



A Comparative Study of Different Technologies for Electronic Toll Collection System

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ABSTRACT: A toll road, also known as a turnpike or tollway, is a public or private roadway for which a fee (or *toll*) is assessed for passage. It is a form of road pricing typically implemented to help regain the cost of road construction and maintenance, which (on public roads) amounts to a form of taxation. The Manual Toll collection system is tedious and time consuming. It requires stopping the vehicle at the toll, collecting cash, giving the acknowledgment and then allowing the vehicle to pass by. The Electronic Toll Collection system is a new system which is designed to enhance the convenience of the driver by cashless transaction. ETC enables reducing the traffic congestion, fuel consumption of vehicles and thus enabling speedy flow. ETC determines whether the cars passing are enrolled in the program, alerts enforcers for those that are not, and electronically debits the accounts of registered car owners without requiring them to stop. There are various technologies used for implementing ETC system. In this paper we focus on RFID technology, Barcode Technology and Quick Response code technology. It aims at comparing the advantages, uses and their features.

KEYWORDS: Toll, ETC (Electronic Toll Collection), RFID technology, Barcode Technology, Quick Response code technology

I. INTRODUCTION

Electronic toll collection (ETC) is a technology enabling the electronic collection of toll payments. It is a universally and rapidly accepted technology. This system is capable of determining if the vehicle is registered or not, and then informing the authorities of toll payment for the violations if any. The most obvious advantage of this technology is the opportunity to eliminate congestion in tollbooths; especially during festive seasons or during week off when traffic tends to be heavier than normal, it also reduces operating cost for toll authorities, reduces fuel consumption. Other than this obvious advantage, applying ETC could also benefit the toll operators by better audit control of centralized user accounts.

Toll collection can be done electronically by using various methods like RFID, Barcode, QR code technology etc. RFID is a term used to identify vehicles automatically with the help of radio waves which passes through the toll booth. A vehicle holds an RFID tag which contains unique identification number assigned by RTO or traffic governing authority. Whenever the vehicle passes the toll booth, the tax amount will be deducted from his prepaid balance.

A barcode can be mounted on the side mirror of vehicle and barcode reader scans that barcode and then it checks that the user and vehicle is registered or not. A barcode is a series of parallel black bars and white spaces, both of varying widths. Bars and spaces together are called elements. Different combinations of the bars and spaces represent different characters, such as numbers or letters. Each combination or sequence of bars and spaces is a code that can be translated into information related to the vehicle. A barcode reader is required to read a barcode. Barcode readers may be fixed, portable batch, or portable RF.

The QR code can be printed on the number plate itself or on the inner side of windshield. Quick Response code technology has fast readability and huge storage capacity. The QR code consists of black modules (square dots) arranged in a square grid on white background, which can be read by an imaging device (such as a camera). The QR code is detected as a digital image by a semiconductor sensor and is then digitally analyzed by a programmed processor.



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Major Steps involved in Electronic Toll Collection:-

- **Automatic Vehicle Identification (AVI):-** The AVI system is used to determine the identity of the vehicle which is passing through ETC tollbooth for charging the toll to the corresponding customer. While passing through toll lane, a receiver communicates with the tag installed on the rear-windshield of the vehicle and reads the vehicle information.
- **Automatic Vehicle Classification (AVC):-** AVC system contains sensors installed at the toll lanes which are used to identify the type and class of vehicle for charging proper toll. Charge depends upon vehicles' weight and size. The vehicle type may include light vehicles or the heavy vehicles. A vehicle class can be determined by the physical attributes of the vehicle, number of occupants in the vehicle, number of axles in the vehicle.
- **Violation Enforcement Systems (VES):-** VES captures images of the license plates of vehicles that pass through an ETC tollbooth without a valid ETC tag. To identify and record violations, special cameras are used to take photographs from the violating vehicle's license plate. VES helps in tracking of theft vehicle.

II. LITERATURE REVIEW

In the era of technology development most of the conventional systems are modified as automated system. Due to automation minimum human interference is required and thus increasing the overall efficiency of the system. In 1959 the Noble Prize Winner William Vickery was the first to propose a system for Electronic tolling for Washington Metropolitan Area. In 1960's and 1970's a free flow tolling was tested with fixed transponders at the undersides of the vehicles and readers, which were located under the surface of the highway. ETC was first introduced in Bergen in 1986 operating together with traditional tollbooth. Electronic Toll collection (ETC) system is basically designed for an uninterrupted toll collection, which has become an important part of intelligent transportation system. There are various technologies which can be adapted for this system; each technology has its own principles, advantages and limitation. Basically three technologies are discussed in this paper ETC using RFID, Barcode and Quick Response Technology.

