approaches are possible/feasible before deciding its own policies.

NHAI should consider experimenting with a few different approaches in partnership with difference concessionaires. With experience and data, a suitable approach can be decided in the future. It should, however, be pointed out that any system will require some penalties for violators, and this may require suitable changes in some of the laws.

Recommendations for Effective Operation of ETC

Framework to deal with violators

14.1 Clear framework to penalize violators - For an ETC to work effectively, violators have to be penalized. Currently, the toll plaza operator has no power to penalize the violator, and the legal framework does not permit this penalty. It should be clear that unless there is an enabler law to penalize violators, no ETC system can work. So, while technology solutions must be developed, a suitable legal framework must be put in place for ETC to work.

Incentives to shift from manual to ETC system

14.2 Incentives to migrate to ETC - Unless there are incentives in the ETC system for the users, technology solutions will be of little use. So, suitable incentive schemes must be devised to facilitate the migration of users to ETC.

Incentives for toll operators to deploy ETC

14.3 Incentives for toll operators - Similarly, if the toll plaza operator does not see significant benefits from the system, he will not fully deploy the ETC. While there should be a mandatory requirement of provisioning ETC lanes in the Model Concession Agreement (MCA), it is essential to keep interests of toll operators in mind and provide suitable incentives.

Clear training and awareness processes

14.4 Training and awareness - Suitable drives should be made for user training and awareness – with better awareness, adoption can be faster, and the number of violations can be reduced.

Mandatory RFID tags for vehicles

14.5 Tag installation - Once the ETC system has stabilized, RFID tags on all vehicles may be made mandatory – manufacturers can install the tag at production time for new vehicles, and existing vehicles can be required to get themselves tagged. This will avoid problems related to user sticking his own tag, and also has huge benefits for monitoring, traffic planning, enforcement, security, etc, and can be done easily as the cost of tags is low.

The location for tag sticking should be standardized by NHAI. E.g. it can be some specific location in the windscreen on a car/truck/etc, and can be some similar location for a 2-wheeler and a 3-wheeler.

Centralized, networked system for managing toll transactions

14.6 Central Toll Clearing House - The CTCH is a centralized system on the Cloud that will be accessed by various stake holders like Toll Operators, NHAI, banks etc. For facilitating this process, some of the requirements of CTCH are mentioned below:

Allow approved registrars to issue Tags

(i) It should allow approved registrars/vendors to “issue a Tag (ID)”. This means, allow the vendor to enter the ID (and the system should check for duplicates), and other information such as owner of the vehicle, type, and number plate.

Allow recharge of Tags through a variety of networks

(ii) It should allow “recharge” of the balance of a Tag(ID). This should include various mechanisms for recharge – through credit card, bank transfer, cash, phone banking, etc. The recharging should be easy and possible anywhere in the country, through any agent, and leveraging existing financial instruments and networks.

Allow debit transactions through authorized vendors

SMS alerts for transactions, and service for users to check their balance

Caching of database in local toll operator computers

Clear mechanism to handle tag during vehicle sale

Mechanism to handle multiple tags on vehicle

Location aware updates for transactions and recharge

Clear mechanisms to ensure the reliability and security of data

A portal to share data with the public

(iii) It should allow transaction for debit from authorized vendors, much like credit cards do. Using this facility, the toll plaza operators (or any other approved vendor) can do a debit. However, as the amount of money involved is small, the level of security needs to be less. This will also require reconciliation (say on a daily level) so payments due to vendors are transferred to them, ensuring good response time. The debit transaction need not be fully online – the transaction can be recorded on the local computer of the toll operator and updated on the CTCH later (at regular intervals, perhaps). This feature allows toll operator to function even when the link is down.

(iv) It should send an SMS to the owner for every transaction done.

(v) It should provide a Call Center/SMS based method for users to check the balance in their account.

(vi) As checking of whether there is sufficient balance or not has to be done quickly, it should be possible on local computers at the toll plaza. Hence, the CTCH should allow caching of the database at toll operator computers.

14.7 Mechanisms to handle tag during vehicle sale - Suitable mechanisms should be built to handle the case of when vehicle is sold (either the tag is transferred, or the tag is destroyed and the new owner buys and sticks a new tag.)

14.8 Handling multiple tags - If a vehicle has multiple tags, the system should identify this and handle it suitably (e.g. select one tag randomly and charge the toll to the account with that tag.)

14.9 “Location aware” caching update – Intelligent, location aware updates can substantially reduce the volume of data transmitted and allow for speedy updates.

Updates of account due to “recharge” to the local toll plaza clients should be done quickly and not wait for the regular update, as someone might want to recharge and immediately pass through a toll plaza. Again, location aware update can be used to immediately update only the toll plazas in the vicinity, and the rest get the information when main synchronization is done.

14.10 Ensuring reliability and security of data - Reliability, high availability, and security of the system are extremely important and these should be ensured through suitable means like replication, mirroring, logging, and recovery mechanisms.

14.11 Public portal - A critical infrastructure such as a national toll system should regularly share data with the public. This can be done by CTCH providing a public portal which will provide all users with information about the highway system and toll plazas, and will allow them to drill down on the performance by region, toll plaza, etc. It will not provide information on individual vehicles. So, users can see information like:

(i) A map of highway system with toll plazas marked on it. Further information about each toll plaza can be provided – who is the operator, public utilities available at the toll plaza, etc.

