Evaluation of Philippines' Electronic Toll Collection System for North Luzon Expressway

Louie Mari GUGOL[a], Takahiro IZAWA[b], Grace GUETA[c]

[a,b,c] *De La Salle University – Manila, 2401 Taft Avenue Manila 1004, Philippines*
[a] *E-mail: epsilonblue@rocketmail.com*
[b] *E-mail: izawa.soluna@rocketmail.com*
[c] *E-mail: padayhag.grace@yahoo.com*

Abstract: With the latest improvement done on North Luzon Expressway (NLEX), it is expected that the number of riders for both North Bound and South Bound will rise. For a more continuous flow of traffic, an Electronic Toll Collection (ETC) system was introduced to help alleviate traffic congestions; specifically at Toll Plazas. The paper shows how the introduction of NLEX's ETC system helped alleviate traffic by decreasing the service times at Toll Plaza; thus increasing the capacity of motorists it can accommodate. By using Queuing Theory, the researchers were able to show the significant difference in performance of Toll Plazas when using ETC. The paper also expounds on the factors that contribute to the delays and long queues experienced at Toll Plazas and recommends ways to help improve the service.

Key Words: ETC, Queuing Theory, Service Time, Toll – Lane Capacity

1. INTRODUCTION

1.1 Electronic Toll Collection System

The Federal Highway Administration (FHWA) defined Intelligent Transportation System (ITS) as the application of modern technology to increase the safety and efficiency of transportation systems (1998). These devices include, but not limited to, sensors, computers, and communication technologies and management strategies. One of ITS applications would be the Electronic Toll Collection (ETC) systems where its research begun since 1959, (proposed by Nobel Economics Prize Winner William Vickrey for Washington Metropolitan Area) and has started to be integrated into the transportation system at present all over the world. These systems are expected to greatly reduce service times at toll plaza by reducing transaction times compared to manual toll collection (Diaz, 2005).

The ETC system was first installed at Metro Manila Skyway and South Luzon Expressway or SLEX in August of 2000 followed by North Luzon Expressway or NLEX in early 2005. The ETC system at SLEX is called E-pass and NLEX is called EC-tag. The ETC system used by these two expressways has the same technology, thus making their service times almost the same but they differ in price. E-pass cost Php1,700.00 and have prepaid card with denominations of Php200.00, Php500.00 and Php1,000.00, while EC-tags have rentals that range from Php112.00 monthly or Php2,000.00 upfront payment (easytrip.ph, 2008).

Table 1. The Metro Manila ETC System (Sigua, 2009)

	SLEX	NLEX
Length, km.	48	84
Technology: DSRC 5.8 Ghz	US-Based Transcore	Egis Projects S.A. of France
Daily Volume	270,000	200,000
% ETC Users	20	6.5

1.2 Objective of the Study

The study aims to evaluate the newly rehabilitated and extended NLEX. In detail, the objective is to assess the amount of delay of the individual lanes of Dedicated EC-tag, Mix and Cash Toll booths; their service time, lane capacities and the number of queue each lane can handle then compare the different modes of payment with one another. The study also aims to find out the specific factors that affect the delays experienced at Toll Plazas and recommend ways to improve the service. The researchers would also compare the results to other ETC-using expressways to see the progress of the Philippines in terms of transportation.

