EVALUATION AND IMPROVEMENT OF TOLL COLLECTION SYSTEM IN SRILANKAN EXPRESSWAYS

CASE STUDY FOR COLOMBO-KATUNAYAKE EXPRESSWAY

H.B.N.S.Kumara

(148308D)

Degree of Master of Engineering

Department of Civil Engineering

University of Moratuwa

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Sri Lanka

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Thesis submitted in partial fulfilment of the requirements for the degree

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DECLARATION

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ABSTRACT

With the latest development, three Expressways were opened for public in Sri Lanka and it is expected that the number of riders for expressway network will rise. The pay toll system in road is based on the traditional method which is collecting the toll by road barriers installed at the entrance & exit points of Expressways. Although in this system the toll is collected directly from the drivers, the existence of barriers causes increased travel time, increased fuel consumption and consequently increased pollution in the road environment. For a more continuous flow of traffic, an Electronic Toll Collection (ETC) system was introduced in Colombo – Katunayake Expressway (CKE) since June 2015 to help alleviate traffic congestions; reduce environmental pollution, reduced cash circulation, integration of the financial system, more passenger comfort, reduce the service time specifically at Toll Plazas.

This research focuses on the economic and technical analysis of existing toll collection systems in Colombo-Katunayake Expressway. The study is aim to evaluate the newly established ETC Toll collection System CKE.

In detail, the objective is to assess the amount of delay of the individual lanes of dedicated for MTC and ETC; their service time, lane capacities and the forming of queue in each lane and compare with the different modes of toll systems used in other countries. The study also aims to find out the specific factors that affect the delays experienced at Toll plazas & decrease the system performance and proposed suitable, recommend ways to improve the service. Not only that the study is focused on the evaluation of economic loss due to the delays in toll lanes and level of lane utilization by each mode of vehicles. The analysis of the current toll systems in CKE under the system, financial, traffic, environmental, infrastructure and socio-economic aspects would be conducted using SWOT analysis.

Then, the different toll collection methods & technologies are studied under this research and compared characteristics, performances of each individual technology. Analysis is done for identify the appropriate ETC toll collection method. Further, fuzzy logic based MADM (Multiple Attribute Decision Making) approach is employed for selection of optimal ETC system for Sri Lankan Expressways.

Consequently, short-term and long-term recommendations for Sri Lankan road tolling system are proposed in terms of transportation.

DEDICATION

To

My Loving Parents and Wife

Who Always Encouraged Me towards Success

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LIST OFABBREVIATIONS

ANPR	Automatic Number plate Recognition
BOC	Bank Of Ceylon
CCC	Customer Care Center
CCTV	Closed Circuit Tele Vision
CEFTS	Common Electronic Fund Transfer System
CKE	Colombo Katunayake Expressway
DMT	Department of Motor Traffic
EOM&M	Expressway Operation Maintenance & Management
EPR	Expressway Road Pricing
ETC	Electronic Toll Collection
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Position System
IC	Inter Change
MADM	Multiple Attribute Decision Making
MBT	Minimum Balance Threshold
MLFF	Multi-Lane Free Flow
MTC	Manual Toll Collection
NFC	Near Field Communication
OCH	Outer Circular Highway
OCR	Optical Character Recognition
OOCEA	Orlando-Orange County Expressway Authority
POS	Point of Sale
RDA	Road Development Authority
RFID	Radio Frequency Identification Device
SE	Southern Expressway
SLIPS	Sri Lanka Interbank Payment Slips
SMS	Short Message service
TG	Toll Gate
VMS	Variable Massage Sign

1. INTRODUCTION

1.1 Background

Providing of reliable, quick, Comport, safe and efficient transportation system to the public is the main objective of good transportation system. The road network is the key of the transport under aspects of mobility and access. Foundation of the economic development of a country depends on the road network system. To achieve satisfactory economic growth in a country it is required good and efficient road network. The government of Sri Lanka have constructed few expressways and opened to the public since year 2011. Now a days, new expressways are constructing for future transport needs of the public.

Vehicle ownership of the country is increasing annually and usage of road facilities & trip generation also significantly growing up. As a result it can be experienced significant traffic jams in peak hours in highways by adversely affecting for economy, human health, environment as well as the safety. Presently, over 150 kilometres of Expressways are operating in Sri Lanka and other Expressways as well as local roads development programmes are conducting to minimize the traffic issues.

Accordingly, Southern Expressway (E01) was completed and opened for public since 27 November 2011. This is the first E - class road in Sri Lanka and consisted with four lanes in both direction from Kottawa to Galle. E01 was extended to Matara and opened for public in 2014. The length of Expressway from Kottawa to Imaduwa is about 126.3 km. This is an access controlled toll road and the allowed speed limit is 80-100 kilometre per hour.

As third Expressway section, the Colombo – Katunayake Expressway (CKE), E03 was opened for public in 27 October 2013. This Expressway section is consisted with three toll gates which are located at Peliyagoda, Ja Ela & Seeduwa (Figure: 1). The E03 is connected with Bandaranayke Airport and Colombo city with 25.8 km long Expressway by giving lots of economic & social benefits to the society.

The newest expressway is the Outer-circular Expressway (E02) and Its phase I from Kottawa to Kaduwela connecting Southern Expressway (E03) section about 11.0 km was opened to public from March 2014 and phase II from Kaduwela to Kadawatha section about 8.9 km was opened to public from September 2015.

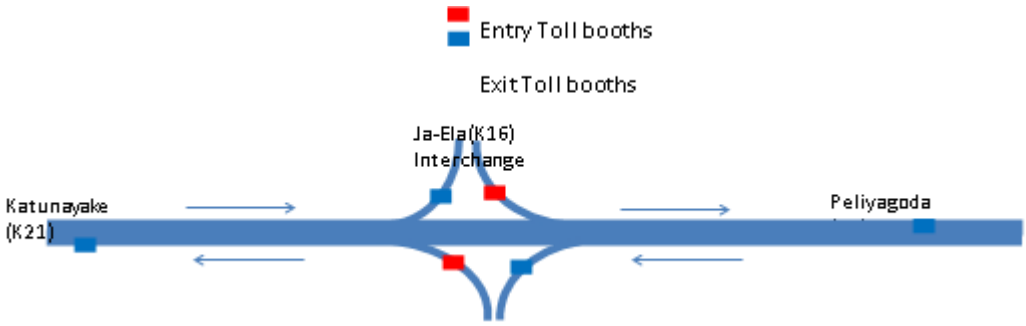


Figure 1: Locations of the Toll Stations on CKE

E01 & E02 sections are consisted with 15 nos. Inter Changes to provide connectivity to other local access roads. The map below shows the current operational Expressway network.

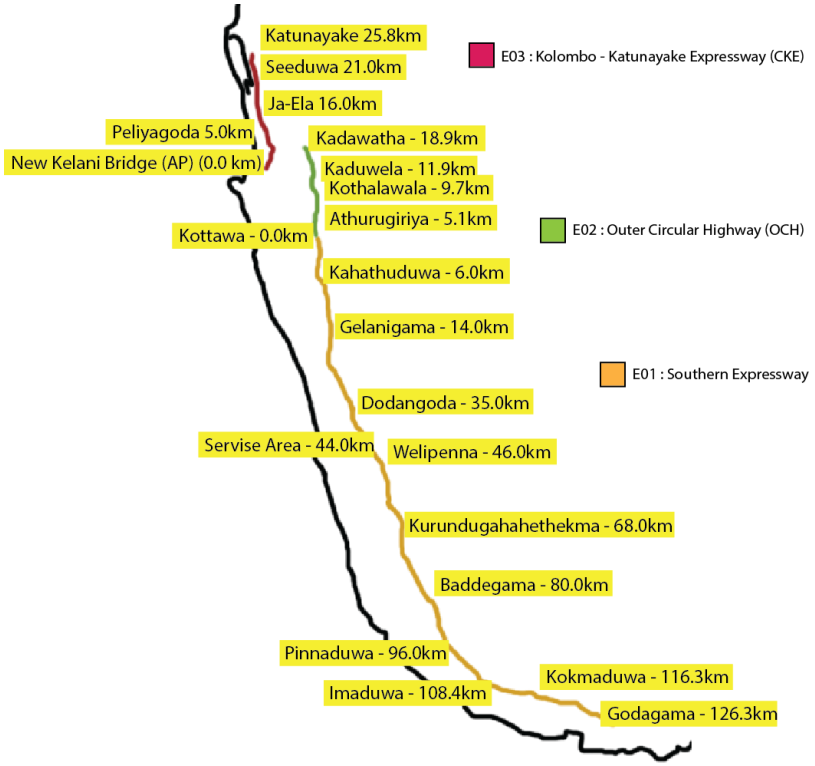


Figure 2: Currently operated Expressway Network in Sri Lanka

(Source: http://www.exway.rda.gov.lk/index.php?page=expressway_network)

The Expressway road network is to be expanded to 500 kilometres by near future and the details are shown in Table 01.

Table 1: Details of Expressway Network in Sri Lanka

Expressway Section				Length, km
E	**Expressway**	**From**	**To**	
E-01	Southern Expressway	Kottawa	Matara	126.3
		Matara	Kataragama	80
E-02	Colombo Outer- Circular Expressway	Kottawa	Kerawalapitiya	29.2
E-03	Colombo-Katunayake Expressway	New Kelani Bridge	Katunayake	25.8
E-04	Central Expressway	Kadawatha	Dambulla	137.1
E-05	Kandy Expressway	Pothuhera	Galagedara	32.5
E-06	Ruwanpura Expressway	Kahathuduwa	Pelmadulla	71.8
E-07	Colombo Port City Elevated Expressway	New Kelani Bridge	Port City	5.3
E-08	New Kelani Bridge- Athurugiriya Expressway	New Kelani Bridge	Athurugiriya	17.3
Total				525.3

(Source: Expressway Operation Maintenance and Management Division - RDA)

The Government of Sri Lanka is specially given more concentration for expressway constructions and annually invested their local funds as well as foreign funds. The Table 02 is Summarizes the projected government expenditure on Expressways in recent years. It can be seen that the considerable amount of public funds have spent up to 2017 (National Road Master Plan 2007-2017).

Table 2*:* Expected Expenditure for Highway Sector in Billion Rupees

(Rs. Billion)

	Expressway Construction												
	Length (km)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Colombo-Katunayake	25.1	2.9	10.1	10.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.6
Southern Expressway	130.0	8.0	7.1	5.9	8.0	10.0	2.0	0.0	0.0	0.0	0.0	0.0	41.0
Outer Circular Highway	28.0	2.9	5.4	11.1	6.0	6.0	5.6	0.0	0.0	0.0	0.0	0.0	37.0
Colombo-Kandy	98.0	0.0	0.2	1.4	10.7	13.3	10.0	6.0	0.0	0.0	0.0	0.0	41.6
Colombo-Jaffna	213.0	0.1	0.1	0.5	0.5	1.0	7.0	12.0	18.0	20.0	20.0	8.8	88.0
Extension Southern Expr.	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.0	7.0
Total	594.1	13.9	22.9	29.3	25.4	30.3	24.6	18.0	18.0	20.0	22.0	13.8	238.2

(Road Development Authority, 2007)

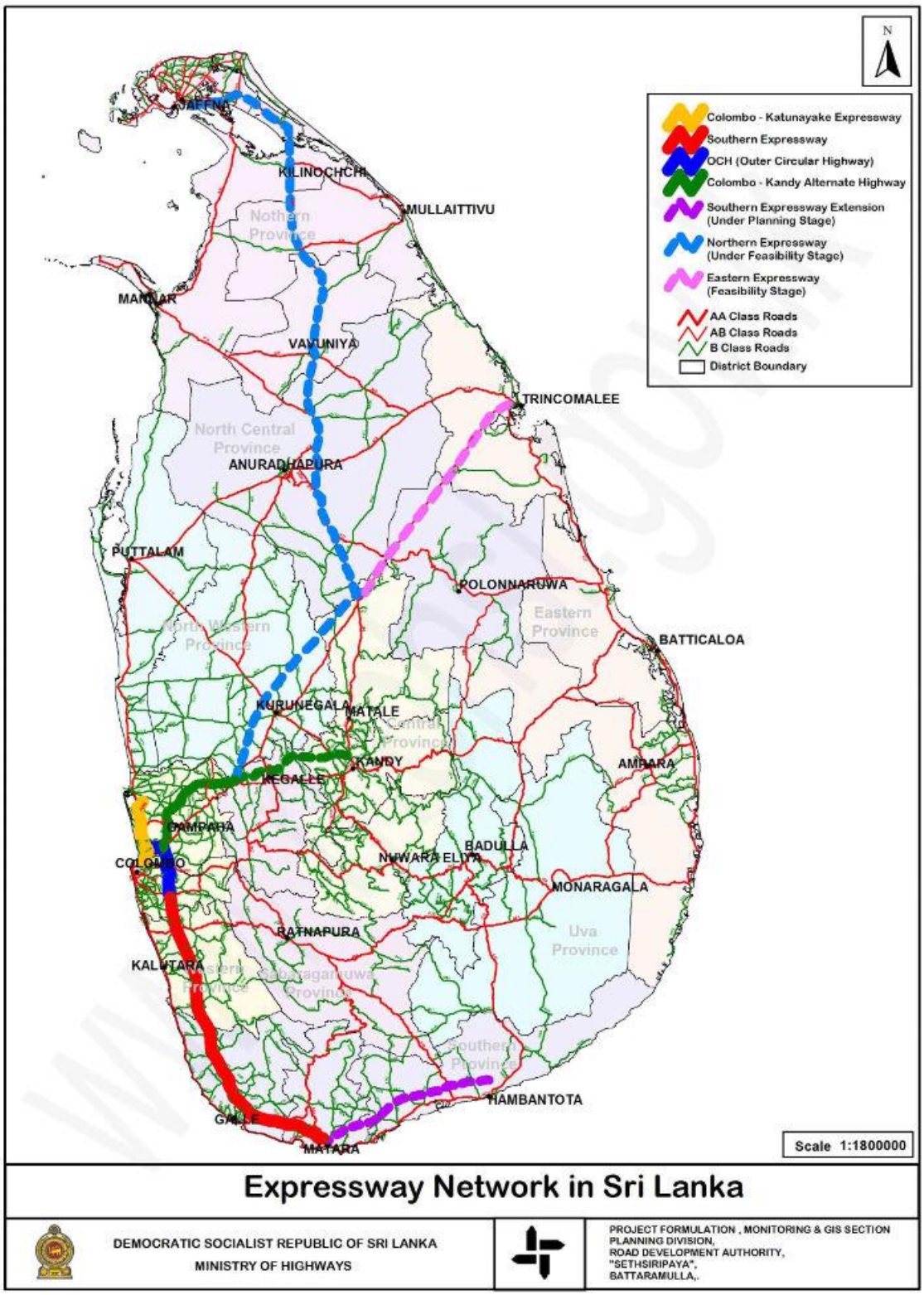


Figure 3: Expressway Network in Sri Lanka

(Source: https://www.researchgate.net/figure/2-Proposed-Sri-Lankan-expressway-network_fig14_320372560)

When consider the Toll systems in existing expressway sections, the Southern Expressway & Outer Circular Expressway are closed system and running under the manual toll collection using the Point Of Sale (POS) system. Southern Expressway was the first toll road with entire manual operation in Sri Lanka. The Colombo-Katunayake Expressway is the first toll road with ETC system and it is operating together with manual (MTC) & Electronic toll (ETC) facility. ETC system was implemented since July 2015 and operated as pilot project under the Expressway network.

Table 3: Toll Collection details of E01 & E03

Expressway	Toll Collection	System
Southern Expressway (E01)	Manual	Using Point of Sale Machines (POS)
Colombo-Katunayake Expressway (E03)	Manual	Web base Tolling Management System (developed by ZTE soft)
	Electronic	ETC - RFID System

Figure 4: POS Machine used in SE

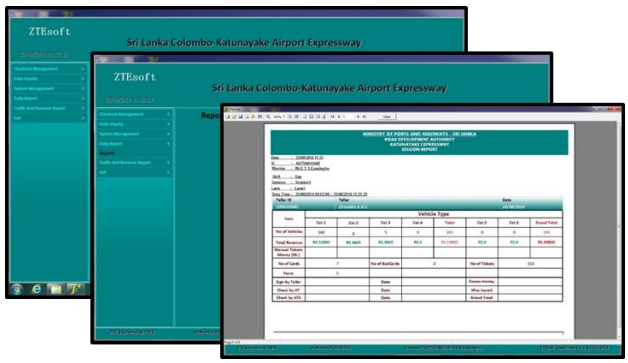


Figure 5: Toll Management System used in CKE

Electronic technology based automated User Fee (Toll) collection systems are considered as the applications of Intelligent Transport Systems (ITS) and element of information and communication technology that allows for nonstop toll collection at any time. Under the manual operation, Expressway users must be wait or stop at toll gates for the payments and developed huge vehicle queue, pollution, delay and higher user cost. By implementing of ETC, it can be expected to provide quick, reliable, accurate, eco-friendly and smooth toll operation for Expressway users.

1.2 Problem Statement

According to statistics vehicle population has become more than 7.0 million and more than 5.0 million of vehicles out of this are in operation. Commuters spend considerable time on the roads to fulfil their transport needs by burning fuel, spending extra money and time. The Government was executed some road network & transport improvement projects related to widening, rehabilitation, maintenance, construction of bridges overpasses since the past. Even though, the traffic growth is very significant the road facilities were not sufficient to cater the demand. In the past, demand for expressway was not significant and now it has become very heavy. As a one alternative, the Expressways were opened to the public in October 2011 to manage the traffic demand. After five years, the Expressways also were congested like other urban roads with considerable vehicle queue.

Annually the vehicle traffic demand for Expressways is increasing and the formation of vehicle queue and congestion in exit points will be gone up. When consider the traffic flow, lane capacities and Level of service of the Expressway is not worst and the traffic congestion at toll gate location can be experienced in peak time. Due to this, considerable time delay and low highway performance are experienced in entrance & exit points at Expressways.

At present Electronic Toll collection (ETC) lanes are implemented and still the congestion & vehicle queue can be observed in entrance & exit toll gates in Expressways.

Introducing of ETC is also not effectively contribute to above traffic issues and it is required examine whether their effectiveness, system capacity and performance are sufficient to cater the future expressway demand.

1.3 Objectives of the Study

The Colombo-Katunayake Expressway is consisted with both Manual & ETC toll facility and Objectives of this study are to identify factors, indicators, issues and drawbacks in existing toll collection system and evaluate the performance with comparing other international expressways. Hence, develop and enclose the possible recommendations to the existing toll system for future implementations to mitigate or minimize existing draw backs. Further, other toll collection methods which are using in other countries will be studied and supposed to select the suitable toll method for Sri Lankan Expressways based on analytical strategy. Following objectives are considered under this studies.

- Identifying of traffic behaviours at entrance & exits of E03.
- Investigation of efficiency & the drawbacks of existing Toll collection system
- Economic & financial analysis of existing toll collection based on waiting time, service time, delays, resource allocation etc.
- Propose suitable ways for improvements of existing toll collection system to cater the increasing traffic demand if presence of any congestion, delays, inefficiencies cause for decreasing the throughput of toll lanes in Expressways.
- Study of other ETC methods used in the world and propose suitable ETC method for Sri Lankan Expressways based on multi criteria selection method.

1.4 Scope of Work

The study focuses on economical, engineering, social and transport aspects of existing toll system in E03. To achieve these objectives, below mentioned manoeuvres and processes were applied.

- Studied the arrangement of Toll plaza, toll lanes which are allocated as entrance & exit in each location.
- Existing MTC & ETC toll paying procedure, service time, delay time; peak time & queue were studied.
- Traffic study was carried out and identified the Peak time, Peak day, and Peak month corresponding to the ETC & MTC vehicles in each toll gate location.
- Existing MTC system was studied and identified the drawbacks using SWOT analysis
- Growth of ETC customer registration was analysed and compared with the demand for ETC in past years.
- Analysed the financial losses due to the waiting (delays, queue), allocation of operational staff, promotional works etc.
- Drawbacks of existing ETC system related to technical, operational & other means were investigated and evaluate the performance using SWOT analysis
- Efficiency of existing ETC toll system was compared with other ETC methods.
- Proposed suitable improvements for existing toll system as well as for future toll systems.
- Studied the ETC technologies which are used by other countries & find out the appropriate ETC technology for Sri Lankan Expressways.

2. LITERATURE REVIEW

2.1 Toll Collection System

Toll collection is the most important process in any Expressway because the maintenance & the operation processes are done with collected revenue. Many countries are using more precise ways to collect tolls from road users. The manual toll collection system will be closed or opened or both systems together based on the geometry, design and operational requirement. The toll fee for the journey varies with respect to the type of vehicle and the number of kilometres travelled. Other hand, the Toll collection system will be varied with their technology and operation methodology.

2.2 Toll Collection Methods

2.2.1 Manual Toll Collection (MTC)

Collection of toll charges shall be done using manual method. All or few operations of following process which are Identification of vehicle, Classification of vehicle, Toll Fee collection (Transaction), Issuing of User Fee Receipt, Barrier or Toll gate operation & keeping of necessary records will be done by the operator who is assigned to the toll booth. The few process of above can be done with automated mechanical system. Users can be paid their toll charges by cash, credit cards, debit cards, smart cards as a manual payment mode.

2.2.2 Electronic Toll Collection (ETC)

All of the activities of this toll lane shall be done using automated system. As such to do the complete the transaction, it is required to complete following processes. The Vehicle Recognition, Vehicle classification, Transaction Processing (Maintaining customer accounts through Database), Violation Enforcement (Police patrols, Physical Barriers, Automatic number plate recognition-Video, other Enforcement Systems) will be done automatically via electronic devices which are fixed on toll lane to complete the successive transaction. These types of toll lanes are operated under various technologies and are the most popular toll method in the world. ETC

users can be paid their toll charge by using prepaid or post-paid payment options as their willingness.

It is required to open a **prepaid** account with Expressway toll authority and required to maintain positive balance in his account by making prepayments. Before entering the Expressway, the owner or the driver of the vehicle requires to pay the adequate money as cash advance to their given user account number (Account ID). The toll operation office trace all user information through central server and the data base. Then, they carry out the user fee deductions and instantly maintain the relevant balance in each user account.

Under the **post-paid** account no need to pay before using the Expressway. After using the Expressway, the usage information are sent via the SMS or internet. Then Expressway user should be paid the bill. End of the month the toll charges are deducted from credit card. If not the toll charges are paid as monthly bill at the end of each month. Nowadays, this payment can be done via mobile apps or online payment system in easy way.

2.2.3 Mixed Toll Collection

Mixed toll collection system is a combination of above two toll technics. Under the Mixed system it was offered ETC and at the same time cash payments. Throughput of mixed type of toll lanes is higher than the fully manually operated toll lanes. Some other countries such as Holland, India, Philippines are using mixed toll systems and at the same time both manual & ETC users can be served.

2.3 Elements of Toll Collection System

Basically any of the toll collection system is consisted with following elements.

- Vehicle Identification
- Vehicle Classification
- Toll Enforcement

Under the manual method all or few process of above will be done with manual means and under the ETC system all the process will be done automatic means.

2.3.1 Vehicle Identification

Before deciding the toll charge corresponding to the vehicle, it is essential to identify the details of vehicle such as Vehicle number, vehicle type, registration, no of axles etc. Under the manual method this task has been done by operators. But using electronic devices, it can be done quickly & accurately. Optical Character Recognition (OCR) technics use to identify the information from a motor vehicle. Under the ETC, Automatic Vehicle identification (AVI) technology is used and while passing vehicle through toll lane, a receiver communicates with the tag installed on the rear-windshield of the vehicle and reads the vehicle information. Varies non-invasive technologies, soft wares and high definition cameras are used for Automatic Number Plate Recognition in Expressways based on the cost, accuracy, efficiency & durability.

2.3.2 Vehicle Classification

For determination of toll charge, it is required to identify the vehicle class. The vehicle classification is done by Teller/operator in manual system and automatically done by electronic devices in ETC methods. Vehicles are categorized into various classes where different amounts of tolls are charged based on the class. Vehicle Classification systems are included various devices that measure the physical characteristics of vehicles. Normally vehicle classification can be done based on axle/tire arrangement of vehicles, Size/heights/length of vehicles and their gross weights. Then the toll charges shall be assigned based on lane occupancy as passenger car units (PCU), purpose of uses (public, private, commercial etc.) axle damaged to the road pavements by each category of vehicles. Technically developed laser curtains, sensors, antennas, cameras, weigh bridges are used for automatic vehicle classification purpose by various toll authorities.

2.3.3 Toll Enforcement

Some users used to have the expressways without paying the toll at exit and required to send the violator's information to the police for enforcement process. Most commonly used method for violation enforcement is providing of array of high definition cameras with Automatic License Plate Recognition and Optical Character Recognition (OCR) capabilities. Automatically take the photograph of the number plate and send to vehicle owner/driver to pay the fee or higher the toll fee with some administrative cost. For ETC, take snap photograph of the vehicle number plate of the non-registered vehicle which were passed through ETC lane. To identify and record violations, special cameras are used to take photographs from the violating vehicle's license plate. Some countries such as London, Sweden, Maryland, Canada are used these technologies to control the theft in expressways.

2.4 Traffic Terminology

2.4.1 Throughput

Throughput is the number of vehicles passing through the toll lane over a defined or short period of time. Normally it is considered during one hour period of time. (Transportation System Engineering, Dr. Tom V. Mathew, IIT Bombay, February 19, 2014)

2.4.2 Demand

Demand is the sum of throughput and the number of vehicles queued up at the toll lane or toll plaza during unit time or one hour period. (Transportation System Engineering, Dr. Tom V. Mathew, IIT Bombay, February 19, 2014)

2.4.3 Waiting Time/Delay Time

Waiting time/Delay time/Down time is the time interval for which one has to wait in the queue until reach the toll payment action or service and before the action/service actually occurs.

2.4.1 Service time/ processing time in Toll booth

Service time is the length of the payment process at a toll booth. As such the time requires to complete the transaction per vehicle which enter in to the toll booth until exit the customer from the toll booth.

The service time does not include the waiting time in the queue.

$$\text{Service Time} = \frac{\text{Total time in seconds}}{\text{Number of Vehicles}}$$

2.5 Service Rate in Toll Booth

The number of vehicles serves in unit time is called service rate.

$$\text{Service Rate} = \frac{60\text{s} \times \text{time interval for arrival rate (min)}}{\text{Average Service Time (seconds) per vehicle}}$$

2.6 Toll Collection System in Sri Lankan Expressways

2.6.1 Southern Expressway, E01 and Outer Circular Highway, E02

There are 11 number of Toll stations on the Southern Expressway, E01 (SE) all of which only provide Manual Toll Collection (MTC) facilities which create a closed user fee system.

The Outer Circular Highway (OCH), E02 is connected to the Southern Expressway at Kottawa and has four number of toll Stations that provide a closed toll network together with the Southern Expressway.

Toll collection on the SE and OCH is implemented by using a small hand-held ticketing terminal, which is connected to the central server system by using GPRS communication. Specially, the SE & OCH use Point of Sale (POS) machine system for its user fee collection.

The ticketing terminal can issue an entrance ticket manually by the Teller at the entrance booth with a bar code printed (consists of information regards entrance ID, vehicle category, entrance teller ID, date and time) on the ticket. At the exit point, the user shall return the entrance ticket to the Teller. He will scan the bar code with aid of the similar type of machine and based on the travel distance and the vehicle type, exit receipt will be issued. All collected data is uploaded to the central server via GPRS for generation of toll reports.

Following issues were identified related to the MTC system operated SE & OCH.

- Existing toll management systems are not compatible with CKE (E03).
- No automatic vehicle identification and classification system
- Very primitive system used in SE & OCH compared to systems typically implemented in other countries
- Ticket data transmitted by GPRS connection meaning data transmission is very slow
- Sudden GPRS signal interruption happens at some areas of the expressway and disrupts the normal behaviour of ticket issuing causing traffic congestion near the toll plazas
- Real time ticket validation is not possible
- End-to-End reconciliation reports are not available from the system reports

2.6.2 Colombo-Katunayake Expressway (CKE), E03

The Colombo – Katunayake Expresway (CKE), E03 is consisted with three toll stations at Peliyagoda, Ja Ela & Seeduwa. Figure 01 & 02 show the locations of toll stations on CKE.

This is an open tolling system with entrance plazas at Katunayake and Peliyagoda. There are also entrance toll plazas at the Ja-Ela interchange with closed system.

Table 4: Toll Collection System in CKE

Toll Gate /Interchange	MTC		ETC		Total		Geometry/IC Type
	Entry	Exit	Entry	Exit	Entry	Exit	
Peliyagoda	Open	4	Open	1	Open	5	Line
Ja Ela	2	2	2	2	4	4	Diamond
Seeduwa	Open	4	Open	1	Open	5	Line

(Source: Expressway Operation Maintenance and Management Division - RDA)

The toll management system of E03 is computer based system and consists of both Manual and Electronic Toll Collection systems with centralized management. Each lane can be configured in Manual Toll Collection or Electronic Toll Collection modes. The system supports only one mode of function at a time and can be switchable within 10 minutes of time. Electronic Toll Collection was introduced to reduce the delay at toll gate by collecting the toll fee electronically. It makes faster tolling operations possible because drivers need not to stop at the toll gates for the payment but passing through in a specified speed (At present 15km/hr.).

2.6.3 MTC facility in CKE

The MTC system on the CKE operates in two distinct ways. When a vehicle enters the expressway via one of the entry plazas at Ja-Ela the driver is provided with a Radio Frequency Identification Device (RFID) card that contains details of the vehicle class, as determined by the Teller, and the entry time and date.

Upon entering the system, the driver passes the RFID card to the Teller who places it on the reader in the toll booth at exit point and the data written on the tag is displayed. The toll is then calculated based on the vehicle class and the distance travelled.

Vehicle classification is done manually, if the teller in the exit plaza thinks the class on the tag is different from the vehicle in front of him a discrepancy will arise and need to be addressed according to pre-defined procedures.

When a vehicle doesn't enter the expressway at Ja-Ela the driver will not receive an RFID pass. When the vehicle reaches an exit plaza the toll will be calculated based

on the class of the vehicle and it will be the maximum amount for the length travelled on Expressway.

Following issues were identified related to the MTC system operated in Colombo-Katunayake Expressway.

- Existing toll management systems are not compatible with SE, OCH.
- No automatic vehicle identification and classification system
- End to End reconciliation from the system reports is not available.

2.6.4 Common issues in MTC System

Following common issues were identified related to the MTC system in Sri Lankan Expressways during the operation and toll payments process. Most of the incidents were happened due to the technical and user behaviours.

(i). Users came to exit point without having money

Some users were come without having toll fee them self and making trouble at toll gates. Based on the past experience in CKE, considerable numbers of incidents were reported as follows.

Table 5: Users came to the Exit point without having money in CKE

Year	No of Incidents				
	Peliyagoda IC	Ja Ela IC	Seeduwa IC	Total	Average per Month
2014	12	128	6	146	12
2015	14	216	6	236	20
2016	30	83	30	143	12
2017	46	49	49	144	12
Total				**669**	**14**

(Source: Expressway Operation Maintenance and Management Division - RDA)

Due to happening of these kinds of incidents, unnecessary delays in toll lanes, additional operational activities, and legal procedures are involved with user fee operation in the toll points.

This issue was happen due to following reasons.

