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Technical Memorandum

Date: October 13, 2015

To: Maine Turnpike Authority

From: Rick Gobeille, P.E.

Subject: York Toll Plaza Replacement Project
Toll Plaza Lane Analysis

PURPOSE

This study was conducted to determine the number of toll lanes that would be required for the design of the York Toll Plaza Replacement Project. During the course of this analysis, considerations were made for a range of parameters, including multiple annual growth rates of traffic, a range of E-ZPass Transponder market shares and an analysis of lane needs during the construction phasing for the project. The toll plaza lane analysis provided in this technical memorandum was first presented to the Maine Turnpike Authority Board on December 18, 2014. This memorandum updates our analysis to include the last full year of data.

METHODOLGY

Jacobs developed a static spreadsheet-based model of the York Toll Plaza. The model utilizes the traffic data collected, toll transaction processing rates appropriate for the various methods of payment, designation of staffed lanes and open road toll lanes (ORT) and the effects queueing has on traffic.

We first requested detailed toll transactions for a full year from September 1, 2014 through August 31, 2015. Data was provided that segmented traffic by hour, by lane, by vehicle class and by method of payment. Our modeling considers traffic on a continuous 24 hour basis because queues occur over time. A queue resulting from one hour of very high traffic volume that exceeds capacity can recover quickly if subsequent hours have lower traffic volumes. Morning and afternoon rush hours are typical of this. Conversely, extended periods of traffic that exceed capacity by smaller amounts may generate significantly longer queues in both duration and length. Thanksgiving and major holiday weekends are examples of this.

With the adoption of E-ZPass, the key element in the sizing of toll facility lane requirements is the volume of cash-paying traffic. A plaza should be designed to accommodate periods of highest total, E-ZPass and cash paying traffic volumes. Highest cash-paying traffic volumes often occur during holiday and weekend peaks when the percentage of cash-paying traffic is highest. The Jacobs model addresses each of these conditions.

As presented to the Turnpike and agreed to, we utilized the 15th highest days for total traffic and cash paying traffic as the baseline threshold for establishing lane requirements. In the design year, there should be no significant queues for the 15th and each subsequent day for the balance of the year.

SUMMARY OF DATA COLLECTED

As part of the analysis, daily traffic volumes were ranked by total daily volume and total cash volume. As expected, the highest traffic volumes are clustered around the major holidays and summer weekends. High volume and high cash paying traffic days do not always align. Outside of those 20 to 25 highest volume and cash paying traffic days (with total traffic well above 35,000 vehicles per direction), total volumes quickly level off at levels between 15,000 and 35,000 vehicles per direction. Figures 1 and 2 show the E-ZPass and total volumes ranked highest to lowest by day for southbound and northbound traffic. Tables 1 and 2 list selected dates ranked for both total and cash paying traffic.

