REVIEW DRAFT

I-5 Columbia River Crossing Partnership:
Traffic and Tolling Analysis

Identification and Evaluation Of Plaza Operation Models

Working Paper 3.3

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PLAZA MODEL OVERVIEW

The purpose of this working paper is to identify and evaluate the operational models that are available to analyze toll plaza conditions. Vollmer has extensive experience in working with toll facilities in a number of states to develop plaza operations models to process traffic more efficiently.

Recent examples include toll plaza work done for the Garden State Parkway and the New Jersey Turnpike in New Jersey. We were hired by the New Jersey ETC Consortium prior to the implementation of Electronic Toll Collection (ETC) on the Parkway and the Turnpike in order to help design the toll plaza layout to include ETC. Hourly plaza models were developed to estimate the future market share rates of ETC in order to determine the number of dedicated lanes that would be needed for each of the payment types (ETC, manual, and automatic coin machines) at the existing toll plazas. These two roadways have some 55 toll location points over a combined 292 miles, and the characteristics of each of the plazas vary greatly.

We have also performed plaza operations studies in Georgia, Texas, New Hampshire, West Virginia and at the Peace Bridge in New York State. Studies have included processing rate analyses, queuing studies, ETC plaza layout, lane assignment and corresponding staffing requirement analyses, among others. Many years ago, we worked with toll authorities to optimize their lane assignments between automatic and manual collection. As time progressed, we worked with the same authorities to implement ETC, both out in the toll plaza, as well as in the back-office implementation. Now, since ETC has become more common, we are still working with the same authorities to implement open road tolling into these same plazas. Each project has been unique, but the methodology of determining plaza sizes and layout operations based on demand and observed traffic processing rates has been the same.

We have developed a series of spreadsheet models that can be applied to individual toll plazas in order to analyze their overall operations. There are several factors that are input to each model, and the outputs are hourly lane requirements for manual and/or electronic tolling alternatives. For the I-5 Columbia River Crossing Partnership: Traffic and Tolling Analysis, this spreadsheet model plaza operations forecast methodology can be applied quite efficiently to size plazas by payment type.

Toll Plaza Dynamic Simulation

Models have been successfully used to simulate toll plaza operations, and are quite effective in helping to visualize the operations at a toll plaza. The level of effort required to run this type of model is greater than what needs to be done to develop and run the spreadsheet models, especially for the level of analysis required for this project. Simulation models do not size toll plazas, rather, they provide information about the operating conditions. For this project, the plaza needs to be sized and the lane alignments determined in order to be modeled using simulation; this is all output from the spreadsheet model.

As part of a project for the MTA Bridges and Tunnels in New York City, we developed a year-long calibrated toll plaza simulation model, and found that the results were within a few percentage points difference using our spreadsheet models. In addition, we conducted a toll plaza operations study for the New Hampshire DOT to examine the number of high speed ETC lanes and manual cash lanes required to serve the demand at the I-95 Hampton Toll Plaza. A spreadsheet toll plaza capacity model determined that 2 high-speed lanes and 9 manual lanes are required to adequately serve a maximum one-way demand of some 6,000 vehicles. Subsequently, a simulation model was developed using the Paramics software modeling tool, and the simulation confirmed that the toll plaza configuration determined by the spreadsheet capacity model would not produce any vehicle queues at the toll plaza.

VISSIM

The VISSIM model is an example of an available toll plaza simulation model. While VISSIM has been used in toll plaza operations simulation, the spreadsheet model is a more efficient tool for this project's level of analysis. VISSIM would be a useful tool to simulate toll plaza operations when plaza refinements are needed on an existing layout. In addition, VISSIM is useful in queue analysis and in determining if plaza queues back up into upstream interchanges and ramps. The visual tool provided by VISSIM cannot be provided by a simpler spreadsheet model.