Figure 1. Balintawak Toll Plaza in North Luzon Expressway

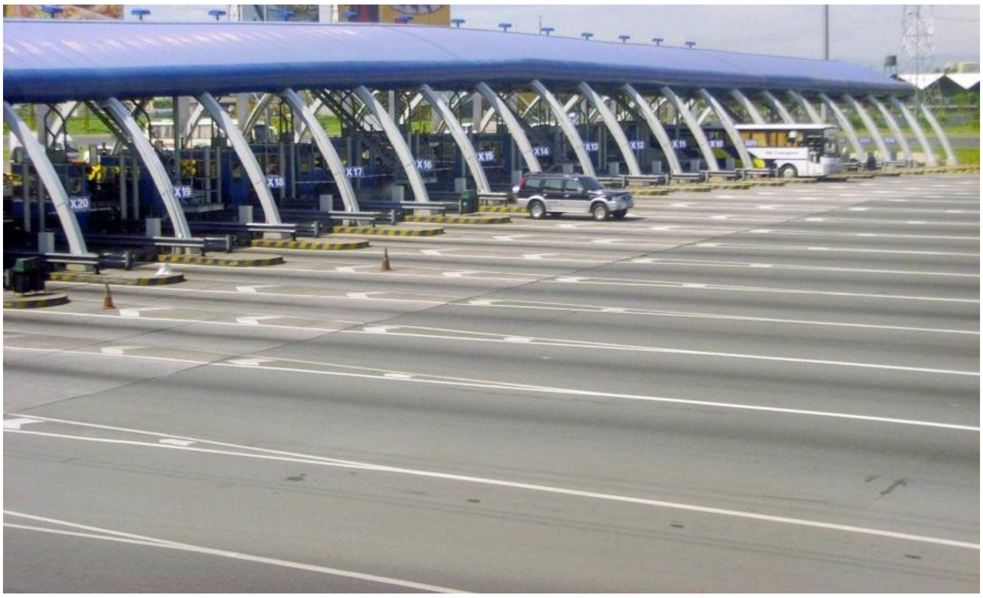

Figure 2. Bocaue Toll Plaza in North Luzon Expressway

2. REVIEW OF RELATED LITERATURE

2.1 Queuing Theory

Queuing Theory in general is not limited to trivial activities such as the behaviour of queues when waiting in line in shops or restaurant; it has many various applications, specifically in the designs for toll plazas. Generally, a Queue System may be divided into four parts: the arrival, the queuing discipline, the service mechanism, and the cost structure (Nosek, 2001). The arrival dictates a randomness of when the vehicle enters the whole system. According to Padayhag (2003), the Poisson distribution is frequently used to describe the randomness of the arrival pattern. The queuing discipline refers to the manner of which the queue is formed when the vehicle is rendering service. For Toll Plazas, the discipline frequently used would be the FIFO – First-In First-Out indicating the first vehicle to arrive would be the first to leave. The service mechanism dictates how the service is rendered for the vehicle; the service pattern for each vehicle is at random, mainly modelled by using exponential distribution or truncated normal distribution according to Padayhag (2003). Lastly, the cost structure mainly refers to how the vehicle exits the rendered service. Examples of factors affecting this would be the number of toll booths and the speed of the operator. By applying the theorems presented by Gerlough and Huber (1975), the research group of Diaz (2005) were able to make the simple models to estimate the average delays experienced in each booth.

$$E(v) = \frac{\rho}{1-\rho} * \frac{1}{\lambda} \tag{1}$$

$$\rho = \frac{\lambda}{\mu} \tag{2}$$

$$E(s) = \frac{1}{\mu} \tag{3}$$

$$E(w) = E(v) - E(s) \tag{4}$$

where,

E(v)	: average time spent in toll plaza (hours / vehicle)
ρ	: utilization factor
λ	: average arrival rate (vehicles / hour)
μ	: average service rate (vehicles / hour)
E(s)	: average service time in toll booth (hours / vehicle)
E(w)	: average waiting time (hours / vehicle)

2.2 Capacity of Toll Booths

According to Feng Bor Lin (2001), toll lane capacity primarily relies on the toll collection method; thus by comparing the capacity of ETC using lanes to that of manual payment lanes, the difference between them in terms of capacity and delay will be more clearer to understand. Based on a research method in Korea that were used by Chang, Oh, and Chang (2001), they were able to determine that in order to obtain the capacity of a toll, service times are required. With this knowledge, Padayhag (2003) was able to formulate a simple model in calculating the capacity of a toll booth.

$$C\ Toll\ Gate = \frac{3{,}600\ sec * N}{E(s)} \tag{5}$$

where,

C Toll Gate	: capacity of toll gate (vehicle / hour / lane)
N	: number of toll booths
E(s)	: average service time in toll booths (seconds / vehicle)

2.3 Simulation Process

Based on a research by Padayhag (2003), by doing a simulation process of the data gathered manually, one will be able to identify the consistency of the data and be able to determine the accuracy of the manually gathered data.

For their research, the arrival rate pattern used was Poisson Distribution and for the service rate pattern they used Normal Distribution for their randomness since it is the most common behaviour for both the service and arrival rate. From their research, they were able to develop the following models for Arrival Rate and Service Rate.

Arrival Rate Generator:

$$t_1 = -\left(\frac{1}{\lambda}\right)\ln(RN_1) \tag{6}$$

where,

λ	: average arrival rate (vehicles / hour)
RN_1	: Random Number from 0 to 1 (Poisson Distribution)

Service Rate Generator:

$$t_2 = -\left(\frac{1}{\mu}\right)\ln(RN_2) \tag{7}$$

where,

μ : average service rate (vehicles / hour)
RN_2 : Random Number from 0 to 1 (Normally Distribution)

By using these generators, they run the program for a period of two hours. Then compared the results obtained from the simulation to the manually obtained data. As a result, they were able to obtain an error that is less than 10% thus determining that the results obtained are precise more than 90% of the time.

3. FRAMEWORKS

3.1 Conceptual Framework

There are four parts for the study. It comprises of the data gathering, computation, simulation and comparison. Data gathering is done by acquiring video recordings and traversing through Balintawak and Bocaue Toll Plazas (Northbound and Southbound). Service time and Arrival time is obtained by observing the video recordings and measuring the time with the use of a stopwatch. The Service time is the instance the vehicle stops at the toll booth and leaves the toll booth. The Arrival time is the time it enters and leaves the benchmark. After which, the queue delay and capacity of each individual lane per hour is computed. To further assess the data, a simulation process is used. To make the simulation program's result realistic, the assumptions below are made.

Table 2. Assumptions for Replication of Existing Characteristics (Padayhag, 2003)

Arrival pattern	Random; Poisson distribution
Service Pattern	Exponentially distributed
Number of Servers/channels	Multi-server/ Multi-channel
Queue Discipline	First-in-first-out
Vehicle Composition	Vehicle mix considered homogenous
Approach time	Constant approach time
Minimum Speed Limit	60kph