- Open entrance without having barriers in CKE
- User behaviour and lack of awareness about toll road
- Negligence of users
- Complexity of identify the Expressway from other National Highways

(ii). Paying Toll Fee by Foreign Currency

Some foreign users are willing to pay toll by foreign currency because of the CKE is the access link to Bandaranayke Airport. Even though, still the toll fee was accepted by only local currencies (LKR) in Sri Lankan Expressway. Hence, it is required to implement methodology to accept paying toll by selected foreign currencies to avoid inconvenience to both users as well as Authority.

(iii). Paying Toll Fee by Credit card /ATM cards

Most of the local and foreign users are willing to pay toll by their credit cards or debit cards. Many users have credit cards and they ask to pay toll by credit cards at exit points. Implementing facility for paying toll by bank cards in Expressways will give solutions for above issues as well.

(iv). Environmental & Health Issues

Under the MTC system most frequently, vehicle queue is formed along Expressway ramps and generate more emissions by the vehicles. This will adversely affected to the environment and create huge money losses due to burning of extra fuel. When accelerating the vehicle closer to the toll booths, large amount of emissions were released from vehicles and directly affected for health of the Tellers who are working in toll booths. Some Tellers are still getting medical treatments due to occupation for long time in this kind of highly polluted environment.

Implementing of automatically operated toll system (ETC System) instead of manual system is the solution for this issue as minimizing the human involvement for toll collection process in Expressways.

(v). Social Issues

Expressway user/Drivers and Teller (operator) in the MTC toll booth are communicating in every seconds to do the transaction for toll. During cash collection, some conflicts are daily reported related paying bills, change cash, customer service, responses, greetings, service delays, system failures, nature of giving money or receipt, asking road information etc. This will effect for productivity of the service and indirect losses. Under the MTC system it is very difficult to minimize, human conflicts which are happening in toll payments due to poor ethics & attitudes of operator as well as the motorist.

Conducting of training programs for staff members, conducting of awareness programme for Expressway users via public media such as television, newspapers will be useful to minimize above issues.

(vi). Maintenance of Toll lanes & Toll building

Most frequently MTC toll lanes have become dirty due to falling of lubricant/oils on the pavement surface. This will be unpleasant and cause for the road safety in rainy days. Hence it is required to carry out cleaning & maintenance activities frequently for MTC lanes.

Thus, Toll booth buildings, lane kerbs are have become dirty due to the contacting of emissions released by vehicles during the acceleration at toll booths. Therefore, it is required to carry out the washing & painting of toll buildings & lane kerbs.

2.6.5 ETC Facility in CKE

The ETC system operates using RFID passive technology at 920-925 MHz & It is a very limited system compared to more advanced systems currently in operation in other countries. The some features of the existing ETC system are as follows.

This system requires ETC customers to slowdown the vehicles to lower speeds and to maintain proper distance between vehicles at the ETC lane for accurate detection and smooth operation of the system. During the detection of the e-tag at the ETC toll gate, the roadside antenna reads the e-tag to get the entrance station and vehicle category to calculate the toll fee. It also updates the account balance in the E-tag.

The ETC system is directly connected to Bank of Ceylon (BOC) ETC system via a peer-to-peer link. The connections between the RDA ETC server and other components are shown in the illustration below.

ETC Tag/Transponder

ETC Antena

ETC Data Converter

Lane Camera

Figure 6: Devices used in ETC system in CKE

(Source: Expressway Operation Maintenance and Management Division - RDA)

The RFID antenna is located at the top of the toll lane. The Bank of Ceylon (BOC) ETC server is connected within the BOC system. Collection account is a pool of accounts which has the sum of all ETC account balances and details of each account balance.

All transaction details and recharge details of customers are frequently updated in the RDA ETC system. Customer usage data is sent to the BOC once a day and total usage is transferred from the BOC collection account to the RDA account daily.

Customers can apply to join the ETC scheme either online or at the Customer Care Centre (CCC). However, they must visit the CCC to collect the RFID card. The E-tag is then affixed to the windscreen of the vehicle after the registration process is completed. All the details of vehicle, including vehicle classification details, are written to the E-tag permanently.

There is no automatic vehicle classification system or number plate recognition system installed at the ETC toll plazas. There are CCTV cameras at every toll booth which collects information, including the license plate, of each vehicle passing through the MTC and ETC lanes.

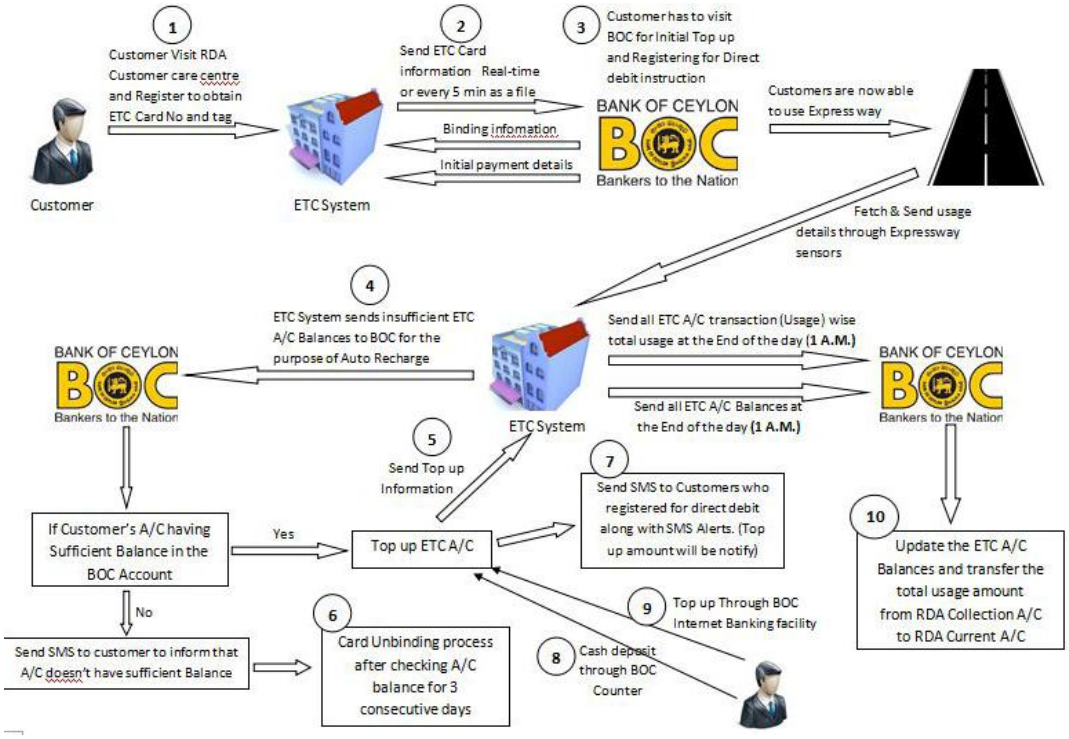


Figure 7: Service Flow of existing ETC system of CKE

(Source: Expressway Operation Maintenance and Management Division - RDA)

A seven-digit ETC account number is issued to each customer. This account number is used when topping up the account. During this process, the money will be transferred to the ETC collection account maintained by the Bank of Ceylon (BOC).

The BOC is the only bank linked directly with the ETC system currently. It is possible for BOC customers to automatically top-up their ETC account or to do so manually at any BOC branch. Users who don't have a BOC account can top-up their ETC account using either a Common Electronic Fund Transfer System (CEFTS) or the Sri Lanka Interbank Payment System (SLIPS) transfers. The service flow of the existing ETC system of Colombo-Katunayake Expressway is shown in Figure 7.

2.6.6 Technical Issues of current ETC system

Followings are some of the issues related to traffic, technical, toll management system which was experienced under the existing ETC system used in CKE, E03.

2.6.6.1 Developing of vehicle queue in ETC lanes

Vehicle queue was developed in ETC lane at Peliyagoda TG in peak time due to higher demand and the lower level capacity of lane (veh./hr/lane). The service rate of the existing ETC facility is not sufficient and traffic jamming was occurred in peak time.

Figure 8: Developing of vehicle queue in Peliyagoda Exit

Figure 9: Developing of vehicle queue in Entrance toll plaza -D at Ja Ela IC

(Source: Expressway Operation Maintenance and Management Division - RDA)

2.6.6.2 Vehicle Detection Reliability

Currently there is an issue in detecting vehicles arriving at the ETC lane until they are very close to the antenna and have reduce their speed to approx. 15 km/h. This reduction in speed has the effect of minimizing the benefits of ETC throughput due to vehicles having to slow down significantly so the transaction time is very like the MTC toll lanes, approx. 10- 12 seconds.

2.6.6.3 Orientation & Placement of ETC Tag

The tags provided should be designed for use on metalized windscreens to work correctly. The current tags provided have problems when affixed to certain windscreens. This would lead to the conclusion that they are not suitable for use on metalized windscreens.

In Sri Lanka, the problem of tags not working on metalized windscreens has been worked around by affixing the tag to the sunroof of the vehicle which is not metalized and so there is no problem of interference with the tag.

2.6.6.4 Multiple Charging

Another issue that has presented itself in the ETC system is the effect where antenna in adjacent lanes detects vehicles in the wrong lane and this causes the vehicle to be charged twice. The diagram below shows the scenario.

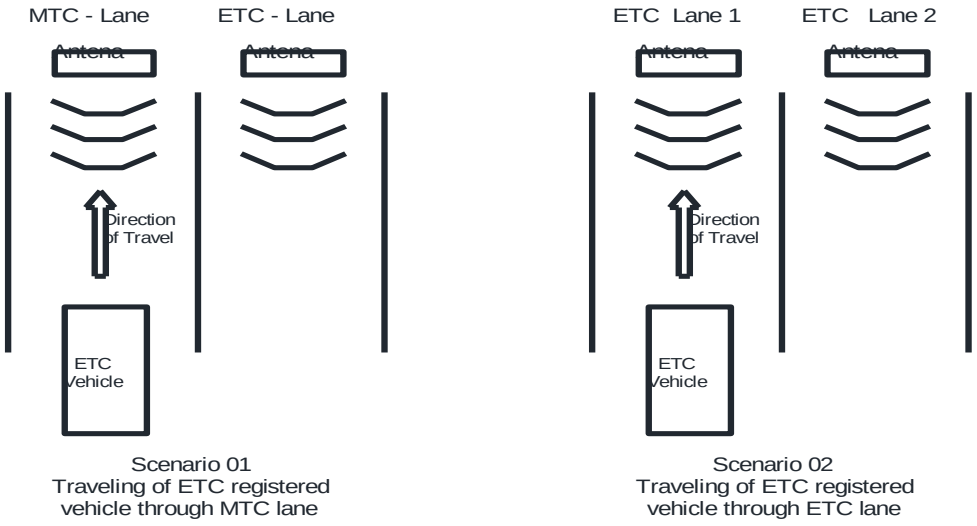


Figure 10: Multiple Charging incidents in ETC system

In scenario 01, an ETC registered vehicle travelling through the MTC lane as pay by cash is also detected by the antenna in ETC lane. In this way, the user pay twice as manually by cash and electronically (ETC) as well.

In scenario 02, an ETC registered vehicle travelling through the ETC lane 1 detected by the antenna in this lane, but it is also detected & charged by the antenna in ETC lane 2. In this way, the users pay twice as electronically (ETC) for each ETC lane.

To avoid this situation following maters shall be consider in technical improvements.

- Restrict the field of the antenna to cover only the area of the carriageway associated with the lane it is covering.

- Triggering the antenna to only switch on when a vehicle equipped with an RFID tag enters the detection zone in front of the antenna.

2.6.6.5 Enforcement System

Presently, it is not available any ITS technics in this toll system to catch the unpaid vehicles before exit from Expressway. Currently, this process is done by manually by Tellers/operators who are assigned by EOM&M division. Hence, the service of Tellers/Operators in ETC toll booths is essential for existing ETC system because of these officers should be done enforcement related activities and handled the traffic at the moment where abnormal incidents were happened.

2.6.7 User Issues related to the existing ETC system

2.6.7.1 Maintaining of minimum 20m gap

It is required to maintain 20 m gap between front vehicle for detect the vehicle through the antenna. Some of the ETC users do not maintain the required gap between front (ahead) vehicle and this may cause for wrong vehicle detection. The advisory information sign boards have been installed either side of the Expressway sections for the guidance. Even though, some user behaviours are somewhat bad & cause for inconvenience to the other users.

2.6.7.2 Insufficient Balance

When Customer's balance drops to or below Minimum Balance Threshold (MBT) level then: "TOP-UP NOW" will be displayed on the electronic sign at the exit ETC Lane. Then the customer should top up his account in right time and if the ETC account balance is insufficient, ETC barrier will not open. As per the clause no. 11 &12 in the ETC agreement, Customer will be required to reverse backwards if safe to do so and divert into the adjacent manual cash payment lane.

Even though, some ETC users do not top up their ETC accounts in right time and hindrance to the other ETC users because of traffic issues in ETC lane.

2.6.7.3 Maintaining of 15 km/h drive speed at ETC gates

Some users do not maintain the low speed as 15 km/h at ETC gates and this will lead for technical errors and detection issues. The advisory information sign boards have been installed either side of the Expressway sections for the guidance. Even though, some user behaviours are somewhat bad & cause for inconvenience to the other users.

2.6.7.4 Divert to the MTC lane when fail the ETC lane

As per the clause no. 13 of the agreement, ETC user/Account holder should be used the manual cash payment lane if ETC system not be operational. But some users hesitate to do so and argue with operation staff personal to allow them to go without paying for cash lane.

2.6.7.5 Behind Vehicle exit with front vehicle without charging from ETC Account

Some users try to exit from toll gate with driving his vehicle by keeping closer to the front ETC vehicle without making deduction from his ETC account. When open the

gate for front ETC vehicle, the second vehicle drive same time continuously after front vehicle keeping minimum gap between them as a single vehicle fleet. This time system detect only front ETC vehicle and second vehicle pass through the ETC gate without deduct toll fee from his ETC account. There is some technical issue in this system and user can pass without paying their ETC account under free of charge. Hence, it is required to monitor ETC vehicle passage by assigning Tellers in ETC booths under the manual methods to minimize the revenue loss.

2.6.8 Common issues in ETC System

2.6.8.1 Allocation of Staff for ETC duty

Presently, Operators/Tellers are assigned by the RDA to carry out 24 hrs operation (during day & night) in ETC toll booths. Under the existing ETC system, it is difficult carry out ETC operation without operator's involvement. The staff members are required to carry out following activities.

(a). Manual enforcement (recording & sending information of unauthorized/ unpaid vehicles)

(b). Traffic handling at peak time at ETC lanes (Vehicle traffic propagate due to user behaviour, technical matters, insufficient balance in ETC account, poor maintaining of 20 m gap, poor maintaining of vehicle speed 15 km/hr at ETC booth, inserting of MTC vehicles etc.)

(c). Directing of ETC vehicles to the adjacent cash paying (MTC) lanes when fail the ETC lane due to technical issues.

2.7 ETC Toll Collection Technologies

Various Toll collection methodologies have been used by other countries for collection of expressway toll charges. Continuous improvements are common for any kind of system to minimize the errors and enhance the productivity. Initially most of the countries were used various manual methods for toll collection. These manual based methods are also continuously improved under the various new technologies to get higher productivity, efficiency and user-friendliness.

Due to increasing of vehicle ownership, demand for Expressways and innovation of new technologies and in efficiency of manual toll methods, the ETC toll methods were introduced by various countries to provide good service to expressway users. Now days internationally recognized highly technical based ETC systems are used by other countries for their expressways to give accurate, reliable and efficient service for the customers. The graphical representation of technology based growth of toll collection systems in the world is shown in figure 11 as follows.

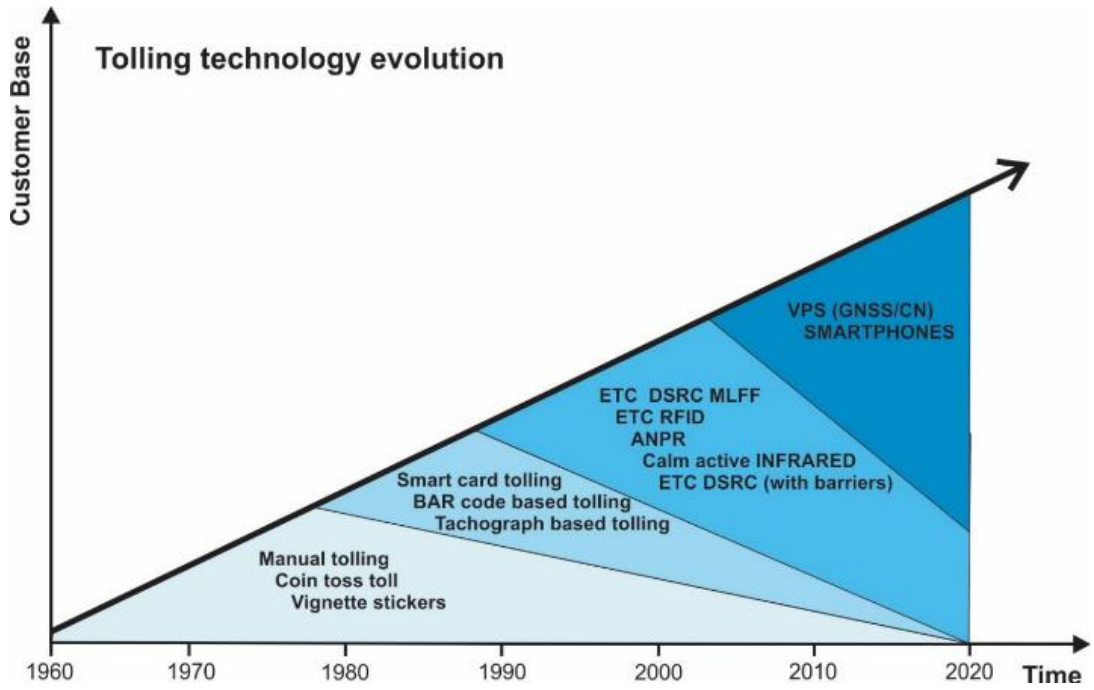


Figure 11: Technology based Growth of Toll collection systems

(Source: Comparative Analysis of the Macedonian Road Tolling System with EU Trends, Draxenko Glavic, Marina Milenkovic, Milos N. Mladenovic)

When study the toll collection systems used in the world, following technologies can be identified.

1. Manual Toll Collection Technologies
    - Coin Toss Toll
    - Vignette Stickers

2. Automated Toll Collection Technologies

    - Video Tolling (ANPR)
    - Dedicated Short Range Communication (DSRC) with Barriers
    - Dedicated Short Range Communications (DSRC) with Multi Lane Free Flow (MLFF) System
    - ETC with Bar Code System
    - QR Code System
    - ETC with Radio Frequency Identification (RFID) Technology
    - Vehicle Positioning System (VPS, GNSS/CN) Technology
    - Calm Active Infrared Technology
    - Tacho graph Toll Technology
    - Smart Phone Toll Technology

2.7.1 Study of ETC Technologies

(i). Video Tolling (ANPR)

Video tolling is modern technology and implemented using high definition cameras, Optical Sensors, computers, Servers and other equipment. This system is implemented based on Automatic Number Plate Recognition (ANPR) technology and Optical Character Recognition (OCR) software. Mainly the toll charging and enforcement processes are done using ANPR & OCR facilities. The user requires to register in the system to create a user account before enter the Expressways. The user accounts can be obtained as prepaid or post-paid as per the user wiliness. Vehicle images of toll non-payers as well as violators are taken using ANPR technology. These images of the vehicle number plates are sent to the central server to OCR software process to identify the numbers & characters in licence plates and check details against the registered vehicle list. Then send the details to the system to deduct toll payments from their account based on vehicle category and Expressway travel distance.

The images of the violators or non-payers are used as evidence to take legal actions. Sometime the manual checking and back office processes are carried out to enhance the accuracy as well as further varication. But it can be used DSRC or GNSS technology together with ANPR to avoid manual verification processes. This system is used in London, Sweden, Maryland, Canada, Australia, Chile, South Africa and other countries.

- Require high implementation Cost
- Involves Lower operational cost
- Require less road side equipment
- Unreliable in bad/tempestuous weather conditions
- Difficulties of charging from vehicles which are not registered in the data base
- Violation enforcement facility is available

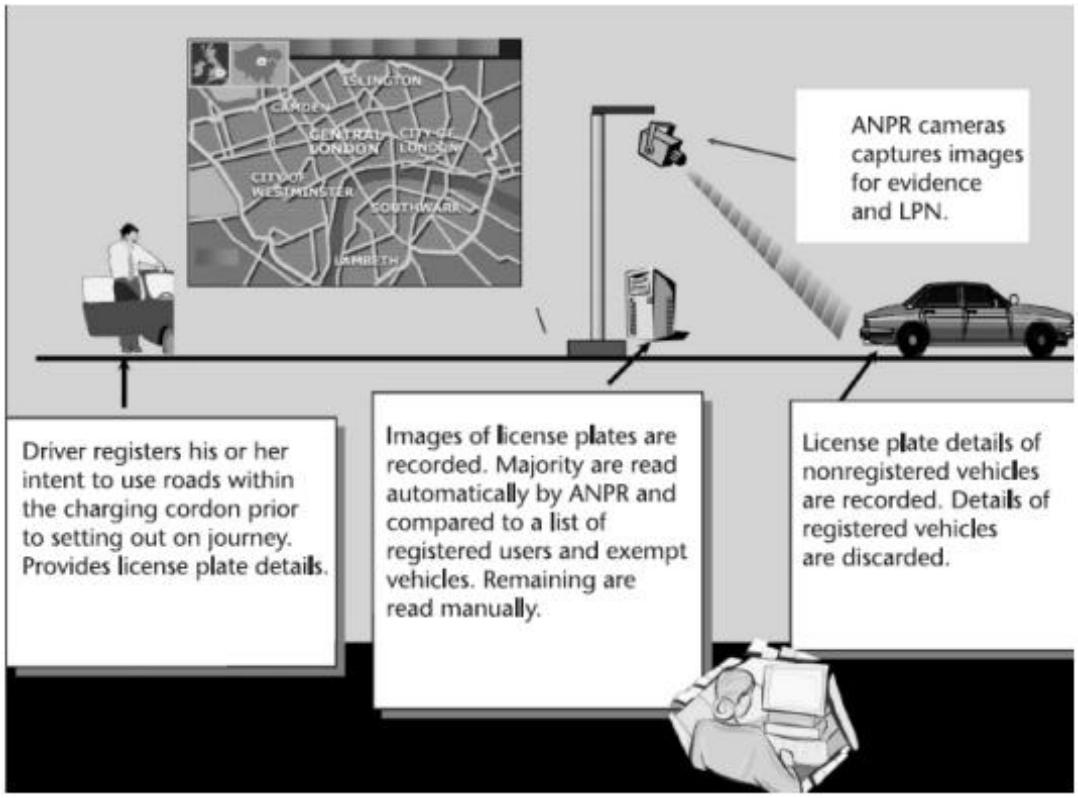


Figure 12: Schematic of an ANPR scheme performance

(Source: Technology options for the European Electronic Toll Service, 2014)

(ii). Dedicated Short Range Communication (DSRC) with Barriers

This is an ETC system and not requiring vehicle's stopping at toll gates for toll payments. This is contact less toll technology used by many countries in the world. If DSRC used in the toll plaza with barriers, the vehicle speed shall be 40km/h.

Following features can be noticed related to this system.

- Required to fix On Board Unit (OBU) or ETC tag to communicate with antenna
- Antenna, Data converter, lane camera are another devices fixed in toll gate
- Require to reduce the vehicle speed to 10-40 km/hr
- No enforcement method & cost
- No number plate recognitions
- Higher service rate than the manual system

(iii). Dedicated Short Range Communications (DSRC) with Multi Lane Free Flow (MLFF) System

This technology was implemented since 1980. This is advance version of the above method and do not require toll barriers, toll booths or toll plazas. The antennas, converters, cameras are fixed on gantries above the motorway. The users can travel with own speed under the given limits by changing the lanes when passing under toll device equipped portal. This system is also popular contact less toll technology used in the world. This method can be used for open tolling by implementing few gantries in selected locations to trace the vehicle in Expressway. Following features can be noticed related to this system.

- Construction of gantries/portal is required instead of toll plaza & toll lanes
- Mobile Device, OBU is required to installed in the vehicle

- Consist with significant enforcement methods & cost
- High level of service
- Typically Accuracy will be more than 99.7%
- Issues happened due failures of OBU or its battery.
- Can be detected vehicle speed up to 180km/h using high performance cameras

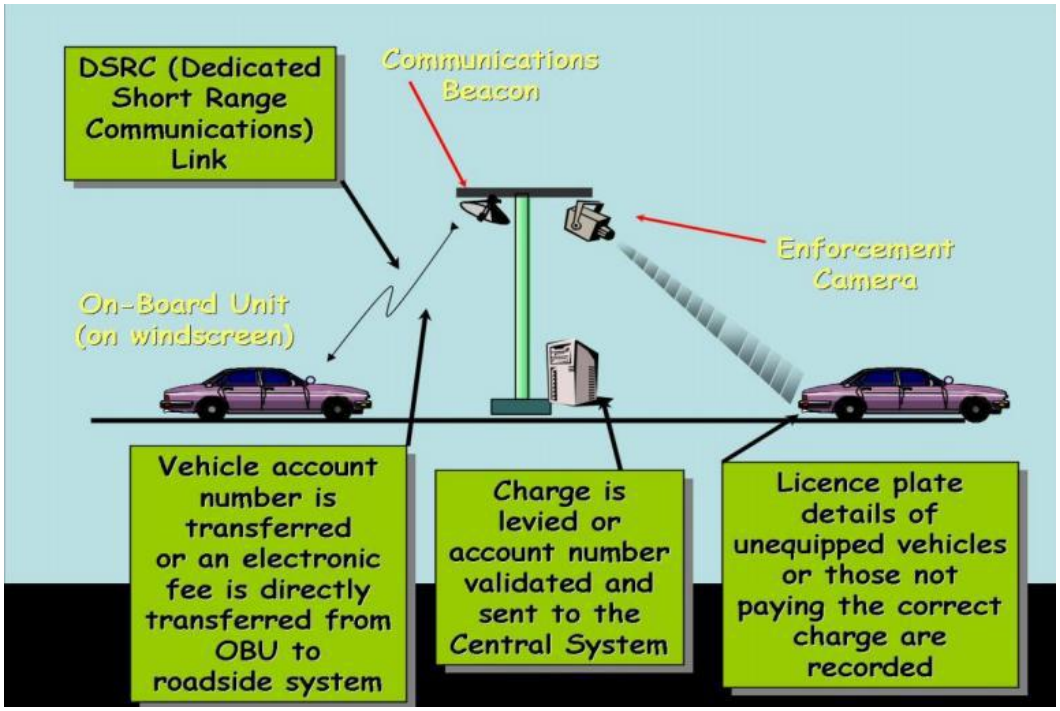


Figure 13: DSRC Tolling Mechanism

(Source: International Journal of Advanced Research in Computer Science and Software Engineering, Volume 4, Issue 7, July 2014)

(iv). Bar Code Technology

Bar code system is the oldest technology and the simplest method. This is a sub category under DSRC. The, barcode is consist with black strips and white strips printed in white background. Widths of the black & white grids are different each other and generated as per the given information to the system. This method is one of the ETC systems and barcode label is fixed to the windscreen or front number plate on the vehicle. Owner details, vehicle details, date time and other information

are included for bar code in the sticker. The barcode label is read by laser scanner fixed on gantry or toll barrier when the vehicle passes through the toll lane. If any error hand reader device can be used.

Figure 14: Bar Code image

(Source: https://en.wikipedia.org/wiki/Barcode, International Journal of Innovative Research in Computer and Communication Engineering magazine, February 2016)

If the owner's account is lower balance or insufficient the toll barrier will be opened and the warning massage will be sent to the user via SMS or email immediately. If unregistered vehicle entered to the toll gate, the warning alarm is generated to catch the unauthorized vehicle by Police under the enforcement system.

- Tag (Bar-code printed Sticker), Barcode Reading device (Laser), Camera, Computer, Central Server are the devices in this system
- Unreliable technology (Can be easily imitated)
- Lack of Flexibility
- Less accurate in crummy weather condition
- Data reading speed is slow
- Quick respect to the manual
- Low level of service
- Can be stored one dimensional numeric code (only holds information in the horizontal direction)
- Less storage information (capable up to 20 character data)
- Easy to be theft
- Consist with significant enforcement methods & cost

(v). Quick Response (QR) Code Technology

Quick Response Code or QR Code technology is a machine readable optical label that contains information about the transaction or items. The QR code is consist with black & white matrix as spreading in horizontal & vertical direction as two dimensional manner. The QR This technology is initially applied by Japan for automotive industry. The QR code consists of black colour dots or modules. These are set on a white background as a square grid patterns. This QR code can be sticked in the number plate or windscreen to detect at toll booth of Expressways. When pass the vehicle through the toll gate CCTV cameras take a snapshot of the vehicle. The QR code is also included in this image. Image processing devices such as scanners, cameras use to identify the QR code data.

Figure 15: QR Code Image

The small optical QR code scanner is installed for spot recognition. The scanner is recorded the QR code of the passing vehicles in digital format. All these data is transferred to remote computer & central data base according to order of date and time.

(Source: International Journal of Innovative Research in Computer and Communication Engineering, February 2016, https://en.wikipedia.org/wiki/QR_code)

Required information and data are collected from horizontally and vertically printed dot modules in the QR code image. Then imaging data is processed and interpreted to identify the Expressway user from the register. Following features can be noticed related to the QR code system.

- It can be scanned and read by a camera-equipped smartphone by downloading a scanner app
- Two Dimensional (can be stored data horizontally & vertically)

- Higher storage than bar code (storage is capable up to 7100 character data)
- Support for multiple data types
- Can detect from any direction (360 degree) by eliminating any interference and negative effects from backgrounds
- It can be recovered and read up to 30 - 35% of the destructed or partially lost data due to any of the reason

(vi). Radio Frequency Identification System (RFID)

RFID is also another ETC method used in many countries and RFID tag/sticker/transponder is fixed on vehicle number plate or the windshield. The RFID tag scanning & detection is done by RFID antenna, readers & decoders which are fixed at the toll station. Presently, this ETC method is used in CKE.

The Transponder consisted with an embedded chip and an antenna. The data is sent to the reader at toll plaza by the antenna couple with the microchip embedded in transponder. The chip is used to store the owner's & vehicle's data.
The RFID transponders can be categorized based on the capacity of the memory chip and its programming capacity (Smith, ITS Decision, 2002):

Type I: The chip does not have any processing capabilities and the information on it is fixed (read only).

Type II: These type of chips have an updateable area which can be used to encode information such as time and point of entry etc. (Read Write type).

Type III: These type of tags contain a microprocessor. They can be used to communicate information such as account balance, owners or vehicle's details with sensors which are fixed in overhead locations of toll plaza and roadside. These type of chips can be introduced as "smart" tags (Once read many type).

Mr. Shishir Aima (Automated Toll Plaza System Using Radio Frequency Identification Device (RFID) On Highways) explains working procedure of RFID system as follows.

