

## Simulation of Queuing Model for Electronic Toll Collection Smart Card Systems

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**Abstract:** National Automatic Toll Collection System (NATCS) using Radio Frequency Identification (RFID) tag contains electronically stored information which can be read from up to several meters away. The Electronic Toll Collection System (ETC) executes the automatic payments of transportation fee without stopping a toll gate in express ways. The proposed toll-plaza will be act as a multi-plaza. Vehicles are classified with weight and speed. Multi-plaza takes the benefits of controlling the overloading, identifying theft. Operations Research Methods are used for the study of design and optimization of transportation systems. This study proposes an Optimal Queuing Model to minimize the queue and average waiting time of the vehicles in toll booths. The design can be further developed to aid the Satellite Surveillance Systems once all toll gates are networked. Experimental results signify that the proposed approach with ETC Smart Card Systems doubled the accuracy and produced adequate results.

**Key words:** ETC, RFID, NATCS, QMS, smart card

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### INTRODUCTION

Technologies for ETC are regarded to be quite important in terms of proficiency of traffic. ETC can shrink congestion, increase operating efficiency, improve travel time, shrink pollution and improve safety of the roadway facility and adjacent corridors. It will be hard to convince users of ETC Systems if they have to use separate prepaid cards for each toll gate operation (Li, 2010). RFID is a highly stable technology and used for tracking, tracing and identifying objects. It reduces operational cost by the need for human operators that collect information and in revenue collection. The system could automatically open and close the gate as well as automatically sent the message to the owners of the vehicles (Kamarulazizi and Ismail, 2011).

The aim of multi-plaza is used to maximize efficiency of the toll plaza by reducing queuing time and average waiting time in tollgate (Nowacki *et al.*, 2008). It is also used to enhance the number of vehicles fleeting in tollgate. There are some drawbacks are available in existing ETC System. The main problem of toll plaza is how we optimize the queue length of vehicles and the time of customers in the system. So that system is not applicable for heavy vehicles and multi axle vehicle, etc.

(Sathya and Samth, 2012). Another problem is existing system allowed all the payment type like prepaid, postpaid and cash. So, more confusion was occurring and delay the time period.

**Problem formation:** Out of many toll plazas in TN border, researchers selected only in Krishnagiri-Hosur region, km 87+500 of National Highway No. 07. Researchers collected the data of cars, light motor vehicles, bus, truck, heavy vehicles and multi axle vehicles passing the toll gate at both office and peak time. After that, we find the simulation of all the data using QMS (Queuing Model Simulator).

Queuing Theory Method is used in analyzing toll booth problems. To improve the traffic capacity, researchers consider by vehicles arrival time, service time, departure time and the number of tollbooths. If the number of tollbooth increases, the service time, average waiting time and queue length also decreases (Yu *et al.*, 2011). Researchers have considered four types of the payment systems at toll plaza: cash, touch card, electronic payment and ETC smart card. At each gate of toll plaza one or multiple type payment system is available. Researchers measured only eight gates on toll plaza in the forth coming study. Researchers

also consider that the customers are following M/M/1/∞/FCFS Queuing system at each gate of toll plaza, i.e.:

- The arrivals to the toll plaza are winning place according to poisson process
- The service times are exponentially distributed
- The customers are served on first come first serve basis
- There is no limit of the customers at toll plaza

**MATERIALS AND METHODS**

First option would be to separate the lanes and to offer only one type of payment system at every tollbooth. The disadvantage of a separate lane system is that certain tollbooths can be underutilized while others may be overloaded. This can be increase inefficiency in operational usage. Second option would be to offer all types of payment systems like cash, credit card and electronic payment at all tollbooths and have the vehicles queue in one line. The disadvantage, however is that the wide range of service times introduces variability (Radwan *et al.*, 2009). Another option would be to offer only one type of electronic payment system at every tollbooth. The advantage of this case is that it provides more operational flexibility and increases the efficiency of the tollbooths.