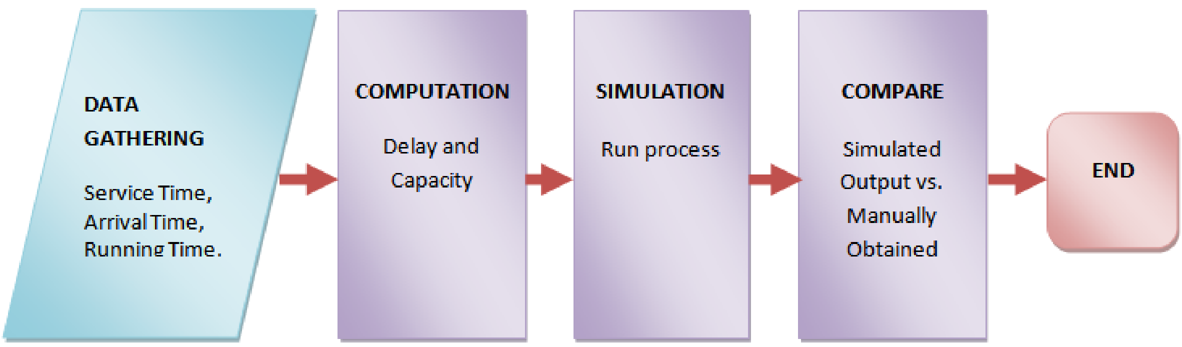

Figure 3. Conceptual Framework for NLEX

By making an arrival rate generator and a service rate generator from the assumptions made, the researchers are able to compare a simulated version of the data manually gathered. The manual outputs and simulated outputs are compared to each other for precision. The percent difference between the two should be less than 10% (Feng Bor Lin, 2001), otherwise the data gathering should be repeated.

3.2 Theoretical Framework

The evaluation of the performance of the different lane types in NLEX is analysed by getting the service time and delay of each lane type. The video recordings of the toll booths and toll plazas are the primary source of data which is provided by the Manila North Toll-ways Corporation or MNTC. All vehicles captured in the video streams are used for data; once the vehicle enters NLEX, the data gathering begins. When the vehicles enters NLEX, the researchers will then record each action it undergoes during its travels; these are the type of vehicle, the type of lane it undergoes, its arrival time at the toll booth, the delay it experienced, the service time before the vehicle is able to exit the toll booth and the type and amount of payment it offers. As shown in figure 4, the researchers will only follow and repeat the framework until the duration of the video stream is done.

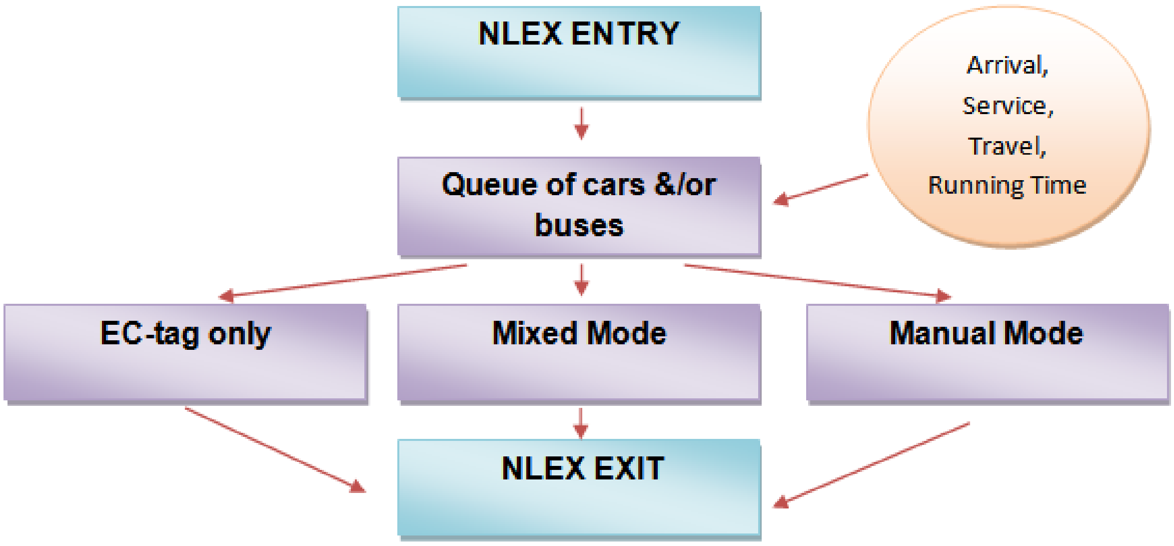

Figure 4. Theoretical Framework for NLEX

4. METHODOLOGY

4.1 Selection of Toll Plazas

Only those recognized by the Manila North Toll-way Corporation as the busiest toll plazas will be taken into consideration. The toll plazas have toll booths that are exclusive for specific modes of payment; ETC, Mixed, and Cash Only. There are also exclusive lanes for different vehicle classes (Class-1 Only, Class-1 & 2, Class-2 Only, and Class-3) to ensure the consistency of the data.

4.2 Gathering the Data

The MNTC provided the necessary video footages of the Toll plazas and Toll booths of North Luzon Expressway that were identified as the busiest; Balintawak and Bocaue Toll Plazas. The researchers were restricted to do an on-site toll booth surveying due to safety hazards and thus relied on the videos provided by the MNTC and on-site toll plaza surveying (the researchers used their own vehicle and EC-Tag) for the necessary data.

4.3 Tools

The tools used for this research were a stopwatch, counter and EC-Tag device. The Stopwatch is to acquire the service rates and arrival rates of each individual toll booth, the counter is to count the vehicles in queue and EC-Tag device is for evaluating the service time of ETC along the toll plazas (Balintawak and Bocaue).

The programs used for the study were Microsoft Excel 2010, Microsoft Word 2010, Windows Media Player, Incident Player and Microsoft Visual Basic.

4.4 Study Procedure

The researchers gathered the video recordings from Manila North Toll Corporation by weekly basis to process the data as soon as possible and to allot time for the videos to be exported; it takes 24-hours before a video recording is ready for export from the servers of MNTC. The videos acquired were three-hours long and within its span is the expected peak hour of the day. The videos taken were in the middle of the week and are recorded within a fairly-weathered day. Due to the unavailability of toll booth videos in ETC-dedicated lanes, the researchers manually collected the data using a class-1 vehicle and an EC-Tag device. The researchers drove along the specified toll plazas in a span of 4-hours and driving through their ETC-dedicated lanes and manually timing each transaction.

