

Electronic Toll Collection: A Summary and Analysis of Current Practices with Application to San Juan, Puerto Rico

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Abstract

Electronic Toll Collection (ETC) can sufficiently increase toll plaza capacity without the necessity of expensive expansion. Although a few potential problems exist, ETC provides many desirable benefits in addition to increased capacity, such as reduction of labor costs, lower maintenance costs, better security of funds, lower pollution, and increased safety. However, before implementing an ETC system, it is necessary to analyze the state of the current system, determining whether an ETC system is appropriate and, if so, which lane configuration will best accomplish the desired goals.

In order to establish the parameters that require consideration when evaluating a potential ETC system, five case studies are presented and analyzed. The primary parameter for consideration demand. If the demand at the plaza does not currently meet determined minimum thresholds, it may not be efficient to implement an ETC system. Other factors which should be considered are expected market penetration, lane mix, and signaling.

Analysis techniques for capacity and queuing at toll plazas are presented. With the use of commonly available data from area transportation models and toll audits, it is possible to perform analysis resulting in optimal lane configurations, including ETC lanes. Additionally, queuing characteristics, such as maximum wait time, can be determined from this analysis.

The queuing and capacity techniques are exemplified in an application to the Massachusetts Turnpike for one plaza. The results of this application are then calibrated and used to analyze different configurations for the Buchanan Toll Plaza in San Juan. It is found that if Tren Urbano is not built, ETC may be a useful, if not necessary, technology to implement, as demand at the plaza will increase beyond the available capacity within a few years. The implementation of Tren Urbano will decrease demand at the toll plaza dramatically and, consequently, it may not be necessary to build any ETC lanes. However, ETC may still provide desirable benefits in this case, and should be further explored.

The principal conclusions from this work are as follows: 1) ETC design information is lacking and a generalized body of knowledge and evaluation technique needs to be developed. 2) ETC systems are generally rated as beneficial and desirable. 3) Increasing capacity through electronic toll collection or other toll plaza configurations is possible, but may increase toll collection costs and clog roadways downstream of toll plazas. 4) The tolling situation in Puerto Rico needs more investigation to make a better decision about the use of ETC on the island.

Key Words: *Electronic Toll Collection (ETC), queuing, capacity analysis, toll plaza*

Introduction and Conclusions

Toll collection is an important aspect of many highway systems. However, it poses four major difficulties: 1) traffic must come to a complete stop, 2) without enough capacity, queues form at toll plazas, 3) cash collection and processing is expensive and complicated, and 4) customers are inconvenienced by toll plazas. One new technology that effectively deals with these difficulties is Electronic Toll Collection (ETC). Although ETC is generally known to be beneficial and desirable, no generalized body of knowledge and evaluation techniques currently exists. In order to evaluate the possible implementation of new ETC systems, it is necessary to first conduct a preliminary evaluation of the system based on certain parameters such as demand and forecasted market penetration. Next, a capacity and queuing analysis is useful in order to develop appropriate lane configurations. These analysis tools are explored and applied to a toll plaza in San Juan, Puerto Rico to evaluate whether ETC might be a useful and desirable technology to implement.

Background

ETC technology generally involves some type of attachment to the patron vehicle, such as a tag or sticker, and a transmitter/receiver array at the tolling location. There are many issues to consider when designing an ETC system. Those pertinent to toll authority planning officials are: 1) overall system architecture, 2) accuracy and reliability, 3) health and safety, 4) traffic operations, 5) service and maintenance, and 6) accounting and tag distribution. Although the initial cost of an ETC system can be in the millions of dollars, subsequent savings in maintenance and labor costs make the technology a fairly cost efficient way of increasing toll plaza capacity.

Naturally, a few privacy and legal issues exist with ETC systems. The first is enforcement, which refers to the method used to assure that ETC lane patrons pay the appropriate toll and penalize those who do not. Currently, this issue is dealt with in three ways: gates, enforcement officials, and high-speed video and tape. The second issue is privacy and security since ETC systems can record transaction time, place, direction, and possibly entrance and exit points. It is crucial the individual toll records be highly safeguarded to avoid and misuse of this data.

San Juan is the center of most of Puerto Rico's commerce, cultural, educational, transportation, and governmental activities. In the past several years, the SJMR has been experiencing rapid growth in trip-generation and trip-making, without corresponding increases in facilities such as roadways and toll plazas. The travel demand patterns are causing large daily backups and lengthy congestion throughout the region. The recent development of a high-speed rail service called Tren Urbano will hopefully alleviate some of these backups. However, it may also be necessary to reconfigure some of the toll plazas on the two main expressways serving the island: PR-22 and PR-52. Converting some of the lanes to ETC will not only alleviate the congestion problem through increased capacity, but will also provide other benefits, such as increased convenience to users, lower labor and maintenance costs, and better security of funds.

Methodology

The methodology used to conduct this research consists of collecting current data, augmenting knowledge with case studies, and development of queuing and capacity models. The queuing and capacity models were applied to the Massachusetts Turnpike for calibration, and then applied to the San Juan Metropolitan Area.

First, literature on the subject of toll collection and Electronic Toll Collection (ETC) was reviewed and important information summarized. The majority of the documents reviewed were published by transportation research associations (See Annotated Bibliography).

Then, a specific set of toll facilities was chosen to be surveyed using questions in the field of toll collection and ETC. Responses from participating toll agencies were then summarized into case studies. Each case study is then analyzed using five different criteria: general characteristics, toll lane configuration, ETC system characteristics, most congested toll plaza, and qualitative features. Several conclusions were made in the areas of technology, ownership arrangements, reliability, patron views, and characteristics of success.