Figure 1

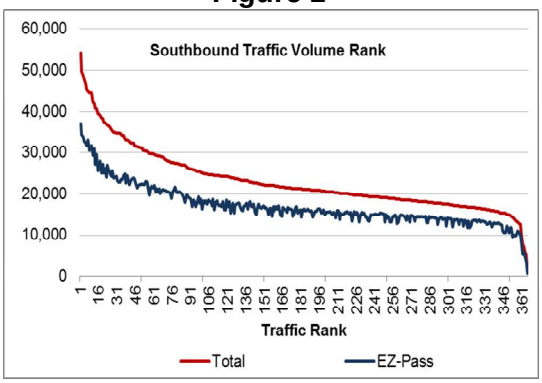


Figure 2

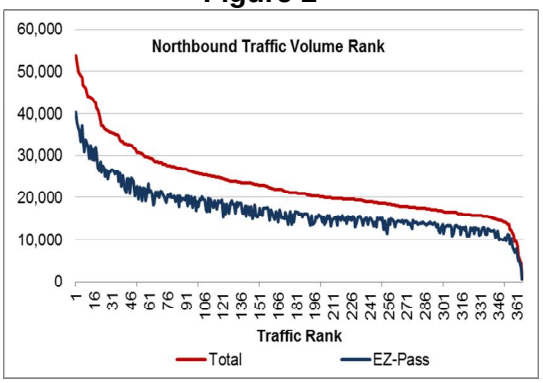


Table 1

Southbound Traffic Volume Ranks				
	Highest Total Traffic		Highest Cash Paying Day	
	Date	Total Volume	Date	Cash Volume
1st Highest Day	July 5, 2015	54,272	July 5, 2015	17,113
5th Highest Day	July 19, 2015	46,586	July 19, 2015	14,198
10th Highest Day	August 30, 2015	44,502	August 8, 2015	13,594
15th Highest Day	August 1, 2015	39,510	August 23, 2015	12,715
20th Highest Day	August 22, 2015	37,443	August 14, 2015	11,273

Table 2

Northbound Traffic Volume Ranks				
	Highest Total Traffic		Highest Cash Paying Day	
	Date	Total Volume	Date	Cash Volume
1st Highest Day	July 2, 2015	53,875	July 3, 2015	15,678
5th Highest Day	July 3, 2015	48,957	July 31, 2015	14,252
10th Highest Day	July 10, 2015	44,635	July 2, 2015	13,520
15th Highest Day	August 21, 2015	43,319	August 21, 2015	11,866
20th Highest Day	July 11, 2015	39,682	August 16, 2015	11,526

DESCRIPTION OF MODEL

Jacobs has modeled the York Toll Plaza utilizing our internally developed static toll plaza model. The model operates in two basic modes. The first mode works in an unconstrained manner and

is used to identify the number and type of lanes required for a toll plaza to have no vehicle queueing. The second mode constrains the number of toll plaza lanes and estimates the duration and length of vehicle queues for a specific volume and mix of approaching traffic.

The basic model utilizes traffic data that is segmented by time of day (hourly), vehicle type (car or truck), and the method of toll payment (cash and E-ZPass). Other primary inputs used by the model include lane type (staffed and E-ZPass), vehicle processing rates (staffed lane, E-ZPass ORT lane), and reduced processing rates for the various lane types when traffic becomes congested.
The model also considers annual growth of traffic and future changes in the mix of payment methods. For future estimating growth rates and payment method changes, traffic is further segmented into three periods (peak, off-peak and shoulder). The periods are used to better represent changes in E-ZPass rates and traffic volume growth rates. Table 3 represents the northbound hourly segmentation of traffic and the changes in method of payment forecasted for the 15th highest traffic day of the opening year (2018) of the analysis. Looking at the "E-ZPass Market Share" column differences in the percentage of E-ZPass by hour can easily be seen ranging over the 24 hour period from a minimum of 54.81 percent to a maximum of 78.25 percent for cars. For all vehicles, E-ZPass market share ranged from a low of 68.37 percent to a maximum of 82.91 percent in this analysis.

Table 3
Toll Plaza Model Hourly Traffic Segmentation
Opening Year, 15th Highest Traffic Day in Northbound Lanes

			Car Volume		Truck Volume		E-ZPass Market Share	
Time	**Time of Day**	**Weekly Volume**	**Staffed / Cash**	**E-ZPass**	**Staffed / Cash**	**E-ZPass**	**Car**	**Total**
12 am - 1 am	Off Peak	343	74	185	9	75	71.37%	75.79%
1 - 2	Off Peak	252	44	110	11	87	71.47%	78.19%
2 - 3	Off Peak	199	28	74	9	88	72.59%	81.41%
3 - 4	Off Peak	279	65	79	16	120	54.81%	71.00%
4 - 5	Off Peak	272	46	67	18	142	59.13%	76.47%
5 - 6	Off Peak	439	57	163	18	201	74.08%	82.91%
6 - 7	Off Peak	748	118	392	29	209	76.85%	80.33%
7 - 8	Off Peak	1,250	221	795	32	202	78.25%	79.75%
8 - 9	Off Peak	1,442	311	904	35	192	74.39%	76.00%
9 - 10	Off Peak	1,715	394	1,086	28	207	73.38%	75.39%
10 - 11	Shoulder	2,359	572	1,511	46	230	72.53%	73.80%
11 - 12 pm	Shoulder	2,921	745	1,875	44	257	71.55%	72.98%
12 pm - 1 pm	Shoulder	3,332	877	2,124	71	259	70.77%	71.54%
1 - 2	Shoulder	3,551	924	2,315	68	244	71.47%	72.05%
2 - 3	Peak	4,007	1,002	2,718	62	225	73.06%	73.44%
3 - 4	Peak	3,953	1,014	2,714	35	190	72.80%	73.46%
4 - 5	Shoulder	3,630	874	2,562	50	144	74.56%	74.54%
5 - 6	Shoulder	3,477	796	2,506	38	137	75.88%	76.01%
6 - 7	Shoulder	2,622	697	1,778	27	120	71.83%	72.38%