After gathering the video recordings, the researchers processed each video by manually timing each individual toll booths for their service time. They then record each individual's service time in an excel file. The researchers also comments on service times which are unusual (example, a 20 to 40 seconds difference from the others due to large bills or lax toll operator).

Figure 5. Toll Booth Footage for Service Time

For the arrival times of vehicles, the researchers set up a benchmark for the toll plaza video acquired from MNTC. When a vehicle enters the benchmark, the researchers records the time it takes for the vehicle to reach the other end of the benchmark. After which they then record the arrival time of each vehicle for a specific lane. The benchmark is set where only a maximum of 10 vehicles will be accommodated to verify the claim of MNTC that the toll plaza is configured such that only 10 vehicles in queue will be expected (2012).

Figure 6. Toll Plaza Footage with Benchmark for Arrival Rate

After getting all of the service times and arrival times for each individual lane, the researchers used Queuing Theory (see section 2.1 and 2.2) to determine the average waiting time of the lane for a specific type of payment, the average service rates, the average arrival rates, and capacity. The model for the capacity is used since not all toll booths are in operation.

After getting the values from queuing theory, the researchers did a simulation process similar to Padayhag (2003) in order to determine the precision of the data gathered from the research. The algorithm below, modelled after Padayhag's research, shows how the simulation is conducted; having the same parameters set by Padayhag (shown in table 2).

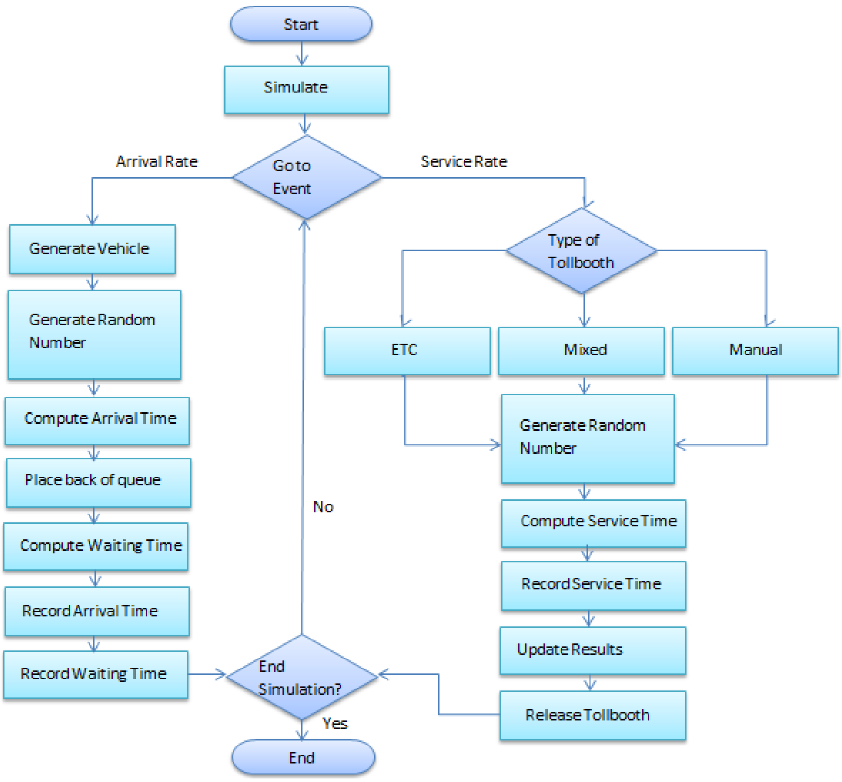

Figure 7. Simulation Algorithm

After determining the precision of the study and has not reached the 10% error validity limit (Lin 2001), the researchers expounded on the factors that affected the delays experienced at the toll plazas. The researchers then compared the service rates, and capacity of North Luzon Expressway to South Luzon Expressway which also uses an ETC system. The researchers also compared the data from North Luzon Expressway to the existing data available of ETC-using countries.

5. DATA ANALYSIS

The tables below represent the toll booth allocation for class 1 and class 2. For Balintawak, N01 to N13 corresponds to the toll booth1 to toll booth 13. The row below the toll booth number is the type of payment the toll booth caters. For Bocaue, the toll booth representation is from X01 to X17.

Table 3. Legend for Toll Allocation

Legend	Type
MPL	Cash Lane
MPL/ETC	Mixed Lane
ETC	Dedicated EC-Tag Lane
SPR	Spare Lane

Table 4. Balintawak Toll Allocation for Class 1 & 2 Vehicles

N01	N02	N03	N04	N05	N06	N07
SPR	ETC	ETC	MPL/ETC	MPL	MPL	MPL

N08	N09	N10	N11	N12	N13
MPL	MPL	MPL	MPL/ETC	MPL/ETC	MPL/ETC

Table 5. Bocaue Toll Allocation for Class 1 & 2 Vehicles

X01	X02	X03	X04	X05	X06	X07	X08	X09
SPR	SPR	SPR	ETC	ETC	MPL/ETC	MPL/ETC	MPL	MPL

X10	X11	X12	X13	X14	X15	X16	X17
MPL	MPL	MPL	MPL	MPL	MPL	MPL/ETC	MPL/ETC

Looking at tables 4 and 5, toll booths N11 to N13 and X16 to X17 are the only lanes that caters both class-1 and class-2 vehicles while the rest are solely for class-1 vehicles. Since some toll booths share class-1 and class-2 vehicles, it is expected that the queues formed will be longer since most class-2 vehicles are buses which has a spacious body that both contribute to the length of queue and the time of service. Also, most of the time there are only about 2 of the same toll lane types are open unless it is necessary. According to MNTC, the toll operators are given penalties if the queue of the lane they are operating reaches 20 thus the toll operators avoid such scenarios. If the toll supervisor sees that the queue in the toll plaza starts to get longer then the toll supervisor suspends the break of the toll operator and resumes his or her work. They do not open other toll booths unless the demand is getting higher. Example of which is the case of Bocaue Toll Plaza at night where some toll booths are closed off since the demand is not high.