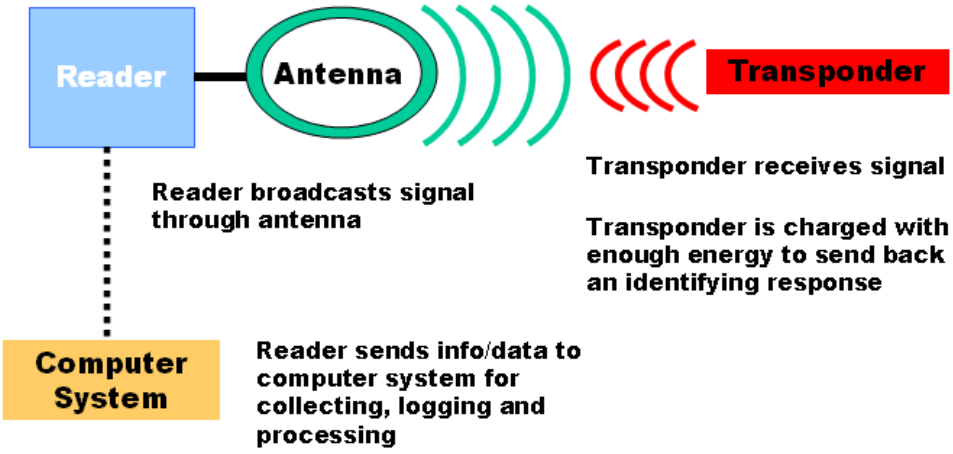


Figure 16: Working Technology of RFID system

(Source: ISOR Journal of Mobile Computing & Application (IOSR-JMCA), Volume 3, Spt. - Oct.2016)

Other hand, the RFID transponders can be categorized based on power supply mechanism as follows (Smith, ITS Decision, 2002).

(a). Passive RFID Transponder – These cards are powered by the signals of the reader and have to read shorter range. The device is considerably small due to absence of on-board power supply system. Other hand, the data storage capacity is also become very low.

(b). Semi-Passive (Semi-Active) RFID Transponder – This type of transponder is consisted with small battery for continuous power supply. Physical appearance is almost same with passive tag. Even though, it has

higher memory capacity than the passive type. This transponders are quickly responded for the signals.

(c). Active RFID Transponders – This type cards have batteries to supply power to generate longer range signals to deliver the data. Thus the facility is available to plug the device with vehicle power supply system. The large capacity of memory is available in this device. The data range is also greater than other two.

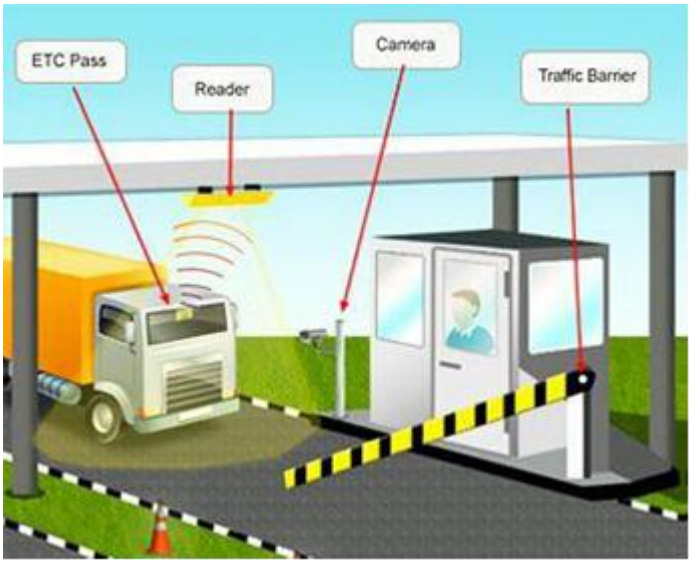


Figure 17: ETC system using RFID Tag

(Source: IOSR Journal of Mobile Computing & Application (IOSR-JMCA), Volume 3, Issue 5 (Sep. - Oct. 2016), PP 10-14)

When the vehicle reach to the toll station, the system will be checked the ETC account balance. Then the relevant toll fee will be charged automatically from user's ETC account. According to the transaction, the system will be up dated the balance via central server and automatically prepared the billing statement. Then, transaction details of billing statement will be sent to the vehicle owner or registered user as a SMS or an e-mail. Following features can be noticed related to the RFID based ETC system.

- Consist with RFID Transponder, Reader (Converter/Decoder & Antenna), Host computer & Server system
- Similar to DSRC method
- OBU is RFID transponder with micro cheaper & power supply unit
- RFID tags are basically classified as Active, Semi passive and Passive tags
- Max. speed at toll booth is 10-30 km/h
- Enforcement shall be setup using cameras with ANPR at Toll plaza to identify violators

(vii). Vehicle Positioning System (VPS/GNSS)

Vehicle positioning technology based ETC methods are used some countries for expressway tolling. Global Navigation Satellite System (GNSS) and GSM/GPRS/3G/4G communications technologies are used for this toll system. On Board Unit (OBU) is installed in the vehicle. The GPS is installed in the OBU device to trace the start and end location of the vehicle. Transaction data will be sent to the main server through the GSM/3G/4G networks. For this communication, dedicated VPN (Virtual private network) based on GSM/GPRS mobile communication network will be used.

The owner or driver of the vehicle should be registered for ETC facility and obtained the OBU card. Then it is required to get the payment mechanism as post-paid or Pre paid.

When the users enter to the Expressway toll gate, coordinate relevant to current start point will be taken from GPS and sent to the central data management unit. After the vehicle arriving to the exit point, GPS coordinate will be taken and charged for travel distance. The transaction details will be sent to Management Centre by the GSM module through mobile network. Then all transactions data will be verified by the control system and sent back to the Interfacing hardware device. The enforcement facility is available to catch the non-payers and the violators

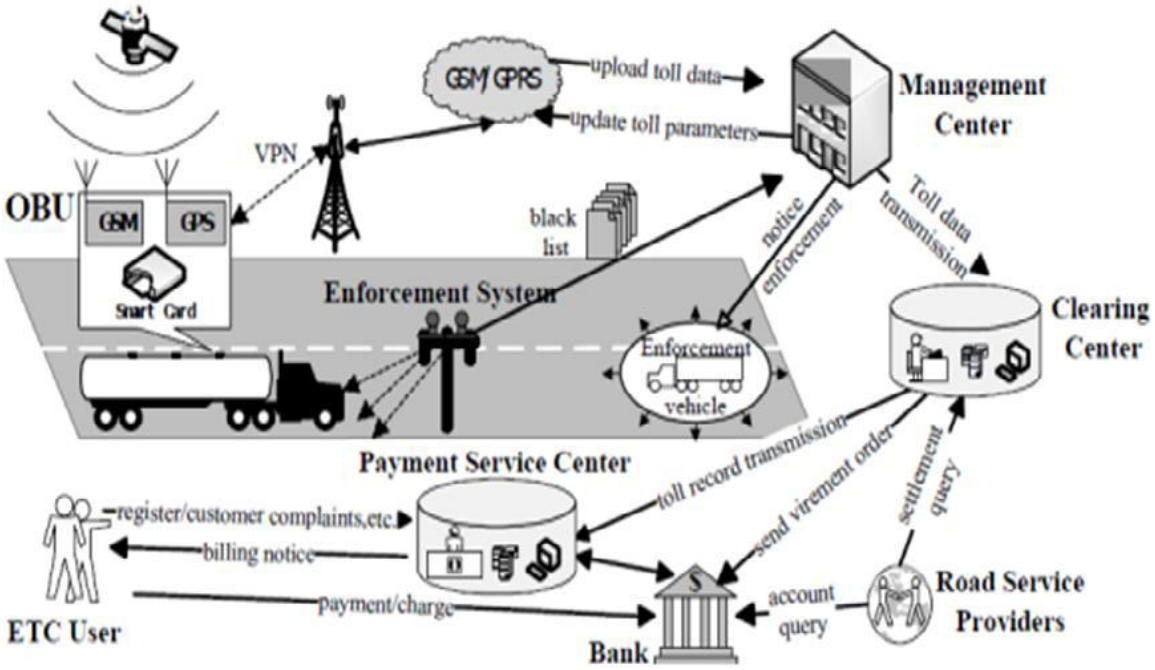


Figure 18: Schematic use of GNSS systems

(Source: International Journal of advanced Research in computer and Software Engineering, Volume 4, Issue 7, July 2014, PP 621-625)

Following features can be noticed related to the VPS based ETC system.

- Higher Level of Service
- High Operational Expenditure
- High capital Expenditure
- Violation Enforcement facility

(viii). Calm Active Infrared

Calm Active Infrared technology based ETC system can be considered as a modern technology with respect to the other methods. The Radio Frequency Identification method as well as the Dedicated Short Range Communication method are similar to the Calm Active Infrared. Relevant registration information and other details are installed in On board equipment which is fixed in the vehicle. When compare with other toll technologies following matters can be concluded.

- Data reading speed is high
- Accuracy is high

- Reliability is high - Efficiency is high
- It can be worked in any environment conditions

Even though, following are some of drawback in this technology. This technology is also still under the development level and required carry out research to identify other aspects.

- High cost
- Problems of Interference
- Lack of interoperability
- Vendor support

(ix). Tacho graph Tolling

Tacho graph based toll is mainly used for heavy vehicles such as Lorries & trucks. The toll charges are based on the millage travel on motorways. To record the mileage used in motorways, the On Board device is fixed on the vehicle connecting to the odometer. The On board equipment is connected with Tacho graph using electronic mechanism.

Mainly the road pricing is based on the distance travelled on the particular expressway section. Not only are that gross weight of the vehicle & emission level some other factors considered to formulate the toll fee. Now a days the on board device has been improved with good communication capacity. The Emotach is one of the developed on-board equipment used in Swiss roads with chip card data transfer system via Bluetooth communication facility. The GPS and DSRC technologies are supported with this device and can be used for the enforcement objectives. This is the second generation of the on board devices used for tacho graph ETC system. . (Engdahl, 2013)

Following features can be noticed related to the Tacho graph based ETC system.

- Accuracy is in low level respect to the other ETC system (with errors of ±4% on data recordings).

- Toll has Charged for total millage travelled (it should be charged for only distance travelled on the Expressways)
- Price or Toll charge can be doubt due to travel distance issue

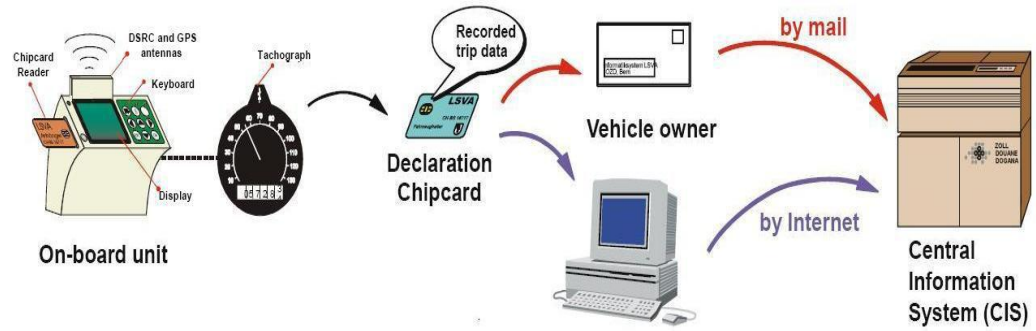


Figure 19: Tachograph based toll system

(Source: Technology Options for European Electronic Toll Service, 2014)

(x). Smart Phones Apps

Although smartphone apps should not be used while driving, they are increasingly being provided by both toll chargers and service providers to improve user convenience. Apps include features to allow users to check their account balance before commencing their journey and top-up accounts directly from their banking app if required.

Application of Smart phone for ETC system of Expressways is a user friendly method. The memory capacities and data processing speed are higher than the other on board devices and e tags. Smart phone apps is consisted with user friendly interface and easy to use. The users can get other facilities or information such as best route, navigation, toll fee and payment details by same device. The smart phone solution is more benefited for user because of low equipment cost, other user facilities, and can be get connection for 24 hours. The smart phone application for Expressway is in high level of accuracy and manufactures were ensured the accuracy rates as 100%.

Following table 6 explains some mobile and smart phone based toll systems in other countries.

Table 6: Details of Mobile Phone used Expressway projects

Category	Countries of implementation	Example
Mobile phones and smartphones used to monitor toll expenses	South Africa US (Texas)	AfriGis Tollmate
Mobile phones and smartphones used to pay tolls integrated with a OBU through NFC integrated with DSRC or GNSS/GSM infrastructure	Portugal	C2S Project
Mobile phones and smartphones equipped with RFID tag residing on the phone	US (Florida)	GeoToll
Mobile phones and smartphones used as a tag through WiFi connection	India (Karnataka State) (Brazil, Indonesia, US, and South Africa in 2014)	m-Tool

(Source: Technology Options for European Electronic Toll Service, 2014)

Even though, there are few draw backs in smart phone based toll systems as follows.

- Identification of vehicle categories
- Battery life
- It is required to implement additional number of base station to ensure the coverage in the area

(a). Wi-Fi Technology

Wi-Fi is used for transfer the data & voice from one location to another specified location. It is required to connect with network facility or service such as to transfer data from location to location or multi locations. Wi-Fi is a radio frequency specification and can be used for some devices such as smart phones, computers, cameras (digital), audio players (digital) etc. Smart phone with Wi-Fi connected via wireless network access point can be used for ETC operation to avoid stopping vehicles for toll paying. It is required the smart phone with Android version 4.2 or above operating system. The toll payment can be deducted from only the registered

users and others will be reported for enforcement legal procures. Enforcement facilities can be implemented with integrating DSRC with HD camera system.

Figure 20: System layout at toll booth using Wi-Fi

(Source: Technology Options for European Electronic Toll Service, 2014)

m-toll is One of the worldwide smart phone based toll method has used in the countries such as India, Brazil, Indonesia, US and South Africa etc. using Fi-Fi technology. Road side equipment and servers are fixed on the toll plaza and can be detected vehicle from 600m distance.

Figure 21: Functions of m-Toll System

(Source: Technology Options for European Electronic Toll Service, 2014)

As per the papers, m-toll has being tested pilot project in India from November 2013. Wi-Fi technology base ETC system in not expensive and currently this technology is implemented in Delhi-Mumbai route, Mumbai & Ahmeda in India. As such, this method has introduced in Brazil, Indonesia, Us & South Africa in 2014 (GeoToll, 2013).

(b). Satellite/ GPS Technology

In the case of video tolling, a recent innovation is to use the Global Position System (GPS)/ Global Navigation Satellite System (GNSS) location data from the smartphone to confirm the presence of the user at a toll point. This eliminates the need for manual verification of the vehicles number plate and provides a kind of half-way house to a full on-board unit. Geotoll is one of the example for GPS based RFID equipped smartphones application for toll collection in US, Florida. The smartphone couple with RFID chip and used as OBU. The toll gate or toll barrier is recognized by the RFID chip embedded tag which is attached to the phone. When reach the vehicle to toll gate, the GPS technology will activate GoeToll application installed phone device in the vehicle.

(c). Near Field Communication (NFC) Technology

This technology is used for smartphones, card readers and other similar type of equipment or devices to communicate with each other with contactless manner. Some countries are used NFC technology with smart phones for toll collection process in Expressways. The C2S project is one of the example developed by Portugal. Under this project, On Board equipment integrates DSRC and GNSS with a smart phone are interconnected using NFC technology. ANPR method is used in this project to identify the vehicles because of the on board device is unable to detect the vehicles. Under this mobile phone application, the user can make toll payment by a simple touch using NFC facility. The figure 22 shows the functions of the C2S system.

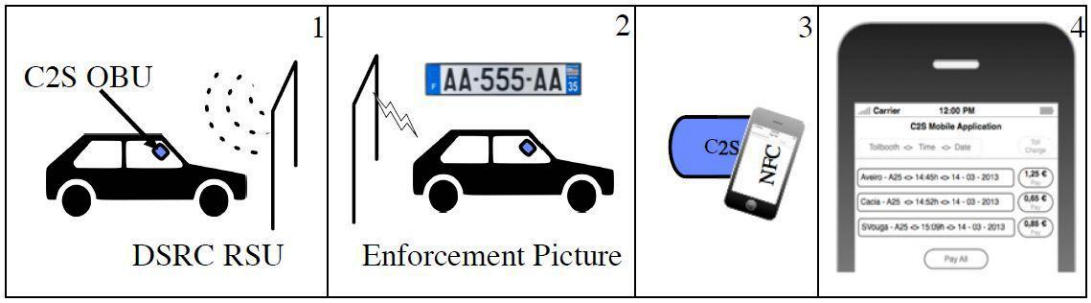


Figure 22: Process chat of C2S Project

(Source: Technology Options for European Electronic Toll Service, 2014)

3.0 METHODOLOGY

3.1 Traffic Study for CKE

The study requires correctly identified traffic behaviours in CKE in hourly, daily weekly, monthly and yearly basis. The data was collected to identify the peak time & peak day based on the vehicle traffic data available in Expressway Operation Management and Maintenance division (EOM&M) of RDA. As such, following steps are carried out.

- Based on the collected traffic data from EOM&M division of RDA, Average daily MTC & ETC exit traffic variation in CKE and their compositions are calculated.
- The peak time service rate and vehicle traffic demand in each lane at Peliyagoda, Ja Ela & Seeduwa toll plazas are calculated based on the peak time traffic data obtained from EOM&M division.
- Peak time vehicle arrivals in exit toll gates at Peliyagoda & Ja Ela are obtained by field survey and manual counting using the video records. Then the Individual delay and vehicle queue length in above toll gates are determined by plotting the service curve and arrival curves.

3.1.1 Delay Calculation

To get the waiting time / Delay time at toll gates following strategies and procedures were used.

- The critical exit ramps of the E03 based on the traffic volume and ramp arrangement were identified.
- Peak month, Peak days & Peak hours corresponding to the critical ICs were found based on the traffic data available in EOM&M division
- Vehicle service rate was obtained based on the traffic data obtained from EOM&M division
- Hourly Vehicle count for 24 hrs were obtained by conducting a field survey and reviewing the CCTV video streams to obtain arrival rate relevant to the above selected Toll plazas.

- Based on traffic survey data, the graphs for arrival & service corresponding to the critical ICs were plotted.
- Maximum queue and highest individual delay were identified using above graphs.
- Financial analysis due to delay and relevant comparison of toll system based service time are done by using above obtained values.

3.1.1.1 Graph of Cumulative Number of Vehicle vs. Time

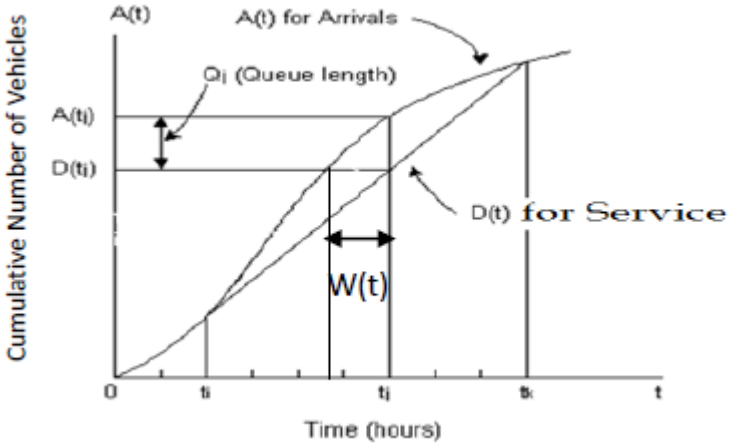


Figure 23: Graph of Cumulative Number of Vehicle vs. Time

According to the graph,

- Qt (Queue length) - Vertical distance between A(t) and D(t) at time t, represents the number of vehicles in the queue
- Area of A(t) & D(t) - the total delay or cumulative delay from all vehicles
- Slope of A(t) - represents the Arrival rate
- Slope of D(t) – represent the Departure rate
- When queue is present the departure rate will equal the service rate
- W(t) Horizontal distance between A(t) and D(t) represents the delay to vehicle arriving at time t.

3.1.2 Estimation of Financial Losses due to delay

Time value cost, user cost, vehicle operation cost are increased due to the delays at toll gates in peak time. Only the time value loss based on the toll fee is considered under this study. Accordingly, the peak hour travel time loss at Peliyagoda, Jaela ICs for all type of vehicle categories are calculated. Then the annual loss due to peak time delay is calculated.

Travel time saving due to E03 = Travel Time in A3 road – Travel time in E03

Financial Value of travel time = Toll fee for specific vehicle category (LKR) / Saving for vehicle category Travel time saving due to E03 (min.)

Financial loss due to waiting time = Time delay experience at toll gate x Financial Value of travel time saving for vehicle category

Financial loss per hour = Financial loss for all vehicle category x 60 (LKR/hr)

Annual financial loss = Financial loss per hour x Total congested time (hrs) per year

3.2 Evaluation of ETC system in CKE

The existing ETC system is studied under the following areas.

- ETC Registration & Usage
- Estimation of loss due to ETC discount
- Estimation of ETC Lane Utilization

3.2.1 ETC Registration & Usage

Monthly details of ETC registration & vehicle usage during past years in CKE are collected from EOM&M division and compared to identify the behaviour of ETC system.

3.2.2 Estimation of Financial loss in existing ETC system

Following reasons have caused for financial losses generated due to implementation of existing ETC system in CKE.

(i). Allowing of 10% discount for each transaction

(ii). Underutilization of existing lanes and developing additional vehicle queue

(iii). Staff Allocation - Required to assign Tellers for ETC booth (same as MTC booth) to handle abnormal incidents due to Enforcement, technical failures, user behaviours etc.

3.2.3 Estimation of loss due to ETC discount

Annual Revenue and discount amounts are collected from EOM&M division of RDA & compared by tabulating in the Table 25.

3.2.4 Estimation of ETC Lane Utilization

There are six ETC lane available in CKE as two entrance lane and four exit lanes at Peliyagoda, Ja Ela & Seeduwa toll plazas. It is required to investigate the current ETC demand of CKE and minimum requirement of ETC traffic to recover the initial investment. Following calculations are carried out to get the shortfall.

It is allowed 10% day time for each transaction done by any category of vehicle. Thus, it is charged Rs. 6.00 from each transaction as Bank Of Ceylon (BOC) service charges.

RDA contribution from ETC at day time = Categorized toll fee – 10% discount – Rs. 6.00 of BOC service Fee

In addition, it is deduct Rs. 50.00 from each transaction at night time (from 21:00:00 to 04:59:59) as per the government budget proposals.

RDA contribution from ETC at night time	= Categorized toll fee – 10% discount – Rs. 6.00 of BOC service Fee – Rs.50.00 discount as budget proposal
Weight Factor of exit vehicles	= No of exit vehicles in categorized toll fee / Total no of exit vehicles
Weighted Contribution per vehicle	= RDA contribution Rs. (Day/Night) x Weight Factor
Total cost (Rs.)	= Fixed Cost (Rs.) + Variable Cost (Rs.)
Fixed Cost (Rs.)	= Capital investment + Loan repaid with annual Interest
Variable Cost (Rs.)	= Operation Cost + Maintenance Cost + Improvement & rehabilitation cost
Short fall of daily throughput in ETC exit	= Daily break even ETC traffic in all exit lanes – Actual daily average ETC traffic in all exit lane

3.2.5 Estimation of loss due to allocation of Staff

Considerable amount of money is spending annually for allocating of staff for the 24 hrs operational duty in ETC toll lanes. In this estimation it is considered the staff allocated only for ETC toll lanes other than the ETC customer care centres and toll offices.

Monthly loss due to staff allocation	= No of staff members x Average monthly salary with allowances
Annual Loss	= Monthly Total loss x 12

3.3 Selection of best ETC method for Sri Lankan Expressways

This study approaches the problem by applying MCDA tools to evaluate the suitable tolling system for Sri Lankan expressways. Here, it was consider the experts opinions, ideas for measured weights. Fuzzy & VIKOR approaches are followed to generate a list of ranking order based on performance, service quality, and efficiency in each toll collection system.

The evaluation procedure of this study consists of several steps as shown as follows. It was identified the important service quality dimensions and criteria corresponding to the each toll collection technologies. Under evaluation criteria, it was calculated the weightages related to the parameters by using MDL approach. By using Fuzzy theory, linguistic variables were defined and constructed the Fuzzy decision matrix with Fuzzy ratings. Then, it was conducted VIKOR approach to obtain the final ranking results.

As such the flow chart of proposed evaluation framework for selection of Toll collection technology is shown in Figure - 24.

3.3.1 Methodology for Selection

Following methodologies are used for this selection criterion.

i. Modified Digital Logic (MDL)

ii. Fuzzy Logic

iii. VIKOR Approach

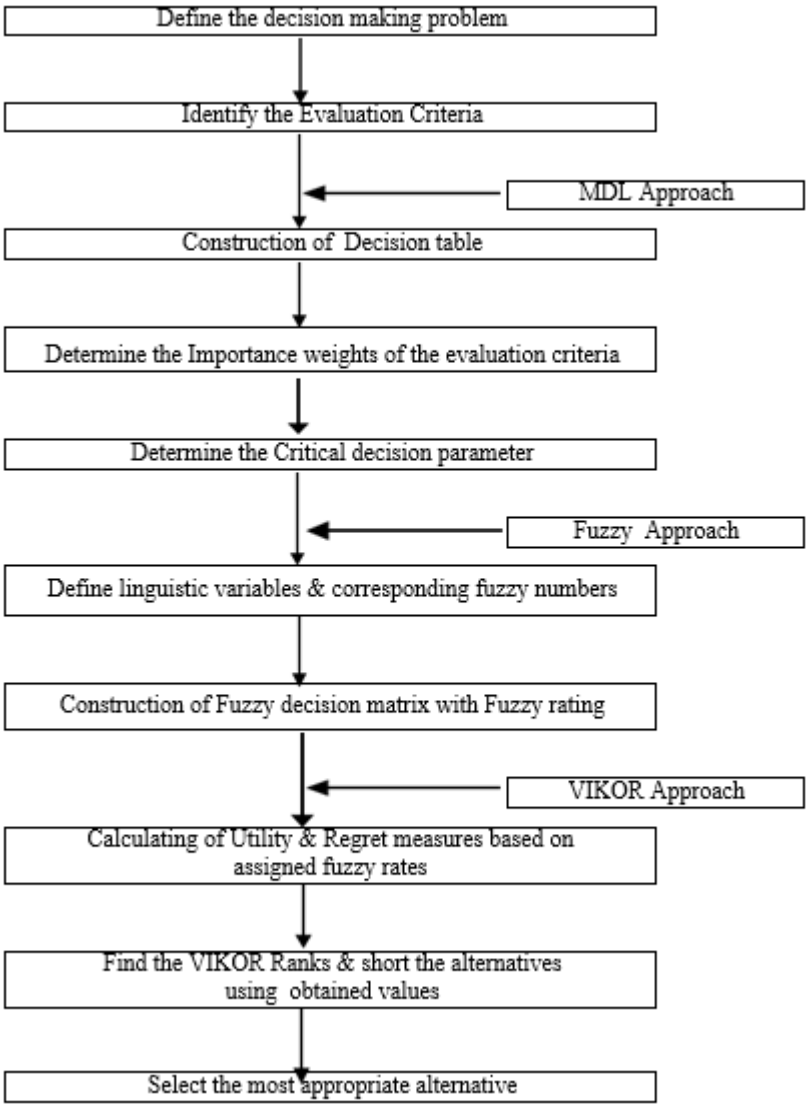


Figure 24: Proposed Evaluation framework of Toll collection technology selection

3.3.1.1 Modified Digital Logic (MDL)

Different factors or parameters can be identified when doing the study for choosing an appropriate method or technology for the country. When compare the identified parameters together, each one has different weightage based on its economic. Technical, financial, infrastructure, durability, public welfare aspects of the country. Modified Digital Logic can be used to compare and estimate the significance of each attributes/parameters by giving priority value under the above condition.

All parameters are consisted with unequal or different impacts for choosing a suitable ETC technology for the Sri Lankan Expressways. Therefore, it can be done by giving appropriate weight based on the priority of parameters. MDL technic can be used for selection of most critical parameters.

The Weightages for each parameter are given as follows.

1 - For Less priority

2 - For Equal Priority

3 - For More Priority

Equation (1)

$$\text{Final Weight (Wi)} = \frac{\text{Positive Decision}}{\text{Summation of all positive Decisions}} = \frac{Pi}{\Sigma_{i=1}^{n} Pi}$$

It can be prepared relative decision matrix by pair wise comparison of each parameters and allocating 1, 2 and 3 weightage values as less, equal and higher priority parameters.

3.3.1.2 Fuzzy Approach

The Fuzzy logic was introduced in 1965 and used for non-numerical based analysis. This method is applied for solving the riddle which are difficult to understand the clear limits or boundaries. This is based on the public, expertise observations obtained as non-numerical information.

3.3.1.3 Fuzzy Number

Under the Multi Criteria Decision Making (MCDM) problems, set of Fuzzy numbers are introduced to analysis haziness and variations in given ratings by the specialist. A Fuzzy number is a generalization of a real number where each single value is

connected to a set of possible values assigned weights between 0 and 1. Commonly used types are Triangular Fuzzy numbers and Trapezoidal Fuzzy numbers for the analysis.

3.3.1.4 Triangular Fuzzy Numbers

Following figure 25 is shown the membership function *f(x)* represented by a, b, c for Fuzzy set A′. This representation of member ship function is called triangular fuzzy number.

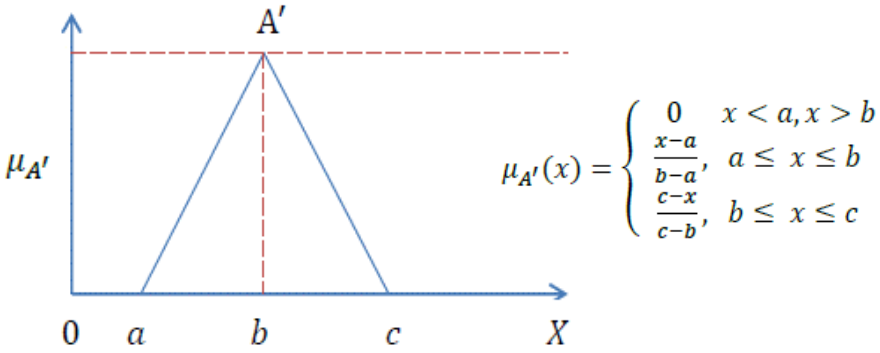


Figure 25: Membership function of triangular fuzzy number

Considering the straight lines in the figure 25, it can be represented following relationships.

Equation (2)

$$\frac{1}{b-a} = \frac{y}{x-a} \quad \Rightarrow \quad y = \frac{x-a}{b-a}$$

Equation (3)

$$\frac{1}{c-b} = \frac{y}{c-x} \quad \Rightarrow \quad y = \frac{c-x}{c-b}$$

Above formulas are represented the membership function $\mu A'$ as shown in Figure 25.

3.3.1.5 Trapezoidal Fuzzy Number

The quadruple a, b, c, & d are represented Trapezoidal Fuzzy numbers with the membership function *f(x)* for fuzzy set A' in figure 26.

The membership function $\mu A'$ is expressed as in Equation 4.

