New Hampshire DOT

Research Record

Experimental Traffic Control Device Testing at New Hampshire Toll Plazas

Purple Lights for E-Z Pass Wayfinding

Final Report

Prepared by Vanasse Hangen Brustlin, Inc. for the New Hampshire Department of Transportation, in cooperation with the U.S. Department of Transportation, Federal Highway Administration

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16. Abstract

This report includes a description of the testing and evaluation methodology of the "E-ZPass^{SM} Purple Light Experiment." Purple lights with advanced signs were installed as supplemental traffic control devices for northbound and southbound E-Zpass^{SM} movements along the I-93 approaches to the Hooksett Toll Plaza (north and south Toll Lanes #4 and #5). The purpose of the purple lights was to improve toll plaza operations and safety through the reduction in the number of conflicts created by last minute lane changes at the toll booths and weaving maneuvers that take place between the approach lanes and the toll booths. The Hooksett test site was selected because of the unique characteristics of the horizontal and vertical geometrics that connect to the toll plaza from the north and south. In addition, this site is prone to early morning fog, a condition that may be susceptible to improved traffic operations given these wayfinding lights.

The purple light experiment was conducted and evaluated under a scope of work derived from a similar experiment using "purple dots" as wayfinding devices conducted in the fall of 2005 by Kittelson and Associates, Inc. for the Maryland Transportation Authority (MTA). The traffic operational analyses and the presentation of results in this report were prepared for consistency in cross comparison with results from the MTA's purple dot experiment. Two distinctly different procedures were used in evaluating the effectiveness of the purple lights; field data evaluated by several measures of effectiveness (MOE's) and a customer survey.

The statistical analyses of the four MOE's and customer survey revealed changed driver behavior in several respects, during a four-week period in October 2006. The report includes a number of potential modifications for further testing.

An Appendix containing data collected during this study is available from the NHDOT upon request.

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Experimental Traffic Control Device Testing at New Hampshire Toll Plazas

Purple Lights for E-ZPass℠ Wayfinding

I-93 Tolls Hooksett, New Hampshire

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Executive Summary

The New Hampshire Department of Transportation (NHDOT) has undertaken a project using experimental traffic control devices that are intended to improve wayfinding for *E-ZPass*SM customers. Vanasse Hangen Brustlin, Inc. (VHB) has been retained to monitor and evaluate the effectiveness of these traffic control devices. This report summarizes the results of the experiment.

This report includes a description of the testing and evaluation methodology of the "*E-ZPass*SM Purple Light Experiment." A verbal approval to conduct this study was obtained from the Federal Highway Administration (FHWA) on October 25, 2006. A written approval was received by the NHDOT on October 31, 2006. A copy of the FHWA approval letter can be found in the Appendix.

Purple lights with advanced signs were installed as supplemental traffic control devices for northbound and southbound *E-ZPass*SM movements along the I-93 approaches to the Hooksett Toll Plaza (north and south Toll Lanes #4 and #5). The purpose of the purple lights is to improve toll plaza operations and safety through the reduction in the number of conflicts created by last minute lane changes at the toll booths and weaving maneuvers that take place between the approach lanes and the toll booths. The Hooksett test site was selected because of the unique characteristics of the horizontal and vertical geometrics that connect to the toll plaza from the north and south. In addition, this site is prone to early morning fog, a condition that may be susceptible to improved traffic operations given these wayfinding lights.

Evaluation and Results

The purple light experiment was conducted and evaluated under a scope of work derived from a similar experiment using "purple dots" as wayfinding devices conducted in the fall of 2005 by Kittelson and Associates, Inc. for the Maryland Transportation Authority (MTA). The traffic operational analyses and the presentation of results in this report were prepared for consistency in cross comparison with results from the MTA's purple dot experiment. Two distinctly different procedures were used in evaluating the effectiveness of the

purple lights; field data evaluated by several measures of effectiveness (MOE's) and a customer survey.

Traffic Operational Analyses and MOE Evaluations

Four measures of effectiveness (MOE's) were identified and evaluated to determine if the purple lights improved wayfinding for *E-ZPass*SM customers or changed driver behavior. The four MOE's are intended to measure the change in the occurrence of last minute lane changes occurring near the toll booths, and the percent of *E-ZPass*SM customers traveling through each of the dedicated *E-ZPass*SM lanes. Field observed data were collected during "before" and "after" conditions to isolate the effect of the experimental treatment. Data was also collected during several time periods to capture peak and off peak traffic conditions. The "after" condition considers separate observations for both a steady (solid) purple light and a flashing purple light.

A statistical analysis test called the "test of proportions" was used to evaluate each MOE to determine if changes in results are "statistically significant". Statistical significance indicates that the purple lights had a true effect on the performance measure when comparing the "before" and two "after" data conditions. In addition, statistical significance indicates whether any observed difference in the "before" and two "after" data conditions was and was not likely due to chance. In this experiment, statistical significance means there is a 95 percent probability that if the same experiment was repeated, the same result would occur.