The time needed to set up the VISSIM model for this project would be great in order to simulate the plaza activity and processing rates. There is no existing toll plaza that can be entered into the VISSIM model, and this generic demand input would be generated from a simpler spreadsheet demand model as a starting point. In addition, manual overrides would be required to properly use VISSIM to determine the delays associated with paying a toll for non-open road tolling scenarios. Additional programming would be required to model the impact of conflict modeling (weaving and merging) that would occur before, at and downstream of the toll plaza. This detail is a level of sophistication that exceeds the scope of this phase of work.

In addition, much of the modeling and analysis that has been done in the Portland/Vancouver region has focused on the peak periods of travel. The VISSIM output would continue this trend, by focusing on specific hours of peak traffic. While the peak hour is important to be able to model, as it often drives the lane requirements, it is also important that the toll plaza operates efficiently during other times of the weekday as well as on weekends when the traffic is made up of a very different group of travelers with varying electronic toll collection (ETC) market shares and plaza demands. VISSIM could be used to analyze non-peak periods, but that would require generating multiple model runs and could prove to be time consuming.

Spreadsheet Model

The Garden State Parkway and New Jersey Turnpike spreadsheet models were the result of a significant data collection effort in which frequency of use and familiarity with E-ZPass (electronic tolls) information was collected. Based on this extensive field research plus other similar data collection, we have developed a solid base of information that has been used successfully and efficiently in plaza operations models to predict electronic toll collection market share rates and various other payment type breakdowns based on the toll structures in place.

The inputs that are needed for the spreadsheet model development are listed below and detailed in the I-5 Corridor Application section that follows:

- Toll Rate – The first decision to be made must be the development of a toll schedule. What is the base toll for passenger cars? Are there going to be HOV discounts or time of day discounts? What will be the truck toll differential? These toll policies need to be determined by the project team.

- Payment Type – Once the toll rate is determined, then the vehicle classes will be broken down into exact change, cash with receipt and/or change, and ETC. ETC can be done using either high-speed lanes (open road tolling) or by using toll plaza lanes. Payment types will be developed in working with the project team.

- ETC Market Share – The major factors that determine the ETC market share will include the existing ETC use in the region, the amount of marketing and promotion that will go into the ETC program, and whether or not there will be a discount for ETC use. Market share rates will be determined based on experience in other regions.

- Processing Rates – Once the above factors are determined, then processing rates can be analyzed. The processing rates for cash patrons will be based on the amount of the toll and how many coins/dollars are needed for payment and how many coins/dollars will be given as change. A $1 toll is easier to collect than is a $1.15 toll; and a $1.25 toll is easier to collect than a $1.15 toll. The ETC processing rates will be determined by whether it is high-speed or collected through a toll plaza lane. Vollmer will determine these rates based on prior experience.

The spreadsheet model will provide a snapshot of a 24-hour period, using either typical weekday and/or weekend tolled traffic volumes with graphic outputs that provide a look at the entire day's toll plaza demand. A sample of a Garden State Parkway toll plaza output is provided in Appendix A. This spreadsheet is a sample of one site out of approximately 40 toll plazas that were analyzed to size the number of lanes for ETC installation. Each of the 40 sites had four analysis days (May weekday, May Saturday, July weekday, and July Saturday), which led to over 160 days that the ETC requirements were examined. The amount of seasonality in the I-5 and I-205 corridors as well as the difference between weekday and weekend traffic will determine if separate analyses will need to be performed for this project.

I-5 Corridor Application

The I-5 and I-205 Columbia River crossing plaza operations spreadsheet models we recommend for use are based on 24-hour tolled volumes forecast at the toll collection points. Each hour's total volume will also be broken into vehicle type: SOV, HOV and Trucks. The hourly traffic volumes will also be categorized into off-peak, shoulder, and peak periods, since the driver characteristics are likely to vary between the periods. During the peak commuting hours, it is likely that the share of auto trips is high, while the commercial truck trips are low. During the off-peak periods, the relative share of commercial vehicle traffic in the corridors would likely be higher. In addition, the ETC adoption rates are likely to be higher during the peak periods, since the share of frequent, regular travelers will be the greatest during this time, and these travelers are most likely to use ETC because of the ease of use, or for financial incentives.