Equation (4)

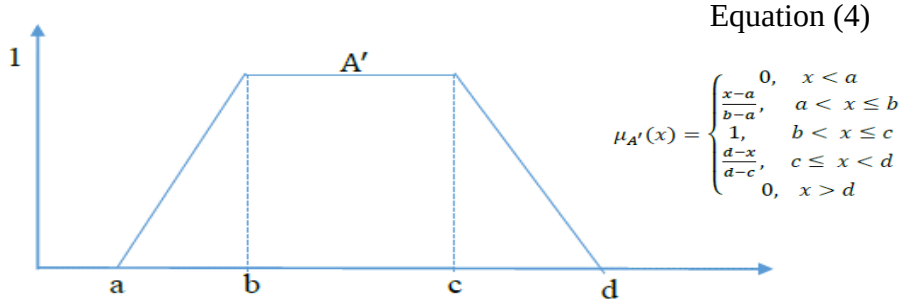


Figure 26: Membership function of Trapezoidal fuzzy number

3.3.1.6 VIKOR Approach

To obtain an acceptable solution for a decision making problem, the VIKOR method can be used and it is also a latest tool used for analysis. Under VIKOR analysis, all selected alternatives are ranked and sorted against the various decision criteria. It can be obtained accurate, close and real solution by using VIKOR technic for multi decision problems.

3.3.1.7 Selection procedure

Following steps are followed to do the required calculations for the selection process.

Step (i). Compare the each alternative corresponding to the technological parameter. Then, the MDL weights (Wj) are calculated.

Step (ii). The membership functions and relevant Fuzzy numbers are defined.

Step (iii). By considering the alternatives and parameters, the Decision matrix (D) is developed.

Where,

n - Technological parameters (Criteria)

m- Technologies (Alternatives)

$$D = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \ldots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \ldots & x_{2n} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ x_{m1} & x_{m2} & x_{m3} & \ldots & x_{mn} \end{bmatrix}$$

Step (iv). Normalization

Normalization is done for analysis the properties under two criterion as cost criterion (lower desired value) and benefit criterion (higher desired value). Following Equation 5 & 6 are used for both analysis to do the normalization.

$$\mu_{ij} = \left(\frac{x_{ij1}}{x^{+}_{ij1}}, \frac{x_{ij2}}{x^{+}_{ij2}}, \frac{x_{ij3}}{x^{+}_{ij3}}, \frac{x_{ij4}}{x^{+}_{ij4}} \right), \quad j \in J \qquad \text{Equation (5)}$$

$$\mu_{ij} = \left(\frac{x^{-}_{ij1}}{x_{ij1}}, \frac{x^{-}_{ij2}}{x_{ij2}}, \frac{x^{-}_{ij3}}{x_{ij3}}, \frac{x^{-}_{ij4}}{x_{ij4}} \right), \quad j \in J' \qquad \text{Equation (6)}$$

Where,

$x^{+}_{ij4} = \max(x_{ij4}),\ j \in J$ and $x^{+}_{ij4} = \min(x_{ij1}),\ j \in J'$

J corresponds to benefit criterion and J' corresponds to cost criterion.

Step (v). Defuzzification

To get crisp values for each criterion related to considered alternatives, the defuzzification can be used. Calculation of crisp values can be done by using Equation 7 which shown below. The quantitative numerical values for the linguistic variables & fuzzy numbers are given considering the opining of the expertise and the decision makers. Accordingly, using the equation 7, corresponding crisp values are determined.

Equation (7)

$$f_{ij} = \text{Defuzz}(x_{ij}) = \frac{\int \mu(x).xdx}{\int \mu(x).dx}$$

$$= \frac{\int_{x_{ij1}}^{x_{ij2}} ((x - x_{ij1})/(x_{ij2} - x_{ij1})) \cdot xdx + \int_{x_{ij2}}^{x_{ij3}} xdx + \int_{x_{ij3}}^{x_{ij4}} ((x_{ij4} - x)/(x_{ij4} - x_{ij3})) \cdot xdx}{\int_{x_{ij1}}^{x_{ij2}} ((x - x_{ij1})/(x_{ij2} - x_{ij1}))dx + \int_{x_{ij2}}^{x_{ij3}} dx + \int_{x_{ij3}}^{x_{ij4}} ((x_{ij4} - x)/(x_{ij4} - x_{ij3}))dx}$$

$$= \frac{-x_{ij1}x_{ij2} + x_{ij3}x_{ij4} + (1/3)(x_{ij4} - x_{ij3})^2 + (1/3)(x_{ij2} - x_{ij1})^2}{-x_{ij1} - x_{ij2} + x_{ij3} + x_{ij4}}$$

Step (vi). Determination of ideal and negative ideal solutions

The ideal solution f* and the negative ideal solution f^- can be obtained by using equation 8 & 9.

$$f^* = \{\max f_{ij}\} \qquad \text{Equation (8)}$$

$$f^- = \{\min f_{ij}\} \qquad \text{Equation (9)}$$

Step (vii) Calculation of Utility and Regret measures

$$S_i = \sum_{j=1}^{n} W_j \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)}; \quad \forall i \qquad \text{Equation (10)}$$

$$R_i = \text{Max}_j \left[W_j \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)} \right]; \quad \forall i \qquad \text{Equation (11)}$$

Where,

Si is utility measures and Ri is regret measures

Step (viii). Determination of VIKOR index

Equation (12)

$$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1-v)\left[\frac{R_i - R^*}{R^- - R^*}\right]; \forall i$$

Where,

Qi - is the i th alternative VIKOR value,

ν - Represents the group utility weight,

Under the unsupervised condition, ν is normally considered as 0.5.

$S^* = \text{Min}_i(S_i)$; Equation (13)

$S^- = \text{Max}_i(S_i)$; Equation (14)

$R^* = \text{Min}_i(R_i)$; Equation (14)

$R^- = \text{Max}_i(R_i)$; Equation (14)

The lowest value of the VIKOR index (Q_i) corresponding to the each parameter and the alternatives is considered for the best alternative for selection process.

3.3.2 Most Critical Parameter

Following parameters are identified for the selection of best ETC toll method for Sri Lankan Expressways based on the discussions with officers of EOM&M division, toll expertise, reports published by other researchers and experts.

Table 7: Description of MDL parameters

Parameter		Description
Accuracy	P1	Ability of system to identify the vehicle category and relevant toll fee correctly
Compatibility	P2	Ability to integrate new toll system with other toll technologies or upgrading of existing technology to new technology (System Integration)
Congestion Reduction	P3	Ability of reduce the vehicle queue forming or congestion at toll plaza under the operational & economic aspects such as fuel cost saving, reducing of peak hour traffic, environmental pollutions, reducing of travel time, reducing of service time etc.

Cost	P4	This include the cost for construction, implementation, operation, management & Maintenance cost
Data Processing Speed	P5	Ability of reading, detecting and conveying the information/data of the vehicles moving via toll lanes to the servers/ processing units under normal conditions.
Access/Detection Speed	P6	Capability of the devices and technology to detect the vehicle access through the toll plaza during congestion at peak (less space between consecutive vehicles) and high speed
Easiness	P7	Consists with facilities for easy handling for all users and shall be user-friendly technology
Flexibility	P8	Same technology may also serve in several other manner such as Navigation requirements, traffic surveillance, investigation accidents, and vehicle theft controlling/prevention purposes.
Implementation	P9	Ability of implementation new technology with existing available resources and the financial capacity of the country.
Maturity	P10	Ability of the system to identify its shortcomings, negative aspects before those are critical or problematic in future
Negative Environmental Impacts	P11	Bad or harmful effects such as pollutions, vehicle congestion, noise, emissions to the environment due to the toll technology
Reliability & Acceptance	P12	Willingness of the all users including customers, drivers, operators, authorities to accept the technology based on the system reliability, their own experience, understanding and judgements.
Simplicity of System/Network	P13	Toll Management system should not be complex and always it should be simple to trouble shoot the errors in the network for continue smooth Operation & its connection.
Theft Detection	P14	Ability to detect the unauthorized vehicles and availability of mechanism to notice them by alarm, siren or other means

4.0 DATA COLLECTION AND ANALYSIS

4.1 Traffic Analysis

4.1.1 Peak Month

According to the vehicle exit traffic in CKE, the highest traffic was experienced in month of December in each year. Hence, the highest vehicle traffic was reported in December 2017. Monthly MTC & ETC total exit traffic variation in CKE is shown below.

Table 8: Monthly Total vehicle Traffic in E03

Month	Total Traffic				
	2014	2015	2016	2017	2018
January	530,973	579,351	735,318	791,188	883,596
February	467,973	541,630	659,352	686,552	764,325
March	519,665	601,901	715,974	776,593	842,967
April	525,997	581,935	666,272	720,913	790,201
May	529,221	604,663	683,035	743,661	815,144
June	522,567	596,966	683,668	723,983	812,925
July	559,022	639,990	749,020	805,776	
August	625,049	670,668	786,633	852,292	
September	566,945	652,589	731,327	791,445	
October	578,175	649,214	729,335	791,874	
November	550,886	625,595	710,571	778,883	
December	657,032	765,876	854,090	925,904	
Total	6,633,505	7,510,378	8,704,595	9,389,064	4,909,158

(Source: Expressway Operation Maintenance and Management Division - RDA)

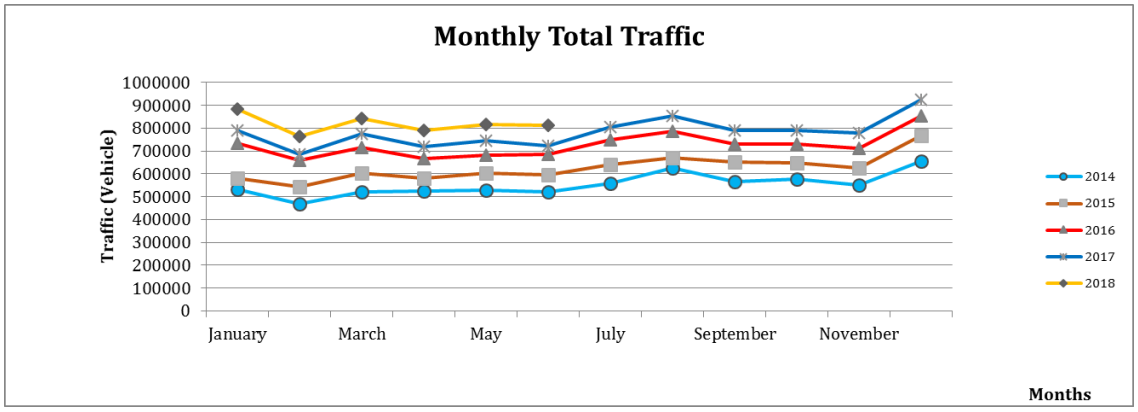


Figure 27: Monthly Total Traffic Variation in CKE

Monthly MTC exit traffic variation in CKE are shown in table 9 and figure 28 as follows.

Table 9: Monthly MTC vehicle traffic in E03

Month	Total Traffic				
	2014	2015	2016	2017	2018
January	530,973	579,351	667,787	687,291	759,337
February	467,973	541,630	591,534	592,283	651,942
March	519,665	601,901	638,571	663,902	717,832
April	525,997	581,935	595,546	630,886	683,973
May	529,221	604,663	602,466	639,545	690,511
June	522,567	596,846	598,320	618,787	693,494
July	559,022	634,341	660,695	692,127	
August	625,049	641,363	695,287	739,393	
September	566,945	607,457	637,833	679,196	
October	578,175	595,562	630,960	674,545	
November	550,886	570,763	614,491	661,023	
December	657,032	704,721	759,400	810,572	
Total	6,633,505	7,260,533	7,692,890	8,089,550	4,197,089

(Source: Expressway Operation Maintenance and Management Division - RDA)

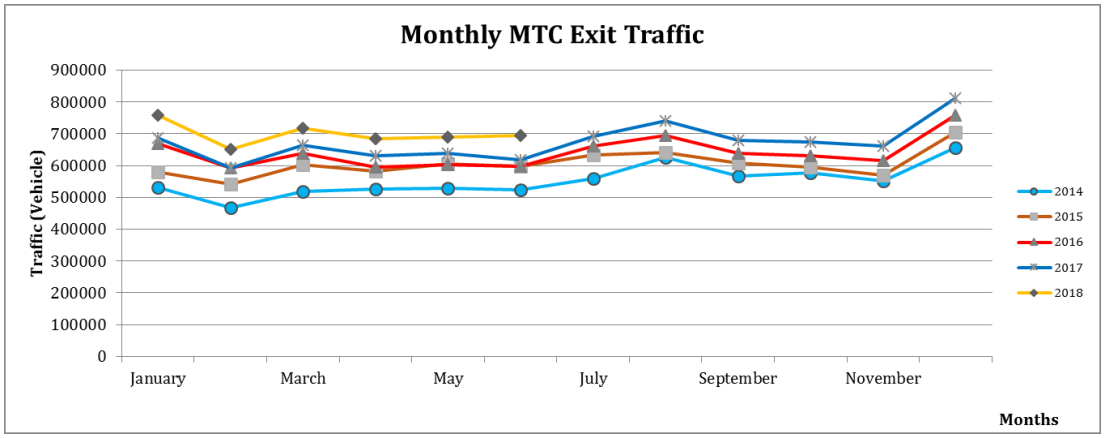


Figure 28: Monthly MTC Traffic Variation in CKE

(Source: Expressway Operation Maintenance and Management Division - RDA)

Monthly ETC exit Traffic variation in CKE are shown in Table 10 and Figure 29 as follows.

Table 10: Monthly ETC vehicle traffic in E03

Month	Total Traffic			
	2015	2016	2017	2018
January		67,531	103,897	124,259
February		67,818	94,269	112,383
March		77,403	112,691	125,135
April		70,726	90,027	106,228
May		80,569	104,116	124,633
June	120	85,348	105,196	119,431
July	5,649	88,325	113,649	
August	29,305	91,346	112,899	
September	45,132	93,494	112,249	
October	53,652	98,375	117,329	
November	54,832	96,080	117,860	
December	61,155	94,690	115,332	
Total	249,845	1,011,705	1,299,514	712,069

(Source: Expressway Operation Maintenance and Management Division - RDA)

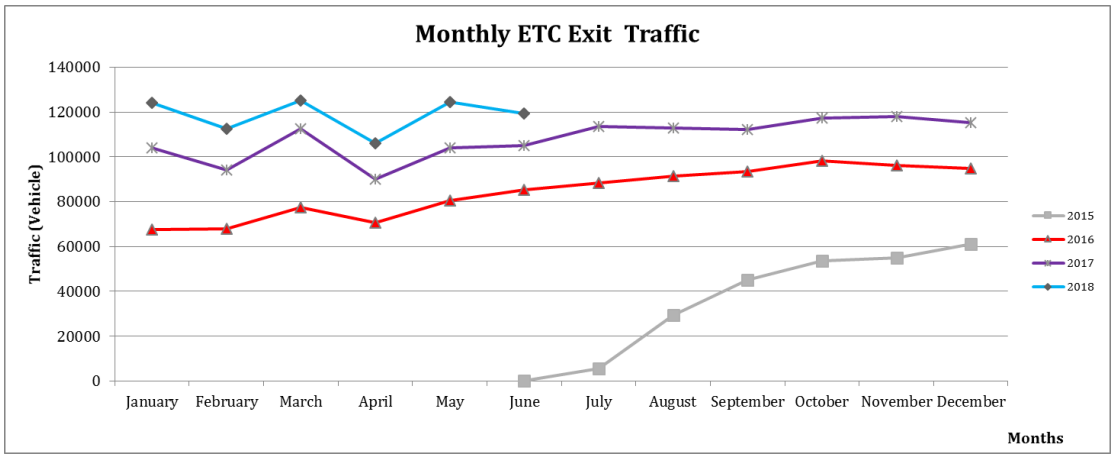


Figure 29: Monthly ETC Traffic Variation in CKE

The annual growth rate of MTC & ETC exit vehicle can be shown as follows.

Table 11: Average Daily MTC & ETC Exit Traffic variation in CKE

Mode	MTC			ETC		
Year	Traffic	Composition	Increment %	Traffic	Composition	Increment %
2014	18,174		-	-	-	-
2015	19,892	94.23%	9.45%	1,219	5.77%	-
2016	21,019	88.38%	5.67%	2,764	11.62%	-
2017	22,163	86.16%	5.44%	3,560	13.84%	28.80%
2018 (mid)	23,188	85.50%	4.63%	3,934	14.50%	10.50%

(Source: Expressway Operation Maintenance and Management Division - RDA)

Base on above table, it can be seen that the incremental increase for MTC exit traffic seems to be gradually decreased and for ETC it was drastically decreased.

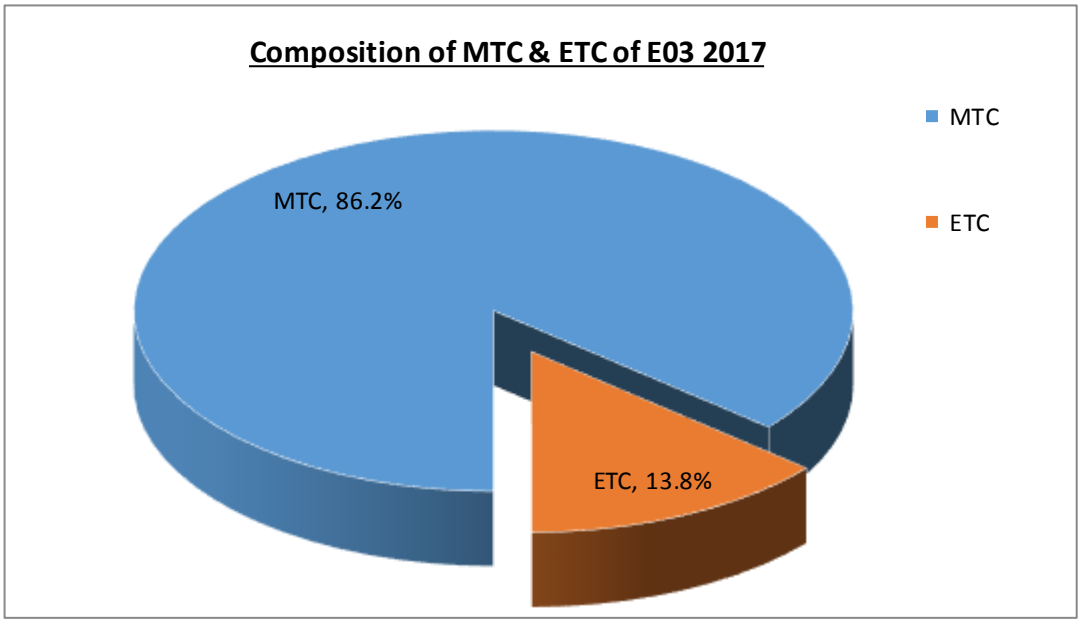


Figure 30: MTC & ETC vehicle composition of CKE in year 2017

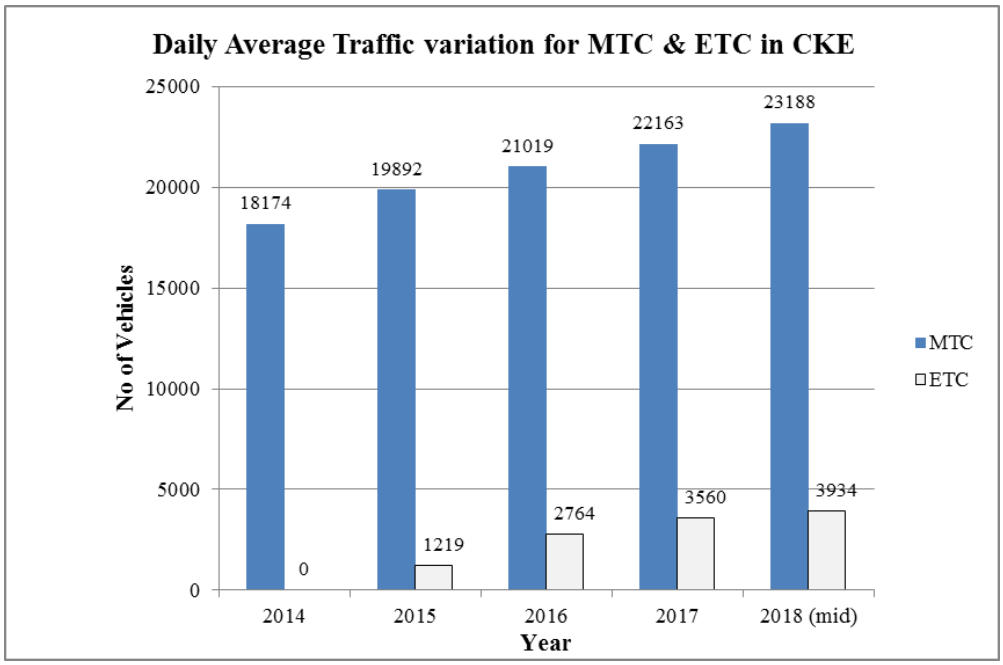


Figure 31: Daily Average exit Traffic variation for MTC & ETC

The average daily traffic for MTC vehicles seems to be gradually increased. But, the average daily traffic for ETC vehicles is slowly increased. Even though, the ETC composition was gradually increased during past few years.

4.1.2 Peak Day & Peak Time

Past vehicle traffic data relevant to busy days, busy months which experienced by EOM&M division were collected & analysed. Then the busy times and busy days for each ICs were obtained from EOM&M division. These busy days and times related to the Peliyagoda, Ja Ela & Seeduwa Exit are shown as follows.

For MTC vehicles

- Peliyagoda - 07.30 a.m. - 09.30 a.m. Monday & Friday
- Ja Ela (Entrance) – D1 - 07.00 a.m. - 09.00 a.m. Monday & Friday
- Ja Ela (Exit) – A1 - 17.30 p.m. - 20.00p.m. Friday
- Seeduwa - 16.30 p.m. - 20.30 p.m. Friday & Saturday

(Source: Expressway Operation Maintenance and Management Division - RDA)

For ETC vehicles

- Peliyagoda - 07.00 a.m. – 09.00 a.m. Monday & Friday
- Ja Ela (Entrance) – D2 - 06.30 a.m.- 08.30 a.m. Monday & Friday
- Ja Ela (Exit) – A2 - 17.30 p.m. – 19.30 p.m. Tuesday
- Seeduwa - 07.30 a.m. – 08.30 a.m. &

  17.30 p.m. – 19.30 a.m. Friday

(Source: Expressway Operation Maintenance and Management Division - RDA)

4.1.3 Critical Interchanges

As per the past observations of EOM&M division of RDA, the Peliyagoda & Ja Ela IC (only in Peliyagoda- Ja Ela directional Entrance & Exit) were identified as critical Interchanges in CKE. Usually, the considerable vehicle queue can be observed in Peliyagoda & Ja Ela toll plazas during the aforesaid peak days and the peak times.

At Peliyagoda Exit

Peliyagoda Inter Change is consisted with five number of toll lanes and constructed as at grade straight line geometry. Significantly heavy vehicle queue can be observed in MTC lanes as we as in ETC lane at Peliyagoda Exit in peak time. It has provided four number of MTC lanes and one number of ETC lane for cater the peak vehicle demand. Even though, the existing facilities are not sufficient to dissipate the peak time vehicle traffic and require to increase number of toll lanes. Not only is that it required to increase the number of ETC lanes to dissipate the peak traffic in future.

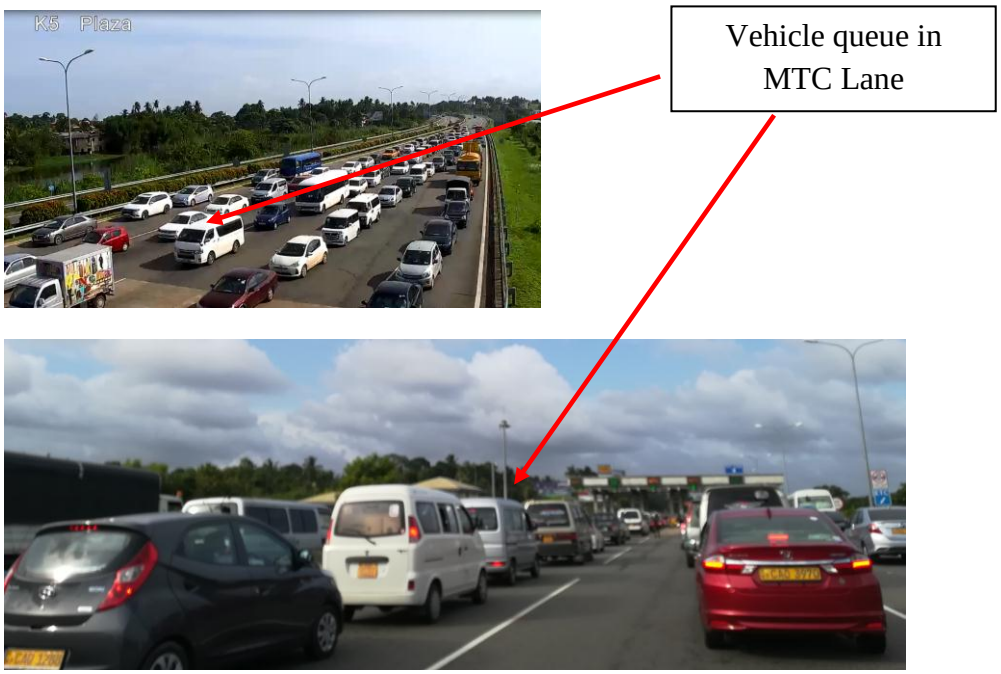


Figure 32: Vehicle Queue at exit toll plaza at Peliyagoda

Traffic data was collected at Peliyagoda exit toll plaza and determined the delay experienced by MTC vehicles in peak hours.

At Ja Ela Toll Plaza -A,

Je Ela Interchange is diamond type and consisted with four number of toll plaza configured as plaza A, B, C & D. Plaza A & C are operated as exit toll plaza and plaza B & D are operated as entrance toll plaza. The Considerable vehicle queue can be observed in MTC lane as well as ETC lane at Ja Ela Exit in peak time. Not only that in certain peak days, it can be observed vehicle queue in entrance lanes in plaza D in Ja Ela – Peliyagoda direction. It is provided only one lane for ETC & one lane for MTC respectively to cater the peak demand at Ja Ela IC. These facility is not sufficient to dissipate the peak time vehicle traffic and as a result heavy vehicle queue was developed towards the expressway. It is required to increase the number of toll lanes to avoid traffic jam in peak time as well as to use the lanes in emergency situations such as breakdown, urgent maintenance, repairs, power failures, system failures etc.

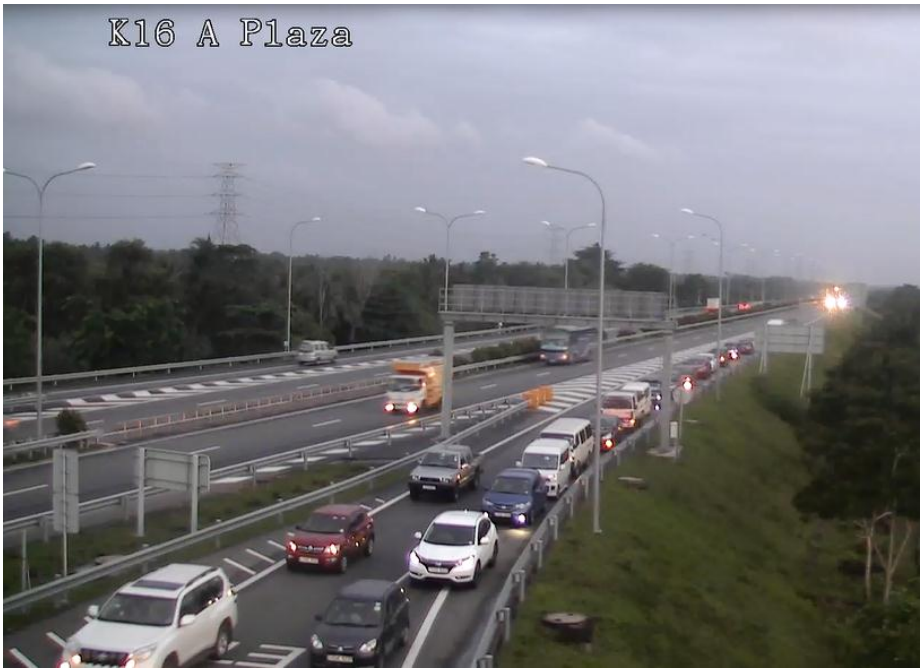


Figure 33: Vehicle Queue at exit toll plaza A at Ja Ela

The data related to hourly Served number of vehicles for 24 hours period at A1 MTC exit at Ja Ela, toll plaza – A was obtained from EOM&M division , RDA and determined the delay experienced by MTC vehicles in peak hours

4.1.4 Delay Time

At Peliyagoda Exit

Traffic data for Service rate corresponding to the 11th December 2017, Monday were obtained from EOM&M division and manually collected the hourly arrival rate during peak period by observing the CCTV video steaming.

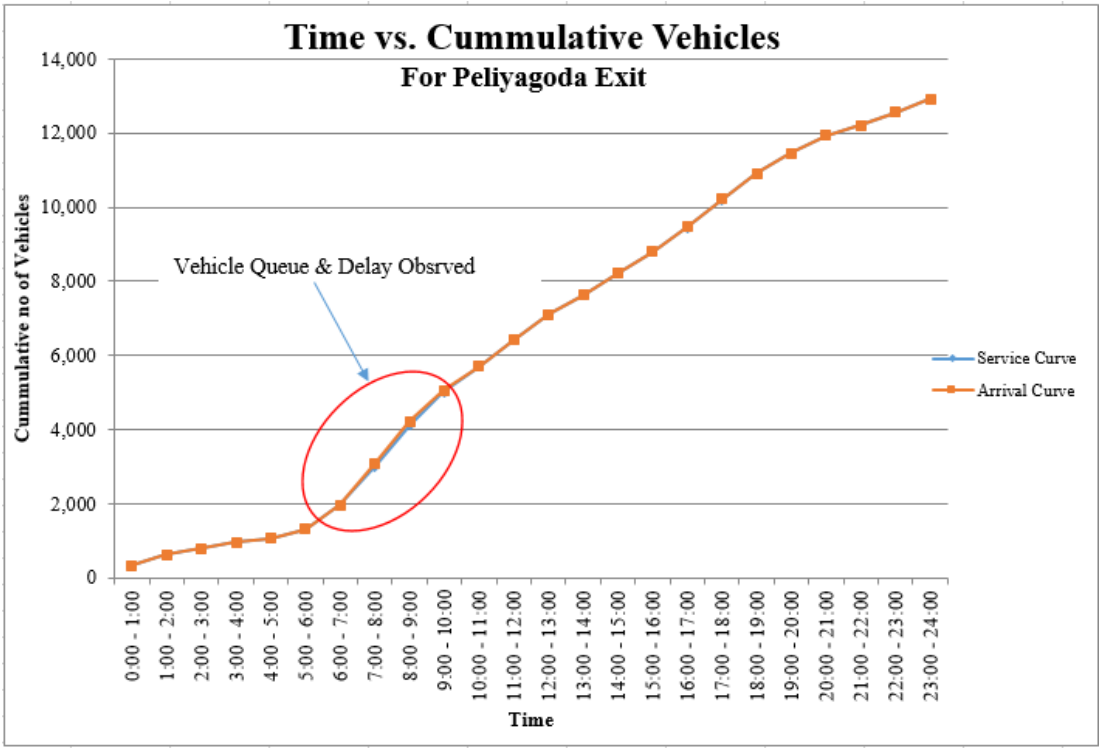
Table 12: Arrival & Service traffic at Peliyagoda exit

Time, hrs	No of MTC Vehicles (Lane L2,L3,L4 & L4)			
	11.12.2017, Monday			
	Service		Arrival	
	Service Rate	Cumulative	Arrival Rate	Cumulative
0:00 - 1:00	339	339	339	339
1:00 - 2:00	284	623	284	623
2:00 - 3:00	173	796	173	796
3:00 - 4:00	167	963	167	963
4:00 - 5:00	110	1,073	110	1,073
5:00 - 6:00	240	1,313	240	1,313
6:00 - 7:00	643	1,956	659	1,972
7:00 - 8:00	1,048	3,004	1118	3,090
8:00 - 9:00	1,117	4,121	1139	4,229
9:00 - 10:00	902	5,023	825	5,054
10:00 - 11:00	686	5,709	655	5,709
11:00 - 12:00	697	6,406	697	6,406
12:00 - 13:00	689	7,095	689	7,095
13:00 - 14:00	533	7,628	533	7,628
14:00 - 15:00	578	8,206	578	8,206
15:00 - 16:00	594	8,800	594	8,800
16:00 - 17:00	651	9,451	677	9,477
17:00 - 18:00	745	10,196	747	10,224
18:00 - 19:00	710	10,906	682	10,906
19:00 - 20:00	544	11,450	544	11,450
20:00 - 21:00	478	11,928	478	11,928
21:00 - 22:00	279	12,207	279	12,207
22:00 - 23:00	353	12,560	353	12,560
23:00 - 24:00	353	12,913	353	12,913

(Source: Expressway Operation Maintenance and Management Division - RDA)

Considering the cumulative Service rate and Cumulative Arrival rate, the graphs were plotted against to time as follows.