7 - 8	Shoulder	2,909	729	1,994	41	145	73.22%	73.52%
8 - 9	Shoulder	2,227	593	1,523	26	85	71.97%	72.19%
9 - 10	Off Peak	1,585	448	1,011	20	105	69.30%	70.46%
10 - 11	Off Peak	981	269	632	22	58	70.13%	70.33%
11 - 12 pm	Off Peak	661	200	378	9	74	65.36%	68.37%
Total		**45,155**	**11,102**	**29,494**	**764**	**3,795**	72.65%	73.72%

There are three other significant aspects of the toll plaza queuing model. All calculations for trucks are made using passenger car equivalents. For our analysis of the York Toll Plaza we considered single truck processing rates to be equivalent to the processing rate of two passenger vehicles. The model also is designed to address the restrictions on plaza throughput when queue lengths extend back to the main travel lanes of the divided highway. Based on the proposed plaza layouts, the model first limits vehicle processing rates when there was a total of approximately 4,000 linear feet of queue or about 114 vehicles, and then constrains processing rates at 8,000 linear feet or 228 vehicles. The model cumulatively addresses queueing. Any unprocessed traffic in the constrained model is added to the demand volume in the next hour. The model would then correctly forecast extended periods of vehicle demand exceeding capacity.

The outputs of the model will recommend lane type configurations for a number of configurations and time periods as well as queue lengths and durations when the configurations of the plaza lanes are specifically defined.

MODEL PARAMETERS

Several parameters in addition to traffic volumes were considered for the York Toll Plaza model in order to determine the number of required lanes. Many of these parameters are based on our professional judgement developed from our experience on these types of project nationwide. The following discusses those parameters.

Traffic Growth, The model included an analysis by hour for all 365 days. Traffic was grown annually through the design year 2043. In consultation with the Turnpike staff, our base analysis considered 1.4 percent annual traffic growth, a number consistent with that used by the Authority. We also ran a sensitivity case for 2 percent annual traffic growth through 2043. Growth rates higher than 2 percent were not considered. At those levels of growth for the design year 2043, traffic volumes would exceed the mainline capacity of the Turnpike.

Lane Types and Vehicle Processing Rates Two lane types were considered for the York Toll Plaza. First, cash toll lanes that would process cash and E-ZPass for both cars and commercial vehicles typically requiring vehicles to stop. Second, Open Road Toll lanes (ORT) that process E-ZPass transactions at normal highway speeds were considered. Vehicles in the cash lanes were processed at a rate of 325 vehicles per hour (VPH). Vehicles in the ORT lane were processed at a rate of 1,800 VPH.

Adjustments were made to address the longer transaction times of commercial vehicles and the effect of queuing restricting access to the ORT lanes. Commercial vehicles were converted to the equivalent of two passenger cars to represent the longer processing time for trucks. Large queues for cash paying customers may restrict traffics ability to reach the ORT lanes. In

consideration of the proposed geometry of the toll plazas we have modeled constraints on the ability of the plaza to process all traffic demand. When the total vehicle queue reaches 115 vehicles, the processing rate of the ORT lanes was reduced to 1,400 VPH; it was further reduced to 1,000 VPH when the total queue exceeded 230 vehicles.