**Models for proposed system:** Queuing can limit the number of variants to be examined while simulation compares and evaluates the different variants (Ceballos and Curtis, 2004). A review of the two possible queuing systems with six types of vehicles, labeled X, A, B, C, D, Y as illustrated in Table 1-4 with the combined approach. Here, the simulation is necessary to evaluate the performance, optimize the concepts and results from queuing theory. The justification line is set to before 10 km of where the tollgate is placed. After every 2 km, display board is blinking the number of vehicle moving between justification line and mixed split line. The mixed split line is placed on the 2 km away from the tollgate (Fig. 1):

- Type X denote for both two and three-wheelers
- Type A denote for SCV vehicle
- Type B denote for LCV vehicle
- Type C denote for HCV vehicle
- Type D denote for MAV vehicle
- Type Y denote for exempted vehicle

Table 1: Arrivals and service times

Vehicle type	Arrivals (number min <sup>-1</sup> )		Service time (sec)
	Justification line	Mixed split line	
X	10	5	15
A	5	3	8
B	7	2	9
C	4	3	7
D	5	1	6
Y	1	-	1

Table 2: Waiting times (sec)

Vehicle type	Queuing system waiting time (sec)	
	Mixed service	Mixed split line
X	20	10
A	125	35
B	240	26
C	292	40
D	428	45
Y	5	1
Mean	137	12

Table 3: Distribution of preferred payment system

Payment type	SCV	LCV	HCV	MAV
ETC smart card	20	18	16	4
ETC only	9	7	NA	NA
Card payment	21	10	5	3
Cash	76	81	90	92

Table 4: Average service times per vehicle type (sec)

Payment type	SCV	LCV	HCV	MAV
ETC smart card	1	1	1	1
ETC only	3	2	NA	NA
Card payment	8	8	8	8
Cash	15	15	15	15

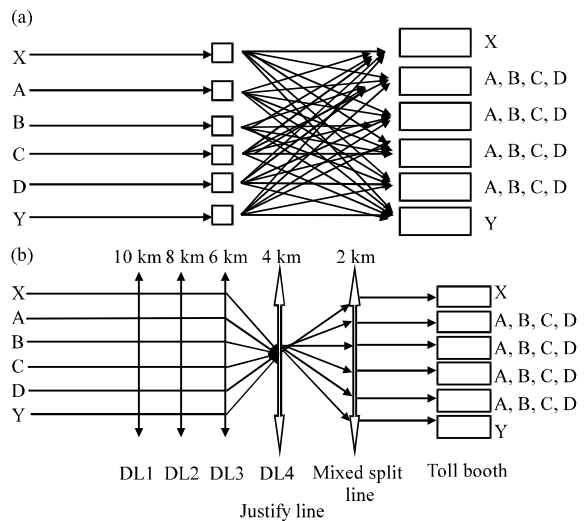


Fig. 1: Possible Queuing Systems at tollbooths; a) System 1: overflow service in existing system and b) System 2: mixed split with justify line in proposed system

Table 5: Results for mixed with Justify Line Payment System

Toll booth	Payment system	Work load (%)	Waiting time (sec)
1	ETC smart card	10.40	0.5
2	ETC smart card	10.25	0.4
3	ETC only	30.20	1.5
4	ETC only	28.12	1.0
5	Card payment	98.21	38.0
6	Card payment	97.07	35.0
7	Cash	91.62	56.0
8	Cash	88.07	54.0

### RESULTS AND DISCUSSION

To simulate the toll plaza under study with mixed payment and mixed line with justify line payment system. The node 1-8 represents the queue at eight tollbooths with First In First Out (FIFO) facility. Four types of services are provided by the server after the queuing node (Table 5).

### CONCLUSION

In this study, researchers have discussed electronic toll collection using Simulated Queuing Model in Toll Collection System. With the elimination of human interaction in the entire toll collection process, researchers can create a better ETC smart card system. It can also drastically improve the efficiency of toll stations and the traffic abilities of the toll road used for justification line, display board and mixed split line. This proposed system designed could automatically detect the identities of the vehicle and performed the billing in accordance to the identity of each vehicle as prerecorded in the RTO database. The whole system is very convenient and save much more time. The models envisage tempting solutions to the optimal number of toll booths for a given plaza.

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