Model Input

There are several decision-making steps that are used as input in the operations models as discussed in the following sections.

Toll Rate

The toll rate policy will need to be determined and applied to the various vehicle types in the corridors. At the outset, we will estimate a toll to be charged in order to cover the debt payments for project area improvements (costs to be provided by others). This will be a starting point, and we can work with the team to develop a detailed toll rate policy that sets rates for passenger cars and trucks, and determines what/if any discounts will be applied to HOV and/or ETC payments. For example, HOVs may receive discounted toll rates in order to encourage carpooling during the peak periods, while trucks may be charged different rates during peak periods in order to reduce truck traffic during high-volume commuting hours.

Payment Type

The next modeling step is to estimate what payment types will be accepted at the toll plaza. Based on preliminary discussions, it is our understanding that exact change baskets will not be considered in these tolling scenarios since the toll rate will likely be $1 or higher. Remaining modes of payment include manual and electronic toll collection. Manual lanes will have a mix of exact change customers and customers who will need change made and/or receipts provided. ETC is another option, and can be implemented in high-speed lanes as well as in tollbooth collection. The payment type can be expected to change as time goes on and as the ETC market share becomes greater. For this reason, we would perform an "early" and "steady state" estimate of payment type mix.

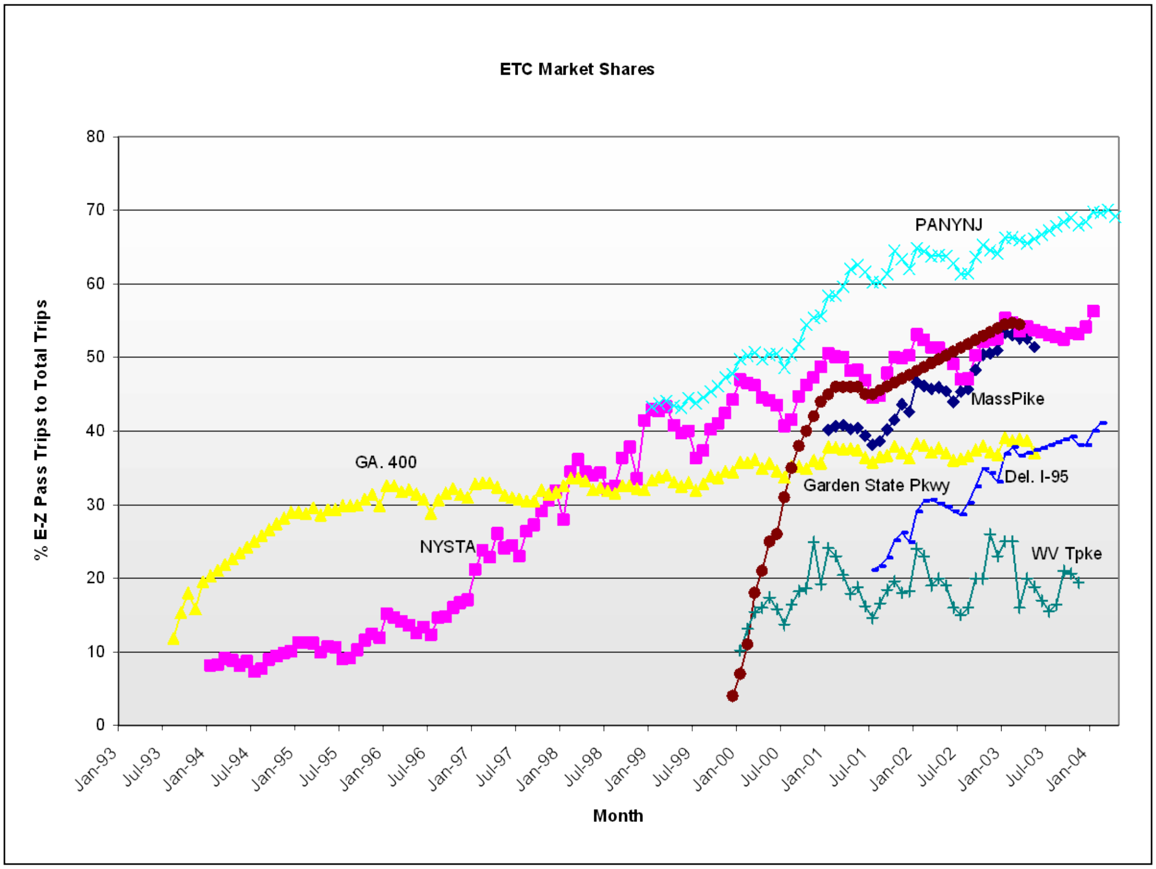
Processing Rates

Vollmer has measured processing rate information for a variety of tolls and has developed a range of processing rates to be used in plaza operations models. Depending on the toll amount and collection method, ETC could be anywhere from two to six times faster than manual toll collection. Manual toll collection rates could range from 300-500 vehicles per lane per hour (vplph), and ETC could range between 1,200 vplph for tollbooth collection to approximately 2,000 vplph in high-speed collection lanes. Specific rates will be determined for this project when the plaza lane requirements are determined.