The drawbacks of Manual toll collection are discussed in research article [1]; the article focuses on use of RFID technology which makes use of radio frequency waves for detecting a vehicle. Further the article proposes the process of automatically debiting the customer's account as and when vehicle passes through the tollgate without stopping the vehicle and thus making the process work more efficient.

In research article [2] the components involved in ETC using RFID i.e.:- RFID tag, RFID reader and their working is focused. Further it also adds that this technology is able to offer reliable and effective data collection even in harsh environment. This method provides new capabilities for collection, management, dissemination, storing, and analyzing information.

The research article [3] the principles, advantages and limitation of using RFID technology is discussed, also the article strongly agrees that RFID's potential benefits are large. The use of this technology will help to improve the traffic abilities at toll road. The Data information are also easily exchanged between the motorists and toll authorities, thereby enabling a more efficient toll collection by reducing traffic and eliminating possible human errors. The research article [4] supports the efficiency of the technology and adds saying that it is a highly stable and convincing technology.

With reference to article [5] we know that ETC can also be implemented using Barcode laser technology, in which the barcode tag is attached to the number plate of the vehicle and can be read by barcode scanner. The barcode can have several information related to the vehicle, the most important being the bank account number and RC details which enables to have a check of forged vehicle. The article [6] further adds on the benefits of using barcode technology also the different features like security, accuracy, cost involved of RFID and barcode technology are compared.

In article [7] the focus is on the use of Quick Response code which is a two dimensional barcode which has the capacity to store more data. It also proposes the benefits of using QR code like high capacity, less storage space, dirt and damage resistant. The working of QR code is discussed in article [8] accordingly the technology works on the basis of two levels the lane level and software level. The lane level help in taking snapshot of the vehicle and recognising the number plate. The software levels help in checking whether the vehicle is forged or not. In article [9] a comparative study of 1D and 2D barcode is done. The benefits of 2D barcode is discussed in more detail.

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In research article “An Advanced Technology Selection Model using Neuro Fuzzy Algorithm for Electronic Toll Collection System”[10] the focus is on selecting the optimum technology which makes the process efficient and simple. Technology selection is a complex process, and requires the understanding of the stages prior and stages after the implementation. It is a multi-dimensional process requiring the analysis of a wide range of internal and external factors.

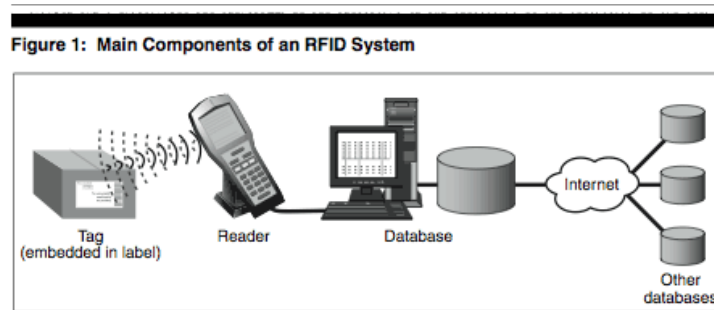
Although there are different technologies selection of appropriate technology is a challenging task. Accordingly for selecting the optimum technology a comparative study has been done on RFID, Barcode and QR code technology, various features are considered for the comparison.

III. WORKING OF DIFFERENT TECHNOLOGOES

A. RFID Technology

An ETC system commonly utilizes radio frequency identification (RFID) technology. Radio frequency identification (RFID) is a generic term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves. The waves coming from the RFID reader are not dangerous and are similar to those waves coming from car radio.

RFID is an automated data-capture technology that can be used to identify, track, and store information contained on a tag. A radio frequency reader scans the tag for data and sends the information to a database, which stores the data contained on the tag. A complete RFID system consists of a transponder (tag), reader/writer, antenna, and database.



Source: GAO.

RFID Tag: An RFID tag, or transponder, consists of a chip and an antenna. A chip can store a unique serial number or other information based on the tag’s type of memory, which can be read-only, read-write, or write once read-many (WORM). The antenna, which is attached to the microchip, transmits information from the chip to the reader. These tags are classified as either active or passive tags. Active tags have internal batteries that allow a longer reading range, while Passive tags are powered by the signal from its reader and thus have shorter reading range.