Figure 8. Toll Operator coming back from break

Listed below are the tabulated results extracted from the video recordings. Except for the ETC-dedicated lanes (data was collected manually), the researchers obtained at least two videos for each specific lane type; due to the unavailability of the videos during the study period.

Table 6. Service Rates for Balintawak Toll Plaza

Toll No.	Mode	Service Time (sec/veh)	Service Rate (veh/hr)
2	ETC	1.64	2212
4	Mixed	10.71	336
5	Cash	7.68	469
6	Cash	9.66	373
9	Cash	8.21	438
11	Cash	38	121
12	Mixed	8.53	422
13	Mixed	8.35	431

Table 7. Service Rates for Bocaue Toll Plaza

Toll No.	Mode	Service Time (sec/veh)	Service Rate (veh/hr)
4	ETC	1.68	2145
6	Mixed	16.3	221
7	Mixed	8.33	432
11	Cash	15.45	233
12	Cash	16.32	221
13	Cash	16.24	222

Based from tables 6 and 7, it is seen that the service times of ETC lanes are very fast when compared to mixed lanes and cash lanes. For mixed lanes, it may be faster or slower to cash lanes. For the cash lanes for Balintawak and Bocaue, they are different because the toll rates are not constant for Bocaue unlike Balintawak which has a constant rate.

Table 8. Tabulated Inter-Arrival Times of Toll Plazas

	Arrival Times (sec/veh)		Arrival Rates (veh/hr)	
Mode	**Balintawak**	**Bocaue**	**Balintawak**	**Bocaue**
ETC	7.81	9.12	461	395
Mixed	20.87	16.62	173	217
Manual	65.84	33.44	55	108

The results in table 8 show the average inter-arrival rates of vehicles to the toll plazas from the benchmark. The arrival rates are from what the researchers are able to properly time due to the limitation of the visibility the video has as shown in figure 6.

Based from the observations of the videos of each toll booth and the data extracted from them, there are three factors that affects the service times of each individual toll booth. These are large bills, teller's work ethics, and the behaviour of the motorists.

To further asses the toll booths in the toll plazas, the researchers broke down what type of vehicles and what kind of transaction is undertaking inside the toll booth. The tables below show the percentage of transactions throughout the time period of the study.

Table 9. Overall Breakdown for Balintawak

Toll No.	Mode of Payment	Number of Users	Percentage (%)	Average Service Time (sec/veh)
5	Exact	40	14.18	6.3
	Large Bills	32	11.35	20.47
	Tap	54	19.15	5.1
	Normal	156	55.32	6.21
6	Exact	32	17.98	9.57
	Large Bills	20	11.24	18.93
	Tap	38	21.35	7.89
	Normal	87	48.88	8.28
9	Exact	34	17.53	6.84
	Large Bills	29	14.95	22.04
	Tap	12	6.19	5.54
	Normal	119	61.34	7.86
12	ETC	1	0.45	8.16
	Exact	40	18.18	6.61
	Large Bills	26	11.82	19.13
	Tap	8	3.64	6
	Normal	146	66.36	7.53
13	ETC	113	21.04	1.76
	Exact	64	11.92	5.75
	Large Bills	112	20.86	17.97
	Tap	22	4.1	5.55
	Normal	225	41.9	7.46

The researchers characterized the modes of payments as follows: Exact – giving the exact amount of money to the toll operator, Large Bills – the motorist gave bills of Php500.00, Php1000.00 and/or higher, Tap – an ETC used only by jeepneys in a form of a card (not catered in ETC-dedicated lanes), and Normal – bills that is neither exact nor large billed.

Motorists with large bills has the greatest impact for service rates; from an average of 6.21 sec/veh to 20.47 sec/veh in which the queue tends to get longer during this time. One reason is the toll operator authenticates the bill first then prepares the change and the receipt. The toll operator also must recount the change before giving it to the motorist. After which, the motorists recounts the money before departing the toll booth.

Figure 9. Authentication of Large Bills

To further evaluate this claim, the researchers grouped together all the motorists that give large bills for their toll payment. The figure 10 shows the percentage of the type of vehicle that gives out large bills.