The statistical analyses of the four MOE's reveal that the purple lights have statistically changed driver behavior in the following respects.

- Reduced the occurrence of cash paying customers traveling in and thus changing lanes from dedicated *E-ZPass*SM lanes into the adjacent cash lanes near the toll booths with the implementation of either a 'steady/solid" or "flashing" purple light;

- Reduced the percentage of *E-ZPass*SM customers in Cash Lanes (#2 and #3) that also accept *E-ZPass*SM transactions with the implementation of either a 'steady/solid" or "flashing" purple light;

- Reduced the number of toll violations in Lanes #3, #4, #5, and #7 with the implementation of a "steady/solid" purple light as a wayfinding device; and

- Reduced the number of toll violations[1] in Lanes #3, #4, and #5 with the implementation of a "flashing" purple light as a wayfinding device.

These findings are based on data collected at the Hooksett Toll Plaza within a four week period in October 2006. As drivers become more accustomed to the purple lights the performance may change over time. The changes in driver behavior that were observed and those found to be statistically significant were small changes in the total volume of Turnpike travelers. The purple lights were not observed to cause any negative impacts to toll plaza operations or safety.

Customer Survey

In addition to the MOE evaluation, an online and paper survey was conducted to gather feedback from *E-ZPass*SM customers regarding the purple light experiment. Two hundred and nineteen (219) customers responded to the survey. Of the 219 customers, 152 (69%) responded through the internet, 30 (14%) filled out the paper survey at the Southbound Safety Center, 24 (11%) filled out the survey at the Northbound Safety Center, and 13 (6%) of the customers filled out the survey at the *E-ZPass*SM Customer Service Center. Of the respondents, 135 (62%) were traveling northbound and 84 (38%) were traveling southbound.

The survey consisted of nine questions that assessed whether or not drivers recognized and understood the meaning of the purple lights and whether or not the purple light was helpful. The survey also provided the opportunity for *E-ZPass*SM customers to provide suggestions for improving not only the purple lights, but also toll plaza operations in general.

The results of the survey reveal that the purple lights were well received by *E-ZPass*SM customers who use the I-93 Hooksett Toll Plaza. Based on the survey, 51% of the *E-ZPass*SM customers used the purple lights to guide their vehicles to the dedicated *E-ZPass*SM lanes and 67% of *E-ZPass*SM customers believed that the purple lights were helpful. Interestingly, under poor lighting (twilight, overcast or nighttime) conditions or during inclement (rain or fog) weather these percentages increase to 70% of the *E-ZPass*SM customers using the purple lights to guide their vehicles to one of the dedicated *E-ZPass*SM lanes and nearly 80% of *E-ZPass*SM customers surveyed believe that the purple lights were helpful.

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1 It is noted that the violations that were recorded and provided for data reduction may not be "true violations" by definition. An event recorded as a violation may have been attributed to an erroneous data reading from the *E-ZPass*SM equipment or attributed to some other factor. Nevertheless, the data that is summarized as follows reflects a consistent comparison between the four conditions.

Finally, of those *E-ZPass*SM customers who found the purple light helpful, 67% surveyed stated a preference to the purple light in "flashing" mode as opposed to the "steady/solid" purple mode.

Recommendations

To maximize the effective use of lights as a wayfinding device and to increase customer satisfaction, the following modifications are recommended for further testing:

- Test the effectiveness of flashing yellow lights as opposed to flashing purple,
- Install back plates on the overhead signal housing to aid in visibility;
- If purple lights are used, increase the intensity of the light emitting diodes to increase visibility during full day light conditions; if this is not feasible, consider installing a photocell that activates the purple lights only under diminished lighting conditions;
- Implement a "wig-wag" flashing mode in the light display as opposed to a steady/solid mode to aide in the visibility of the lights.
- Fabricate larger advanced signs and mount them on overhead sign structures as opposed to the smaller advanced signs that were post mounted across from one another within the guard-railed median and adjacent to the paved shoulder.

1 Introduction

The New Hampshire Department of Transportation (NHDOT) has undertaken a project using experimental traffic control devices that are intended to improve wayfinding for *E-ZPass*SM customers. Vanasse Hangen Brustlin, Inc. (VHB) was retained to monitor and evaluate the effectiveness of these traffic control devices and summarize the results of the experiment. A description of the proposed experimental program, the project study area, and the data collection methodologies and measures of effectiveness (MOE's) are presented below.

Background

The New Hampshire Department of Transportation (NHDOT) through its Bureau of Turnpikes is responsible for constructing, managing, operating and improving toll facilities in New Hampshire. The New Hampshire Turnpike System presently consists of 93 miles of limited access highway, 36 miles of which are part of the U.S. Interstate Highway System, comprising a total of approximately 631 total lane miles. The Turnpike System is comprised of three limited access highways: the Blue Star Turnpike (I-95) and the Spaulding Turnpike, which are collectively referred to as the Eastern Turnpike, and the Central Turnpike. The Turnpike System uses an open barrier system of toll collection consisting of 10 toll plazas (5 main line and 5 ramps). Figure 1 illustrates the location of NHDOT's toll facilities and the three limited access highways that compose the Turnpike System.