According to graph in figure 34, longest delay & queue length are shown corresponding to the 8.00 a.m. – 9.00 a.m. time period. Then,



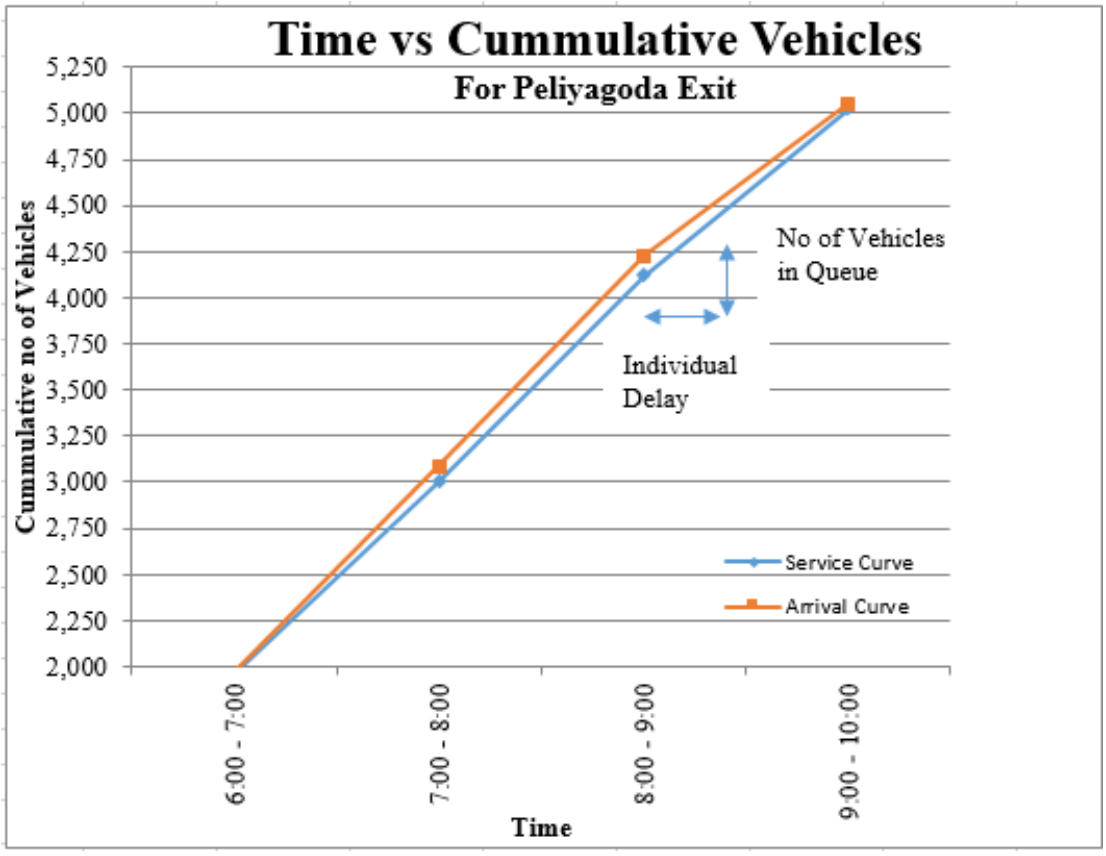


Figure 34: Graph of Time vs. Cumulative Vehicles at Peliyagoda Toll plaza

Individual Delay = Horizontal distance of the graph

= (60min x 2.5 mm/ 24mm) = 6.25 min

No of vehicles in the Queue = Vertical distance of the graph

= (500 vehicle x 2.5 mm/ 11mm) =113 Vehicle

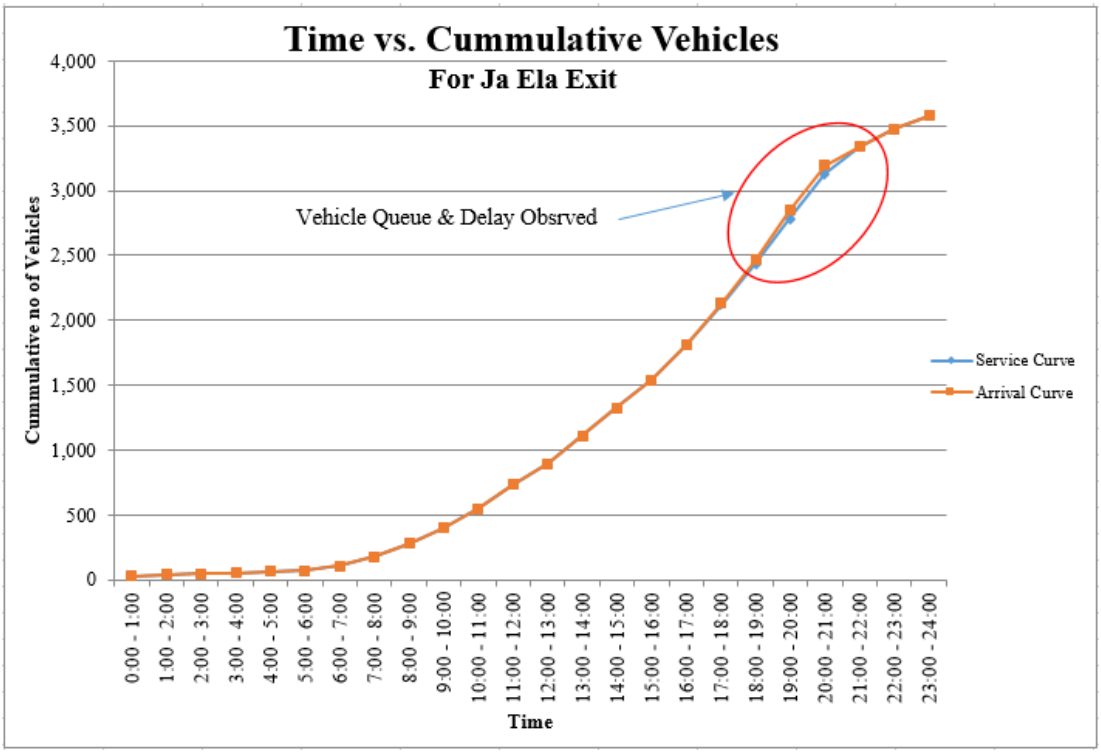
At Ja Ela Exit (A Plaza)

Traffic data for Service rates corresponding to the 15th December 2017, Friday were obtained from EOM&M division and manually collected the hourly arrival rate during peak period by observing the CCTV video steaming.

Table 13: Arrival & Service traffic at Ja Ela Exit

Time, hrs	No of MTC Vehicles (Lane A1)			
	15.12.2017, Friday			
	Service		Arrival	
	Service Rate	Cumulative	Arrival Rate	Cumulative
0:00 - 1:00	31	31	31	31
1:00 - 2:00	12	43	12	43
2:00 - 3:00	4	47	4	47
3:00 - 4:00	6	53	6	53
4:00 - 5:00	10	63	10	63
5:00 - 6:00	10	73	10	73
6:00 - 7:00	32	105	32	105
7:00 - 8:00	71	176	71	176
8:00 - 9:00	107	283	107	283
9:00 - 10:00	114	397	114	397
10:00 - 11:00	154	551	154	551
11:00 - 12:00	183	734	183	734
12:00 - 13:00	161	895	161	895
13:00 - 14:00	213	1,108	213	1,108
14:00 - 15:00	217	1,325	217	1,325
15:00 - 16:00	213	1,538	213	1,538
16:00 - 17:00	271	1,809	271	1,809
17:00 - 18:00	310	2,119	320	2,129
18:00 - 19:00	316	2,435	325	2,454
19:00 - 20:00	349	2,784	355	2,809
20:00 - 21:00	346	3,130	333	3,142
21:00 - 22:00	206	3,336	194	3,336
22:00 - 23:00	141	3,477	141	3,477
23:00 - 24:00	100	3,577	100	3,577

Considering the cumulative Service rate and Cumulative Arrival rate, the graphs were plotted against to time as follows.



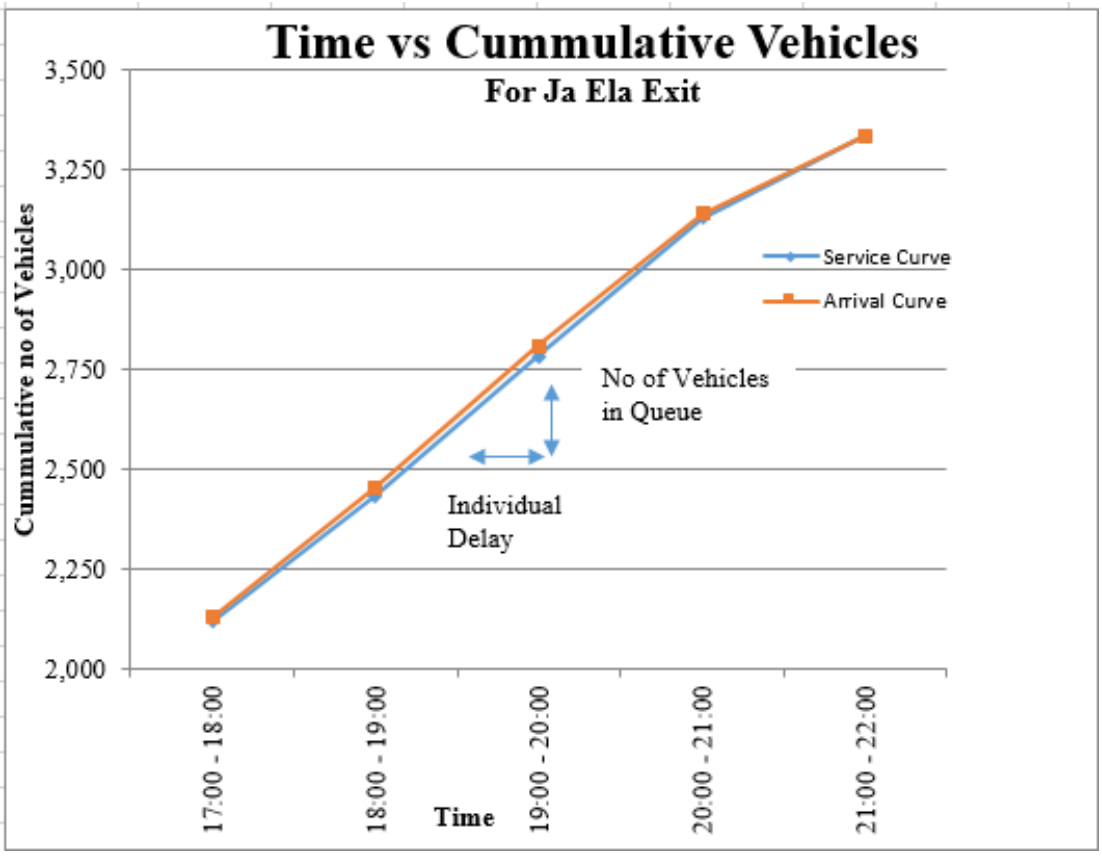


Figure 35: Graph of Time vs. Cumulative Vehicles at Ja Ela Toll Plaza - A

According to graph in Figure 35, longest delay & queue length are shown corresponding to the 19.00 pm – 20.00 pm time period. Then,

Individual Delay = Horizontal distance of the graph

= (60min x 3.0 mm/ 40mm) = 4.5 min

No of vehicles in the Queue = Vertical distance of the graph

= (500 vehicle x 3.0 mm/ 54mm) =27 Vehicle

4.1.3 Service Time

4.1.3.1 Service time for MTC lanes

At Peliyagoda Exit

Peak time exit traffic on 11.12.2017 Monday in all MTC lanes at Peliyagoda ICs were obtained from EOM&M division. Then the peak hour vehicle traffic in each lanes were tabulated in Table 14 and calculated the average service time as follows.

Table 14: Service Time for MTC lanes in Peliyagoda Exit

Time period	**No of MTC Vehicles (11.12.2017)**			
	Lane 2	**Lane 3**	**Lane 4**	**Lane 5**
07:00 - 8:00	267	263	250	268
08:00 - 9:00	291	282	261	283
09:00 - 10:00	224	263	163	252
Total	782	808	674	803
Average per Hour	261	269	225	268
Average per Minute	4.3	4.5	3.7	4.5
Service Time, Sec	13.8	13.4	16.0	13.4
Average Service Time, Sec	14.2			
Average Demand in lane per hour	254			

(Source: Expressway Operation Maintenance and Management Division - RDA)

At Ja Ela Exit

Peak time exit traffic on 15.12.2017 Friday in A1 MTC Exit lane at Ja Ela IC was obtained from EOM&M division. Then the peak hour vehicle traffic in lane A1 were tabulated in Table 15 and calculated the average service time as follows.

Table 15: Service Time for MTC lane (A1) in Ja Ela Exit

Time period	No of Vehicles in Lane A1
18:00 - 19:00	316
19:00 - 20:00	349
20:00 - 21:00	346
Total	1,011
Average per Hour	337
Average per Minute	5.62
Service Time, Sec	10.68

(Source: Expressway Operation Maintenance and Management Division - RDA)

Based on Table 12 & 13, it can be seen higher hourly demand for Ja Ela exit than the Peliyagoda MTC Exit lanes.

4.1.3.1 Service time for ETC lanes

At Peliyagoda Exit

ETC exit traffic details during the month of December 2017 in lane 1 at Peliyagoda IC were collected from EOM&M division and the summary is shown in annex A.

Accordingly, peak days highest ETC exit traffic data are summarized in Table 16 and calculated the service time as follows.

Even though, peak hour demand for exiting ETC toll lanes are low and it can be observed certain peak traffic in Peliyagoda exit in morning time. The service time is depend on driver's behaviour, efficiency of devices & lane occupancy etc.

Table 16: Service Time for ETC lane (A1) in Peliyagoda Exit

Date	**No of Vehicle**
	Lane 01
	7.00 - 8.00 hr
06.12.2017	393
07.12.2017	400
08.12.2017	394
12.12.2017	393
13.12.2017	424
18.12.2017	409
Total	2413
Average Per Hour	402
Average Per Minute	7
Service Time, sec	9

(Source: Expressway Operation Maintenance and Management Division - RDA)

4.2 MTC System

4.2.1 Comparison of MTC System with other countries

Manual Toll collection system is still used by some countries under various technologies and their performances are in different levels. Hence, it is very wroth to compare Sri Lankan MTC lane capacity with other internationally used system to evaluate the performance of existing MTC system. Table 17 shows the comparison with other countries.

Table 17: Comparison of MTC capacities

Country	Manual Lane Toll Capacity (Veh. /hr**)**
OOCEA	300-480
India	200-250
Philippines	121
Sri Lanka	330

(Source: Evaluation of Philippine's Electronic Toll Collection System for North Luzon Expressway, Louie Mari GUGOL, Takahiro IZAWA, and Grace GUETA)

Based on table, it can be seen Sri Lanka is not behind to other MTC using countries. Even though, it is required to do improvements to reduce the service time to achieve higher vehicle capacity in MTC lane.

4.2.2 Financial Loss due to vehicle queue at peak time

Estimation of approximate financial loss due to congestion at Exit booth at Peliyagoda

Average Speed Allowed in E03	= 100 km/h
Travel distance of E03	= 25.6 km
Travel Time	= 15.36 minutes

On a weekday, Travel from Peliyagoda New Kelani Bridge end to Katunayake Airport end via Colombo-Puttlam Road (A03) road under usual traffic,

Travel Time in A3	= 52 minutes
Travel time saving due to the E03	= 36.64 minutes
User pay travel time saving for **Cat.1** vehicle	= 300.00 LKR
Financial Value for 1 minute travel time saving	= 8.19 LKR/min
Time delay experienced at Peliyagoda exit	= 6.25 minutes
Hence, Financial loss due to waiting time	= 51.17 LKR
Total no vehicles passed during the peak hour	= 1060 Vehicles

(1060 vehicles had left from all four MTC lanes from 8.00 a.m. to 9.00 a.m.)

Financial Loss per hour for each category of vehicle for 6.25 minute waiting time in the queue at Peliyagoda Exit is calculated as follows.

Table 18: Peak time Category wise loss due to waiting at Peliyagoda

Vehicle Category	Toll Fee	Cost per Minute	Loss due to waiting time	No of vehicles in peak time	Total Loss per peak hour
Cat.1	300.00	8.19	51.17	975	49,904.48
Cat.2	450.00	12.28	76.76	48	3,661.47
Cat.3	600.00	16.38	102.35	34	3,479.80
Cat.4	800.00	21.83	136.46	3	409.39
				1,060	57,455.14

Financial loss due to the congestion per peak hour = 57,455.14 LKR

Expected Cumulative Congested time duration per week = 5 hours

Congested time duration per year = 270 hours

Total Financial loss due to the congestion per year = **15,512,887.21 LKR**

Estimation of approximate financial loss due to congestion at Exit booth at Ja Ela IC

Similar procedure shall be followed to estimate the financial loss incurred by vehicles that undergo 4.5 minutes waiting time in the queue.

Average Speed Allowed in E03 = 100 km/h

Travel distance of E03 = 15.5 km

Travel Time = 9.3 minutes

On a weekday, Travel from Peliyagoda New Kelani Bridge end to Ja Ela via Colombo-Puttlam Road (A03) road under usual traffic,

Travel Time in A3 = 37 minutes

Travel time saving due to the E03 = 27.7 minutes

User pay travel time saving for **Cat.1** vehicle = 200.00 LKR

Financial Value for 1 minute travel time saving = 7.22 LKR/min

Time delay experienced at Ja Ela exit = 4.5 minutes

Hence, Financial loss due to waiting time = 32.49 LKR

Total no vehicles passed during the peak hour = 350 Vehicles

(350 vehicles had left through MTC lane, from 19.00 a.m. to 20.00 a.m.)

Financial Loss per hour for each category of vehicle for 4.5 minute waiting time in the queue at Ja Ela Exit is calculated as follows.

Table 19: Peak time category wise loss due to waiting at Ja Ela

Vehicle Category	Toll Fee	Cost per minute	Loss due to waiting time	No of vehicles in peak time	Total Loss per peak hour
Cat.1	300.00	7.22	32.49	322	10,462.09
Cat.2	450.00	12.64	56.86	16	909.75
Cat.3	600.00	14.44	64.98	11	714.80
Cat.4	800.00	21.66	97.47	1	97.47
				350	12,184.12

Financial loss due to the congestion per hour = 12,184.12 LKR

Expected Cumulative Congested time duration per week = 5 hours

Congested time duration per year = 270 hours

Total Financial loss due to the congestion per year = 3,289,711.19 LKR

Total Financial Loss due to congestion at Peliyagoda & Ja Ela

Toll booths of E03 Per year **= 18,802,598.40 LKR**

Hence, the approximate annual total financial loss due to congestion at Peliyagoda & Ja Ela ICs in CKE (E03) will be Rs. 18,802,598.40.

4.2.3 SWOT Analysis for MTC System

Table 20: SWOT Analysis for MTC System of CKE

Aspect	Strength	Weakness	Opportunities	Threats
MTC System	- can be upgraded - performance is satisfactory respect to the POS system - Reliable than POS system	- Data processing speed is slow	- Continuous improvement of devices, technology & quality	- Manual verification is needed for full effectiveness
		- cannot be integrated with other toll systems		- the implementing of a centralised toll management system will be un-viable under the economic & political aspects
		- Traffic & revenue reports are not compatible	- Enhance hourly demand/capacity	- Getting system/software developer's assistance for long period
			- Improve the enforcement	- Issues in Vendor supports
		- Vehicle Classification errors	- Introduce automated vehicle classification mechanism	- Developing the system by adding new facilities
Traffic	Low vehicle queue respect to the POS system used toll lane	- Traffic Congestion	- Construction of additional Toll lanes/booths	- Diversion of users to other roads
		- Considerable Delays	- Providing of Separate lanes for cat.3 & cat. 4 in peak time	- Revenue reduction
		- Stopping required	- Providing of efficient Toll system for cater the peak demand	- Traffic in alternative roads
		- Less service rate	- Improve the service rate	- Developing of vehicle queue & increase Accidents
Financial (Capital/Toll)	No	- Higher investment respect to the POS system	-Use of cost effective efficient toll system	-Require long recovery period to achieve the breakeven
		- Maintenance & system developments are expensive	- Conducting of promotional programmes	- Issues in Vendor supports
		- only available one payment method	- Introducing of more payment methods	

Environmental	Less emission level respect to other local roads	- Increase the air pollution	- Introducing proper automated toll system to reduce the acceleration & deceleration to minimize the emissions - Construction of toll booth with emission proof technics	- Negative impact on Environment
		- Increase the emissions of greenhouse gases		- Negative impact on public health
		- Increase the noise		
Socio-Economic	Time saving & improve the safety respect to other road users	- Increase user cost - Increase vehicle operation cost	- Introducing efficient, speed, accurate, user-friendly toll system with reasonable toll rates - Reduction of Accidents	- Decrease user acceptance - Decrease demand
Infrastructure	Less maintenance and higher durability of the existing solid structures	- Ramp lengths are not sufficient	- Fabricated steel toll plazas with proper safety measures	- Reduction of productive of the system
		- Toll plazas are concrete solid structures	- Additional lanes for emergency/ peak demand	- Operators/users safety issues
		- Available number of lanes are not sufficient	- underground/elevated safety access for toll booths	- Additional operational activities are involved
		- No any emergency toll booth/lanes	- providing access roads for toll plazas	- wastage of resources and financial loss
		- No any service roads/ safe access to the toll booths/lanes/plazas	- Developing of manual toll booth with facility to prevent enter the vehicle emissions	

According the Table 20, the existing manual toll collection system in CKE is required to improve to achieve satisfactory service to the road users and good to get income for toll authorities.

4.3 ETC System

4.3.1 ETC Registration

ETC registration in Colombo - Katunayake Expressway was commenced with effect June 2015 and the registration was gradually decreased up to December 2015. The monthly average registrations were about 729 & 472 vehicles in year 2015 & 2016 respectively. In year 2017, it was about 409 vehicles and table shows the growth of ETC registration. Hence, in year 2018, the monthly average ETC registration was 403 and it is gradually decreasing.

Table 21: ETC Registration Details

Month	**Year**			
	2015	**2016**	**2017**	**2018**
January		595	512	494
February		423	389	322
March		703	429	409
April		623	322	373
May		362	341	403
June	13	519	411	416
July	1002	432	406	
August	1312	471	417	
September	1041	423	453	
October	622	380	445	
November	521	363	402	
December	590	369	382	
Total	**5101**	**5663**	**4909**	**2417**
Monthly Avg.	**729**	**472**	**409**	**403**
Growth Rate		**-35.2%**	**-13.3%**	**-1.5%**

(Source: Expressway Operation Maintenance and Management Division - RDA)

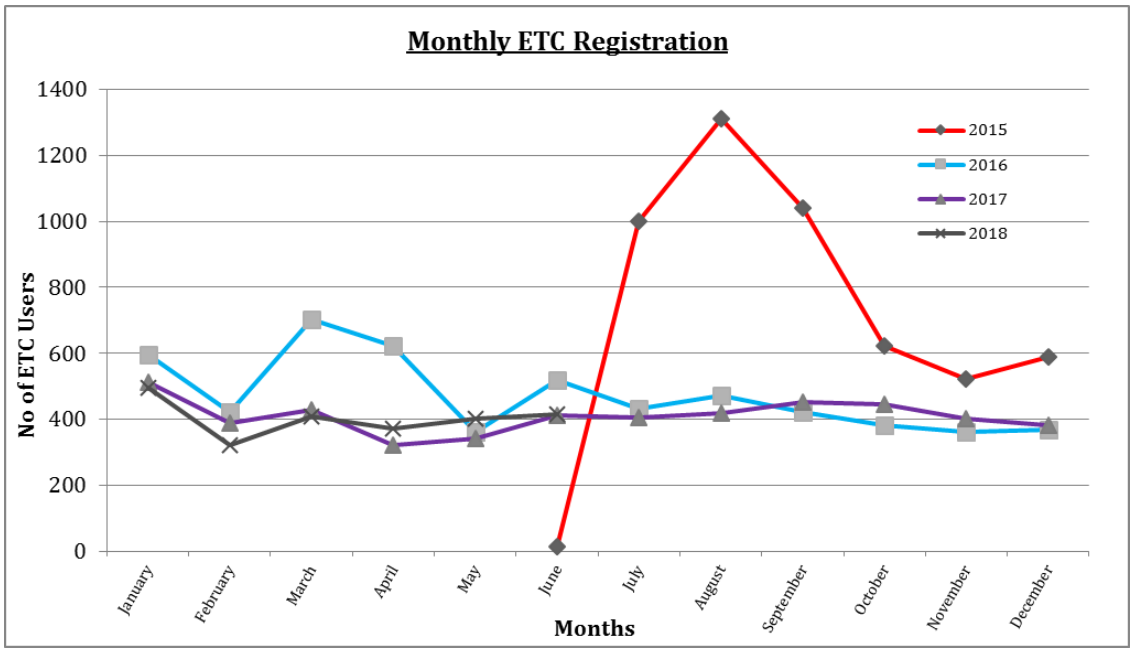


Figure 36: Monthly ETC registration in CKE

As per the study, annual ETC registration goes down in year 2017 with respect to the 2016. Not only that the figure shows the average monthly ETC registration is also decreasing in these recent years. Hence, it can be supposed that the ETC growth had reached a threshold around 400 veh./month and cannot be expected further growth in future under the existing conditions.

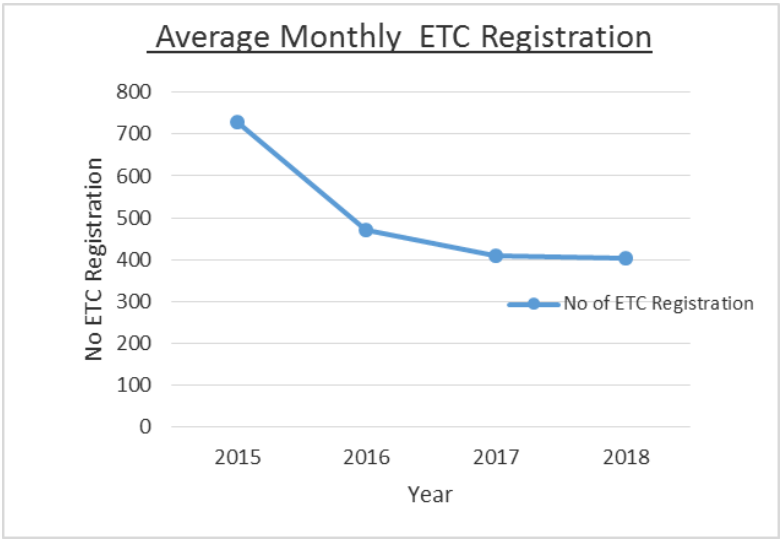


Figure 37: Monthly Average ETC Registration in CKE

4.3.2 ETC Usage

Considering the ETC vehicle traffic up the end of June 2018, it can be summarised the data for Average Daily Traffic (ADT) as follows.

Details of ETC vehicle usage in exits of CKE are shown as follows.

Table 22: ETC Usage Details

Month	**Year**			
	2015	**2016**	**2017**	**2018**
January		67,531	103,897	124,259
February		67,818	94,269	112,383
March		77,403	112,691	125,135
April		70,726	90,027	106,228
May		80,569	104,116	124,633
June	120	85,348	105,196	119,431
July	5,649	88,325	113,649	
August	29,305	91,346	112,899	
September	45,132	93,494	112,249	
October	53,652	98,375	117,329	
November	54,832	96,080	117,860	
December	61,155	94,690	115,332	
Total	**249,845**	**1,011,705**	**1,299,514**	**712,069**
Daily Avg.	**1219**	**2764**	**3560**	**3934**
Growth Rate			**28.8%**	**10.5%**

(Source: Expressway Operation Maintenance and Management Division - RDA)

According to the Table 22, the Average Daily ETC traffic is increasing and the growth rate is gone down. Daily Average ETC usage in 2018 was 3934 vehicles and increment is 10.5% respect to the year 2017.

Table 23: Relationship between ADT & ETC Registration

Year	2015	2016	2017	2018 June
Cumulative ETC Registration	5101	10764	15673	18090
Average Daily Traffic (ADT)	1219	2764	3560	3934
Ratio % (ADT/ETC Registration)	23.89%	25.68%	22.72%	21.75%

(Source: Expressway Operation Maintenance and Management Division - RDA)

When consider the Average daily traffic and cumulative Registration of ETC users, it can be seen the ratio between above factors is decreasing during the last years.

4.3.3 Comparison of ETC System with other countries

As per the data collected from CKE, the peak time ETC demand is 402 number of vehicle per hour and it can be compared with other ETC using countries as follows.

Table 24: ETC Lane Capacity details of other countries

Country	ETC Capacity of Lane (Veh,/hr)
Holland	1800
OOCEA	1850
India	1600
Philippines	2212
Sri Lanka	402

(Source: Evaluation of Philippine's Electronic Toll Collection System for North Luzon Expressway, Louie Mari GUGOL, Takahiro IZAWA, and Grace GUETA)

Base on that data, it can be seen that the Sri Lanka is behind to other countries. The existing ETC system in Sri Lanka is still in the developing stage and required further improvements. The existing customer base is also poor and required to carry out promotions, awareness programmes for ETC which is popular in society to make large customer base.

4.4 Financial Analysis for ETC

4.4.1 Estimation of Loss due ETC discount

The 10% discount for each ETC transaction was allowed since the starting of ETC facility in CKE. This discount was allowed for ETC customers by RDA as promotional strategy to get popular among the public. Even though, considerable amount of public funds are still losing due to allowing of 10% discount to the ETC users.