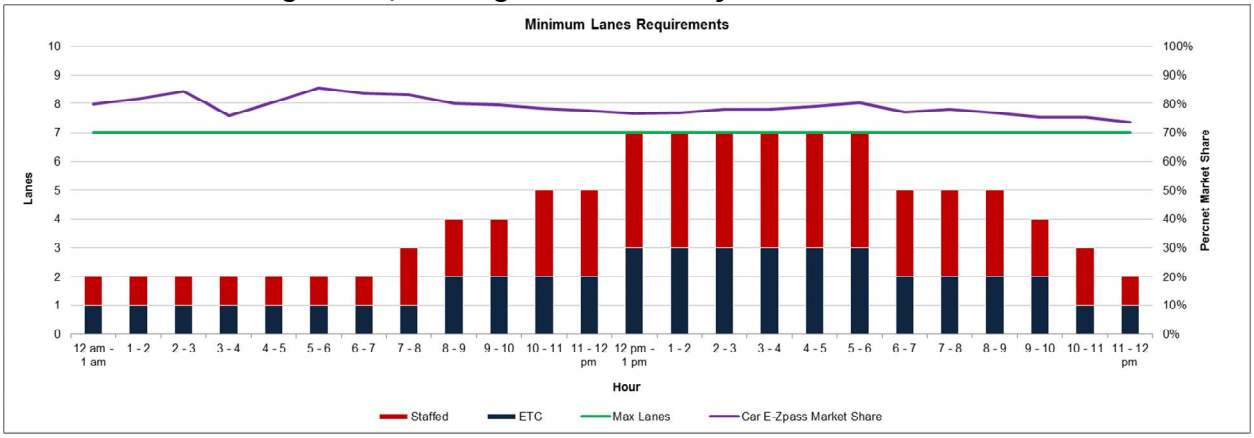
E-ZPass Market Shares The percentage of vehicles paying with E-ZPass is also a factor in determining the number of lanes required for the toll plaza. Most significantly, lower levels of E-ZPass result in higher volumes of cash paying traffic that results in higher numbers of cash lanes required. The percentage of traffic paying with E ZPass varies by time-of-day, day-of-week and month-of-year. Our model varies E-ZPass for every hour. For our base case analysis and experience, we estimated that E-ZPass transaction percentages would grow to average in the low 80 percentage range from today's low 70 percent range. Some days, and even some hours, would be higher and some lower. Typically, the highest percentage paying with E-ZPass occurs during peak commuting hours, with the lowest percentage occurring during holiday and vacation periods when there are large numbers of infrequent travelers.

Low and high sensitivity cases were run on E-ZPass market shares. For the low case it was assumed that the E-ZPass share of transactions would grow to an average in the mid 70 percent range. Conversely, the high range grew E-ZPass transaction shares to the mid 80 percent range. In our opinion, because of the mixed commuter / recreational nature of the Maine Turnpike, the base case in the low 80 percent range is the most likely to occur.

SAMPLE DAILY MODEL OUTPUT

Figure 3 graphically depicts the output from our model for northbound traffic on the 15th highest traffic day in the design year. This is the base case, with 4 cash lanes and 3 ORT lanes and E-ZPass market shares close to 80 percent. The blue bars depict the required number of ORT lanes and the red bars depict the required number of staffed lanes, all by hour.

Figure 3
Sample Constrained Toll Plaza Model Output
Design Year, 15th Highest Traffic Day in Northbound Lanes



BASE CASE ANALYSIS

Table 4 summarizes our base case recommendations for toll lanes in both southbound and northbound directions. (Note, the table shows results for the first highest traffic day.) It is important to note that there will continue to be some 15 to 20 days annually with traffic queues longer than one-hour in duration. These occur primarily during major holidays and summer weekends. There are expected to be de minimus queues for the remaining days throughout the design period for the base case assumptions of traffic growth and E-ZPass market share. These may be caused by an irregular arrival rate of traffic or other unique situations not associated with normal traffic operations. The required lanes for the full plaza are also shown graphically in Figure 4.