All plazas include three toll collection options: *E-ZPass*SM (which was first implemented in New Hampshire during the fall of 2005), automatic lanes for cars with exact change, as well as attended lanes for all classes of vehicles. The latter systems of toll collection have been in place since the 1950's.[2]

As illustrated in Figures 2 and 3, the NHDOT currently provides lane guidance using both overhead and post mounted signs approaching the toll plazas for each of the three toll collecting options. Exact change lanes are positioned to the left, *E-ZPass*SM lanes are centrally located, and manual lanes are located to the right. As the percentage of *E-ZPass*SM customers continues to rise, it is increasingly important to provide clear guidance to *E-ZPass*SM Only lanes. Exact change or make change customers who inadvertently find themselves in an *E-ZPass*SM lane have been

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2 NHDOT website, http://www.nh.gov/dot/bureaus/turnpikes/index.htm.

known to stop, back up, or swerve between lanes which adversely impacts safety and operations at the toll plazas.

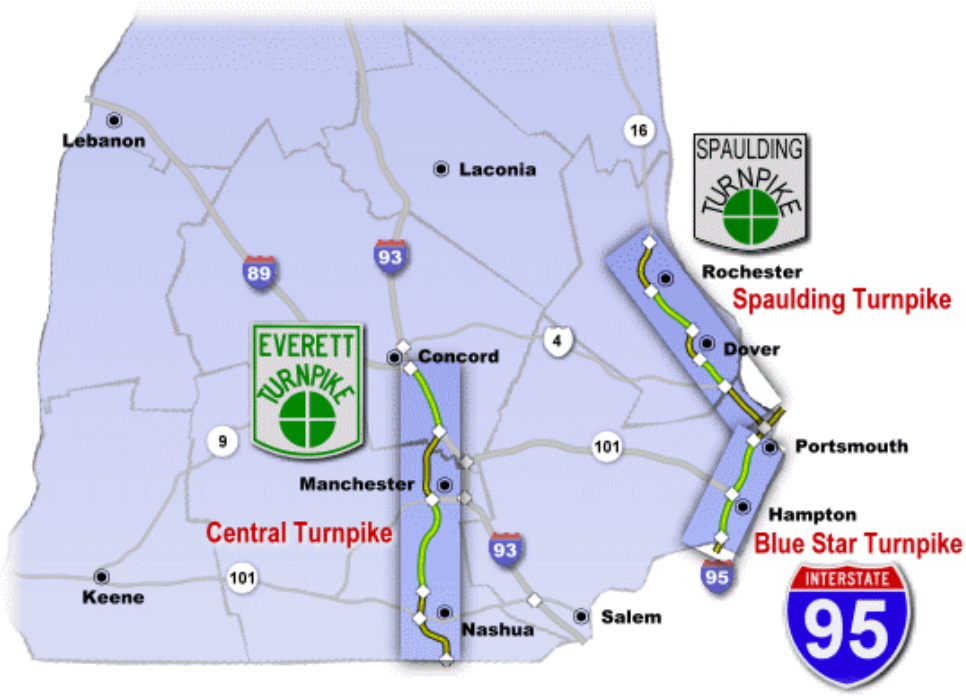

Figure 1 – The New Hampshire Turnpike System

Figure 2 – Advanced Signs For Lane Guidance

Problem Statement

As documented in a recent problem statement by the Maryland Transportation Authority, "currently there is limited guidance within published documents for applying traffic control devices at toll plazas. Toll agencies across the United States have traditionally dealt with the design and operation of toll plazas on a case-by-case basis; therefore, the method used to guide motorists through toll plazas varies from one toll facility to the next. This lack of continuity and consistency can lead to driver confusion and subsequent safety and operational deficiencies." [3]

In New Hampshire, overhead panel signs indicate lane usage. These signs are supplemented by a flashing yellow light that is post-mounted at ground level and an overhead green or red light, which indicates whether the lane is open or not. Figure 3 illustrates each of the existing lane guidance control devices used at New Hampshire toll facilities. Studies conducted by the New York State Thruway Authority indicate that use of green signal indications above the dedicated *E-ZPass*SM lanes (similar to the New Hampshire setup) attracted cash-paying customers into the *E-ZPass*SM only lanes. There is a need to consider and evaluate other ways of safely and efficiently guiding *E-ZPass*SM customers to the dedicated *E-ZPass*SM lanes.

Figure 3 – Existing Lane Guidance at New Hampshire Toll Plaza's

3 Experimental Traffic Control Device Testing at Maryland Toll Plazas, published by Kittleson & Associates, Inc., Baltimore, MD, March 9, 2006

It is proposed to apply and test purple lights with supplemental advanced signage as experimental traffic control devices at toll plazas in New Hampshire to quantify their safety, operational, and overall effectiveness at guiding *E-ZPass*SM customers into dedicated *E-ZPass*SM Only lanes. The knowledge gained from this research effort will assist the NHDOT and others in developing a standard practice for applying traffic control devices at toll plazas. The knowledge and information obtained from the experiment will be shared with other toll agencies to improve industry practice.