ETC Market Share

The ETC market share will be estimated for an "early" timeframe, which may be within 0-6 months of tolling initiation, as well as for a future timeframe under steady state conditions. The ETC market share percentages will be determined based on our experience in other areas of the country where similar tolling systems have been introduced. The following figure shows the ETC market share rates and how they have increased over the years with the growth of ETC. This figure includes the New York State Thruway, Garden State Parkway, West Virginia Turnpike, Massachusetts Turnpike, I-95 in Delaware, Port Authority of New York and New Jersey crossings, and Georgia 400. In some cases missing data was extrapolated.

Figure 1 – ETC Market Shares



A review of the figure suggests that there are several factors at play in the evolution of a toll system's market share of E-ZPass use. The New York State Thruway continued to grow as other agencies were added to the E-ZPass system. However, some of those new agencies have exceeded the system wide E-ZPass market share of the Thruway. Factors such as frequency of travel, proximity to other facilities, discounts and travel time advantages all contribute. In reviewing the data, the single factor that correlates across the data is frequency of travel. West Virginia's market share when compared to the Port Authority's (which serves the high commuter traffic into and out of New York City) is the best example of this.

The ETC ramp-up rates will be combined with experience that we have working in Colorado on new toll roads to determine how the I-5 Corridor travelers will react to paying a toll. In addition, we will use market share information gathered from both Southern and Northern California toll facilities.

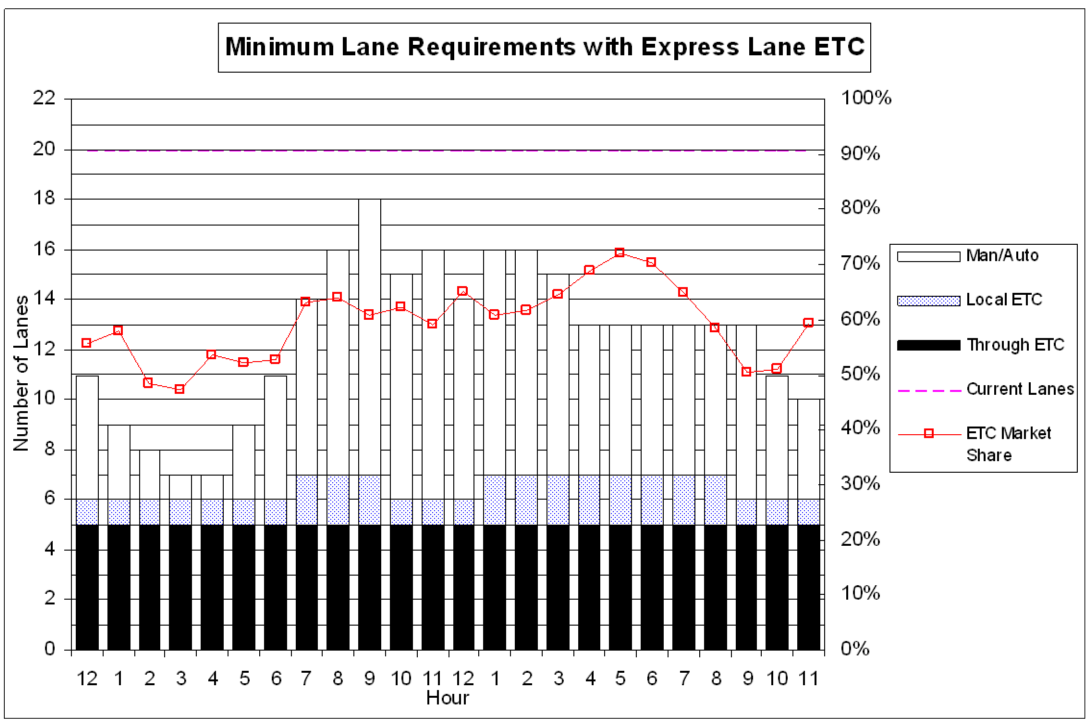
The early and steady state analyses are important in the design and sizing of the toll plaza operations since tolls must be collected on the first day when the electronic toll collection market share will be at its lowest point. Because of space restrictions, it is likely that a significant marketing effort will need to be conducted in order to have a high electronic toll collection market share penetration on the opening day.