RFID Reader: In order for an RFID system to function, it needs a reader. RFID reader is a scanning device that is capable of reliably reading the tags and communicating the results to a database. A reader uses its own antenna to communicate with the tag. When a reader broadcasts radio waves, all tags designated to that frequency and within range will respond. A reader also has the capability to communicate with the tag without a direct line of sight, depending on the radio frequency and the type of tag used.

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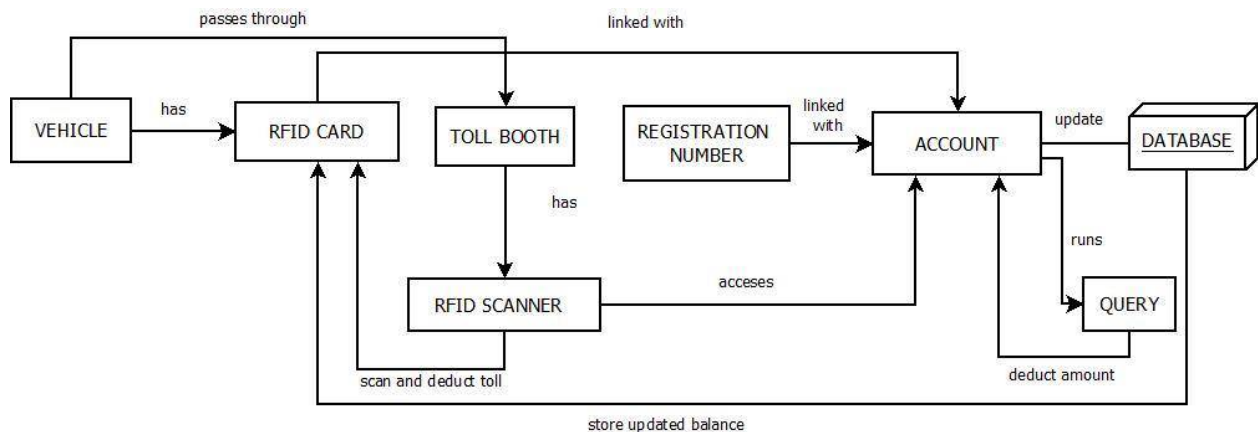


Fig : Working of RFID Technology

Whenever any person buys a vehicle, one first needs to get his or her vehicle registered at the RTO office. RTO officials will not only assign a number plate to it but also will give a RFID enabled tag. This card will have a unique ID feasible to use with that vehicle only. They will also create an account for the use of that particular smart card and maintain transaction history in database. User needs to deposit some minimum amount to this account. Every time a registered vehicle approaches the toll booth, first the Infrared sensors will detect the presence of the vehicle. It will in turn activate the RFID circuit to read the RFID enable tag fixed on the rear-windshield of the vehicle. Transaction will begin; depending upon the balance available toll will be deducted directly from the user's account. The software further updates the details in the Centralized database server. It also triggers mechanism to generate the bill and will be sent to user as a text message.

B. Barcode Technology

A barcode is a series of parallel black bars and white spaces, both of varying widths. The barcode simply provides a reference number that tells a computer to access information. A barcode reader is required to read a barcode. Barcode readers may be fixed, portable batch, or portable RF. Fixed readers are attached to a host computer and terminal, and transmit one item at a time as the data is scanned. Barcodes are simple to use, accurate, and quick.

Barcode Tag can be installed on the front number plate of vehicle. This system depends on four devices.

- Tag Barcode
- Barcode Reader : Laser
- Traffic controller system
- Central Server

Traffic controller system is computer system which manages the traffic in single row or line by using traffic signals. The Central server stores the data which comes from different toll plaza. A local computer of every toll plaza is connected to central server through Internet. Every barcode contains the following details of owner RC (Registered Challan) which includes vehicle number, vehicle type, owners name, owners address, date of purchase, Account number and Mobile number.

Working of Barcode Technology

When the vehicle enters the toll plaza, the embedded laser in the barrier reads the barcode and it retrieves information and deducts the toll amount from owners account. If the balance is not enough in the owners account, the barrier will still be lifted, but a warning email or an SMS will be sent to the owner otherwise the deducted amount is sent to the owner via email or SMS along with location and the next toll booth number. Before lifting the barrier, the server checks whether the vehicle is registered as well as valid or not. The registered owners have the barcode embedded in their vehicles and any complaint of the stolen vehicle is sent to the police using toll server database which makes the vehicle invalid. Thus a valid vehicle is the one which does not have any complaint against them. If the vehicle is both registered and valid, then the barrier is lifted otherwise alarm is generated to make the police alert and police will contact.