Experimental Treatment and Location

The Hooksett Toll Plaza located along the Central Turnpike between Manchester and Concord, New Hampshire was selected as the testing site for the proposed purple light with advanced informational signage. The advanced informational signage directed motorists to look for the experimental purple lights. The Hooksett test site was chosen because of the unique horizontal and vertical alignment characteristics on the approaches to the toll plaza as described in the following paragraphs. In addition, this site is prone to early morning fog, a condition that may be improved with wayfinding lights that can burn through the fog for navigation. Figure 4 shows the location of the Hooksett Plaza in relation to the Central Turnpike.

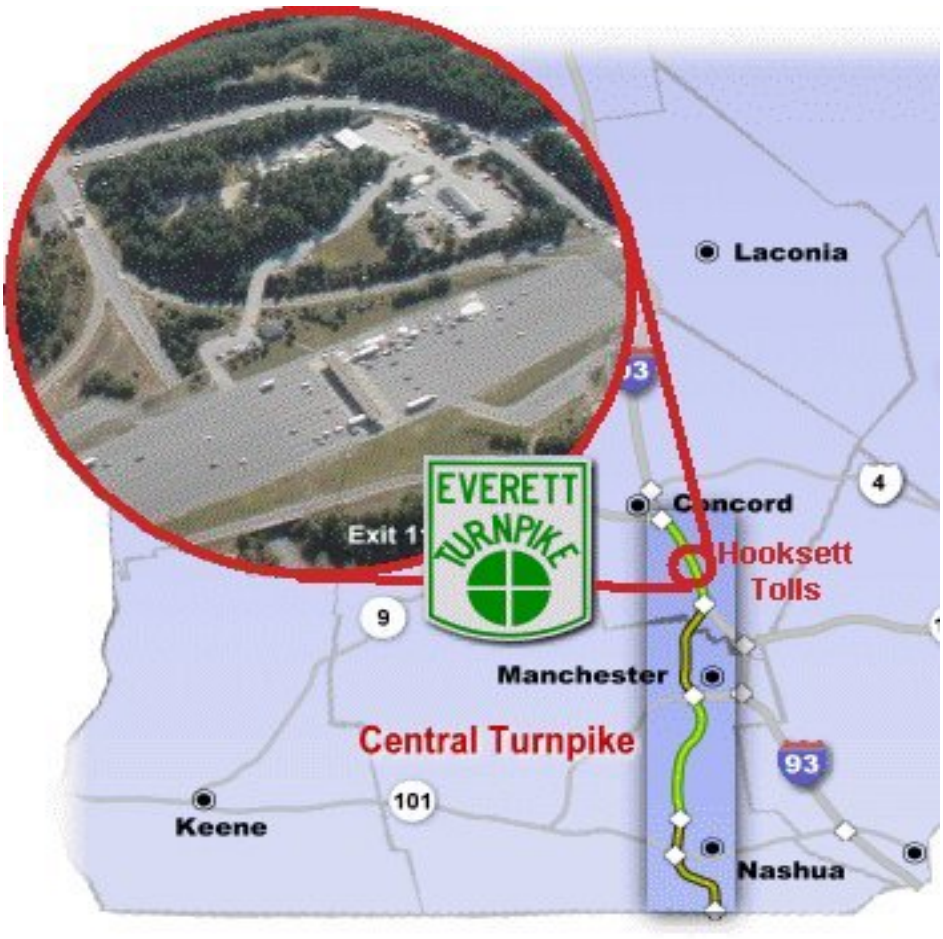

Figure 4 – Location of the Purple Light Experiment

The northbound approach to the Hooksett Toll Plaza has four approach lanes that are formed from the junction of (2-lane) I-293 and (3-lane) I-93 located approximately two miles south of the toll plaza. As shown in Figure 5, there is a crest vertical curve located approximately ¼ mile in advance of the toll plaza that limits the view of the tolls until a motorist is within a thousand feet of the toll plaza, by which time the four approach lanes expand to the multiple toll lanes. Two sets of overhead sign structures located approximately ½ and 1 mile in advance of the toll plaza inform motorists of lane guidance for each of the toll collection systems. The four approach lanes widen and feed into seven toll lanes numbered consecutively from right to left. During peak flow events, there is an option to increase the number of northbound toll lanes from seven to eight or nine using (reversible) lanes from the southbound direction; however, during this experiment an equal number (7) of northbound and southbound toll lanes were maintained. Generally, toll lanes #1 and #2 operate as manual/attended lanes with *E-ZPass*SM accepted, toll lanes #3, #4, and #5 are dedicated *E-ZPass*SM only lanes with a 10 mph posted speed limit, and toll lanes #6 and #7 are exact change lanes (with no *E-ZPass*SM accepted). However, during the experiment toll lane #1 was closed for construction related purposes, toll lanes #2 and #3 were manual/attended lanes with *E-ZPass*SM accepted, toll lanes #4 and #5 were dedicated *E-ZPass*SM only lanes, and toll lanes #6 and #7 were exact change lanes. Figure 6 shows the northbound toll lane configurations during the experiment.