Calculations and Operating Plans

Based on traffic volume and market share, the model calculates future volumes for each transaction type. The estimated number of lanes is calculated by dividing the volume by the processing rate, and manual lanes will remain separate from ETC lanes since cash paying customers cannot use ETC lanes. The summary operating plan generated for each model proposes to use the greatest number of ETC lanes required during the 24-hour period and to staff the manual lanes by their hourly needs. If two-way collection is implemented, then the minimum number of lanes needed will be determined to analyze the option of using reversible lanes.

The following figure is a sample of the output graphics, showing the lane requirements at a 20-lane toll plaza with manual, automatic, "local" ETC (toll booth) and "through" ETC (high speed) lanes. At this toll plaza, there are a total of 20 possible lanes that are available to be used. A total of five high speed ETC lanes are needed at the plaza. These lanes process vehicles at highway speeds and are not variable throughout the day. The other lane requirements by payment type can vary throughout the day in order to meet changing traffic demands. At 3am, one local ETC lane and one manual/automatic lane need to be open, while at 5pm, two local ETC lanes and 6 manual/automatic lanes are required. During the PM Peak (5pm), the ETC market share is at it's peak (over 70%), and since more vehicles can be processed through ETC than through the manual lanes, the overall lane demand is less than it is during the midday when the market share using ETC is less (between 60-65%).

Figure 2 – Sample 24-hour Spreadsheet Model Output



The spreadsheet model previously used in Delaware and New Hampshire has estimated queues associated with toll plazas. Both upstream and downstream entrance and exit ramps are taken into consideration when determining the plaza layout and lane dedication in order to minimize the need for multiple-lane weaving. Similar analyses can be done to determine the impact of close entrance and exit ramps along the Columbia River crossings.

Recommendation

At the Phase 2 level of effort, it is suggested that the spreadsheet models of toll operations be used to estimate the appropriate design and configuration and likely market analysis of Electronic Toll Collection. The spreadsheet models would provide an efficient 24-hour analysis of toll plaza demands to size the toll plaza. Having worked on dozens of toll plaza operations studies, we are able to fairly quickly and easily, and without the use of simulation models, come to the answer needed at this stage of work. There are various aspects of toll plaza design where simulation models, such as VISSIM, are particularly effective. But again, at this stage of work, we do not believe they are necessary to provide the answers needed for this assignment.

