Evaluation of Electronic Toll Collection Along South Luzon Expressway and Manila Skyway

Grace U. Padayhag

M.S. Civil Engineering (Transportation Engineering), 2002 Department of Civil Engineering, University of the Philippines Diliman

Adviser:

Dr. Ricardo G. Sigua Associate Professor, Department of Civil Engineering University of the Philippines Diliman

Abstract: The aim of the study is to investigate the different types of toll-collecting booths along the toll plazas, which includes the service rate of vehicles passing through the toll plazas. The analysis proved that the dedicated E-pass lane has a lesser tollbooth transaction time. The usage of the E-pass lane was not maximized in spite of the speedy transaction because more vehicles still pass through the conventional tollbooths, which causes frequent congestion especially during rush hours. The mixed-mode lane is fairly slower than the exclusive E-pass lane. It was also observed that the lane capacity and delay of toll-lanes also vary widely with the type of toll-collecting booth. The queue delay in mixed-mode scheme is significantly less than for the purely manual scheme.

1. INTRODUCTION

Intelligent Transportation System (ITS) is defined as "the application of advanced sensor, computer, electronic, and communication technologies and management strategies – in an integrated manner - to increase the safety and efficiency of the surface transportation system" (FHWA, 1998). One of the ITS applications is the Electronic Toll Collection (ETC) System which was introduced locally on August 2000 to help reduce transit times and traffic congestion for commuters, streamlining toll transaction processing and enhance auditing capabilities.

The ETC system was installed along sections of the newly elevated toll road, the Metro Manila Skyway, and the existing toll road, the South Luzon Expressway (SLEX). The SLEX covers about 48 km. of roadway in a north-south direction, connecting Metropolitan Manila to the different provinces of Southern Luzon such as Cavite, Laguna and Batangas. There are 32 toll plazas consisting of 154 tollbooths comprising the SLEX system. Of the 154 toll lanes, 106 are equipped with ETC system and 18 of these currently have lanes dedicated to E-pass users. The dedicated lanes are located at the following toll plazas and interchanges: Manila Skyway toll plazas, C-5, Nichols A and B, Sucat, Bicutan, Alabang, Doña Soledad, and Calamba.

What is the ETC system and how does it work? Electronic Toll Collection (ETC) system uses various technologies to allow the manual in-lane toll collection process to be automated in such a way that customers do not have to stop and pay cash at a tollbooth. To avail of an E-pass, a motorist buys a credit card-sized tag that must be attached to the inside surface of the vehicle's windshield behind the rearview mirror. The tag contains a memory chip that is loaded with PhP500 pre-paid value. Antennas read the value of the card and the result is indicated by signal light. A green light indicates that the motorist has adequate fund loaded in the tag. A yellow light is a warning to replenish the card. Red light means that the motorist has an insufficient loaded value. The device debits the toll fee once the motorist exits toll gate.

In Figure 1, an overhead antenna (1) reads the account information provided by the transponder (2) and deducts the correct toll from the prepaid account. The patron toll display (3) tells how





much prepaid account has been charged. Traffic signal (4) flashes if there is sufficient account left in the prepaid card, and lane barrier (6) rises allows the vehicle to exit the toll plaza then an exit loop (7) closes out the transaction.

1.3 Study Objectives

The objective of the study is to evaluate the existing ETC system installed along South Luzon Expressway and Manila Skyway. In particular, it aims to determine the service times of different modes of payment in the toll plaza, the toll-lane capacities and the motorist's waiting times or queue delays. The study also aims to compare the utilization of lanes of the toll plaza, from manual tollbooth transaction to mixed-mode scheme – E-pass/cash or E-pass/exact toll – and up to the dedicated E-pass toll-lane. In this study, simulation process will be used to compare the observed queue delay values with the simulated data.

The service rates of the tollbooths with or without E-pass services or combination of both schemes are evaluated. Only queue delays along Nichols Toll Plaza A and Bicutan Entry are evaluated. The percentage of time in queue is evaluated at Bicutan Entry with specified distance using car length since the length of queuing section is fixed due to the presence of an intersection upstream and this causes the flow to be dispatched by batch, prior to the toll plaza. On the other hand, Nichols Toll Plaza A is evaluated using the travel time and delay method. Video cameras are used to depict the delay condition experienced at Nichols Toll Plaza A wherein a benchmark of 64.5 meters downstream - away from the tollgate was set to make sure that as the vehicle reached that reference point, a delay is then determined. A reference point was set simply because the video camera is not capable to capture a wider picture and also some graphic ads and signs hinder the observation of the queue formation at the Nichols toll plazas. However, queue delays along Bicutan Exit and Nichols Toll Plaza B are not evaluated in view of the fact that visibility is not feasible and can only be made possible if aerial survey will be done which is expensive.

2. REVIEW OF RELATED LITERATURE

In Korea, one of the research methods relating traffic flow to accidents is the collection of traffic volume data and calculation of the volume-to-capacity ratio where one of the selected study areas for analysis is a tollgate. According to Chang, *et al.* (2001) calculating the capacity of the tollgate, requires service time. Below is the formula in determining the tollgate capacity (Equation 1).

C toll gate = $\frac{3,600 \text{sec} * (\text{the } \# \text{ of toll booths})}{\text{service time}}$ C toll gate = Capacity for toll gate section
(1)

According to Feng Bor Lin (2001), toll lane capacity depends primarily on the method of toll lane collection and vehicle mix; they can vary substantially. Toll lane capacities are governed by vehicle processing time, which is defined as the headway between the rear ends of queuing vehicles when they cross a specified reference line near a booth.