Figure 5 – Northbound Crest Vertical Curve In Advance Of The Hooksett Tolls

The southbound approach to the Hooksett Toll Plaza has three approach lanes originating from the junction of I-93 and I-89 to the north in Concord. There is a horizontal curve in advance of the tolls that limits visual sight of the tolls to ½ mile

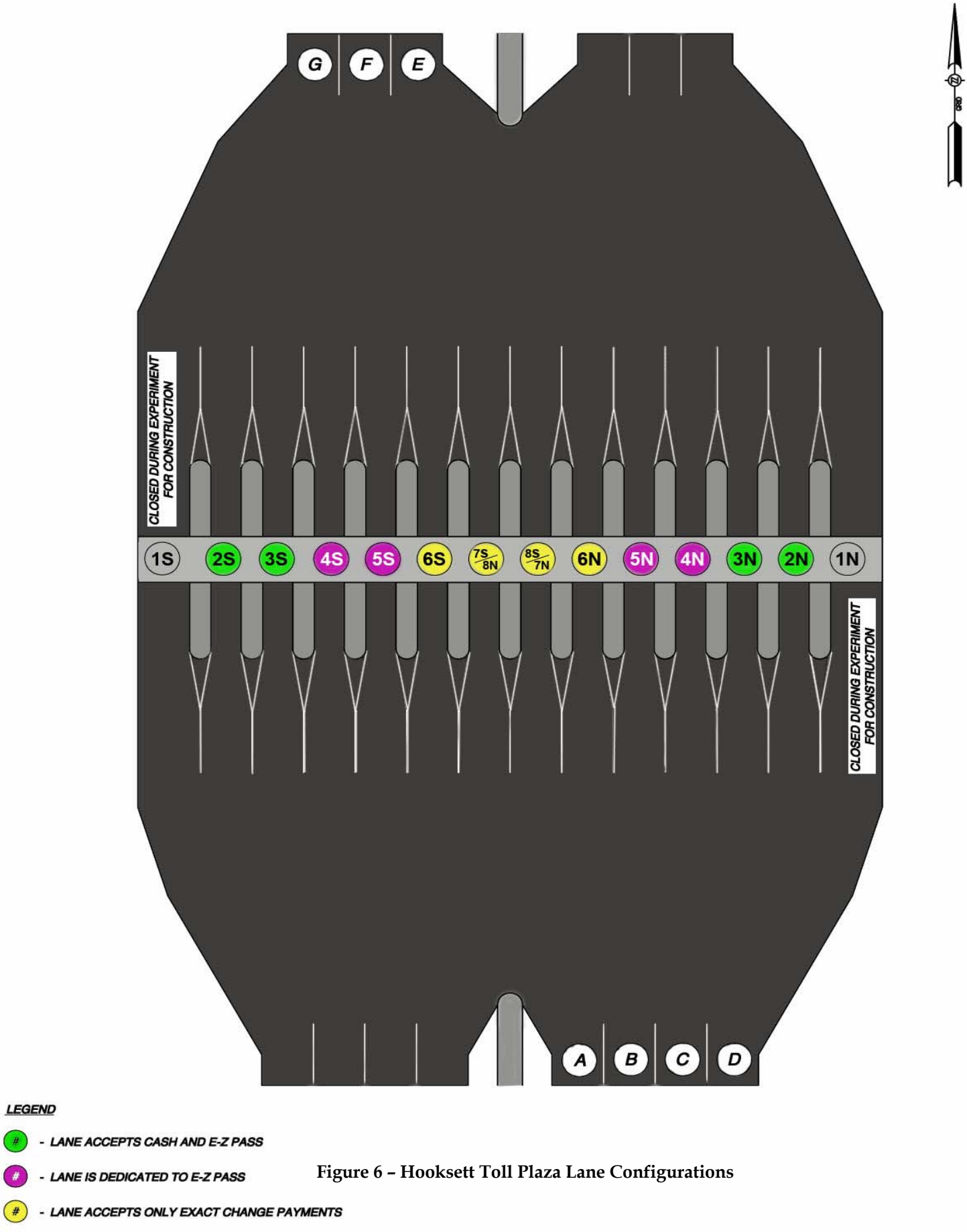

Figure 6 – Hooksett Toll Plaza Lane Configurations

of the plaza. However, there is still several thousand feet of 3-lane roadway for a motorist to position his vehicle accordingly to payment method prior to the lanes widening to the multiple toll lanes. The horizontal alignment approaching the toll plaza is shown in Figure 7. In addition to visual recognition of the toll plaza, two sets of overhead sign structures located approximately ½ and 1 mile in advance of the toll plaza provide motorists lane guidance for each of the toll collection systems. Figure 7 depicts the overhead sign structure located ½ mile in advance of the toll plaza. The three approach lanes widen and feed into seven toll lanes numbered consecutively from right to left. As previously stated, there is an option to increase the number of southbound toll lanes from seven to eight or nine using (reversible) lanes from the northbound direction. Generally, toll lanes #1 and #2 operate as manual/attended lanes with *E-ZPass*SM accepted, toll lanes #3, #4, and #5 are dedicated *E-ZPass*SM only lanes with a 10 mph posted speed limit, and toll lanes #6 and #7 are exact change lanes (with no *E-ZPass*SM accepted). However as with the northbound side, during the experiment toll lane #1 was closed for construction related purposes, toll lanes #2 and #3 were manual/attended lanes with *E-ZPass*SM accepted, toll lanes #4 and #5 were dedicated *E-ZPass*SM only lanes, and toll lanes #6 and #7 were exact change lanes. Figure 6 also exemplifies the southbound toll lane configurations during the experiment.

Figure 7 – Southbound Horizontal Curve In Advance Of The Hooksett Tolls

The purple lights shown in Figure 8 were installed above the *E-ZPass*SM guide signs by the NHDOT Bureau of Traffic maintenance crew on Thursday, October 12, 2006. The purple lights were made from an integrated pattern of blue and red light emitting diodes (LEDs) enclosed within a 12-inch signal head. The LED pattern resulted in a bench tested purple colored indication in a bandwidth within the visual

spectrum consistent with LEDs used in typical traffic signal installations. The ultimate design of the purple lights that were implemented in the field was the best of four alternatives, which included various configurations of incandescent and LED lights behind purple lenses. It is noted that there is not presently a purple LED available for commercial use based on the difficulty to mix gases and electrical components to generate a purple colored indication.

Figure 8 – Installation and Application of Purple Wayfinding Lights