In order to evaluate the performance of toll plazas covered in the case studies, fundamental queuing and capacity were used to develop models to aid in the analysis. With the use of a computer spreadsheet, the collected data was inputted to determine an approximation of the queuing times and capacity associated with a particular plaza in a particular direction.

The queuing and capacity models developed are applied to plaza 19 of the Massachusetts Turnpike for calibration. Capacity and queuing analysis are performed for future demand ETC and non-ETC configurations and compared to analyses conducted on current demand data.

Finally, all the information was used in an analysis of the highway situation in the San Juan Metropolitan Area. A capacity analysis of the most congested toll plaza in Puerto Rico (Buchanan Plaza) is presented, along with suggested lane configuration changes and conversions to ETC.

Results

Queuing and capacity analyses were conducted on plaza 19 of the Massachusetts Turnpike using current year and 10 year forecast data. Table 6.12 shows a summary of the capacity analyses performed for suggested plaza configurations. For the current year, eliminating lanes when ETC is installed may result in an increase in service. However, for a ten year future forecast, demand will exceed capacity, suggesting the addition of new lanes to increase capacity. However, the capacity model shows that necessary capacity can be added using ETC without having to increase the number of lanes.

Table 6.12 MassPike Plaza 19 Capacity Summary						
Situation / Lane Mix	Manual	ACM	ETC/ACM	Dedicated ECM	Demand (vph)	Capacity (vph)
Current Year – Current Configuration – 15 lanes						
Dominant	7	3	0	0	5400	4905
Non-Dominant	3	2	0	0	2200	2495
Current Year – ETC Configuration – Possible 1 Manual Lane Closed - 14 lanes						
Dominant	5	4	0	1	5400	5605
Non-Dominant	2	2	1	0	2200	2730
Ten Year Forecast – Current Configuration						
Dominant	7	3	0	0	6000	5400
Non-Dominant	3	2	0	0	2429	2495
Ten Year Forecast – Expanded Plaza – 2 new lanes built						
Dominant	7	5	0	0	6000	6005
Non-Dominant	3	2	0	0	2420	2495
Ten Year Forecast – ETC Configuration – Possible 1 ACM lane closed – 14 lanes						
Dominant	4	4	0	2	6000	6460
Non-Dominant	3	1	1	1	2420	2998

The capacity results were used in conjunction with the queuing model to develop wait times and queue lengths for the various configurations. Table 6.13 gives a summary of the queuing statistics under the different demands and configurations.

Table 6.13 MassPike Plaza 19 Queuing Summary		
Situation	Max. Wait (minutes)	Avg. Wait* (minutes)
Current Year – Current Configuration	6.1	0.76
Current Year – ETC Configuration	0	0
10 Year Forecast – Current Configuration	2.9	13
10 Year Forecast – Expanded Configuration	0	0
10 Year Forecast – ETC Configuration	0	0

* for those who do wait

Once the queuing and capacity models were verified with the MassPike example, additional analysis was conducted on Buchanan plaza in Puerto Rico. The current configuration of Buchanan plaza is not sufficient to handle the current traffic at the plaza. Capacity analyses were conducted using current demand levels as well as forecasted demand levels for the year 2010. In addition, various configurations were taken into account for each case, including the effects of the implementation of Tren Urbano, a heavy rail public transit service.

The capacity model shows that for the 2010 No Build Alternative, where Tren Urbano is not constructed, the demand will be accommodated only if some non-dominant direction lanes are reversed and an additional five lanes are constructed. If ETC is added now, and

assuming a market penetration of 40% by 2010, the plaza will not require expansion physically, but several ETC lanes will have to be installed.

As for the alternative where Tren Urbano is constructed, the current number of lanes is adequate enough to handle the capacity. Non-ETC and ETC implementation will reduce the number of lanes required by two.

Table 7.20 provides a summary of the queuing analysis for different demand and lane configurations. ETC becomes essential in the case Tren Urbano is not built, but if construction does proceed, ETC will not be necessary to improve the level of service for the plaza.

Table 7.20 Buchanan Plaza Queuing Summary		
Situation	Max. Wait (minutes)	Avg. Wait* (minutes)
1996 Demand – Current Configuration	46	25
1996 Demand – Alternative Configuration	9.3	1
1996 Demand – ETC Configuration	0	0
2010 No Build Demand – Non-ETC Config.	34	7
2010 No Build Demand – ETC Config.	0	0
2010 Build Demand – Non-ETC Config.	0	0
2010 Build Demand – ETC Config.	0	0

* for those who do wait

The results of the cost analysis show that the cost of toll collection using the recommended ETC configuration is about 67% higher than current collection methods. However, there is some social benefit that results from the use of ETC. Thus, the implementation of ETC is dependent not only cost, but also other factors as well.

Table 7.29 Buchanan Plaza Cost Analysis Summary	
Configuration	Cost per Transaction
Current Buchanan Configuration	\$0.015
Alternate Configuration	\$0.016
ETC Configuration	\$0.025

Discussion

Overall, the implementation of ETC systems is successful. Puerto Rico is an excellent place for the installation of ETC system. The number of drivers, toll levels, and frequency of the toll plazas contribute to the change of ETC success.

However, due to the number of automatic coin lanes in use, the cost per transaction for ETC systems is greater. Also, the use of ETC lanes may allow bottlenecks to appear closer to the city, possibly resulting in greater congestion in the city. Yet, the ETC system does reduce the amount of congestion and time spent waiting in the toll plaza queues. If this benefit is factored into analysis, then ETC is promising.

This research discusses some of the factors one has to take into account in determining whether a toll plaza benefits from the installation of an ETC system. Cost is an important issue, and the benefits of the system must be fully analyzed to justify the higher costs. As the research shows, ETC systems are successful in reducing queue length and waiting times and increasing capacities. However, in order to make final decisions on the implementation of an ETC system, these factors must be analyzed using more advanced methods.

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