Table 25: Approximate Annual discount details in CKE

Year	Traffic (Vehicle)	Revenue before deduction of 10% Discount , Rs. Mn	10% Discount , Rs. Mn
2015 (Mid)	249845	61.61	6.85
2016	1011705	259.30	28.81
2017	1299514	336.78	37.42
2018 (Mid)	712069	184.04	20.45

(Source: Expressway Operation Maintenance and Management Division - RDA)

4.4.2 Estimation of ETC lane Utilization

(a). User Fee Contribution to the RDA by ETC Vehicle

Toll charges and vehicle categories are accordance with the gazette no. 1832/28 dated 17.10.2013. It is charged Rs. 6.00 per transaction by Bank of Ceylon (BOC) from every ETC transaction as service charge or processing charge. Thus, it is allowed 10% discount for every ETC toll payment by RDA as a promotional aspect. Accordingly, under the normal usage (from 05:00:00 a.m. to 20:59:59 p.m.) contribution to RDA from each transaction is shown below.

RDA contribution from ETC at day time = Categorized toll fee – 10% discount – Rs. 6.00 of BOC service Fee

Package I - Day time (from 05:00:00 a.m. to 20:59:59 p.m.)

Table 26: RDA Contribution from ETC at Daytime

Categorised Toll Fee, Rs.	10% Discount Rs.	BOC Service Charge Rs.	RDA-Contribution Rs.
200.00	20.00	6.00	174.00
300.00	30.00	6.00	264.00
350.00	35.00	6.00	309.00
400.00	40.00	6.00	354.00
450.00	45.00	6.00	399.00
600.00	60.00	6.00	534.00
800.00	80.00	6.00	714.00

(Source: Expressway Operation Maintenance and Management Division - RDA)

In addition, it is given another discount Rs. 50.00 per each transaction made by any expressway user in night time (from 21:00:00 to 04:59:59) as per the government budget proposals.

RDA contribution from ETC at night time = Categorized toll fee – 10% discount – Rs. 6.00 of BOC service Fee – Rs.50.00 discount from budget proposal

Package II - Night Time (from 21:00:00 a.m. to 04:59:59 p.m.)

Table 27: RDA Contribution from ETC at Night time

Categorised Toll Fee, Rs.	Deduction of Rs.50.00 (21.00:00 p.m to 04.59:59 a.m)	10% Discount Rs.	BOC Service Charge Rs.	RDA-Contribution Rs.
200.00	50.00	15.00	6.00	129.00
300.00	50.00	25.00	6.00	219.00
350.00	50.00	30.00	6.00	264.00
400.00	50.00	35.00	6.00	309.00
450.00	50.00	40.00	6.00	354.00
600.00	50.00	55.00	6.00	489.00
800.00	50.00	75.00	6.00	669.00

(Source: Expressway Operation Maintenance and Management Division - RDA)

(b). Weighted Factors of ETC Vehicles

Weighted Factor of vehicle = No of exit vehicles in categorized toll fee / Total no of exit vehicles

Weighted Contribution per vehicle = RDA contribution Rs. (Day/Night) x Weight Factor

Considering ETC exit traffic data during month of December 2017, Weight Factor and Weighted contribution per vehicle are calculated as follows.

Table 28: Weighted Factors of ETC vehicles

Categorised Toll Fee, Rs.	No of Exit Vehicles in year 2017	Weight Factor	RDA-Contribution Rs.	Weighted Contribution per vehicle
Day (5:00:00 - 20:59:59)				
200.00	39973	0.3466	174	60.3068
300.00	41053	0.3560	264	93.9721
350.00	1580	0.0137	309	4.2332
400.00	1298	0.0113	354	3.9841
450.00	11934	0.1035	399	41.2866
600.00	4039	0.0350	534	18.7010
800.00	638	0.0055	714	3.9497
Night (21:00:00 - 4:59:59)				
200.00	4601	0.040	129	5.1463
300.00	9033	0.078	219	17.1525
350.00	40	0.000	264	0.0916
400.00	147	0.001	309	0.3938
450.00	611	0.005	354	1.8754
600.00	281	0.002	489	1.1914
800.00	104	0.001	669	0.6033
Total	115332	**1.000**		**252.89**

Vehicle categories and toll charges are based on the Gazette no.1932/28 issued on 17.10.2013 (Appendix C1, C2 and C3).

(c). Estimation of Monthly Cost per ETC booth

(i). Estimation of Fixed cost

Recovery Period	= 30 Years
Construction Cost (Capital Investment), LKR	= 48,285,660,966.50
Annual Interest incurred	= 5.50%
Total Cost of investment (with interest), LKR	= 89,449,185,233.60
Cost per month, LKR	= 248,469,958.98

(Source: Expressway Operation Maintenance and Management Division - RDA)

Estimated monthly total fixed cost of CKE, LKR	= 248,469,958.98
Estimated monthly total Variable cost of CKE, LKR	= 88,340,684.82
Estimated Total monthly cost of CKE, LKR	= 336,810,643.80
No of toll booths in CKE	= 18 Nos.
Then, Estimated monthly cost per toll booth, LKR	= 18,711,702.43
Contribution per vehicle, LKR	= 252.89
Monthly Break even exit vehicles through an ETC booth	= 73993 Nos.
Daily Break even exit vehicles through an ETC booth	= 2467 Nos.

Total number of vehicles to be pass from all **six** ETC booths (considered vehicles exit from four exit booths)

To meet breakeven	= 9866 Nos.

(d). Analysis

As per the available traffic data, (Table 22)

Daily Average number of ETC vehicles pass through the

Six number of ETC lanes (ADT in 2017) = 3560 Nos.

Then, Short- Fall = 6306 Nos.

As per the results, it can be seen the allocated lanes for ETC are underutilized and required more ETC demand to cover the investment.

4.4.3 Estimation of loss due to Allocation of Staff

There are six ETC lane available in CKE and required to use operators to handle the traffic in emergency or peak time, Enforcement activities, attending when technical failures occurred in ETC toll lanes. It is required three team of operators for Day shift (6.30 am to 7.30 pm), Night shift (6.30 pm to 7.30 am) and off shift to carried out 24 hrs operation.

Hence, considering above staff requirement, annual staff cost can be calculated as follows.

Table 29: Specimen calculation for Estimation of staff contribution to the ETC facility

No of ETC toll booths (nos.) in CKE, E03	6
Operational Staff requirement per team [(6 x24/8)/2≈ 9] persons	9
Total Operational Staff requirement [3(6 x24/8)/2x3≈ 9x3] persons	27
Approximate Average monthly staff wages with OT per person (Rs.)	50,000.00
Average Total **monthly** staff wages with OT (Rs.)	1,350,000.00
Approximate **Annual** Loss Due to Allocation of operational staff (Rs.)	16,200,000.00

(Source: Expressway Operation Maintenance and Management Division - RDA)

4.5 Analysis of Issues in Existing ETC System

4.5.1 Analysis of incomplete transactions due to Technical Issues in CKE

The available data related to the ETC technical issues in past years can be summarized as follows.

Table 30: Incidents happened in last years due to technical issues

Item	Incident	Year	
		2016	**2017**
1	ETC Gate Opened for the Behind Vehicle in the queue	757	1,014
2	ETC system error in Ja Ela Entrance & Extra Charge from Customer	49	32
3	When ETC Customer go through MTC lane & charged from ETC account too	84	100
4	ETC gate open for Vehicle in adjacent MTC lane and ETC vehicle which was in the ETC queue left without charging	17	37
5	ETC Account Balance is available but gate did not open	33	79
6	Double Charge from ETC A/C for single journey	3	8
7	Toll fee was deducted from ETC account but did not open the gate	2	0
8	Opened the gate for first vehicle but did not closed, the second vehicle pass the ETC gate without Paying	3	0
9	ETC System failure /Break Down	407	2,535
10	TOP UP update failure of ETC account	2	1
Total		**1,357**	**3,806**
(Incidents/Total ETC Passage) %		0.1%	0.3%

(Source: Expressway Operation Maintenance and Management Division - RDA)

According to table, considerable number of ETC system failures was reported during past two years. Reported incidents for 'ETC Gate open for the behind vehicle and left front vehicle without charging from his ETC accounts" are also increased. When the ETC registered vehicle, go through the MTC lane which is located adjacent to the ETC lane, same time ETC system charge toll fee from his ETC account as multiple charging. These types of incidents are also increased in last year. Sometime, ETC barrier was not opened for some users who are maintaining the sufficient balance on their ETC accounts. The reported cases under this category are around 0.3% on total ETC usage in last year and have been increased since the staring of ETC.

4.5.2 Analysis of incomplete transactions due to user behaviours

The available data related to the ETC technical issues in past years can be summarized as follows.

Table 31: Incidents happened in last year due to user behaviours

Item	Incident	Year	
		2016	2017
1	Did not Paid by the Customer, when insufficient balance available in A/C	17	47
2	Behind vehicle exit with front vehicle without paying	8	35
Total		25	82
(Incident/Total ETC Passage) %		0.002%	0.006%

(Source: Expressway Operation Maintenance and Management Division - RDA)

As per the details shown in table, it seems to be the technical related issues were increased. The system performances are also getting down due data in adequacy of storage capacity, decreasing of the performance of devices etc. It is required to focus on the upgrading of both Software & Hardware.

4.5.3 Analysis of incidents happened due to Operational related Issues

In the peak time, at Ja Ela IC heavy vehicular traffic was occurred and difficult to manage using single lane. At that time, the vehicular traffic for ETC lane was not much and ETC lane converted as MTC lane to dissipate the excess traffic. Due to that, excessive work load was arisen as back office work to deduction of ETC toll charge under the manual method. Other hand, when doing the essential maintenance in ETC lane, allowed to ETC vehicles to pass through the MTC lane as MTC vehicle. This issue is happen due lack additional toll lanes for both MTC & ETC modes to utilise in peak or emergency situations. This will cause to decrease the demand for

ETC. The available data related to the operational issues in past years can be summarized as follows.

Table 32: Incidents happened in last years due to operational issues

Item	Incident	Year	
		2016	**2017**
1	Maintenance in ETC Lane	74	462
2	ETC Lane Convert to MTC Lane	3851	2490
Total		**3,925**	**2,952**
(Incident/Total ETC Passage) %		**0.4%**	**0.2%**

(Source: Expressway Operation Maintenance and Management Division - RDA)

Observed operational related issues were decreased in past years, because of the frequency of lane conversion was minimize and most of the time allowed users to pass through their own lane reserved for MTC & ETC.

4.6 SWOT Analysis for ETC System

Table 33: SWOT Analysis for ETC System of CKE

Aspect	Strength	Weakness	Opportunities	Threats
ETC System	- Can be upgraded - Low cost for Tag/OBU	- Low service rate - Not compatible with other ETC versions	- Introducing of fully automated ETC system	- Manual verification is needed for full effectiveness
		- Low capacity of lane (veh./hr/lane) - No enforcements - No automatic vehicle classification	- Continuous improvement of quality of devices & system	- The creation of a centralised tolling system may be politically and economically unviable
		- In efficient/ slow detection (errors in detection process)	- Improve the Enforcement	- Increasing of theft incidents
		- Multiple charging	- Introduce automatic vehicle classification	
		- Higher frequency of system failures	- Enhance the service rate	
		- Higher frequency of device failures	- Enhance the hourly lane capacity	
Traffic	Efficient & higher reading rate than the MTC system	- Traffic Congestion in peak time	- Additional Toll lanes/booths	- Diversion of users to other roads
		- Considerable Delays	- Providing of sufficient ramp length	- Revenue reduction
		- Keeping of 20m gap between subsequent vehicles	- Enhancing the existing system for reducing processing time by using advanced devices & technologies	- Traffic in alternative roads
		- low vehicle operation speed 15 km/hr	- Introducing of efficient ETC system	- Vehicle queue forming in peak time
		-Insufficient ramp length	- Introducing MLFF based ETC system	- Accident & operational issues
Financial (Capital/Toll)	No	- Discourage of users due to in efficiency	- Carryout effective promotional campaign	- Decrease the net income
		- BOC Service charges (Rs. 6.00)	- Reduction of operation cost	- Increase the operation cost

		- ETC CCC operation cost	- providing of special concession packages to special , regular users	
		- Allowing of 10% discount		
		- Require operators/Teller		
		- Decrease the income		
Environmental	Less emission level respect to MTC vehicles	- Increase the air pollution	- Introducing proper automated ETC toll system	- Negative impact on Environment
		- Increase the emissions of greenhouse gases		- Negative impact on public health
		- Increase the noise		
Socio-Economic	Time saving respect MTC system	- Increase user cost - Increase vehicle operation cost		- Decrease user acceptance - Decrease demand
Infrastructure	No	- Ramp lengths are not sufficient	- Providing of gantries with proper equipment	- Reduction of productivity of the system
		- unavailability of emergency toll booth/lanes	- Additional lanes for emergency/ peak demand	- wastage of resources and financial loss

Based on the SWOT analysis in Table 33, it can be identified so many weaknesses and threats in existing toll system. It means that exiting toll system is on a low level of performance and low comfort for users. As a result, this toll system will not popular among the public and generates low income for toll authority. Hence, it can be stated that it is required technological improvements for the existing toll system.

6. SELECTION BEST TOLL SYSTEM

6.1 General

The vehicle traffic in national highways will be drastically increased in near future and difficult to handle only by improving the existing road infrastructures and required to enhance the Expressway network to dissipate excess traffic in peak time. Hence, the performance and the efficiency of existing Expressways should be improve as to provide better service for the road users. Presently, Sri Lankan Expressway tolling was upgraded and used electronic toll collection system instead of manual process.

Continuous improvements are common for any kind of system to minimize the errors and enhance the productivity. Hence, most of users, expertise, consultants, technical persons and decision makers are discussing about the possibilities of improvement and enhancement of the existing toll collection system.

6.2 Comparison of ETC technologies

When comparing the aforesaid ETC technologies with each other so many differences, equalities can be followed. Following Table 34 & Table 35 are shown the comparison among selected ETC technologies under the various parameters which are publish in the papers and the magazines.

Table 34 is shown the comparison done by Joseph D. Crabtree, Candice Y. Wallace and Natasha J. Mamaril on their research paper in 2008.

Table 34: Comparison of Toll volume, Cost & Accuracy Levels

Toll Options	Toll Volumes (vph)	Cost per Transaction ($)	Accuracy (%)
Manual	250-350	0.35-0.45	98
Automatic Coin Machine with Barrier (5 coins)	450-550	0.28-0.35	98.5
Automatic Coin Machine with Barrier (1 coin/token)	500-700	0.28-0.35	95
Voucher Script	500-900	0.37-0.48	98.5
Automatic Number Plate Recognition (ANPR)	600-1000	2.25	85
Smart Card	700-900	0.10-0.19	99.5
RFID: Dedicated Lane with Barrier	900-1100	0.10-0.19	99.96
RFID: Free Flow Lane	1800-2400	0.07-0.15	99.25

Table 35 is shown the comparison done by Deepashree Mehendale & Reshma Masurekar on their paper "A comparative Study of Different Technologies for Electronic Toll Collection System".

Table 35: Comparison of RFID, Barcode & QR Code technologies

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

(Source: International Journal of Innovative Research in Computer and Communication Engineering, Vil. 4, Issue 2, February 2016)

Table 36: Summary of ETC Technologies

Element/Feature	**Video Tolling**	**Short Range Communication, DSRC**		**Radio Frequency, RFID**		**Vehicle Positioning System (VPS)**	**Electronic Tachograph**	**Bar Code**	**Quick Response Code**	**Calm Active Infrared**	**Smart Phone**
	ANPR	**With Barrier**	**Without Barrier**	**Active**	**Passive**	**GNSS**			**QR Code**		**Wi-Fi/GPS**
Divices	HD Camers	OBU	OBU	OBU/Transponder	Tag/Transponder	OBU (GSM/GPS)	OBU	Tag Barcode	Tag QRcode	Infrared OBU	Smart Phone
	OCR software	Antena	Antena	Antena	Antena	GNSS/DSRC receivers	Tachograph	Reader/Laser	Reader/Scaner	Reader/Scaner	Antena
	Optical Sensors	Optical Sensors	Data Convertor	Converter/Decoder	Converter/Decoder	Enforcement Equipments	Data Base	Camera	Camera	Camera	Camera
	Computer	Lane Camera	Camera	Computer	Computer	Cameras	Chip Card	Computer	Computer	Computer	Computer
	Server System/Data	Toll Booths	Gantry/Portal	Server System/Data base	Server System/Data base	CN/Cellular Network	Computers	Server system	Server system	Server system	Server system
		Server System	Server System			Servers/Data Base	Server System/Data	Data Base	Data Base	Data Base	Data Base
Technology	Video/ANPR/OCR	DSRC	DSRC	Radio Frequency	Radio Frequency	GNSS	GPS	Optical	Optical	Active Infrared	Wi-Fi/GPS
Freequency Range	-	2.4 -5.9 GHz	2.4 - 5.9 GHz	860-960 MHz	860-960 MHz	2.45 GHz	5.8 GHz standards			5.8GHz -100 THz	
Reading Range	100m	1km	100m	100 m	10 m	Minimum 90m	100m	Several inches to feet	Several inches to feet	more than 500m	600m
Travel Speed	>100 km/hr	10-40 km/hr	180 km/hr	No need slowdown	8 -24 km/hr	110 km/hr				160/180 km/hr	
Enforcement	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ANPR	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Data Rate		up to 25 mbs	up to 25 mbs	250 kbs	250 kbs					2-1000 mbs	
Level of service	High	Low (> manual)	High	High	Low	High	Low	Low	Low	High	High
Accuracy	97% - 99%	99.70%	99.70%	99%	99%	up to 99 % (Depends on Satellite Visisbility)	Low Level (Error ±4%)	Low Level	Low Level	> 99%	100%
Cost of OBU	No	15-30 USD	15-30 USD	10-25 USD	1-2 USD	High	Very High	No	No	20-50 USD	No
Installation Cost	Low	High	High	High	High	High	High	High	High	High	Low
Operation Cost	Considerable	Low	Low	Low	Low	High	Low	Low	Low	High	Low
Maintainance Cost	High	High	High	High	High	Low	Low	Low	Low	Low	Low

6.3 Selection of ETC Technology

6.3.1 Modified Digital Logic (MDL)

All parameters/Attributes were pair wise compared each other and developed the relative decision matrix as shown in Table 37. Weightage for individual given by comparing with other parameter as explains in section 3.3.1.1. Then the total weightages corresponding to the each parameter was calculated using the equation 1 shown below.

Equation - 01

$$Wi = \frac{Pi}{\Sigma_{i=1}^{n} Pi}$$

Considering Parameter 1 in table 37,

P1- Accuracy, Pi = 35, $\Sigma_{i=1n}$ Pi =361, then

Wi = 35/361 = 0.09653

Similarly all the weightages are calculated.

Table 37: Relative decision matrix with weights and ranks using MDL

Parameters/Attributes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	Positive Decisions	Weight, W_i	Rank
Accuracy (P1)	2	3	3	1	3	3	3	3	1	3	3	3	3	3	35	0.096953	3
Compatibility (P2)	1	2	1	1	1	1	1	1	1	1	1	1	1	1	13	0.036011	14
Congestion Reduction (P3)	1	3	2	1	3	3	3	3	1	3	3	1	3	1	29	0.080332	6
Cost (P4)	3	3	3	2	3	3	3	3	3	3	3	3	3	3	39	0.108033	1
Data Processing Speed (P5)	1	3	1	1	2	3	3	3	1	3	1	3	3	1	27	0.074792	8
Detection/Access Rate (P6)	1	3	1	1	1	2	3	3	1	1	1	1	3	1	21	0.058172	10
Easiness (P7)	1	3	1	1	1	1	2	3	1	1	1	1	3	1	19	0.052632	11
Flexibility (P8)	1	3	1	1	1	1	1	2	1	1	1	1	1	1	15	0.041551	13
Implementation (P9)	3	3	3	1	3	3	2	3	2	3	3	2	3	3	35	0.096953	3
Matuarity (P10)	1	3	1	1	1	3	3	3	1	2	1	1	3	1	23	0.063712	9
Negative Environmental Impact (P11)	1	3	1	1	3	3	3	3	1	3	2	1	3	1	27	0.074792	8
Reliability & Accepatance (P12)	1	1	3	1	3	3	2	3	1	3	3	2	3	3	30	0.083102	5
Simplicity of System/Network (P13)	1	3	1	1	1	1	1	3	1	1	1	1	2	1	17	0.047091	12
Theft Detection (P14)	1	3	3	1	3	3	3	3	1	3	3	1	3	2	31	0.085873	4
Sum															361	1.000000	

Accordingly, all calculated weightage with their ranks which are summarized in Table 37 as shown in relative decision matrix. As such, the cost is the most important factor to be considered in implementing of new ETC system in Sri Lankan context. The compatibility is the least important parameter in this selection.

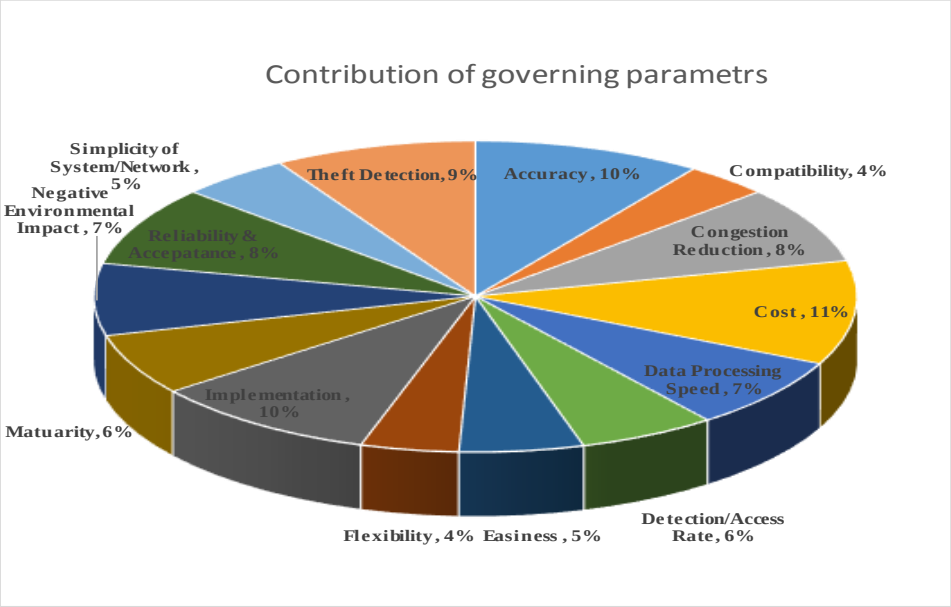


Figure 38: Contribution of Governing Parameters

Further, other factors are also involved with contributing different weightages for this selection process. The socio-Economic strategies of the country are directly affected for fluctuation the contributions of these parameters/attributes.

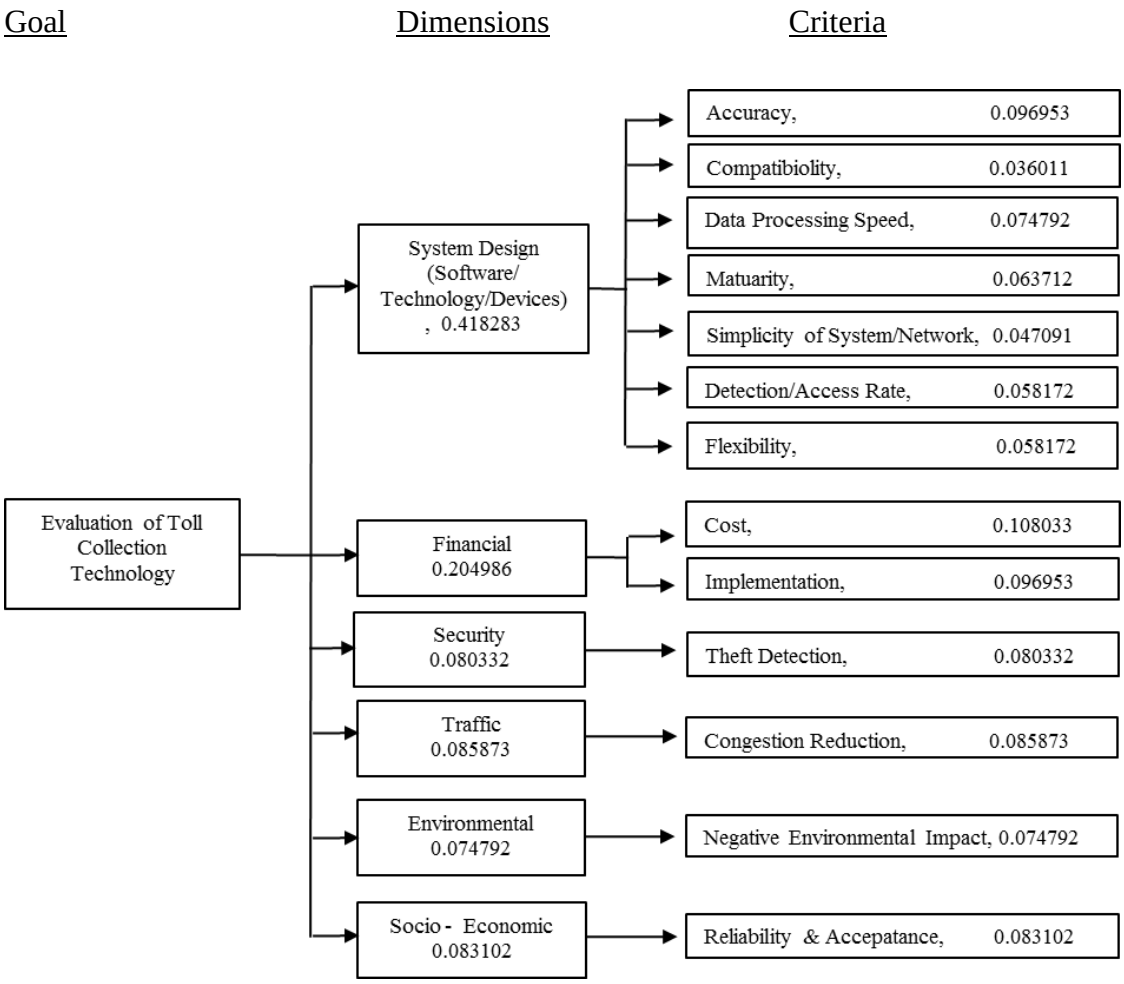


Figure 39: Weights of the criteria

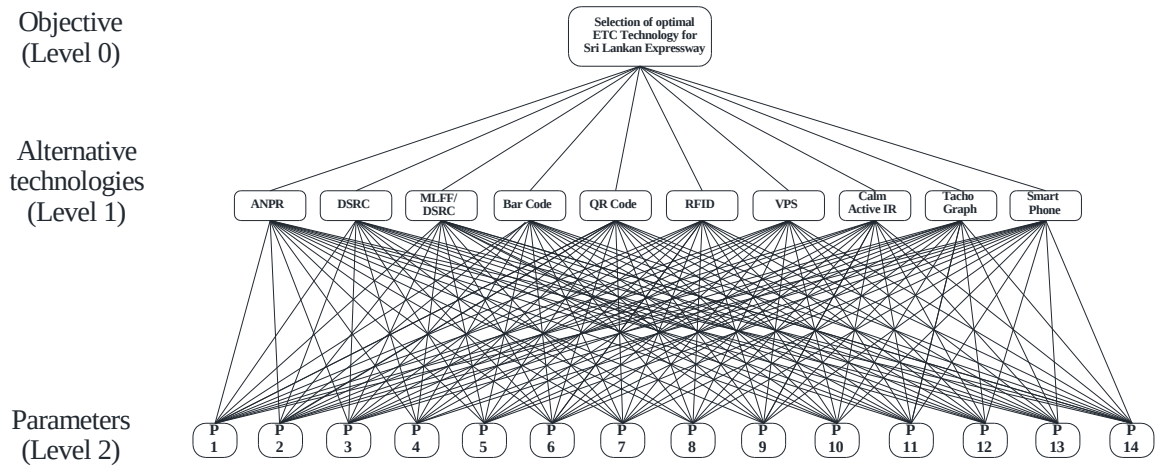


Figure 40: A schematic hierarchy for section of the most suitable ETC technology

6.3.2 Linguistic Variables

Different scale of linguistic variables have been proposed by many authors in their publications. Even though, commonly used types are triangular or trapezoidal fuzzy numbers for the analysis. Table 38 shows linguistic variables for the weights of criteria and performance ratings, based on the use of trapezoidal fuzzy numbers.

Table 38: Linguistic variables and corresponding fuzzy numbers

Linguistic Variable	Notation	Trapezoidal Fuzzy Number
Extremely Low	EL	(0.0, 0.0, 0.1,0.2)
Very Low	VL	(0.1, 0.2, 0.2,0.3)
Average/Fair	A/F	(0.2, 0.3, 0.4,0.5)
Above Average	AA	(0.4, 0.5, 0.5,0.6)
High	H	(0.5, 0.6, 0.7,0.8)
Very High	VH	(0.7, 0.8 0.8,0.9)
Exceptionally High	EH	(0.8, 0.9 1.0,1.0)

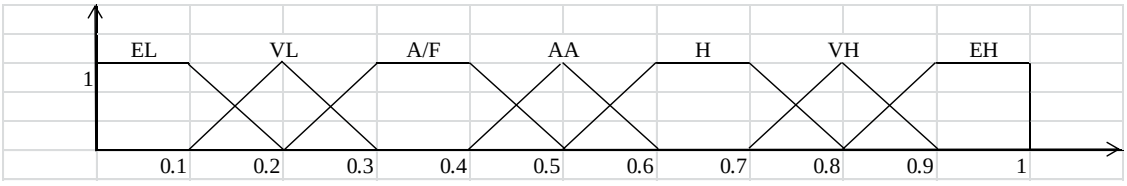


Figure 41: Membership functions of linguistic variables

Several discussions regarding the ETC technologies & alternatives were carried out with technical experts & decision makers such as ETC consultant, Computer Engineer, System Engineers, Data Base Administrators, and Toll Engineers. Then the Tables 38 & 39 were filled based on their ideas by inserting the Linguistic decision matrix with relevant fuzzy numbers. After having discussions with expertise, collect their ideas related to the each ETC technology. Then all information and decisions are summarized and prepared single decision matrix.