A set of advanced signs, detailed in Figure 9, were installed ¼ mile ahead of the toll plazas on Tuesday, October 17, 2006. The 36" x 48" signs consisted of white lettering on a purple background. As shown in Figure 10, the pair of signs was post mounted across from one another within the guard railed median and adjacent to the paved shoulder. The signs were installed relative to mounting height and clear zone requirements in conformance of the guidelines set forth by the Manual of Uniform Traffic Control Devices (MUTCD).

Figure 9 – Advanced Sign Legend

Figure 10 – Advanced Sign Placement along Southbound Approach

Data Collection Methodology and Measures of Effectiveness (MOE's)

Field observed data was collected during "before" and "after" conditions to isolate the effect of the experimental treatment. Data was also collected during several time periods to capture peak and off peak traffic conditions. The "after" condition considers separate observations for a steady (solid) purple light and a flashing purple light. The "after" data was collected 2, 4, 6, 11, and 13 days following the implementation of the purple lights and advanced signs. The relatively short (2-4 day) acclimation period before the "after" data was collected is justified by the toll plaza's heavy use by commuters who use the toll facility frequently during the weekday peak and off peak periods, while weekend traffic is generally comprised of out-of-state traffic drawn to New Hampshire's tourist attractions located throughout the state. No reasonable period within the time frame of this experiment could acclimate the weekend drivers to the new treatments. The data collected during the Saturday weekend is a good indicator of an *E-ZPass*SM users first reaction when confronted with a new traffic control device such as the purple lights.

The number and type of lane change for each approach to the toll plaza was recorded from field observations for each of the "before" and "after" conditions. Statistical analyses were performed to compare the effectiveness of the purple light with respect to lane change maneuvers, volume distribution across toll lanes, and percent violations. The four specific performance measures of effectiveness (MOE's) evaluated under this experiment are:

- MOE #1: Lane changes by *E-ZPass*SM customers.
- MOE #2: Lane changes by cash paying customers.
- MOE #3: Percent utilization of dedicated *E-ZPass*SM lanes.
- MOE #4: Percent of toll violations

Table 1 summarizes the dates, days of the week, and the times that experiment data was field recorded to evaluate MOE's #1 and #2. Further discussion on how and why these times and days were chosen can be found in Chapter 2. The same dates, days, and times were used and expanded to cover an entire week where necessary when reducing the data from the toll lane utilization reports.

Table 1
Dates and Times of Field Data Collection

Date	Day	7am-9am	11am-1pm	4pm–6pm
			"Before" Data	
Oct 10	Tuesday	O	O	O
Oct 11	Wednesday	X	X	X
Oct 12	Thursday	O	X[1]	X[1]
Oct 14	Saturday		X	
Nov 2	Thursday	V	V	V
Nov 4	Saturday		V	
			"After / Steady Purple" Data	
Oct 17	Tuesday	X[2]	X[2]	X[2]
Oct 19	Thursday	X	X	X
Oct 21	Saturday		X	
			"After / Flashing Purple" Data	
Oct 26	Thursday	X	X	X
Oct 28	Saturday		X	

X = Field data recorded in both the northbound and southbound directions.