Figure 4
Northbound and Southbound Required Lanes

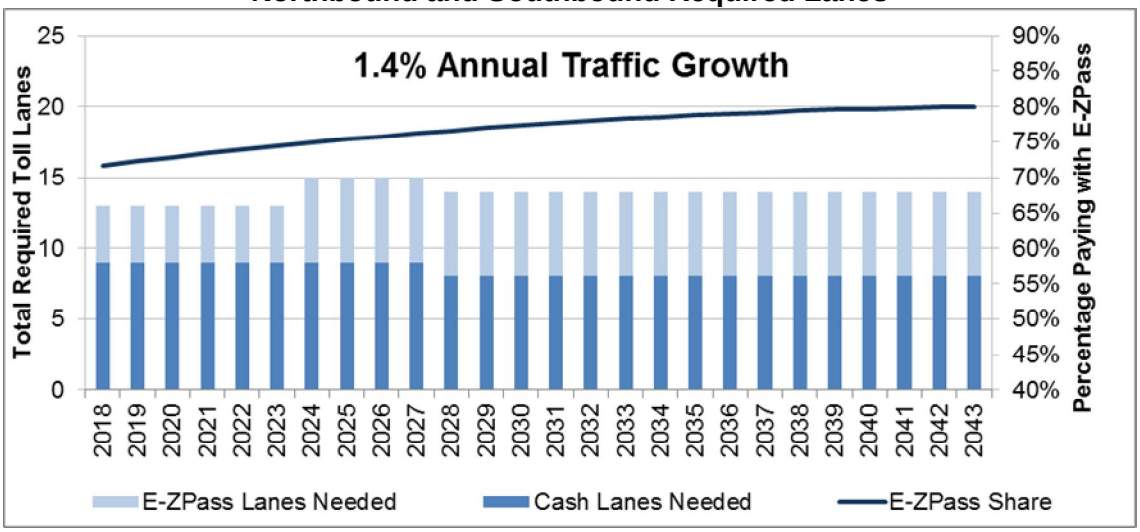
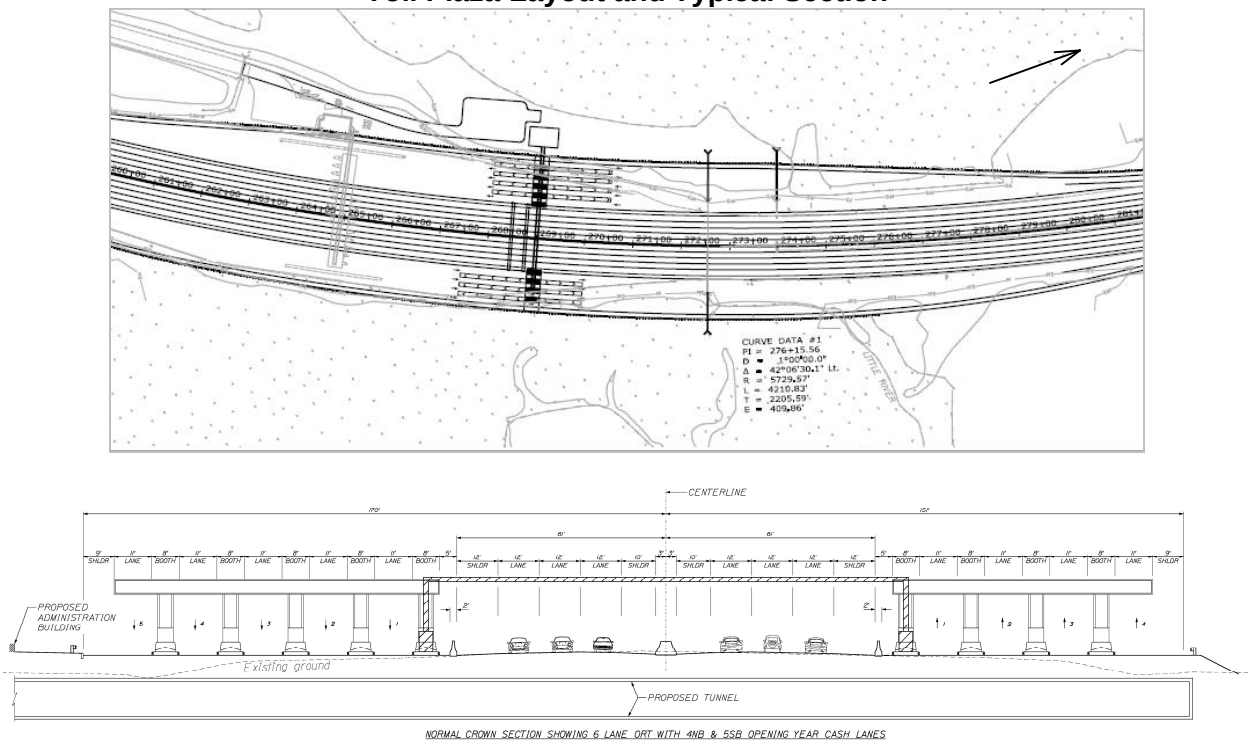