APPENDIX A

Sample Spreadsheet Model Output

A

Garden State Parkway ETC Forecast Model

B

Highway :	Garden State Parkway	
Facility:	Bergen Mainline	
Direction:	Northbound	
Day:	Wednesday May	
Min Lanes:	9	
Max Lanes:	10	

Payment Method	Time of Day	ETC Mkt. Share 3-6	ETC Mkt. Share 6-12	Proc. Rate (veh/hr)
Cash	Peak	49%	56%	450
	Shoulder	48%	61%	
	Off-Peak	55%	62%	
Token	Peak	64%	69%	800
	Shoulder	66%	71%	
	Off-Peak	68%	74%	
Coin	Peak	63%	68%	800
	Shoulder	61%	68%	
	Off-Peak	56%	64%	
ETC Processing Rate:				1200

Lane No.	Plaza Setup - Min. ETC P	S	O	Plaza Setup - Max. ETC P	S	O	Current Plaza	
1							A	(far side branch)
2							M	(far side branch)
3							M	(far side branch)
4							M / A	(far side branch)
7							M	
8							A	
9							A / TKN	
10							M / A	
11							M / A / TKN	
12							M	

Number of lanes	Reg	Branch
Automatic		
Manual		

	3-6 Peak	Shoulder	OffPeak	6-12 Peak	Shoulder	OffPeak
Switch Token to Cash	0%	0%	0%	0%	0%	0%
Switch Token to Coin	0%	0%	0%	0%	0%	0%
Switch Coin to Cash	10%	10%	10%	10%	10%	10%
Tokens Phased Out		no			no	