X[1] = Field data recorded in only the northbound direction.

X[2]= Field data recorded in only the southbound direction.

O = Field data was recorded but upon review was found to be corrupt; data was subsequently discarded.

V = Field data recorded for verification due to the intermittent construction activity in and around the Hooksett tolls during the "Before" condition that may have affected the study results.

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Toll Plaza Operational Analyses and Evaluations

Evaluation of the impacts associated with the purple light experiment requires a thorough understanding of the traffic volumes being serviced by the toll facility. Based on these traffic volumes, a thorough and meaningful evaluation of the various measures of effectiveness can be undertaken. This chapter summarizes the traffic operational results of the experiment.

Traffic Volumes Summary

Hourly traffic volumes by day of week were collected by the NHDOT Bureau of Turnpikes before the experiment to aide in the determination of the appropriate time periods and days of the week to gather experimental data. The bar graph in Figure 11 compares this data. Copies of the count data are provided in the Appendix.

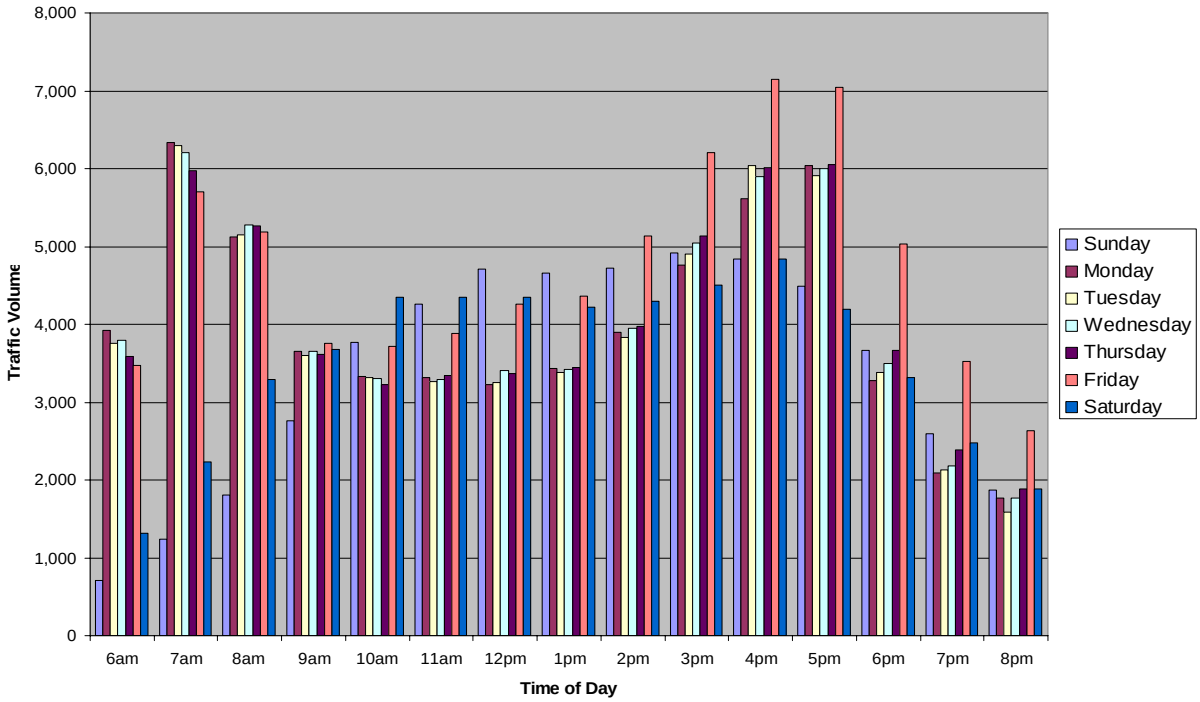


Figure 11 – Typical Hourly Traffic Volumes Thru The Hooksett Tolls By Day-of-Week

Traffic volumes during the mid-week period (Monday through Thursday) are very similar by time of day, with Monday being typically higher in volume in the morning and lower in the evening when compared to the three other days of the week. Traffic volumes on Friday are much higher with longer peak periods than the first- to mid-week (Monday through Thursday) volumes. Based on this evaluation, weekday traffic data collection that is necessary to evaluate the various measures of effectiveness was conducted on Tuesday, Wednesday or Thursday to increase the likelihood that similar traffic patterns would be prevalent to compare "before" and "after" traffic operations through the toll plaza.

Traffic volumes on Saturday are substantially different than the weekday traffic and constant throughout the day not peaking as significantly as during the weekdays. Sunday traffic volumes are substantially different than the weekday and Saturday traffic volumes. As such, typical weekend traffic data was collected on Saturday.