Table 4
Required Lanes for 1st Highest Traffic Day

	1.4% Annual Growth – Base Case E-ZPass 80%							
	SB Lanes				NB Lanes			
Year	Total SB Lanes	Cash	ORT	Highest Day E-ZPass Share	Total NB Lanes	Cash	ORT	Highest Day E-ZPass Share
2018	7	5	2	68.5%	6	4	2	74.9%
2019	7	5	2	69.3%	6	4	2	75.3%
2020	7	5	2	70.1%	6	4	2	75.6%
2021	7	5	2	70.9%	6	4	2	75.9%
2022	7	5	2	71.6%	6	4	2	76.3%
2023	7	5	2	72.3%	6	4	2	76.6%
2024	8	5	3	73.0%	7	4	3	76.8%
2025	8	5	3	73.6%	7	4	3	77.1%
2026	8	5	3	74.2%	7	4	3	77.4%
2027	8	5	3	74.8%	7	4	3	77.7%
2028	7	4	3	75.3%	7	4	3	77.9%
2029	7	4	3	75.8%	7	4	3	78.1%
2030	7	4	3	76.3%	7	4	3	78.4%
2031	7	4	3	76.7%	7	4	3	78.6%
2032	7	4	3	77.2%	7	4	3	78.8%
2033	7	4	3	77.6%	7	4	3	78.9%
2034	7	4	3	77.9%	7	4	3	79.1%
2035	7	4	3	78.3%	7	4	3	79.3%
2036	7	4	3	78.6%	7	4	3	79.4%
2037	7	4	3	78.9%	7	4	3	79.5%
2038	7	4	3	79.1%	7	4	3	79.7%
2039	7	4	3	79.4%	7	4	3	79.8%
2040	7	4	3	79.6%	7	4	3	79.8%
2041	7	4	3	79.7%	7	4	3	79.9%
2042	7	4	3	79.9%	7	4	3	80.0%
2043	7	4	3	80.0%	7	4	3	80.0%

Figure 5 depicts the proposed layout of the York Toll Plaza based on Jacobs' analyses using the toll plaza model. Ultimately, it is recommended that there be 3 ORT lanes in each direction, though they are not needed until 2024 for the highest day in the base case, plus 4 northbound and 5 southbound staffed lanes.

Figure 5
Toll Plaza Layout and Typical Section



SENSITIVITY ANALYSES

Sensitivity analyses were conducted for two additional levels of traffic and E-ZPass growth. The purpose of these sensitivities is to test the ability of the proposed design to work if future volumes and E-ZPass transactions differ from those forecasted in the Base Case. Table 5 summarizes the results for the 85 percent E-ZPass case with 2 percent annual traffic growth. In this unlikely case there would still be no need for four ORT lanes. However, if traffic grew at that rate, there also would not be a sufficient number of travel lanes on the mainline of the Turnpike. Because of this we would consider additional improvements be made only in conjunction with improvements to the mainline travel lanes, otherwise the Turnpike travel lanes will not have the ability to deliver traffic to the toll plaza.

Sensitivity cases were also run for lower levels of E-ZPass growth rates. Summarizing the six specific cases that were analyzed:

- 0 percent annual traffic growth rate
  - 75 percent E-ZPass range
  - 80 percent E-ZPass range
  - 85 percent E-ZPass range

- 1 percent annual traffic growth rate
  - 75 percent E-ZPass range
  - 80 percent E-ZPass range

  - 85 percent E-ZPass range

- 2 percent annual traffic growth
  - 75 percent E-ZPass range
  - 80 percent E-ZPass range
  - 85 percent E-ZPass range

Tables 5 and 6 display the results of the sensitivity runs for likely different rates of growth and different payment mixes. Those tables are based on constraining the required number of ORT lanes at 3. Results shown are for the highest traffic day.