C

D

Minimum Number of Lanes	
Manual	1
Automatic	1
ETC	1

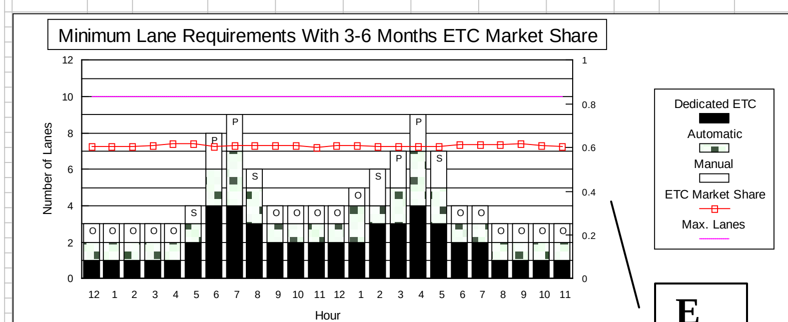
Total Lanes Used: 10 10 10 | 10 10 10

THREE TO SIX MONTHS ETC

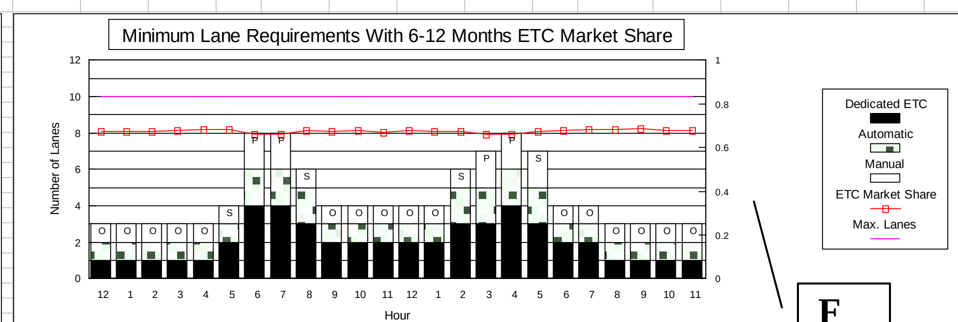
Time	Time of Day	Total Weekday Volume	CURRENT VOLUME Cash	Token	Coin	FUTURE VOLUME Cash	Token	Coin	ETC	ETC Market Share	Required # of Lanes Manual	xcess cap	Auto	xcess cap	ETC	xcess cap
12m-1 am	O	170	15	62	93	11	20	36	103	61%	0.02	439	0.00	800	0.09	1096
1-2	O	113	5	39	69	5	12	27	68	61%	0.01	444	0.00	800	0.06	1131
2-3	O	104	12	35	57	8	11	22	63	60%	0.02	442	0.00	800	0.05	1137
3-4	O	188	21	74	93	13	23	36	115	61%	0.03	436	0.00	800	0.10	1085
4-5	O	663	119	309	235	63	98	92	410	62%	0.14	386	0.00	800	0.34	790
5-6	S	2733	367	1367	999	229	468	346	1690	62%	0.51	220	0.74	205	1.41	710
6-7	P	5975	1224	3036	1715	690	1099	570	3617	61%	1.53	210	1.82	141	3.01	1183
7-8	P	6496	1215	3274	2007	696	1185	667	3949	61%	1.55	204	2.06	752	3.29	851
8-9	S	3982	710	1765	1507	427	604	522	2428	61%	0.95	22	1.38	495	2.02	1171
9-10	O	2863	578	1102	1183	310	348	464	1742	61%	0.69	139	0.84	127	1.45	658
10-11	O	2798	551	1084	1163	297	342	456	1703	61%	0.66	152	0.81	154	1.42	696
11-12n	O	3059	743	1062	1254	387	335	491	1846	60%	0.86	63	0.95	36	1.54	554
12n-1 pm	O	2862	459	1096	1307	262	346	512	1742	61%	0.58	187	0.84	129	1.45	658
1-2	O	3275	680	1263	1332	362	399	522	1992	61%	0.80	87	1.04	766	1.66	407
2-3	S	4096	857	1656	1583	506	567	549	2474	60%	1.13	393	0.90	77	2.06	1125
3-4	P	5109	992	2413	1704	570	873	566	3099	61%	1.27	329	1.39	489	2.58	500
4-5	P	6499	1350	3164	1985	764	1145	660	3930	60%	1.70	136	2.09	731	3.28	869
5-6	S	5320	1157	2397	1766	669	821	612	3218	60%	1.49	230	1.50	397	2.68	382
6-7	O	3211	634	1348	1229	337	425	482	1967	61%	0.75	112	0.99	5	1.64	433
7-8	O	2019	290	874	855	167	276	335	1241	61%	0.37	283	0.41	472	1.03	1158
8-9	O	1622	202	711	709	121	224	278	999	62%	0.27	328	0.22	625	0.83	201
9-10	O	1200	97	552	551	67	174	216	743	62%	0.15	382	0.01	791	0.62	457
10-11	O	781	77	312	392	52	98	154	477	61%	0.11	398	0.00	800	0.40	722
11-12m	O	373	33	137	203	24	43	80	227	61%	0.05	426	0.00	800	0.19	973
24 hour total		65511	12388	29132	23991	7039	9936	8694	39842	61%						

SIX TO TWELVE MONTHS ETC

Time	Time of Day	FUTURE VOLUME Cash	Token	Coin	ETC	ETC Market Share	Required # of Lanes Manual	xcess cap	Auto	xcess cap	ETC	xcess cap
12m-1 am	O	9	16	30	115	68%	0.02	441	0.00	800	0.10	1084
1-2	O	4	10	22	76	68%	0.01	445	0.00	800	0.06	1123
2-3	O	7	9	18	70	67%	0.01	443	0.00	800	0.06	1129
3-4	O	11	19	30	128	68%	0.02	438	0.00	800	0.11	1072
4-5	O	53	80	76	454	68%	0.12	396	0.00	800	0.38	746
5-6	S	177	398	290	1868	68%	0.39	272	0.52	383	1.56	532
6-7	P	598	932	493	3952	66%	1.33	301	1.40	476	3.29	847
7-8	P	604	1005	577	4311	66%	1.34	296	1.61	314	3.59	489
8-9	S	329	514	437	2702	68%	0.73	121	1.04	769	2.25	898
9-10	O	259	287	380	1937	68%	0.58	190	0.60	323	1.61	463
10-11	O	249	282	374	1894	68%	0.55	201	0.57	345	1.58	506
11-12n	O	324	276	403	2056	67%	0.72	125	0.69	245	1.71	344
12n-1 pm	O	219	285	420	1938	68%	0.49	230	0.59	324	1.61	462
1-2	O	303	328	428	2215	68%	0.67	146	0.76	189	1.85	184
2-3	S	389	482	459	2765	68%	0.87	60	1.10	718	2.30	835
3-4	P	495	741	490	3384	66%	1.10	405	1.03	774	2.82	216
4-5	P	663	971	571	4295	66%	1.47	237	1.63	295	3.58	505
5-6	S	514	698	513	3596	68%	1.14	386	1.03	775	3.00	4
6-7	O	282	351	395	2183	68%	0.63	167	0.72	221	1.82	216
7-8	O	140	227	275	1377	68%	0.31	310	0.24	607	1.15	1022
8-9	O	101	185	228	1108	68%	0.22	348	0.08	735	0.92	92
9-10	O	56	144	177	823	69%	0.12	393	0.00	800	0.69	376
10-11	O	43	81	126	531	68%	0.10	407	0.00	800	0.44	669
11-12m	O	20	36	65	252	68%	0.04	430	0.00	800	0.21	947
24 hour total		5850	8357	7277	44028	67%						