Table 39: Linguistic decision matrix of toll technologies for all evaluation criteria

Parameter	Toll Technologies									
	ANPR	DSRC	MLFF/ DSRC	Bar Code	QR Code	RFID	VPS	Calm Active IR	Tacho Graph	Smart Phone
P1	H	H	H	A	A	H	EH	H	VL	EH
P2	H	H	H	A	A	H	H	A	A	VH
P3	VH	H	EH	A	AA	VH	EH	VH	A	VH
P4	H	VH	EH	VL	VL	A	EH	EH	VH	A
P5	VH	H	EH	A	AA	H	VH	EH	AA	VH
P6	VL	H	EH	VL	VL	H	H	VH	H	VH
P7	H	H	VH	VL	VL	VH	A	VL	A	VH
P8	A	A	H	EL	EL	AA	VH	VL	H	H
P9	AA	VH	H	VL	VL	EH	A	VL	AA	EH
P10	H	VH	EH	A	A	EH	H	VL	A	EH
P11	VL	A	EL	VL	VL	A	VL	EH	VL	VL
P12	A	EH	EH	EL	VL	EH	A	EL	A	EH
P13	A	VL	VL	VL	VL	VL	H	VH	H	H
P14	EH	A	VH	A	A	H	A	H	H	H

Table 40: Corresponding fuzzy ratings for assigned linguistic variables

Parameter	Toll Technologies									
	ANPR	**DSRC**	**MLFF/ DSRC**	**Bar Code**	**QR Code**	**RFID**	**VPS**	**Calm Active IR**	**Tacho Graph**	**Smart Phone**
P1	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)	(0.2, 0.3, 0.4,0.5)	(0.2, 0.3, 0.4,0.5)	(0.5, 0.6, 0.7,0.8)	(0.8, 0.9 1.0,1.0)	(0.5, 0.6, 0.7,0.8)	(0.1, 0.2, 0.2,0.3)	(0.8, 0.9 1.0,1.0)
P2	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)	(0.2, 0.3, 0.4,0.5)	(0.2, 0.3, 0.4,0.5)	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)	(0.2, 0.3, 0.4,0.5)	(0.2, 0.3, 0.4,0.5)	(0.7, 0.8 0.8,0.9)
P3	(0.7, 0.8 0.8,0.9)	(0.5, 0.6, 0.7,0.8)	(0.8, 0.9 1.0,1.0)	(0.2, 0.3, 0.4,0.5)	(0.4, 0.5, 0.5,0.6)	(0.7, 0.8 0.8,0.9)	(0.8, 0.9 1.0,1.0)	(0.7, 0.8 0.8,0.9)	(0.2, 0.3, 0.4,0.5)	(0.7, 0.8 0.8,0.9)
P4	(0.5, 0.6, 0.7,0.8)	(0.7, 0.8 0.8,0.9)	(0.8, 0.9 1.0,1.0)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)	(0.2, 0.3, 0.4,0.5)	(0.8, 0.9 1.0,1.0)	(0.8, 0.9 1.0,1.0)	(0.7, 0.8 0.8,0.9)	(0.2, 0.3, 0.4,0.5)
P5	(0.7, 0.8 0.8,0.9)	(0.5, 0.6, 0.7,0.8)	(0.8, 0.9 1.0,1.0)	(0.2, 0.3, 0.4,0.5)	(0.4, 0.5, 0.5,0.6)	(0.5, 0.6, 0.7,0.8)	(0.7, 0.8 0.8,0.9)	(0.8, 0.9 1.0,1.0)	(0.4, 0.5, 0.5,0.6)	(0.7, 0.8 0.8,0.9)
P6	(0.1, 0.2, 0.2,0.3)	(0.5, 0.6, 0.7,0.8)	(0.8, 0.9 1.0,1.0)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)	(0.7, 0.8 0.8,0.9)	(0.5, 0.6, 0.7,0.8)	(0.7, 0.8 0.8,0.9)
P7	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)	(0.7, 0.8 0.8,0.9)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)	(0.7, 0.8 0.8,0.9)	(0.2, 0.3, 0.4,0.5)	(0.1, 0.2, 0.2,0.3)	(0.2, 0.3, 0.4,0.5)	(0.7, 0.8 0.8,0.9)
P8	(0.2, 0.3, 0.4,0.5)	(0.2, 0.3, 0.4,0.5)	(0.5, 0.6, 0.7,0.8)	(0.0, 0.0, 0.1,0.2)	(0.0, 0.0, 0.1,0.2)	(0.4, 0.5, 0.5,0.6)	(0.7, 0.8 0.8,0.9)	(0.1, 0.2, 0.2,0.3)	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)
P9	(0.4, 0.5, 0.5,0.6)	(0.7, 0.8 0.8,0.9)	(0.5, 0.6, 0.7,0.8)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)	(0.8, 0.9 1.0,1.0)	(0.2, 0.3, 0.4,0.5)	(0.1, 0.2, 0.2,0.3)	(0.4, 0.5, 0.5,0.6)	(0.8, 0.9 1.0,1.0)
P10	(0.5, 0.6, 0.7,0.8)	(0.7, 0.8 0.8,0.9)	(0.8, 0.9 1.0,1.0)	(0.2, 0.3, 0.4,0.5)	(0.2, 0.3, 0.4,0.5)	(0.8, 0.9 1.0,1.0)	(0.5, 0.6, 0.7,0.8)	(0.1, 0.2, 0.2,0.3)	(0.2, 0.3, 0.4,0.5)	(0.8, 0.9 1.0,1.0)
P11	(0.1, 0.2, 0.2,0.3)	(0.2, 0.3, 0.4,0.5)	(0.0, 0.0, 0.1,0.2)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)	(0.2, 0.3, 0.4,0.5)	(0.1, 0.2, 0.2,0.3)	(0.8, 0.9 1.0,1.0)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)
P12	(0.2, 0.3, 0.4,0.5)	(0.8, 0.9 1.0,1.0)	(0.8, 0.9 1.0,1.0)	(0.0, 0.0, 0.1,0.2)	(0.1, 0.2, 0.2,0.3)	(0.8, 0.9 1.0,1.0)	(0.2, 0.3, 0.4,0.5)	(0.0, 0.0, 0.1,0.2)	(0.2, 0.3, 0.4,0.5)	(0.8, 0.9 1.0,1.0)
P13	(0.2, 0.3, 0.4,0.5)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)	(0.1, 0.2, 0.2,0.3)	(0.5, 0.6, 0.7,0.8)	(0.7, 0.8 0.8,0.9)	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)
P14	(0.8, 0.9 1.0,1.0)	(0.2, 0.3, 0.4,0.5)	(0.7, 0.8 0.8,0.9)	(0.2, 0.3, 0.4,0.5)	(0.2, 0.3, 0.4,0.5)	(0.5, 0.6, 0.7,0.8)	(0.2, 0.3, 0.4,0.5)	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)	(0.5, 0.6, 0.7,0.8)

Calculation of crisp values is done using the equation (7) mentioned in step 05.

Accordingly, Considering Table 39 & 40, the first parameter is Accuracy (P1) & its Linguistic variable is H- High (0.5, 0.6, 0.7, 0.8)

From Equation (7), all crisp values can be calculated as follows.

$$f_{ij} = \frac{- X_{ij1}X_{ij2} + X_{ij3}X_{ij4} + (1/3)(X_{ij4} - X_{ij3})^2 + (1/3)(X_{ij2} - X_{ij1})^2}{- X_{ij1} - X_{ij2} + X_{ij3} + X_{ij4}}$$

$$f_{ij} = \frac{-(0.5x0.6) + (0.7x0.8) + 1/3(0.8-0.7)^2 + 1/3(0.6- 0.5)^2}{-0.5-0.6+0.7+0.8} = 0.667$$

Similarly all crisp values are summarised in Table 41 as shown below.

Table 41: Calculated Crisp values for assigned fuzzy rates

Parameter	Toll Technologies										Wj	f*	f^-
	ANPR	DSRC	MLFF/ DSRC	Bar Code	QR Code	RFID	VPS	Calm Active IR	Tacho Graph	Smart Phone			
P1	0.667	0.667	0.667	0.367	0.367	0.667	0.944	0.667	0.233	0.944	0.0970	0.944	0.233
P2	0.667	0.667	0.667	0.367	0.367	0.667	0.667	0.367	0.367	0.833	0.0360	0.833	0.367
P3	0.833	0.667	0.944	0.367	0.533	0.833	0.944	0.833	0.367	0.833	0.0803	0.944	0.533
P4	0.667	0.833	0.944	0.233	0.233	0.367	0.944	0.944	0.833	0.367	0.1080	0.944	0.233
P5	0.833	0.667	0.944	0.367	0.533	0.667	0.833	0.944	0.533	0.833	0.0748	0.944	0.533
P6	0.233	0.667	0.944	0.233	0.233	0.667	0.667	0.833	0.667	0.833	0.0582	0.944	0.233
P7	0.667	0.667	0.833	0.233	0.233	0.833	0.367	0.233	0.367	0.833	0.0526	0.833	0.233
P8	0.367	0.367	0.667	0.078	0.078	0.533	0.833	0.233	0.667	0.667	0.0416	0.833	0.078
P9	0.533	0.833	0.667	0.233	0.233	0.944	0.367	0.233	0.533	0.944	0.0970	0.944	0.233
P10	0.667	0.833	0.944	0.367	0.367	0.944	0.667	0.233	0.367	0.944	0.0637	0.944	0.233
P11	0.233	0.367	0.078	0.233	0.233	0.367	0.233	0.944	0.233	0.233	0.0748	0.944	0.078
P12	0.367	0.944	0.944	0.078	0.233	0.944	0.367	0.078	0.367	0.944	0.0831	0.944	0.233
P13	0.367	0.233	0.233	0.233	0.233	0.233	0.667	0.833	0.667	0.667	0.0471	0.833	0.233
P14	0.944	0.367	0.833	0.367	0.367	0.667	0.367	0.667	0.667	0.667	0.0859	0.944	0.367

The Ideal Solution (f*) & Negative Ideal Solution (f^-) are calculated using the equation 8 & 9 given in step 06 & corresponding results are tabulated in table 41.

$$f^* = \{\max f_{ij}\} \qquad f^- = \{\min f_{ij}\}$$

Values for the Utility measure (Si) & Regret measure (Ri) are calculated using the equation (10) & (11) given in step 07 and the obtained values are tabulated in Table 42.

$$S_i = \sum_{j=1}^{n} W_j \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)}; \quad \forall i$$

$$R_i = \mathrm{Max}_j \left[W_j \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)} \right]; \quad \forall i$$

Considering first data set in Table 41 corresponding to the Parameter P1,

$W_{f1} = 0.097$, $f_j^* = 0.944$, $f_j^- = 0.233$, $f_{j1} = 0.667$, Then,

Ri = 0.097 x(0.944 – 0.667)/ (0.944 – 0.233) = 0.03779 (say) 0.038

Similarly calculation can be proceed for all set of data and tabulated the obtained Regret measures in Table 42.

Table 42: Calculated Regret Measures values and Utility Measures values

Parameter	Regret Measures, Ri									
	ANPR	DSRC	MLFF/ DSRC	Bar Code	QR Code	RFID	VPS	Calm Active IR	Tacho Graph	Smart Phone
P1	0.038	0.038	0.038	0.079	0.079	0.038	0.000	0.038	**0.097**	0.000
P2	0.013	0.013	0.013	0.036	0.036	0.013	0.013	0.036	0.036	0.000
P3	0.022	0.054	0.000	0.113	0.080	0.022	0.000	0.022	0.113	0.022
P4	0.042	0.017	0.000	**0.108**	**0.108**	**0.088**	0.000	0.000	0.017	**0.088**
P5	0.020	0.051	0.000	0.105	0.075	0.051	0.020	0.000	0.075	0.020
P6	0.058	0.023	0.000	0.058	0.058	0.023	0.023	0.009	0.023	0.009
P7	0.015	0.015	0.000	0.053	0.053	0.000	0.041	0.053	0.041	0.000
P8	0.026	0.026	0.009	0.042	0.042	0.016	0.000	0.033	0.009	0.009
P9	0.056	0.015	0.038	0.097	0.097	0.000	0.079	**0.097**	0.056	0.000
P10	0.025	0.010	0.000	0.052	0.052	0.000	0.025	0.064	0.052	0.000
P11	**0.061**	0.050	**0.075**	0.061	0.061	0.050	0.061	0.000	0.061	0.061
P12	0.068	0.000	0.000	0.101	0.083	0.000	0.068	0.101	0.068	0.000
P13	0.037	0.047	0.047	0.047	0.047	0.047	0.013	0.000	0.013	0.013
P14	0.000	**0.086**	0.017	0.086	0.086	0.041	**0.086**	0.041	0.041	0.041
Utility Measures, Si	0.480	0.443	0.236	1.038	0.956	0.388	0.428	0.494	0.701	0.264
Max. Regret Measures, Ri	0.061	0.086	0.075	0.108	0.108	0.088	0.086	0.097	0.097	0.088

The S^*, S^-, R^* & R^- are determined using the equation (13), (14), (15) & (16) given in step 8. The obtained values are summarized in Table 43.

Table 43: S*, S-, R*, R- values

Si, Ri Measures	Value
S*	0.236
S^-	1.038
R*	0.061
R^-	0.108

$S^* = Min_i(S_i)$;

$S^- = Max_i(S_i)$;

$R^* = Min_i(R_i)$;

$R^- = Max_i(R_i)$;

Hence, the VIKOR index was calculated for each alternative by using the equation (12) in step 08.

$$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1 - v)\left[\frac{R_i - R^*}{R^- - R^*}\right]; \forall i$$

Consider data of ETC Technology of ANPR in Table 41, Group Utility weight, $v = 0.5$

VIKOR Index, Qi = [0.5x (0.480 – 0.236)/(1.038-0.236)] + [(1-0.5)x (0.061-0.061)/(0.108-0.061)] = 0.152

Similarly relevant Qi values for each technologies are calculated. All calculated, utility measures, regret measures and the VIKOR indexes for each Technology are tabulated in Table 44 as follows.

Table 44: Calculated utility measure, regret measure and corresponding VIKOR ranking

Measures/Index			**Toll Technologies**									
			ANPR	**DSRC**	**MLFF/ DSRC**	**Bar Code**	**QR Code**	**RFID**	**VPS**	**Calm Active IR**	**Tacho Graph**	**Smart Phone**
Utility Measure	**Si**	Distance	0.480	0.443	0.236	1.038	0.956	0.388	0.428	0.494	0.701	0.264
		Rank	6	5	1	9	9	3	4	7	8	2
Regret Measure	Ri	Distance	0.061	0.086	0.075	0.108	0.108	0.088	0.086	0.097	0.097	0.088
		Rank	1	3	2	6	6	4	3	5	5	4
VIKOR Index	Qi	Distance	0.152	0.392	**0.144**	1.000	0.949	0.378	0.382	0.542	0.672	0.300
		Rank	2	6	**1**	10	9	4	5	7	8	3

Then the ranks are given by comparing the each values base on their least value. The obtained lowest value of the VIKOR index (Q_i) corresponding to the above toll technologies is considered for the best alternative for this selection process.

6.4 Constraints in implementing of ETC in Sri Lanka

Sri Lanka is a developing country and when implementing the international technology based ETC method, following constraint will be arisen.

- Cost - Capital Investment, Maintenance cost, Operation cost
- Technical Assistant for operation, updating and future improvements (Service agreements, consultant services, technical barriers, International Technical Standardization etc.)
- Vehicle number plates are not in standard systematic way (consisted with varies numbers, fonts, symbols, colour codes, sizes etc.) and difficult for detection using one mechanism
- Rule, regulations and policies of Government Organizations (Department of Motor Traffic, Telecommunications Regulatory Commission of Sri Lanka and Department of Police)
- Political aspects/ influences
- Absence of National Development Plan
- Opening of Expressway segments occasionally and issues with system integrations
- Vendor supports
- User acceptance , awareness, ethics, attitudes and behaviours
- Un availability of efficient and transparent enforcement system for violators and thefts
- Lack of publicity given by the government and hesitation to obtain involvement from private expertise & investors in the field.
- Reluctant to get assistance of private bank

7. INFRASTRUCTURE IMPROVEMETS

As per study the current layout of toll plazas will not be able to cope with the predicted growth in traffic over the next 20 years. This means that by planning to introduce ETC sooner rather than later will result in benefits to drivers and reduce the need for any additional civil engineering works at toll gates to change their layout to cope with increase traffic volumes.

7.1 Providing of Sufficient Number of Toll lanes

The existing toll lanes are not sufficient to cater for peak demand as well as future demands. Specially, both toll system improvement and the infrastructure enhancement should be done together to obtained maximum benefit through smooth operation. When review the CKE, the existing toll lane arrangement is not satisfactory at Ja Ela & Peliyagoda Toll gates for serving the existing traffic. In near future this will be a big problem and required to construct additional lanes.

The Peliyagoda existing main line toll gate shall be shifted to the Ch. 2+000 km (K02) as a diamond type IC and proposed to operate under 14 toll lanes as 6 numbers of entrance lanes (for both direction) and 8 number of exit lanes (for both direction). But in Ja Ela IC, two lanes are allocated for one direction as MTC & ETC. This lane capacity is not sufficient serve the peak hour demand and required to provide four lanes for one direction as 2 for MTC facility and 2 for ETC facility to satisfy the peak hour traffic, future incremental demand, Emergency breakdown & the maintenance requirement during the operation. Under the first stage, it should be construct the additional lanes at Peliyagoda-Ja Ela direction Entrance & Exit toll plazas due to presence of higher traffic at peak time.

7.2 Toll Plaza Construction

Most of the toll plazas in Sri Lankan Expressways were constructed with RCC concrete by spending large amount of money. Even though, in other international highways, the toll plazas had been constructed as fabricate steel buildings with proper safety arrangements. This is economical than the heavy structures because of the structures can be reused and easily modified. But the concrete buildings cannot be modified easily using same available resource and need to spend money for demolished & transport of debris. Under the Sri Lankan Expressways network improvement, it is proposed to relocate exiting Peliyagoda main line toll plaza at Ch. 2+000 (K02) as Diamond type IC. The existing Toll plaza shall be demolished and reconstructed at K02 location as four toll plaza.

Thus, under the closed toll system it is required to construct another toll plaza for entrance at Seeduwa IC. These are some example that can be happened in future improvement & resource management aspects. Therefore, if it is possible to construct this toll plaza as fabricated structures with proper safety arrangements in other ongoing & proposed Expressways in Sri Lanka it will be very wroth for future.

Figure 42: View of Toll Plazas

(Source: INTERTOLL, The Operator of Choice, Newsletter 2-Quarter 1 2016 Issue: Toll Collection Methods)

7.3 Sufficient Ramp Length at Toll gates

Most of the existing ramp length which are provided at exit & entrance toll gates in Sri Lankan Expressways are not sufficient to facilitate the vehicle queue developed in peak time. The study was carried out by L. G. D. Kumari, P. G. D. Priyadarshana and K. S. Weerasekera to identify Future Impact of Current Toll-Gates on the Capacity of the Southern Expressway. This study shows that most of the existing ramp length at SE were not satisfy for cater the future traffic demand.

When focus on CKE, the existing ramp lengths at Ja Ela IC are also not satisfy to facilitate the present peak hour traffic demand and queue length is developing towards the expressway. Hence, the proposed new IC at Peliyagoda is consisted as diamond type IC and the provided ramp lengths will be not satisfied with the traffic demand.

To avoid the traffic issues, it is required to improve these ramp lengths and the service rate has to be improving using efficient automated toll system.

8. CONCLUSION AND RECOMONDATIONS

8.1 Conclusions

8.1.1 Conclusions based on the study

(i). The performance & level of service of existing ETC system are not in satisfactory level respect to the ETC technologies used by other countries. Hence, it is required to do technological and operational improvements for the existing system to achieve higher throughput and least service time.

(ii). Cost is the most important factor to be considered in selection of best ETC method for Sri Lankan Expressways. As such, the compatibility is the least important factor in this study. Based on the Fuzzy VIKOR analysis with MDL weights, DSRC-MLFF based ETC technology will be the best ETC method for Sri Lankan Expressways.

(iii). Based on this study, it can be given second and third priority for Video Tolling (ANPR) and Smart Phone based ETC methods respectively for implementing ETC in Sri Lankan Expressways.

8.1.2 General Conclusions

Tolling strategies used on the Southern Expressway (E01) and Outer Circular Highway (E02) is closed tolling whereas the tolling strategy used on the Colombo-Katunayake Expressway (E03) is 'Open' tolling. To ensure tolling across the entire length of these roads when they are connected, a new integrated tolling strategy must be implemented.

At present Point of sales (POS) machines are used at the Southern Expressway (E01) and Outer Circular Highway (E02) for MTC whereas a computer based system is used at Colombo-Katunayake Expressway (E03) and an RFID based ticket is provided on entry to drivers.

However, these expressways have different toll collection systems and different standards and are not compatible with each other and this presents issues for their integration. Given the limitations of the current ETC system on CKE described above, it is not recommended that this system be extended to cover the whole Expressway network. Rather a specification should be developed up for a new ETC system to be procured to meet all new future requirements in Sri Lanka.

It can be conclude that existing toll systems used in Sri Lankan Expressways are in lowest technical levels and not enhanced or updated since they were implemented. This is negatively affected for both Expressway EOM&M Division, RDA and for Expressway users.

Currently used toll management systems in Sri Lankan Expressways are not compatible each other and cannot expand for future Expressway network. Other hand, the efficiency of the existing systems will not cater for the future traffic demand. Implementing of different technology based toll management system without having proper integration plan for future Expressway network is led for wasting of time & public funds as well as unexpected technical & operational issues. Hence, during the system integration process, higher cost components are involved for conversion of exiting systems for advance technology based toll system.

Sri Lanka is a developing country and it is required reasonable time period to introduce fully automated toll system in all Expressways. Specially, due to absence of National development policy in the country, gathering of relevant Authorities like Road Development Authority, Department of Motor Traffic, Telecommunications Regulatory Commission of Sri Lanka and Department of Police for one aspect is an arduous task. Due these lapses, implementation of advance technology based automated toll system is Sri Lankan expressways will be getting delayed. Even though, it is required master plan for the toll system integration with future expanding Expressways.

Infrastructure development in expressways should be satisfied the user aspects as well as operational aspects. Specially, the road geometry & the pavement shall be

satisfied the user comfort & safety. Hence, when users reach to the entrance or exit locations of Expressway, the access ramp lengths should be sufficient facilitate for peak or abnormal traffic without causing for normal vehicle flow. Most of the Toll stations in Sri Lankan Expressways were constructed as heavy concrete buildings by investing lot of public funds. Construction of light weight structures such as fabricated steel toll plazas instead of heavy toll buildings will be more effective. The light weight buildings are repairable and can be reused.

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8.1.3 Future Study

Sri Lanka has a very high usage of smartphone apps within South Asia. Any future ETC solution should make use of this fact and include the smartphone as part of the ETC implementation, either as a means of information or payment, or a combination of both. In discussions with University research groups and mobile operators during this study it was found that there is no on-going work in Sri Lanka in mobile applications for ETC. Perhaps this is an area that could be investigated in the future.

8.2 Recommendations

8.2.1 Recommendations for MTC systems

(i). Enhancing performance of Existing devices, equipment and the System

Efficiency of existing Card readers, tickets printers, money counters, detectors, toll barriers, and toll system should be improved to reduce the service time and minimize delay in peak time.

(ii). Providing of separate lanes for heavy vehicles in peak times

Length and service time for heavy vehicles are normally higher respect to the other vehicles. Heavy Vehicles (Buses, Lories & Containers) which are included for Category 3 (composition – 3.2%) & Category 4 (composition – 0.25%) vehicles

shall be directed to the separate lanes at adjacent to the shoulder (RHS) to minimize the inconvenience & delay to other vehicle users in the peak time.

(iii). Introducing new payment options

Currently the clear majority of toll payments are made by cash (LKR). Some customers came to exit points without cash or local currencies. Hence, this should be revised to consider the following options to avoid unnecessary delays, enforcement activities, conflict among user and the operators, and improve the customer demand to the Expressways.

- Credit/debit cards
- Foreign currencies
- Smart cards as Touch & Go system

Figure 43: Facility for use of Credit cards/ prepaid contact less cards for toll payments

(Source: INTERTOLL, The Operator of Choice, Newsletter 2-Quarter 1 2016 Issue: Toll Collection Methods)

(iv). Introducing of mixed/hybrid toll collection lanes

Throughput of existing manual toll collection is to be improved to avoid the developing of vehicle queue in MTC lanes in peak time at toll plazas. Adoption of automated system should be done gradually in Sri Lankan context with manual systems. It can be getting more throughputs during the peak time by using manual & automated mix lanes.

Table 45: Comparison of mixed toll lane capacities

Country	**MTC & ETC Mixed Lane Capacity (Veh. /hr)**
Holland	380-680
OOCEA	450-500
India	600-800
Philippines	396

(Source: Evaluation of Philippine's Electronic Toll Collection System for North Luzon Expressway, Louie Mari GUGOL, Takahiro IZAWA, Grace GUETA)

If any ETC user with an issue such as insufficient balance, technical errors, they also can be used these lanes. User friendliness of any system will be help for higher customer demand.

(vi). Construction of additional MTC Toll lanes with temporary toll booth

Construction of additional toll lanes with minimum facilities in either sides on available land areas at existing toll plazas to continue toll operations only in peak time using temporary movable toll booths will be helpful to manage the excess traffic in the peak time until do the total improvements in future.

8.2.2 Recommendations for ETC System

8.2.2.1 Immediate Actions

(i). Implementation of ETC antenna, reader/decoder, camera system in each ETC Customer care centres at Peliyagoda & Ja Ela to identify the most appropriate location of windscreen to avoid the detection issues in ETC entrance and the Exit points.

(ii).Displaying Stationary Boards, VMS or media awareness programme to improve clear understanding of users regarding MTC & ETC lanes & its usage.

(iii).Enhancing of ETC promotional process with getting service from marketing experts.

(iv). Actions to be taken to encourage the vehicle users to get ETC facility, & Compulsion of registering ETC with certain enforcements to cater the future demand

(v). Developing of fare & systematic concession packages for each categories of ETC users (daily users, weekly users etc.) instead of current toll wavier of 10%.

(vi).Construction of additional toll lane for each ramp at Ja Ela IC to use in emergency situations and peak time with lane configuration as initially ETC1, MTC1, MTC2 (as step 1)& later ETC1, ETC2, MTC1, MTC2 (as step 2).

8.2.2.2 Future Actions

(i). Department of Motor traffic (DMT) & RDA should be work together to clear the Vehicle number plate issue by making methodology to renew the existing numbers as well as new numbers in same standard to help for future ETC implementation. It can be done as issuing RFID tags for all vehicles and enforced (as a rule) to stick in vehicle number plate. Other method is introducing of new number plate with standard specifications or issuing of High Security number plates for all vehicles to identify the details using video tolling under ANPR technology. It may help to identify the stolen vehicles and fake number plates which are used in Expressways.

(ii). Introducing new payment options

Currently the clear majority of toll payments are made by cash. This should be revised to consider the following options:

- On-line via bank account
- Pre-payment facility for regular users – weekly / monthly etc.
- Post payment for occasional users with no RFID tag via ANPR
- Using Mcash, eZcash etc
- Mobile phone payments

(iii). Introduce Automatic Vehicle Classification

Currently vehicle classification is performed manually by the teller for MTC and via declared class encoded on the RFID tag for ETC & MTC.

This should be automated using simple attributes, such as number of axles, or length to provide a validation for the declared ETC class and remove any concerns about wrongly classified vehicles. It is possible to use non-invasive technologies, such as laser curtains or video based solutions so not to damage the highway and allow for easy maintenance.

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(iv). Introducing Automatic Number Plate Recognition (ANPR) based system

When increase the vehicle traffic in Expressways, the existing toll system with barriers will not appropriate to serve the demand. It is required to go for efficient solution like Multi Lane Free Flow (MLFF) ETC system. Absence of barriers that comes with the introduction of DSRC/ MLFF ETC means with the removal of barriers there will need to be an enforcement policy put in place prior to MLFF ETC going live in future.

The main technology to deliver this is ANPR mounted on specific enforcement gantries that also carry additional sensors for automatic vehicle classification and additional cameras for the recording of images of violating vehicles. Mobile enforcement might also be necessary. Introducing Multilane Free Flow (MLFF) system to experience the speed up Expressway Road Pricing (ERP) system in Future

Technically upgrading of existing ETC system with ANPR facility is minimized errors and enhancing the accuracy. It is required to organize relevant Authorities such as Motor Traffic Department, RDA, and Telecommunications regulatory Commission under one concept to implement efficient ETC system

(v). Create environment to obtain more benefit from existing ETC

The existing demand for ETC in CKE is not benefitted for Authority and required to enhance as obtain more benefit from ETC service. Hence, it is required to technical improvements as well as public promotions with some user benefits. Followings are the some proposal corresponding to the above.