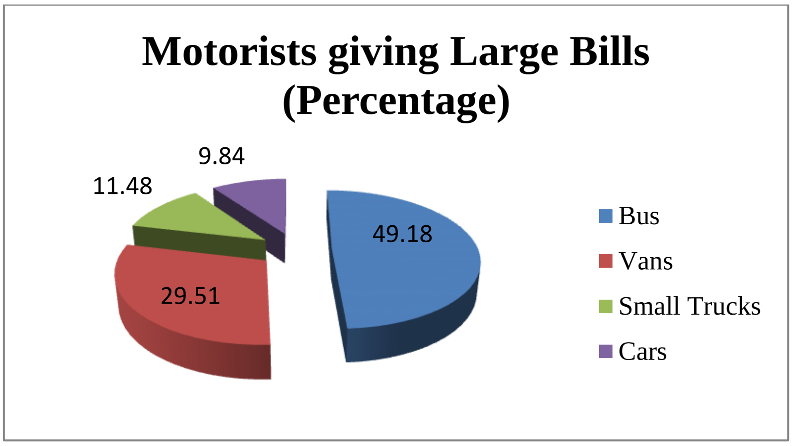

Figure 10. Pie Chart of Motorists giving Large Bills

Based on figure 10, it is seen that 49.18% of the time Buses gives out large bills for their payment at the toll. Primary reason is that bus conductors pay large bills in order to get small denomination of bills which they use as change for passengers. Thus with 49.18% of the time, the motorists will expect that there is a significant delay. This is a disadvantage for the ETC patrons who enter the mixed lanes where buses are, since their convenience is neutralized by the buses.

The researchers also noticed that the service time of a toll booth greatly decreases if the motorist gave the toll operator an exact amount; from an average of 16 sec/veh, it is reduced to a range of 4.0 sec/veh to 7.0 sec/veh (about 43.75% minimum reduction).

The EC-Tag lane's service time is virtually zero since before one vehicle halts to a full stop, the gate automatically opens letting the vehicle maintain its slow speed and exit the toll plaza. Although based from observation and manually timing the vehicle, the service times of EC-Tag lane varies from 0.2 seconds (this is true for small vehicles) up to 5.0 seconds (for those vehicles with big bodies such as mini trucks or buses). Unlike the small vehicles, that are usually used for leisure or work, is not required to halt to a complete stop, those with big bodies are required to halt to a complete stop before their EC-Tag may be read via scanners located at those EC-Tag catering toll lanes. Since the sensors are located above the toll booth and angled downward, the EC-Tag attached to the windshields of those big bodied vehicles are not scanned immediately when compared to those with small vehicles.

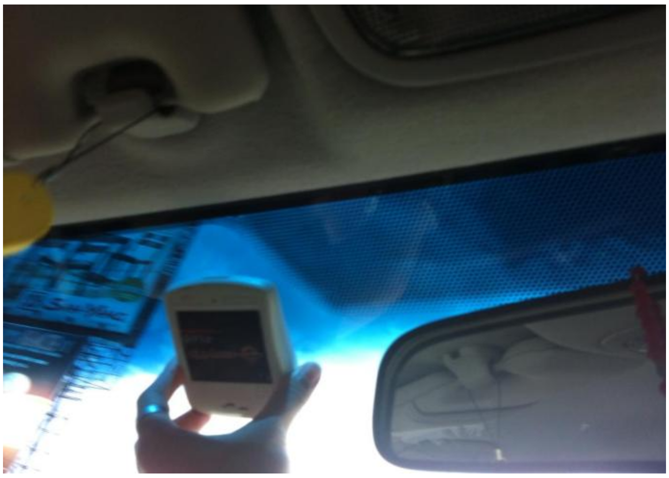

Figure 11. Proper Orientation of EC-Tag

The service times for cash only toll booths and mixed mode toll booths do not differ much in some cases like Bocaue. This is because motorists who frequently pass Bocaue do not experience heavy volume unlike Balintawak, which is the entry point of North Luzon Expressway. This also explains why some toll booths of Bocaue are not operational during the study process.

The work ethics of the toll operator also has an impact on the service time. Based from observations, some tellers tend to do unnecessary things like dancing or sometimes leave the toll booth unattended, probably due to boredom, fatigue, or plain laziness. As a result, the service times of the toll booth starts to depreciate. One solution to remedy the problem is to shorten the shift to maximum of two hours per shift.

Table 10. Summary of Capacity and Waiting Time

Toll Plaza	**Lane**	**Service Rate (veh/hr)**	**Arrival Rate (veh/hr)**	**Capacity (veh/hr/lane)**	**Delay (sec/veh)**
Balintawak	ETC	2212	461	2212	0.43
	Mix	396	173	396	7.00
	Manual	121	55	121	24.53
Bocaue	ETC	2145	395	2145	0.38
	Mix	327	217	327	21.83
	Manual	225	108	225	14.71

Based on table 10, the researchers can incur that ETC users has a lot of advantages with respect to time. There is a discrepancy in the mixed lane for Bocaue because the number of manual paying users outnumbers the amount of ETC using motorists that pass the lane.

One important point that the researchers were able to determine is that the cause of queues are not only because of the operators but also because of the drivers that do not leave the toll booth immediately after the service is rendered, giving results that should have yielded smaller waiting times.

To check the precision of the data that is manually gathered, the researchers based the generators Padayhag (2003) has used for her study for their simulation. The table below shows the summary of the simulation.

Table 11. Tabulated Comparison for Service Rates

Plaza	**Mode**	**Service Rate**		
		Manual	**Simulated**	**%Difference**
Balintawak	ETC	2212	2289	3.42
	Mixed	396	413	4.20
	Manual	121	115	5.08
Bocaue	ETC	2145	2328	8.18
	Mixed	327	322	1.54
	Manual	225	205	9.30

Table 12. Tabulated Comparison for Arrival Rates

Plaza	**Mode**	**Arrival Rate**		
		Manual	**Simulated**	**%Difference**
Balintawak	ETC	461	477	3.41
	Mixed	173	181	4.52
	Manual	55	52	5.61
Bocaue	ETC	395	429	8.25
	Mixed	217	213	1.86
	Manual	108	98	9.71

Based on tables 11 and 12, the researchers were able to validate the data they gathered by comparing the results of the simulation with that of the manually gathered data; they were able to satisfy the limits set by Lin (2001) that the maximum percentage difference should be only 10%.