E



F

Note: P = Peak, S = Shoulder, O = Off-Peak

A. Location Information – This sample model is for the Bergen Toll Plaza (NB direction) on the Garden State Parkway. The traffic data is for a weekday in May, which is non-summer peak volumes. The minimum number of lanes available at this plaza is 9, and the maximum number of lanes available is 10 lanes. This means that there is one reversible lane that can operate northbound or southbound, as needed.

B. ETC Market Share Estimates – This table was created based on data collected in driver surveys, and is used to determine what share of existing cash, token and coin users will transfer to ETC at various times of the day (peak, shoulder and off-peak). For this project, there are two projections – the 3-6 month ETC market share and the 6-12 month ETC market share. This portion of the Parkway has a high concentration of commuters who are regular peak period travelers. Looking at this table, 49% of existing peak hour cash users, 64% of the existing peak hour token users, and 63% of existing peak hour coin users are projected to switch to ETC within 3-6 months of implementation. These numbers are looked up for each payment type in the hourly table below.

Processing rates are also provided for the various payment types. Cash payments are processed at 450 vehicles per hour, while token and coin transactions are much faster at 800 vehicles per hour. These rates are used to determine how many lanes are required to process the hourly volumes, and will vary depending on the toll rate charged and the type of ETC (high speed or tollbooth).

C. Existing Traffic Information – This portion of the model details the existing traffic data. This model was completed prior to the implementation of ETC, so the payment types only include cash (requires change), token and coin (exact change). The Garden State Parkway does not allow trucks, so no trucks are included.

D. 6-12 Month Projection – This segment of the model looks at the hourly volumes by payment type, assuming that ETC has been in use for 6-12 months. Looking at 6-7am, which is a peak hour, there are 598 cash paying, 932 token paying, 493 coin paying, and 3,952 ETC vehicles that need to be processed through the toll plaza. The ETC market share during this hour is 66%, which is derived from a mixture of cash, token and coin users switching to ETC. 598 cash paying drivers will require 1.33 lanes to be processed (598 divided by 450 veh/hr). This is then rounded up to 2 manual lanes. Excess capacity in the manual lanes can be used by exact change or token users who would simply hand their money to a toll collector. Assuming that these 301 vehicles (.67 of manual lane extra capacity = .67*450 = 301 vehicles) are processed in the manual lanes, that leaves 932 (token)+493 (coin) – 301 (using manual lane) = 1124 vehicles to be processed through an automatic lane. Using the automatic processing rate of 800 vehicles per hour, 1.40 automatic lanes are needed (round up to 2 lanes). Finally, the 3,952 ETC hourly drivers can be processed using 4 ETC lanes (3,952/1,200 per lane) = 3.3 lanes.

E. 3-6 Month Minimum Lane Requirement Graph - In the short term (3-6 months) with relatively low ETC market shares, nine lanes are needed to process peak traffic.

F. 6-12 Month Minimum Lane Requirement Graph – Over time, higher ETC market shares reduce the total number of lane from nine to eight lanes.