Table 5
Results for 1st Highest Day

	2% Annual Growth – E-ZPass 85 Percent							
	SB Lanes				NB Lanes			
Year	Total SB Lanes	Cash	ORT	E-ZPass Share*	Total NB Lanes	Cash	ORT	E-ZPass Share*
2018	7	5	2	68.5%	6	4	2	74.9%
2019	7	5	2	69.6%	6	4	2	75.6%
2020	7	5	2	70.7%	6	4	2	76.3%
2021	7	5	2	71.7%	6	4	2	77.0%
2022	8	5	3	72.8%	7	4	3	77.6%
2023	8	5	3	73.8%	7	4	3	78.2%
2024	7	4	3	74.7%	7	4	3	78.8%
2025	7	4	3	75.6%	7	4	3	79.3%
2026	7	4	3	76.5%	7	4	3	79.8%
2027	7	4	3	77.4%	7	4	3	80.4%
2028	7	4	3	78.2%	7	4	3	80.8%
2029	7	4	3	78.9%	7	4	3	81.3%
2030	7	4	3	79.6%	7	4	3	81.7%
2031	7	4	3	80.3%	7	4	3	82.1%
2032	7	4	3	80.9%	7	4	3	82.5%
2033	7	4	3	81.5%	7	4	3	82.8%
2034	7	4	3	82.0%	7	4	3	83.2%
2035	7	4	3	82.5%	7	4	3	83.5%
2036	7	4	3	83.0%	7	4	3	83.7%
2037	7	4	3	83.4%	7	4	3	84.0%
2038	7	4	3	83.8%	7	4	3	84.2%
2039	7	4	3	84.1%	7	4	3	84.4%
2040	7	4	3	84.4%	7	4	3	84.6%
2041	7	4	3	84.6%	7	4	3	84.8%
2042	7	4	3	84.8%	7	4	3	84.9%
2043	7	4	3	85.0%	7	4	3	85.0%

*Note E-ZPass shares are for the first highest traffic day.

Table 6
Results for 1st Highest Day

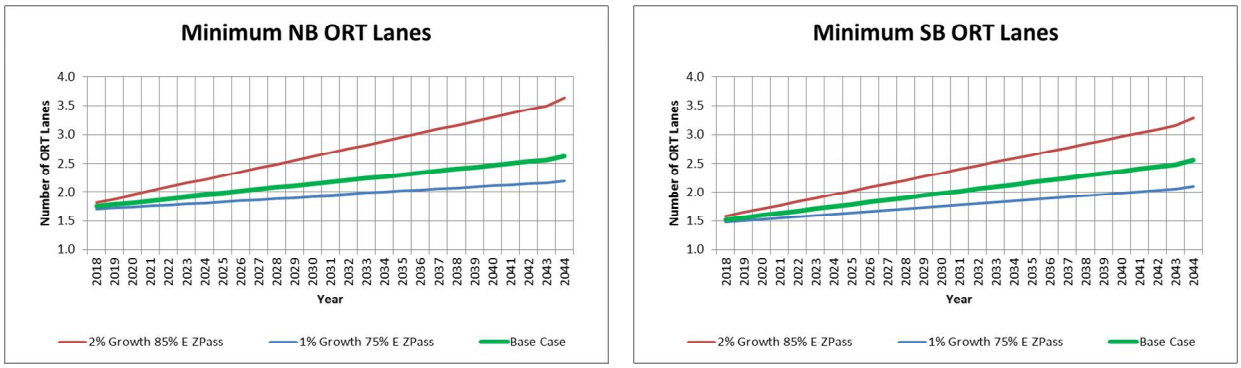
	1.0% Annual Growth – E-ZPass 75 Percent							
	SB Lanes				NB Lanes			
Year	Total SB Lanes	Cash	ORT	E-ZPass Share*	Total NB Lanes	Cash	ORT	E-ZPass Share*
2018	7	5	2	68.5%	6	4	2	74.9%
2019	7	5	2	68.9%	6	4	2	74.9%
2020	7	5	2	69.2%	6	4	2	74.9%
2021	7	5	2	69.6%	6	4	2	74.9%
2022	7	5	2	69.9%	6	4	2	74.9%
2023	7	5	2	70.3%	6	4	2	74.9%
2024	7	5	2	70.6%	6	4	2	74.9%
2025	7	5	2	70.9%	6	4	2	74.9%
2026	7	5	2	71.3%	6	4	2	74.9%
2027	8	5	3	71.7%	6	4	2	74.9%
2028	8	5	3	72.0%	7	4	3	75.0%
2029	8	5	3	72.3%	7	4	3	75.0%
2030	8	5	3	72.7%	7	4	3	75.0%
2031	8	5	3	72.9%	7	4	3	75.0%
2032	8	5	3	73.1%	7	4	3	75.0%
2033	8	5	3	73.4%	7	4	3	75.0%
2034	8	5	3	73.7%	7	4	3	75.0%
2035	8	5	3	73.8%	7	4	3	75.0%
2036	8	5	3	74.1%	7	4	3	75.0%
2037	8	5	3	74.3%	7	4	3	75.0%
2038	8	5	3	74.4%	7	4	3	75.0%
2039	8	5	3	74.6%	7	4	3	75.0%
2040	8	5	3	74.8%	7	4	3	75.0%
2041	8	5	3	74.9%	7	4	3	75.0%
2042	8	5	3	74.9%	7	4	3	75.0%
2043	8	5	3	75.0%	7	4	3	75.0%