The queuing theory has various valuable applications, such as traffic flow, scheduling and facility design. Hence, it is frequently used in simulations. The patrons (not necessarily human patrons) arrive for service, waiting for service if it is not immediate, and leave the system as soon as they are attended (Figure 2).



Figure 2. The Concept of Queuing Theory

There are 6 characteristics of the queuing which process provide an adequate representation of a queuing system; (1) arrival pattern of customers, (2) service pattern of servers, (3) number of service channels, (4) system capacity and (5) queue discipline. Arrivals can be scheduled or at random times; Poisson distribution is used frequently for random arrivals, and scheduled arrivals usually use a constant interarrival rate. The service time pattern, usually random, is mainly modeled by using exponential distribution or truncated normal distribution in which probability is needed to describe the sequence of customer service time. Queue discipline refers to the manner in which customers are preferred for service when a queue has formed. Postulation on queue discipline: FIFO - first in, first out (most common), signifying that the first vehicle to arrive is the first vehicle to leave.

3. TRAFFIC SURVEY

Figure 3 shows the pictures of the traffic survey sites. Two video cameras were set up at the Bicutan toll plaza, one at exit near the tollgate, capturing the vehicles bound for southern direction, and another one at the entry near the PNCC Security Department, capturing vehicles bound for the northern direction. The sites mentioned were surveyed simultaneously during the morning peak hours, 7:30-10:30 AM, and the afternoon peak hours, 4:00-6:00 PM, on June 20, 2001 with a fair weather. The morning peak hour was set from 7:30 to 10:30 AM because truck ban is lifted at 10:00 AM. As such, the strong impact of trucks on the traffic condition at the toll plazas is likewise considered. Oueue delay along Nichols A was also done by video survey simultaneously and was also set up at TESDA building.







Nichols Toll Plaza A



Bicutan Entry Toll Plaza Bicutan Exit Toll Plaza

Figure 3. Traffic Survey Sites

From the video footage, service time, percentage of time that the lane is in queue, and lane utilization of each tollbooth can be acquired. Service time is the time incurred at the instant the vehicle stops at the demarcation line while it waits to be served and at the instant it leaves the tollbooth. Queue delay was determined by manual tallying using stopwatch and by adhering to the basic concept of travel time and delay. Queue delay or stopped time is defined by travel time minus the running time.

4. SERVICE RATE AND TOLL-LANE CAPACITY

The manual scheme of paying tolls shows that it has greater service time in toll transaction, roughly around 15 seconds per vehicle. Mixedmodes have two kinds, one is the E-pass/cash payment and the other is the E-pass/exact toll mode. For E-pass/cash payment, which is a little lesser than the manual scheme, it has an average service time of approximately 8.76 seconds per vehicle while the E-pass/exact toll has an average service time of approximately 4.89 seconds per vehicle. Whereas, dedicated E-pass lane has lesser tollbooth transaction time with an average service time of 1.54 seconds/vehicle. Figure 3 shows the cumulative service times of the 10 toll-lanes of the Nichols A Toll Plaza.

Toll-lane capacity also varies extensively with different modes of toll payment. In the manual scheme, there are still several motorists who patronize the system of manual payment of toll. For this reason, the lanes for cash are more utilized than the recently installed ETC lane with an average toll capacity of approximately 180-400 vphpl. The E-pass lane is not fully utilized due to the reason that few motorists are availing of the E-pass tag kit because of its high cost even though the capacity of the toll-lane with ETC is 14 times higher than that of the conventional tollbooth. Figure 4 shows the toll lane capacity of lane 8 of the Nichols A Toll Plaza.

5. CONCLUSIONS

In general, drivers have a tendency to prefer tollbooth with shorter queue of vehicles, although this is not always true at all times



Figure 3. Service Rate of Nichols A-Afternoon Peak



Afternoon Peak

because they usually end up at the vicinity where the channel of approach traffic is situated. Therefore, lanes that are located at the middle portion of the toll plaza are more appealing to most drivers. Hence, the lane utilization rates of the middle lanes are usually greater than those that are located at the leftmost or rightmost lanes.

It was determined using the *F*-test that the service times of the tollgates vary significantly by the mode of payment employed at the tollbooth. The service time of the tollbooth equipped with the ETC system is 10 times lesser than the manual lanes, 6 times lesser than the E-pass/cash lane and 3 times lesser in processing time at the tollbooth than the E-pass/exact toll.

Results of the simulation show that the values for the average delay are comparable.

6. RECOMMENDATIONS

Approximately 17% of vehicles traversing the SLEX have availed of the E-pass tag kit. However, still many buses line up for the conventional payment of tolls. It is recommended that the vehicles passing through the SLEX daily, especially the bus and truck operators, avail for the E-pass tag kit and make use of the dedicated E-pass lane to increase its utilization rate.

Equilibrium delay at the toll plaza will be useful in the new transport application, the variable message sign (VMS), wherein, the conventional lane users will be accommodated at the dedicated E-pass lane or vice-versa which makes the toll plaza to operate at a mixed-mode scheme only at the instant of severe congestion. Furthermore, the analysis of different type of toll-collecting booths with various kinds of traffic should also be further conducted using the simulation method. The average approach time depends primarily on vehicle characteristics and proportion of the different types of vehicles that has an important impact on the capacity of the toll plaza.

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