(ii) Volume of traffic at different times passing through a toll plaza

- (iii) Toll rates of different plazas, and utilities like determining the total number of toll plazas and amount of toll when going from point A to point B.
- (iv) An user should be able to check balance in his account, and the list of his toll transactions.
- (v) Performance measures – number of complaints, average wait time (will have to be estimated using some models), etc.
- (vi) In general, any information that can be made public should be available under this portal for transparency.

A data portal to enable applications and analysis

14.12 Data portal – While a public portal provides information for the public, a data portal will provide all publishable public information in machine readable formats. This portal would allow third party developers to build web applications based on this data, as well as enable researchers to analyze it and develop models in traffic projection, toll plaza planning, etc. REST style URLs can publish this data and encourage the ecosystem to build applications to take advantage of this data.

Use of open standards and off the shelf systems where possible

14.13 Use of open standards - Where devices are needed (either at user end or at toll plaza end), the proposal should avoid using proprietary standards and opt for open ones such that multiple vendors can provide the device/technology.

Where possible, off-the-shelf technology/systems should be used, particularly for hardware devices – as technologies in this area are now mature, this should be possible for almost all the hardware components.

Encourage manufacturing of ETC systems in India

14.14 Manufacturing in India - In order to overcome the dependency on other countries / technologies for implementation of Electronic Toll Collection in India, it is recommended to import the selected technology for manufacturing in India. Further, the market will drive the competition. As evident in case of mobile phones, the competition brings the prices of OBUs within the reach of a common man.

This will not only bring down the cost of end to end ETC solutions but also develop India's technical capabilities to manufacture and maintain the systems independently.

Other Possible Uses of The System

The system can be potentially used for multiple applications

Payment of parking tickets and fines

Recovering stolen vehicles

Creation of support services surrounding road infrastructure

The RFID based identification system with a CTCH containing records of all the vehicles as well as the balance in the account, has many more possible uses besides the ETC. Some of them are briefly mentioned here. The basic architecture proposed should allow these uses to be supported easily.

- (i) Parking tickets can also be paid through the ETC architecture. The parking lot operator is another vendor for the CTCH. In parking, there can be a toll plaza like reader, or operators with hand held readers can be used.
- (ii) It can also be used for police issued "fines". Currently, paying of fines is a challenge and often involves the owner going to a magistrate for payment. With this system, fines can be paid through CTCH.
- (iii) Better tracking and recovery of stolen vehicles – as stolen vehicles pass through readers, a record is automatically maintained, which can help in tracing such vehicles.
- (iv) Many new services can be offered through the CTCH, e.g. payment for food in drive-through lanes, payment of other types of "small" services on the road.

Many more applications will evolve with this type of system in place, as it provides a unique ID to vehicles, and a centralized database with a lot of information.

Appendix - A

**GOVERNMENT OF INDIA
MINISTRY OF ROAD TRANSPORT AND HIGHWAYS
(PIC SECTION)**

Pariwahan Bhawan, No.1 Parliament Street
New Delhi-110 001.

No.NH-12037/33/2010-PIC

Dated the 20th April, 2010.

O R D E R

Subject:- Constitution of Committee on Electronic Toll Collection (ETC) Technology for use on National Highways.

With the approval of the competent authority, it has been decided to constitute a Committee on Electronic Toll Collection (ETC) Technology comprising the following:-

- | | | | |
|---|---|---|-------------------|
| 1 | Shri Nandan Nilekani,
Chairman, Unique Identification Authority of India (UIDAI) | - | Chairman |
| 2 | Prof. Pankaj Jalote, Director and Professor,
Indraprastha Institute of Information and
Technology (IIT), Delhi | - | Member |
| 3 | Dr. Kolin Paul, Assistant Professor, Department
of Computer Science and Engineering, Indian
Institute of Technology(IIT), Delhi | - | Member |
| 4 | Shri A.V. Sinha, DG(RD) | - | Member |
| 5 | Shri V.L. Patankar, Member(Technical), NHAI | - | Member Secretary. |

2. The Committee shall examine all technologies available for electronic toll collection and recommend the most suitable one for implementation throughout India.

(Sanjay Wakchaure)
20.4.

**(Sanjay Wakchaure)
Executive Engineer(PIC)
For Director General(RD) & SS
Tele.23711527**

To,

- 1 Shri Nandan Nilekani, Chairman, Unique Identification Authority of India (UIDAI).
- 2 Prof. Pankaj Jalote, Director and Professor, Indraprastha Institute of Information and Technology (IIT), Delhi.
- 3 Dr. Kolin Paul, Assistant Professor, Department of Computer Science and Engineering, Indian Institute of Technology(IIT), Delhi.
- 4 Shri A.V. Sinha, DG(RD), M/o RT&H.
- 5 Shri V.L. Patankar, Member(Technical), NHAI.

No.NH-12037/33/2010-PIC

Copy for information to:-

PS to Minister(RT&H)/ PS to MOS(RT&H)(R)/ PS to MOS(RT&H)(K)/ PS to Secretary(RT&H)/
The Chairman, NHAI/ADG(SKP)/All CEs/JS(T&A)/JS(H).

(Sanjay Wakchaure)
20.4

**(Sanjay Wakchaure)
Executive Engineer(PIC)
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