- Use of efficient RFID based ETC system
- Use ANPR as a transition from MTC to ETC as addresses problems with MTC due to space constraints
- Accelerate introduction of MLFF on new Expressway sections
- RDA needs to work with Department of Motor Traffic (DMT) to distribute RFID stickers to achieve targets
- Work with user groups to promote RFID Tag usage e.g. public transport and haulage operator associations

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APPENDIX A1

MINISTRY OF UNIVERSITY EDUCATION AND HIGHWAYS
ROAD DEVELOPMENT AUTHORITY
COLOMBO-KATUNAYAKE EXPRESSWAY
MTC LANE TRAFFIC REPORT

Date : 2018/01/05 17:37
IC : KATUNAYAKE
Monitor : 1000100000(MTC Demo)

IC : PELIYAGODA
Range Time : 2017/12/11 00:00:00~2017/12/11 23:59:59

MTC	Lane					
Time	1	2	3	4	5	Total
2017-12-11 00	0	130	111	98	0	339
2017-12-11 01	0	137	145	2	0	284
2017-12-11 02	0	96	77	0	0	173
2017-12-11 03	0	74	93	0	0	167
2017-12-11 04	0	61	49	0	0	110
2017-12-11 05	0	65	80	58	37	240
2017-12-11 06	0	182	158	163	140	643
2017-12-11 07	0	267	263	250	268	1048
2017-12-11 08	0	291	282	261	283	1117
2017-12-11 09	0	224	263	163	252	902
2017-12-11 10	0	191	199	171	125	686
2017-12-11 11	0	173	197	164	163	697
2017-12-11 12	0	190	181	187	131	689
2017-12-11 13	0	128	167	108	130	533
2017-12-11 14	0	160	174	166	78	578
2017-12-11 15	0	161	168	147	118	594
2017-12-11 16	0	180	160	174	137	651
2017-12-11 17	0	204	192	171	178	745
2017-12-11 18	0	193	178	178	161	710
2017-12-11 19	0	154	151	133	106	544
2017-12-11 20	0	141	159	114	64	478
2017-12-11 21	0	70	103	55	51	279
2017-12-11 22	0	128	126	98	1	353
2017-12-11 23	0	134	105	114	0	353
Total	0	3734	3781	2975	2423	12913

Issued by

Teller Superintendent
E O M & ... Division
Road Development Authority

APPENDIX A2

MINISTRY OF UNIVERSITY EDUCATION AND HIGHWAYS

ROAD DEVELOPMENT AUTHORITY

COLOMBO-KATUNAYAKE EXPRESSWAY

MTC LANE TRAFFIC REPORT

Date : 2018/00/05 14:46
IC : KATUNAYAKE
Monitor : 1000100000(MTC Demo)

IC : JA-ELA
Range Time : 2017/12/15 00:00:00~2017/12/15 23:59:59

MTC	Lane								
Time	B1	B2	D1	D2	A1	A2	C1	C2	Total
2017-12-15 00	2	0	31	0	31	0	7	0	71
2017-12-15 01	4	0	6	0	12	0	5	0	27
2017-12-15 02	1	0	5	0	4	0	3	0	13
2017-12-15 03	1	0	10	0	6	0	2	0	19
2017-12-15 04	2	0	10	0	10	0	3	0	25
2017-12-15 05	3	0	24	0	10	0	5	0	42
2017-12-15 06	14	0	166	0	32	0	15	0	227
2017-12-15 07	31	0	367	0	71	0	21	0	490
2017-12-15 08	39	0	310	0	107	0	30	0	486
2017-12-15 09	29	0	217	0	114	0	21	0	381
2017-12-15 10	18	0	180	0	154	0	28	0	380
2017-12-15 11	33	0	255	0	183	0	17	0	488
2017-12-15 12	42	0	207	0	161	0	41	0	451
2017-12-15 13	35	0	178	0	213	0	26	0	452
2017-12-15 14	38	0	186	0	217	0	27	0	468
2017-12-15 15	33	0	210	0	213	0	39	0	495
2017-12-15 16	48	0	225	0	271	0	33	0	577
2017-12-15 17	55	0	210	0	310	0	48	0	623
2017-12-15 18	74	0	188	0	316	0	52	0	630
2017-12-15 19	76	0	160	0	349	0	56	0	641
2017-12-15 20	70	0	135	0	346	0	26	0	577
2017-12-15 21	26	0	69	0	206	0	12	0	313
2017-12-15 22	11	0	47	0	141	0	10	0	209
2017-12-15 23	6	0	50	0	100	0	14	0	170
Total	691	0	3446	0	3577	0	541	0	8255

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E.O M & . Division
Road Development Authority

APPENDIX B1

Table 02: Hourly Exit Traffic data at Peliyagoda Toll Gate during month of December 2017

Exit IC : PELIYAGODA
Range Time : 2017/12/01 00~2017/12/31 23

MTC		Vehicle Type																														
Day	Item	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
Time, h	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
0	Vehicle	311	274	337	**387**	250	275	269	**322**	397	401	339	268	296	271	362	516	422	389	319	316	296	371	357	379	371	404	408	339	363	446	518	**10,973**
1	Vehicle	314	276	281	**241**	272	189	264	**218**	303	335	284	240	265	285	296	371	353	253	278	299	296	339	371	366	318	359	282	351	306	404	347	**9,356**
2	Vehicle	128	152	144	**161**	129	88	153	**122**	188	173	173	127	150	166	125	199	197	164	133	173	177	201	210	146	136	144	150	214	166	214	208	**5,011**
3	Vehicle	98	112	105	**179**	118	106	148	**173**	164	167	167	124	107	180	200	195	200	144	148	164	185	194	255	208	179	155	183	183	171	159	179	**5,050**
4	Vehicle	110	107	130	**109**	107	106	128	**159**	166	93	110	131	123	165	176	207	132	113	163	124	163	170	147	167	96	135	117	176	132	129	119	**4,210**
5	Vehicle	196	172	161	**207**	169	178	205	**242**	181	182	240	206	176	256	208	186	172	276	243	212	222	269	212	207	145	260	237	239	220	213	229	**6,521**
6	Vehicle	354	326	290	**801**	604	523	517	**594**	368	312	643	578	530	552	520	408	298	668	545	434	539	517	326	219	193	506	507	471	449	369	291	**14,252**
7	Vehicle	397	532	301	**989**	865	933	910	**1,000**	689	473	1,048	923	979	920	917	688	424	1,071	873	855	904	984	571	324	325	667	818	817	852	557	345	**22,951**
8	Vehicle	353	537	311	**1,007**	795	909	958	**1,058**	782	442	1,117	902	1,008	871	965	761	305	1,026	832	929	900	871	594	373	287	561	847	791	891	587	386	**22,956**
9	Vehicle	383	543	400	**741**	701	696	760	**797**	725	536	902	756	804	756	783	724	529	718	724	783	714	728	674	409	326	523	775	720	716	617	538	**20,501**
10	Vehicle	463	617	408	**651**	638	699	687	**636**	771	567	686	627	766	779	674	735	688	694	799	841	801	873	791	501	440	589	804	671	750	704	532	**20,882**
11	Vehicle	567	663	477	**631**	660	694	680	**675**	805	578	697	626	786	712	796	759	675	743	676	871	677	875	890	580	496	645	772	776	743	749	589	**21,563**
12	Vehicle	518	701	442	**625**	627	618	653	**664**	823	561	689	656	708	648	784	756	661	625	698	732	720	817	870	655	547	739	745	756	767	788	640	**21,233**
13	Vehicle	409	557	433	**577**	609	577	574	**546**	660	479	533	583	650	671	673	639	486	569	629	562	703	704	629	539	408	630	592	608	786	734	573	**18,322**
14	Vehicle	459	580	420	**551**	572	605	636	**625**	634	463	578	646	610	593	679	678	494	572	526	696	638	683	643	402	371	547	587	580	714	600	475	**17,857**
15	Vehicle	452	557	479	**598**	519	652	724	**642**	597	515	594	612	590	692	765	656	493	601	380	594	680	755	665	405	488	556	576	741	683	674	488	**18,423**
16	Vehicle	545	558	589	**733**	649	619	857	**734**	667	724	651	675	626	748	846	736	641	646	707	624	819	767	688	576	640	630	640	743	714	642	594	**21,028**
17	Vehicle	554	623	655	**763**	677	562	915	**818**	784	749	745	755	601	892	860	916	909	721	798	671	893	939	874	701	845	813	596	817	790	788	674	**23,698**
18	Vehicle	732	739	761	**674**	641	604	843	**733**	819	840	710	781	647	776	836	932	778	793	732	774	786	916	923	694	857	731	734	797	851	786	794	**24,014**
19	Vehicle	552	638	664	**541**	583	671	600	**706**	683	827	544	679	533	760	915	770	780	602	678	660	740	857	769	634	1,003	724	645	751	710	848	811	**21,878**
20	Vehicle	317	453	499	**348**	344	411	515	**451**	490	595	478	408	555	556	602	543	702	485	480	646	572	701	635	505	822	508	595	572	601	614	528	**16,531**
21	Vehicle	230	320	393	**251**	286	356	286	**377**	349	408	279	346	493	385	383	367	553	333	342	522	468	495	472	438	563	467	549	378	413	461	445	**12,408**
22	Vehicle	311	331	383	**323**	340	282	383	**360**	385	434	353	330	384	327	384	384	431	328	371	359	427	410	420	382	565	453	406	421	348	450	465	**11,930**
23	Vehicle	283	374	349	**348**	345	342	416	**436**	458	451	353	429	367	470	522	524	439	379	372	477	372	469	510	373	537	403	457	398	456	525	406	**13,040**
Total		**9,036**	**10,742**	**9,412**	**12,436**	**11,500**	**11,695**	**13,081**	**13,088**	**12,888**	**11,305**	**12,913**	**12,408**	**12,754**	**13,431**	**14,271**	**13,650**	**11,762**	**12,913**	**12,446**	**13,318**	**13,692**	**14,905**	**13,496**	**10,183**	**10,958**	**12,149**	**13,022**	**13,310**	**13,592**	**13,058**	**11,174**	**384,588**

APPENDIX B2

Table 03: Hourly Exit Traffic data at Seeduwa Toll Gate during month of December 2017

Exit IC : SEEDUWA
Range Time : 2017/12/01 00~2017/12/31 23

MTC		Vehicle Type																															
Day	Item	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
Time, hr	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
0	Vehicle	180	200	240	193	145	167	178	233	287	267	190	174	181	211	206	311	331	205	186	219	254	249	430	305	176	152	190	211	216	376	268	7,131
1	Vehicle	120	116	121	104	104	77	106	140	143	152	117	83	121	119	156	177	173	110	90	122	147	172	208	173	131	105	114	134	137	178	159	4,109
2	Vehicle	96	108	97	75	64	60	106	97	125	121	68	92	57	97	98	116	106	69	88	82	122	120	150	112	95	87	71	100	85	125	113	3,002
3	Vehicle	118	91	126	75	79	77	111	101	99	115	85	128	74	117	99	118	134	85	114	96	118	104	141	119	75	102	89	106	98	113	109	3,216
4	Vehicle	180	157	182	137	157	141	162	152	223	215	178	194	136	209	181	238	207	203	169	157	200	211	282	248	150	196	174	197	181	202	206	5,825
5	Vehicle	350	272	286	259	256	260	312	252	352	324	303	237	254	296	282	343	332	297	297	287	348	332	412	281	269	311	293	308	332	360	277	9,374
6	Vehicle	360	319	234	316	279	337	369	328	398	327	356	312	356	347	368	438	382	351	326	346	434	454	565	381	306	292	401	356	336	391	296	11,061
7	Vehicle	339	365	254	392	384	424	415	403	470	363	422	392	484	452	507	498	433	415	387	468	443	516	604	395	291	324	437	466	392	387	353	12,875
8	Vehicle	374	385	301	369	409	482	448	396	453	364	370	402	428	489	486	483	102	393	453	407	434	503	576	408	381	274	393	402	406	484	314	12,569
9	Vehicle	446	404	290	389	392	448	514	354	441	410	427	427	461	478	489	500	219	404	424	475	569	495	583	440	480	360	437	456	469	471	438	13,590
10	Vehicle	546	386	384	463	423	500	587	462	546	477	395	456	494	560	519	563	576	370	490	527	562	543	680	582	609	521	570	525	502	561	478	15,857
11	Vehicle	551	464	419	560	494	543	612	508	563	599	502	521	518	571	663	662	537	476	517	498	663	616	782	660	765	550	560	665	588	610	548	17,785
12	Vehicle	509	442	354	421	419	434	502	471	569	459	451	478	524	535	568	621	460	482	483	495	588	624	682	515	674	550	523	539	541	678	511	16,102
13	Vehicle	360	407	311	456	411	417	443	487	494	442	443	514	446	414	491	466	405	429	493	478	591	562	607	474	468	471	434	491	520	557	412	14,394
14	Vehicle	434	484	353	429	427	427	452	497	546	442	493	552	533	418	599	466	426	493	536	475	571	614	653	459	393	416	534	527	546	589	432	15,216
15	Vehicle	519	515	453	611	624	548	608	664	682	521	595	680	522	586	708	761	545	618	419	596	677	723	778	561	385	536	566	589	610	728	500	18,428
16	Vehicle	559	573	509	697	653	603	698	754	802	621	678	683	649	757	814	914	601	705	611	759	801	924	834	594	464	592	615	713	818	831	571	21,397
17	Vehicle	526	639	421	657	579	711	654	895	747	595	689	672	715	686	937	904	551	740	707	782	813	903	811	534	417	539	685	694	880	785	548	21,416
18	Vehicle	463	577	420	694	645	656	635	835	716	553	658	629	631	719	803	836	547	671	658	680	817	956	651	486	388	552	648	687	862	775	509	20,357
19	Vehicle	360	508	382	734	636	690	694	840	683	571	683	677	685	734	950	743	525	661	620	726	794	939	682	511	402	524	704	725	846	732	505	20,466
20	Vehicle	302	527	336	655	557	593	633	870	666	469	585	652	667	657	837	590	414	523	665	716	889	825	630	407	290	449	556	643	788	690	464	18,545
21	Vehicle	326	447	338	437	506	509	543	758	544	423	523	591	675	599	663	475	450	608	646	572	732	768	582	424	447	470	474	547	745	554	465	16,841
22	Vehicle	350	417	325	422	449	476	518	616	495	428	437	488	570	633	651	501	422	516	528	558	633	644	533	380	354	409	416	432	526	470	390	14,987
23	Vehicle	304	304	274	279	284	325	382	633	415	335	344	328	430	496	569	448	328	349	423	423	550	598	387	314	325	287	311	326	537	381	307	11,996
Total		8,672	9,107	7,410	9,824	9,376	9,905	10,682	11,746	11,459	9,593	9,992	10,362	10,611	11,180	12,644	12,172	9,206	10,173	10,330	10,944	12,750	13,395	13,243	9,763	8,735	9,069	10,195	10,839	11,961	12,028	9,173	326,539

APPENDIX C1

Toll Rates of E 03 in Gazette No -1832/28 on 17.10.2013

10. The driver of a vehicle who contravenes the provisions of these regulations shall commit an offence and shall on conviction after summary trial by a Magistrate be liable in the case of-

(*a*) a first offence, to a fine not exceeding five thousand rupees; and

(*b*) a second or subsequent offence, to a fine not exceeding fifty thousand rupees.

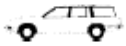
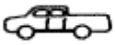
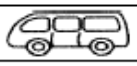
(Regulations 3 and 6)

SCHEDULE

Part A

COLOMBO – KATUNAYAKE USER FEE NATIONAL HIGHWAY (CKE)
USER FEE RATES (Rs.) FOR CATEGORY 1 VEHICLES

	Distances between interchanges 14.58 km 7.56 km		
	Peliyagoda	Ja-Ela	Katunayake
Peliyagoda			
Ja-Ela	200		
Katunayake	300	200	

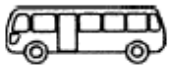
Cars	
	All types of cars
	All types of jeeps
	All saloon station wagons
Dual Purpose Vehicles	
	All cabs (single and double)
	All passenger vans up to 9 seats
	All goods Vans and trucks up to GVW 3500 kg
Light Motor Lorry	
	Lorries and trucks having 2 Axles and 4 Wheels

APPENDIX C2

Toll Rates of E 03 in Gazette No -1832/28 on 17.10.2013

USER FEE RATES (Rs.) FOR CATEGORY 2 VEHICLES

	Distances between interchanges 14.58 km 7.56 km		
	Peliyagoda	Ja-Ela	Katunayake
Peliyagoda			
Ja-Ela	350		
Katunayake	450	300	

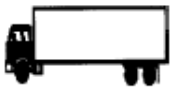
Light Motor Coaches	
	Passenger van having seats more than 9
	All buses having seats more than 9 and less than 33

USER FEE RATES (Rs.) FOR CATEGORY 3 VEHICLES

	Distances between interchanges 14.58 km 7.56 km		
	Peliyagoda	Ja-Ela	Katunayake
Peliyagoda			
Ja-Ela	400		
Katunayake	600	300	

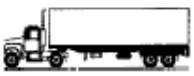
APPENDIX C3

Toll Rates of E 03 in Gazette No -1832/28 on 17.10.2013

Motor Coach	
	All buses having seats more than 33
Light Motor Lorry	
	Lorries and Trucks having 2 Axles and 6 Wheels
Motor Lorry	
	Lorries and Trucks having GVW more than 17000 kg (up to 3 axle trucks)

USER FEE RATES (Rs.) FOR CATEGORY 4 VEHICLES

	Distances between interchanges 14.58 km 7.56 km		
	Peliyagoda	Ja-Ela	Katunayake
Peliyagoda			
Ja-Ela	600		
Katunayake	800	300	

Heavy Motor Coach	
	Combination Buses
Heavy Motor Lorry	
	All vehicles having 4 or more axles.

APPENDIX D1

Estimated Variable cost

Year	Period	Total Expenditure	Monthly Average
Actual			
2013	2 Months	32,233,386.33	16,116,693.17
2014	12 Months	359,320,393.63	29,943,366.14
2015	12 Months	419,666,540.17	34,972,211.68
2016	12 Months	568,645,301.84	47,387,108.49
2017	12 Months	481,324,574.32	40,110,381.19
Forecasted		**1,861,190,196.29**	**37,223,803.93**
2018	12 Months	1,926,495,688.29	160,541,307.36
2019	12 Months	1,507,278,643.26	125,606,553.61
2020	12 Months	1,127,797,829.50	93,983,152.46
2021	12 Months	1,325,248,607.72	110,437,383.98
2022	12 Months	1,950,383,054.26	162,531,921.19
2023	12 Months	908,459,210.21	75,704,934.18
2024	12 Months	969,389,984.75	80,782,498.73
2025	12 Months	1,179,744,947.97	98,312,079.00
2026	12 Months	989,378,430.05	82,448,202.50
2027	12 Months	1,256,154,468.33	104,679,539.03
2028	12 Months	1,076,483,576.61	89,706,964.72
Average		**16,078,004,637.23**	**88,340,684.82**

(Source: Expressway Operation Maintenance and Management Division - RDA)

APPENDIX D2

Loan payment schedule (Rs. Billion)

Step	Year	Loan Payment	Interest 5.5%	Total Loan
1	2014	1.6095	2.6557113	4.2652
2	2015	1.6095	2.5671876	4.1767
3	2016	1.6095	2.4786639	4.0882
4	2017	1.6095	2.3901402	3.9997
5	2018	1.6095	2.3016165	3.9111
6	2019	1.6095	2.2130928	3.8226
7	2020	1.6095	2.124569	3.7341
8	2021	1.6095	2.0360453	3.6456
9	2022	1.6095	1.9475216	3.5570
10	2023	1.6095	1.8589979	3.4685
11	2024	1.6095	1.7704742	3.3800
12	2025	1.6095	1.6819505	3.2915
13	2026	1.6095	1.5934268	3.2029
14	2027	1.6095	1.5049031	3.1144
15	2028	1.6095	1.4163794	3.0259
16	2029	1.6095	1.3278557	2.9374
17	2030	1.6095	1.2393319	2.8489
18	2031	1.6095	1.1508082	2.7603
19	2032	1.6095	1.0622845	2.6718
20	2033	1.6095	0.9737608	2.5833
21	2034	1.6095	0.8852371	2.4948
22	2035	1.6095	0.7967134	2.4062
23	2036	1.6095	0.7081897	2.3177
24	2037	1.6095	0.619666	2.2292
25	2038	1.6095	0.5311423	2.1407
26	2039	1.6095	0.4426186	2.0521
27	2040	1.6095	0.3540948	1.9636
28	2041	1.6095	0.2655711	1.8751
29	2042	1.6095	0.1770474	1.7866
30	2043	1.6095	0.0885237	1.6980
Total		**48.2857**	**41.1635**	**89.4491**

(Source: Expressway Operation Maintenance and Management Division - RDA)

APPENDIX E1

ETC Customer Service Agreement

ETC Customer Service Agreement
Between
The Road Development Authority (RDA)
and
.....

This ETC Customer Service Agreement is made and entered into on this ..... day of ..... 201..... at Peliyagoda in the Democratic Socialist Republic of Sri Lanka

BY AND BETWEEN

The Road Development Authority an authority incorporated under the Road Development Authority Act No 73 of 1981 as amended by Act No 37 of 2009 having its principle office at "Sethsiripaya",Battaramulla, Sri Lanka (herein after called and referred to as the RDA) and which term or expression shall mean and include the said **RDA** or its successors and permitted Assigns of the Fist Part.

AND

.....of ..... bearing National ID No. ..... (herein after called and referred to as the Customer) and which term or expression shall include the said Customer of the Second Part.

The ..... bearing PV No ..... a Company duly incorporated in terms of Companies Act No. 07 of 2007 and having its Head Office at ..... of Sri Lanka (hereinafter referred to as the Customer and which term or expression shall where the context so admits or required mean and include the said Customer or , its successors and permitted Assignees on Second PART.

WITNESSETH

AND WHEREAS, the Party of the First Part has decided to collect the user fee in the Colombo Katunayake Expressway.

AND WHERE AS The party of the Second part has agreed to pay the user fee by using electronic Toll collection system in Colombo Katunayake Expressway.

NOW THIS INDENTURE FURTHER WITNESSETH the Party of the First Part and the Party of the Second Part has agreed to enter into an Electronic Toll Collection Customer Service Agreement and covenants set forth herein the party of the first part and the party of the second part agrees as follows.

1. **Definitions**
   - **"E-tag"** is the electronic device that is permanently installed in the windshield of the vehicle for the purpose of debiting the user fee to the account of the registered vehicle without their stopping when the vehicle passes through an ETC Toll Booth.
   - **"ETC Account"** is a dedicated account linked to an E-tag and the customer must **topup** this account for the purposes of payment of user fees on the expressway.
   - **"ETC System"** is the Electronic Toll Collection System comprising all roadside equipment and main computer systems used in the process of attaining user fees from a vehicle fitted with a valid e-tag.
   - **"topup"** is the act of adding credit to a ETC Account.
   - **"Working Day(s)"** means the time from Monday to Friday, excluding Saturday, Sunday and any other mercantile holidays in Sri Lanka;
   - **"RDA"** means Road Development Authority of Sri Lanka, their successors and permitted assigns;
   - **"Bank"** means the institution designated by RDA that will be interfaced with the ETC system for the facilitation of payment and collection of user fee.

2. **Customer's Rights and Obligations**
   - Customer agrees to use ETC in accordance with The National Thoroughfares Act, No.40 of 2008
   - Customer agrees to be aware of the customer's balance at all times, ensure the customer's account has sufficient balance to make the required user fee payments.
   - Customer agrees to not attempt to use the ETC lane if the customer has insufficient balance on the customer's ETC account.
   - Customer agrees to obey the regulatory 15kmph signs when approaching the ETC lane.
     Customer agrees to keep the customer's distance from the car in front to a minimum of 20m to enable you to be detected. The ETC transaction area is 22.5m from the ETC gate which is highlighted on the road surface with blue paint. If there is a vehicle stuck in the blue area because the barrier has not opened it is the customer's responsibility not to enter the blue zone.
   - If the vehicle in front is stopped at the barrier it is the customer's obligation not to enter the blue painted road surface zone as this could activate the gate for the vehicle in front and then not allow customer through.
   - Customer agrees to drive lawfully on RDA expressways.
   - Customer agrees to keep the customer's details up-to-date (e.g. means of contact and linked vehicle plate details).

- Customer agrees to pay all outstanding tolls, fees and charges when the customer's ETC Account is closed.
- Customer agrees to use the E-tag in accordance with instructions herein.
- Customer agrees to look after the E-tag and return it on RDA's request.

3. RDA's rights and obligations

- RDA shall charge user fee, tolls and charges to the customer's ETC Account when an E-tag is detected on RDA expressway.
- RDA shall take action if the customer does not meet the customer's obligations under this Agreement (which may include closing the customer's ETC Account or any other account registered under customers name)
- RDA shall record and use personal information given by the customer for RDA for the purposes of establishing and maintaining an ETC account and so that the RDA can correctly process the customer's toll charges.
- RDA shall treat the customer's personal information in accordance with national privacy laws in Sri Lanka.

4. ETC account information

The parties agree that the information provided on the Customer ETC Applications Form must be true and accurate. Any false information may lead to the customers ETC Account being suspended and **possible criminal prosecution.**

The parties agree that if the ETC account is for a business, the customer acknowledge that an authorised person must accept or sign these terms and conditions on behalf of the business.

The customer agrees to take the vehicle to the Customer Service Centre when the customer submits the Customer ETC Application Form so that it can be fitted with an E-tag.

The customer agrees that the customer ETC Account starts when customers application is accepted at the Customer Service Centre. The customer agrees that this Agreement will apply to the customer on and from the date of the customer's ETC Account starts.

5. Change of vehicle user

The customer agrees to ensure that all the details on the customer's ETC Account are correct at all times. In particular, customer must ensure that the details of the vehicle on the customers ETC Account are correct. If the details for customer's vehicle are incorrect, then the customer is responsible for updating those details by asking RDA to correct those details by visiting RDA's Customer Service Centre with the vehicle. Customer shall remain responsible for all expressway user fees and charges incurred by that E-tag, until the customer request that the customer's ETC account for that vehicle to be removed.

The customer agrees that if the customer sells or transfer a vehicle, that the customer must take this vehicle to the Customer Service Centre to have the E-tag removed and ETC Account closed.

6. Confirming Customers identity

The customer agrees to keeping a safe record of the customer's ETC Account number and password. It is agreed by both parties that if the customer telephones the Customer Service Centre about the customer's ETC Account RDA will confirm the customer's identity by asking the customer some questions. If the customer visits RDA Customer Service Centre

RDA may ask the customer to provide photo identification to confirm the customer's identity.

The customer agrees that it is the customers responsibility to notify the Customer Service Centre in person if the customer's details are lost or stolen so that they may be changed

7. Statements

The customer agrees that the customer may obtain a printed statement at RDA's Customer Service Centre for the previous month. The customers statement will shows all tolls, fees and charges during the statement period. RDA will charge the customer a fee for each statement RDA provides at the customer's request.

8. Account Balance

The customer agrees that the customer can view customers ETC Account balance when the customer drive through the toll point on the electronic display. Customer can also ask for the customer's balance by calling Toll free No. 1969 or visiting RDA Customer Service Centre.

9. Topping up your ETC Account

The customer agrees that the customer must keep the customer's ETC Account balance positive at all times. The customer can top up the customer's ETC Account using one of these payment options.

10. Topping up using Direct Debit transfer from Bank Account

The customer agrees that the customer can choose a Direct Debit transfer payment option whereby money is automatically transferred from the customer's Bank account to the customer's ETC Account if the Bank has that facility. In accepting this payment option the customer agrees to the terms set out in this Agreement and the Bank direct debit payment terms and conditions.

11. Insufficient balance

If the direct debit is unsuccessful due to insufficient funds in the customer's linked Bank account or Customer has not added credit to the customer's ETC Account by other means, then:

- ETC barrier will not open and the customer will be required to reverse backwards if safe to do so and divert into the adjacent manual cash payment lane.
- If the customer has a direct debit arrangement the customer may put money into the customer's linked Bank account.
- The customer may top-up the ETC Account using an alternative payment options by either paying cash at a Bank branch or money transfer using by Bank mobile phone banking or Bank internet banking.
- The customer may submit to the Customer Service Centre or Bank a new direct debit application form.
- Bank's terms and conditions shall apply as well as any penalties therein regarding dishonoring direct debits.
- RDA will be entitled to charge a dishonor fee to any of the customer's ETC Accounts.
- The customer will not be granted entry through any ETC lane at a Toll Plaza on the expressway if the ETC Account has insufficient balance to pay the user fee amount for the shortest journey on the expressway.

- If the customer wishes to use the Expressway without having sufficient balance to pay for the user fee the customer must use the manual cash payment turnstiles.
- The customer will be required to pay the maximum user fee if the customer does not have a manual entry ticket or entry MTC card when exiting the expressway via the manual cash payment turnstile.
- The customer will be able to enter the expressway via the ETC lane if the customer has sufficient balance for the shortest journey. It is the customer's responsibility to check and ensure the balance is sufficient for the customer's proposed journey.

12. Minimum Balance Threshold

The customer agrees that the customer's ETC Account will have a Minimum Balance Threshold (MBT) level set. When the customer's balance drops to or below this level then:

- "TOP-UP NOW" will be displayed on the electronic display at the exit ETC lane and if available, at entry lanes.
- If the customer has a Direct Debit transfer agreement the customer's ETC Account will be automatically topped up by a fixed sum transferred from the customer's linked Bank account. If the customer subscribe to SMS (mobile phone text messages) the customer will receive a TOP-UP notification.
- It is the customers responsibility to request a higher MBT and/or top-up amount if the customer is a heavy user of the expressway (bus, coaches, courier vehicles, taxis, etc.) to avoid risking having insufficient balance.
- If the customer subscribes to SMS but does not have a Direct Debit transfer arrangement the customer will be notified by text message that the customer's ETC Account balance is low.

13. ETC System Unavailable

It is agreed by both parties that if the ETC System not be operational, the variable message signs on the expressway will be used to advise all motorists to use manual user fee collection (MTC) lanes. RDA shall not be liable for losses or delays incurred by the ETC Account holder having to use the manual cash payment lanes.

14. E-tag care

The customer is responsible for ensuring the E-tag is not subjected to water, moisture ingress or any magnetic interference that could damage the e-tag. In addition, the E-tag is designed to break when removed from the windshield. The customer will be liable for cost of installing a new e-tag.

If the customer's vehicle is stolen or being used by someone for whom the customer does not wish to pay their ETC lane user fee the customer is responsible for immediately notifying the Customer Service Centre so that a block can be placed on your ETC Account.

The customer must take the vehicle to the Customer Service Centre immediately if they believe E-tag may be faulty. If the e-tag is found to be faulty and there are no visible signs of mistreatment it will be replaced.

If the customer is requested by RDA to surrender the customer's E-tag to close the customer ETC Account then the customer agrees to return the E-tag to the Customer Service Centre. The customer must return the E-tag to RDA within 10 working days from either a request from RDA or when the customers ETC Account is closed.

15. Suspending or Closing Customers ETC Account

The customer agrees that the customer's account may be closed:

- If the customer does not keep a positive balance in the customer's ETC Account and tries using an ETC Lane three or more times without sufficient balance to pay for the customer's journey RDA will notify via email or mobile phone or letter that the customer's ETC Account has been suspended (blacklisted) and customer will no longer be able to use ETC. RDA may at its discretion reactivate the customer's ETC Account provided the customer visits the Customer Service Centre and give reasonable explanation and assurances to maintain sufficient balance in the customer's ETC Account. Alternatively or for any repeat re-occurrences of attempting using the ETC lane with insufficient balance shall result in closure of the customer's ETC Account.
- If the customer asks to close the customer's ETC Account in writing, visiting or calling the RDA Customer Service Centre.
- RDA may choose to suspend the customer's ETC Account if no user fees have been charged to the customer's account for a period of three years or more. Before suspending the customer's ETC Account RDA will notify the customer that they are considering suspending the account. RDA may agree to keep the customer's ETC Account open at the customer's request but if the customer fails to respond in 30 days the customer's account will be suspended.
- When closing an ETC Account any remaining positive balance in the account after any outstanding user fees and charges have been applied will be refunded to customer. The customer will be notified by either letter, mobile or email to go to the Customer Service Centre and sign and collect a cheque from the refunded balance.

16. Privacy

The customer agrees that all personal information provided on the Customers Application Form is stored electronically. The customer agree that RDA can collect, use and disclose the customer's personal information to complete RDA obligations and exercise RDA rights under this agreement and accordance with RDA national privacy policies.

The customer agrees that subject tohaving authorized RDA to use the customer's personal information for marketing updates RDA will in the future keep the customer updated on road use events, notify the customer of changes to user fees and any discounts.

17. Enquires and Complaints

The customer agrees that the customer must contact the Customer Service Centre by phone, letter or in person if the customer has any enquires or complaints. RDA's customer service officer will respond to customer as soon as possible. If the customer is not satisfied with RDA response the customer may ask for the matter to be reviewed by the Customer Service Manager. If the customer is dissatisfied with the outcome the customer's matter will be reviewed by RDA head office customer relations team.

18. Amendments to the Agreement

It is agreed by both parties that RDA reserves the right to change any of the terms of this Agreement by mailing to the address given on the ETC Account. If the customer is not satisfied with the amendments the customer can choose to close the customers ETC Account.

19. Liability

It is agreed by both parties that If RDA finds that the customer has been incorrectly charged a user fee, RDA liability will be limited to refunding that overpaid user fee to the customer.

It is agreed by both parties that the E-tag does not function correctly and provided the customer has not caused the damage to the e-tag RDA's liability will be limited to replacing the E-tag.

It is agreed by both parties that RDA does not guarantee that the ETC lanes will always be available or that traffic flow will be uninterrupted.

It is agreed by both parties that RDA does not guarantee ETC equipment will always operate without failure even if the customer has sufficient balance in the customer's ETC Account.

It is the customer's responsibility to stop if the barrier does not open. It is agreed by both parties that the customer or his duly Authorized agent shall be liable for any loss or damaged to roadside equipment and vehicles and injuries as a result of failing to stop.

It is agreed by both parties that RDA shall not be liable to the customer for any loss or damage arising out of any error or delay in processing user fees and charging to the customer's ETC Account (including incorrect user fees).

It is agreed by both parties that RDA shall not be liable for loss of profit, loss of revenue, loss of anticipated savings or loss that would be considered consequential or indirect, irrespective of how that loss was caused and whether arising under this contract or under another principle of law.

If any part of this Agreement is void, unenforceable or illegal that part will be severed from this Agreement and the remainder of this Agreement will remain in full force and effect.

20. Contact information

It is agreed by both parties for general inquiries, queries regarding this Agreement or ETC customer account queries call 1969 or visit the Road Development Authority Customer Service Centre at Thorana Junction, Peliyagoda.

In witness whereof the parties here to have caused this Agreement to be executed on the

..... day of ..... 20.....

....

Customer for RDA

In the presence of

Witness

Page 7 of 7

APPENDIX