The researchers then compared the results of North Luzon Expressway to the previous study on South Luzon Expressway to see if there is a huge difference between the two. Table 13 shows the tabulated comparison between the two.

Table 13. Comparison between NLEX and SLEX

Mode of Toll Collection	**Average Service Times (sec/veh)**		
	SLEX	**NLEX (Balintawak)**	**NLEX (Bocaue)**
Manual Lane	15.00	29.75	15.98
Mixed Lane	8.00	9.08	11.02
ETC Lane	1.92	1.63	1.68

Based from table 13, the researchers were able to notice that there is not much difference between the ETC lanes of both NLEX and SLEX; the results only yielded a percentage difference 16.50% and 13.49%, Balintawak and Bocaue respectively. It also appears that the NLEX's result for their ETC-Lane is faster by 0.3 seconds which people hardly even notice. For the comparison of their mixed lanes, the results yielded values in terms of their percentage difference are the following; 12.65% for Balintawak and 31.76% for Bocaue. This time it shows that SLEX has a faster service time with that of NLEX; SLEX is faster by 1.08 seconds up to 3.02 seconds which is also hardly noticed during transactions in mixed lane toll booths. The biggest difference between the two may be seen in their service times for manual lanes; the percentage difference between Balintawak and SLEX is about 65.92% (about 14.75 second difference from each other) than that of Bocaue which yielded a value of 6.33%. One factor that yielded that to this outcome is that unlike NLEX, SLEX's lane configuration is dedicated for one vehicle class only, making the vehicles with its corresponding service time more homogenous. It can be also inferred that the difference of times between the two expressways may be due to the number of toll booths catering for SLEX and NLEX; even though NLEX has more toll booths, not all booths are open unlike SLEX where all toll booths are operational.

But looking at the ETC-systems for both expressways, it can be inferred that there is not much difference between the two in terms of service times but rather they differ in the capacity they can accommodate since NLEX has more ETC-dedicated lane than SLEX. Thus it can be said that NLEX is more open to the possibility that they are going to cater more ETC-using motorists and can accommodate 2212 vehicles per hour (or up to 4424 veh/hr since NLEX has at least two ETC-dedicated lanes for each toll plaza) and the idea of advertising their ETC system to alleviate traffic congestions in the expressway.

After comparing the two expressways within the Philippines, the researchers compared the results for the Philippines represented by North Luzon Expressway to other ETC-using countries. The table below shows a tabulated comparison with the results of North Luzon Expressway being compared to other ETC-using countries.

Table 14. Comparison of Capacities

Country	**Capacity of Lanes (veh/hr)**		
	Mode of Payment		
	Manual Lane	**Mixed Lane**	**ETC-Lane**
Holland	-----	380 - 680	1800
OOCEA	300 - 480	450 - 500	1850
India	200 - 250	600 - 800	1600
Philippines	121	396	2212

Based from table 14, it can be seen that the Philippines is not behind to those other ETC-using countries. Although by comparing the manual and mixed lanes of Philippines to the other countries, it can be seen that in the Philippines is behind. One reason would be that the Philippines is still in the developing stage of their transportation system thus there are more room for improvement. The big difference in the manual scheme signifies that the Philippines has yet to come up with a better service system that would improve the performance of it. And since the North Luzon Expressway has just been rehabilitated and is still in the process of promoting the use of their ETC, it can be inferred that in the near future the values of capacity above for North Luzon Expressway will be bigger or at least equal to those other ETC-using countries.

6. CONCLUSION

The service times of manually operated toll booths solely rely on the following factors: work ethics of the toll operator, amount of bills paid, and behaviour of the motorists. For the service times of the EC-Tag, it seems that the service time differs according to what type of vehicle it is catering wherein the system has difficulties locating the EC-Tag attached to the windshields of vehicles that are big bodied (e.g. buses, small trucks).

With regards to the serviceability of mixed lanes, it seems that the convenience of having an EC-Tag passing through the toll plaza in a faster manner is neutralized. The amount of motorists using EC-Tag is almost the same as the amount of motorists giving out large bills to be able to exit toll plaza thus rendering the convenience of time for ETC-using vehicles to be nullified.

The toll operators do not open unused toll booths unless it is necessary due to the piling up of queue when it has reached a certain number (in this case, 10 vehicles in the queue). Thus the toll plazas should be able to perform better if they are to open more toll booths during the observed peak hours rather than waiting for the queue to build-up before taking any action.

The ETC of North Luzon Expressway and of South Luzon Expressway does not differ much in terms of serviceability but rather in terms of capacity. It is observed that NLEX is more open to the idea of implementing for the expressway that all or at least most of the motorists should be equipped with their EC-Tag for a more free-flowing traffic within the expressway.

In terms of capacity of individual lanes, it seems that the Philippines is still far behind when compared to other ETC-using countries with respect to Manual Payment and Mixed Payment. When it comes to the ETC-dedicated lanes, Philippines is not behind but rather in-line with the other ETC-using countries. This means that the Philippines, specifically North Luzon Expressway is still in the developing stage for the enhancement of its expressway for the Northern part of Luzon, consequently improving it with the implementation of EC-Tag and its continuing effort to entice other motorists to purchase and use EC-Tag as well.