*Note E-ZPass shares are for the first highest traffic day.

Figure 6 shows the unconstrained required number of ORT lanes for the 15th highest day for each year through to the design year. Three cases are presented in each graph; the Base Case, the high growth high E-ZPass case, and a low growth low E-ZPass share case. As can be seen from the graphs a third ORT lane would be required for all cases by the design year 2043. In order to accommodate the 15th highest day, the third ORT lane would be required north bound

in 2026 and south bound in 2031. Considering the low growth scenarios, the third ORT lane would be required north bound in 2034 and south bound in 2041 to accommodate the 15th highest day. In the case of high rates of traffic growth and a high rate of E-ZPass usage a fourth ORT lane may be required. However, as discussed earlier, the Turnpike itself does not have sufficient capacity to deliver that level of traffic.

Figure 6
15th Highest Day ORT Lane Requirements



CONSTRUCTION PHASING ANALYSIS

We also prepared an analysis for the construction season from late October until late April for the years 2016 through 2018. If the York Toll Plaza were to be reconstructed basically in place during a two year construction period as detailed in other documents there would be a closure of portions of the toll existing toll plaza. Because of the high summer and fall traffic volumes, this activity would need to be conducted during the off-season. Our analysis supports a plaza operating with 2 dedicated E-ZPass lanes and 3 cash lanes in each direction during the construction. With the exception of Thanksgiving, Christmas and Presidents day holidays, this configuration would be sufficient to process traffic. It is suggested that some of the lanes be able to operate in reversible directions as a possible way to mitigate any potential queues on those holidays. It is likely that the queues will be significant on those peak days.

CONCLUSION

Based on the toll plaza lane analysis, we have determined three (3) ORT lanes in each direction, plus four (4) northbound and five (5) southbound cash toll lanes would be required for the York Toll Plaza Replacement Project. This conclusion is based on model developed by Jacobs that analyzes traffic volumes by hour, by lane, by vehicle class and by method of payment. Growth rates for our model were selected in consultation with the Authority. The base case for our analyses used a 1.4% annual growth rate and an E-Z pass rate of 80%. A design year of 2043 was selected for the final year of analysis, and estimates for the number of toll lanes prepared for each year between 2018 and 2043. This analysis shows the gradual evolution of cash lanes to ORT lanes over time. A decision was made to size the toll plaza once, so it did not need to be reconstructed as the growth in E-Z Pass usage occurs. The guidelines for the State of Practice and Recommendation on Traffic Control Strategies at Toll Plaza states new ORT plazas should include the same number of express lanes equal to the number of

approach highway lanes. This guideline only reinforces our recommendation to build three (3) ORT lanes at the onset of construction rather than wait 6 years to reconstruct the plaza to accommodate the E-Z Pass customers demand.