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C. QR code technology

QR code (abbreviated from Quick Response Code) is the trademark for a type of matrix barcode (or two-dimensional barcode) first designed for the automotive industry in Japan. A barcode is a machine-readable optical label that contains information about the item to which it is attached. A QR code uses four standardized encoding modes (numeric, alphanumeric, byte/binary, and kanji) to efficiently store data; A QR code consists of black modules (square dots) arranged in a square grid on a white background, which can be read by an imaging device (such as a camera, scanner, etc.) and processed using Reed–Solomon error correction until the image can be appropriately interpreted. The required data are then extracted from patterns that are present in both horizontal and vertical components of the image.

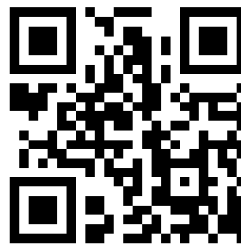


Fig : QR Code image

The above figure shows QR code image as we see the QR code is a two dimensional image and it is a trademark of a matrix type. The system has become popular due to fast readability and large storage capacity.

Working of QR code technology

The format information records two things: the error correction level and the mask pattern used for the symbol. Masking is used to break up patterns in the data area that might confuse a scanner, such as large blank areas or misleading features that look like the locator marks. The mask patterns are defined on a 6×6 grid that is repeated as necessary to cover the whole symbol. Modules corresponding to the dark areas of the mask are inverted.

The Automatic Number Plate Recognition system using QR code consists of two major blocks as shown

- a. Lane level
- b. Software Level

At the lane level, the CCTV (Closed Circuit Television) cameras take a snapshot of the car in such a way that the QR code is also included in the image. Otherwise a small optical QR code scanner can be installed for on spot recognition. As vehicles pass under the camera/scanner their QR codes are digitally recorded. The image/video/QR code embedded information is sent along with the date and time stamp to the remote computer.

The QR code recognition technique is performed at the software level and consists of the following step. If direct information is sent from lane level it is forwarded for searching the record in database. Else if image/video feed is received then focus the QR code recognition software component on to the QR code received to retrieve the information and then search for the record in database.

IV. BENEFITS OF ETC

1. Reduction of fuel consumption as no stopping is required at the toll.
2. No Traffic congestion as the process is fast and does not allow congestion of traffic.
3. As fuel consumption is less it reduces air pollution.
4. Reducing the number of personnel required for toll collection.
5. Making the process easier and faster.
6. Fewer and shorter queues at toll plazas by increasing toll booth service rates.
7. Better audit control by centralized user accounts.



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V. COMPARISON OF RFID, BARCODE AND QR CODE TECHNOLOGIES

The table below shows the comparison of various features for the 3 technologies discussed above.

Features	RFID	Barcode	QR code
Line of site	Not required	Required	Required
Read range	Passive RFID -Up to 30 feet Active RFID -Up to 100s feet	Several inches to feet	Several inches to feet
Technology used	Radio frequency	Optical	Optical
Automation	Fixed scanner don't need human labor	It needs human labor	It needs human labor
Read/ Write	Read write	Only read	Only read
Information capacity	More than QR and barcode	Very less	Less
Ability to withstand to weather conditions	A durable hard case protects these RFID tags from impacts, heat, moisture, and changing weather conditions.	Poor readability sensitive to weather and dirt	It has the ability to do error correction, data in QR code can be recovered even if parts of it are damaged or destroyed by dust
Orientation dependent	No	Yes	No
Cost	Expensive	Cheap	Cheap
Decoder device	RFID reader	Barcode reader	PC, mobile which has decoder software
Reusability	Rewritable	Has to be reprinted each time	Has to be reprinted each time

VI. CONCLUSION

This research paper focuses on the use of Electronic toll collection system. ETC has several advantages so if it is implemented will benefit the travelers as well as the drivers. ETC can be implemented by making use of different technologies. RFID, barcode and quick response code are the techniques discussed in this paper. According to the analysis done considering various attributes we conclude that RFID is a better technology compared to barcode and QR code technology because RFID can store more information as compared to the other technology, both reading as well as writing data can be done on RFID tags, RFID can be tagged from a long distance. If Government takes proper steps in implementing ETC then it would lead to a faster process of toll collection leading to a seamless movement of traffic.

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BIOGRAPHY

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