Figure 12. Advertisement of EC-Tag

Although there were no new methods were used for the evaluation of ETC, there were changes made from the previous study by Padayhag (2003). One is that the researchers were able to take into consideration the type of vehicle the ETC is attached to which indeed affects how the performance of the ETC. Another difference the researchers were able to incorporate was the discovery of another ETC system being used in the toll plaza; the researches called it as Tap. Where if it were to be allowed to be used by all vehicles (the tap is exclusively for jeepneys as observed by the researchers) then the service times would be expected to be faster.

In conclusion, the researchers were able to determine the factors leading to the long service times of the two toll plazas, recognized by the Manila North Tollway Corporation to be the two of the busiest toll plazas in the whole expressway, are those motorists who pays huge bills, the behaviour of the toll operators, and the behaviour of the motorists themselves. The researchers were also able to determine that the toll plazas can perform better if all the toll booths are opened especially during peak hours rather than the waiting for the queue to pile-up. They also inferred that NLEX makes a lot of effort in promoting their ETC system to public transport (EC-Tag for Vans and Buses, Tap for Jeepneys). They also concluded that the NLEX and SLEX does not differ much in serviceability in terms of service times but rather the capacity of the volume they can handle and that NLEX is more versatile in terms of future enhancements, if it is called for. The researchers also concluded that the Philippines, represented by North Luzon Expressway, is not far behind in the technology of Electronic Toll Collection but rather behind in the implementation of it, thus the difference of capacity the toll booths can handle, particularly in the mixed mode lanes.

7. RECOMMENDATIONS

By reducing the service time of each individual toll booth, the queue lines will also have a smaller queue therefore accommodating more vehicles. The three factors that affect each individual toll booth could still be resolved by making some simple changes.

One of the recommendations by the researchers is to separate class 1 vehicles from class 2 vehicles. This is because buses takes up a lot of space and takes up a large amount of time before it is finished with the transaction and leaves the toll booth for the next vehicle to be served. Thus by separating the two, class 1 vehicles, especially the ones with EC-Tags, can pass through the toll plaza without being inconvenienced by the class 2 vehicles.

Another recommendation from the researchers would be to open up more lanes especially during peak hours to avoid long queues. Though they are able to maintain their claim of a maximum of 10 cars in the queue, it would still be better to avoid such queues and deliver customer satisfaction for the motorists to be able to attract more motorists in the future. Also, the researchers also recommends that instead of allocating more manual lanes for class 1 vehicles, they should lessen the allocation and add more for class 2 vehicles since they are main cause of why a queue is built-up. Furthermore, the researchers advise that there be a lane for those motorists who pay the exact amount of toll, adding another type of lane that caters EXACT or EXACT/ETC.

Lastly, almost all public utility jeeps (PUJs) use a card to pay for the toll; the PUJ driver gives the card to the toll booth operator and the operator taps the card to a device (shown in figure 13). After which, the operator gives back the card to the PUJ driver at the end of the transaction. Thus, the researchers also recommend changing the location of the tap device for PUJ; by relocating it to a reachable spot that the drivers can tap the card by themselves to reduce service time and accommodate more motorists.

Figure 13. Toll Operator using tap device for PUJs

REFERENCES

Al-Deek, H. & Klodzinski, J. (2003). Evaluation of Toll Plaza Performance from Adding Express Toll Lanes at a Mainline Toll Plaza. *Transportation of Research Board 83rd Annual Meeting.*

Dalu, S. (2012). AETC: An Automated Electronic Toll Collection Using Zigbee. *International Journal of Information Technology and Knowledge Management*. Vol 5, No. 1, pp. 1-3.

Diaz, C., Madrigal, J., Mappala, A., Palmiano, H., & Sigua, R., (2005) Allocation of Electronic Toll Collection Lanes at Toll Plazas Considering Social Optimization of Service Times and Delay. *Journal of the Eastern Asia Society for Transportation Studies*, Vol 5. 1496-1509

Hill, J. & Rich, J. (2010). How to do Capacity Planning. Retrieved on: August 21, 2012. Retrieved from: http://www.teamquest.com/

Kamarulazizi, K. & Ismail, W. (2010). Electronic Toll Collection System Using Passive RFID Technology. *Journal of Theoretical and Applied Information Technology.*

Levinson, D. & Chang, E. (2003). A Model for Optimizing Electronic Toll Collection Systems. Retrieved on: June 4, 2012. Retrieved from: www.elsevier.com/locate/tra.

Macababbad, R. & Regidor, J. (2009). ITS: Traffic Baseline Information Obtained Using Probe Cars is the Key to Address Metro Manila Traffic Congestion. *17th Annual Conference of the Transportation Science Society of the Philippines.*

Makino, H. & Tsuhi, H. (2006). Electronic Toll Collection System of Japan. *PIARC International Seminar on Intelligent Transport System (ITS) In Road Network Operations.*

Montalbo, C., Ishida, H., Okamoto, N., & Tsutsumi, M. (2005). A Study on the Acceptability of the ETC in Metro Manila and a Framework for Estimating its Environmental Benefits. *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 6, 2530 – 2545

Nosek, R. A. Jr. & Wilson, J. P. (2001). Queuing Theory and Customer Satisfaction: A Review of Terminology, Trends, and Application to Pharmacy Practice. *Journal of Hosptital Pharmacy*, Vol 36, No. 3. 275–279

Padayhag, G. & Sigua, R.. (2003) Evaluation of Metro Manila's Electronic Toll Collection (ETC) System. *Journal of the Eastern Asia Society for Transportation Studies*, Vol 5. 1946-1961

Schmitt, D. (2003). Modeling Toll Plaza Performance. *University of Massachusetts Darmouth.*