MOE Evaluation

The following sections briefly restate the data collection methodology and describe the analysis results and findings for each measure of effectiveness (MOE) for the "before" and "after" conditions. Descriptive observations and statistical analyses were used to evaluate and summarize the effectiveness of each MOE and ultimately the overall effectiveness of the purple light experiment. A statistical test of proportions was used for each MOE to determine if the differences between the "before" and "after" conditions are statistically significant. Statistical significance implies that an intervention (i.e., purple light) has a true effect when comparing the "before" and "after" data. A statistically significant change indicates that the observed difference in the "before" and "after" data is not likely due to chance, as determined by a statistical test. In this experiment, statistical significance means there is a 95 percent probability that if the same experiment was repeated, the same result would occur.[4] The methodology and statistical analysis calculations for each MOE are contained within the Appendix.

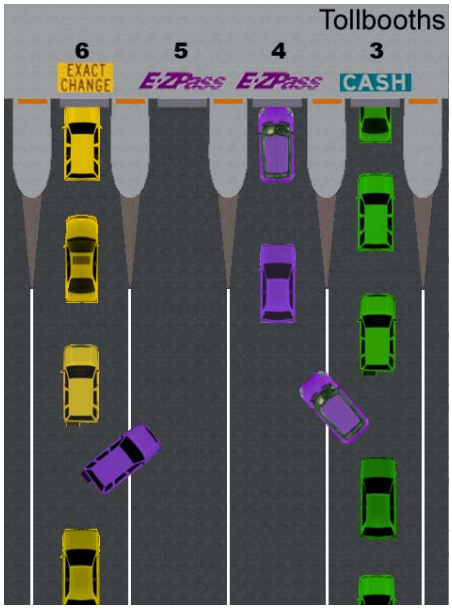
MOE #1: Lane Changes By *E-ZPass*SM Customers

This measure of effectiveness is defined as the percent of *E-ZPass*SM customers who change lanes into a dedicated *E-ZPass*SM lane from a cash paying lane. The percent is calculated based on the number of *E-ZPass*SM customers who travel through the dedicated *E-ZPass*SM lane being observed. This evaluation focused on lane changes

4 Statistical significance meaning in relation to the NHDOT Purple Light experiment is stated and calculated for consistency with the Purple Dot experiment documented in "Experimental Traffic Control Device Testing at Maryland Toll Plazas", published by Kittleson & Associates, Inc., Baltimore, MD, March 9, 2006.

occurring in dedicated *E-ZPass*SM Lanes #4 and #5. MOE #1 data was recorded and reduced in accordance with previous methodologies used in evaluating toll lane changes for similar experiments[5]. As such, a "lane change" was recorded when a vehicle changed lanes from a cash-paying queue into a dedicated *E-ZPass*SM lane. When queues in the cash paying lanes were not present, lane changes were recorded if a vehicle crossed the solid white line near the toll barrier (painted gore). Lane changes into dedicated *E-ZPass*SM Lanes #4 and #5 were assumed to be made by *E-ZPass*SM customers; therefore, MOE #1 does not consider toll violations. Data for this MOE was recorded and reduced through manual observations.

DATA REDUCTION



Data that was reduced for MOE #1 focused on the typical weekday (Tuesday, Wednesday, or Thursday) morning (AM), midday and evening (PM) peak periods as well as the Saturday midday to capture the effects the purple lights had on both commuter (AM and PM) and arbitrary (Weekday and Saturday Midday) users of the turnpike system. Two (2) hours of data during each peak period was calculated to be required to achieve a statistical significance of 95 percent. This calculation can be found in the Appendix.

Lane change maneuvers for this measure of effectiveness were reduced from the following time periods from which data was collected[6]:

"Before Condition"

- Wednesday, October 11, 2006 (11am-1pm, northbound only)
- Thursday, October 12, 2006 (7am-9am, 11am-1pm southbound only, 4pm-6pm)
- Saturday, October 14, 2006 (11am-1pm)

"After (Steady Purple) Condition"

- Tuesday, October 17, 2006 (7am-9am, 11am-1pm, 4pm-6pm / southbound)
- Thursday, October 19, 2006 (7am-9am, 11am-1pm, 4pm-6pm / northbound)
- Saturday, October 21, 2006 (11am-1pm)

"After (Flashing Purple) Condition"

- Thursday, October 26, 2006 (7am-9am, 11am-1pm, 4pm-6pm)
- Saturday, October 28, 2006 (11am-1pm)

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5 "Experimental Traffic Control Device Testing at Maryland Toll Plazas", published by Kittleson & Associates, Inc., Baltimore, MD, March 9, 2006

6 Data was collected in both northbound and southbound directions, unless otherwise stated.

The results of the data reduction are summarized in Table 2.

Table 2
MOE #1 – Percent Lane Changes By *E-ZPass*SM Customers

		NORTHBOUND						SOUTHBOUND					
		Dedicated E-ZPass Lane #5			Dedicated E-ZPass Lane #4			Dedicated E-ZPass Lane #5			Dedicated E-ZPass Lane #4		
Peak Period	Time	Lane Changes To Lane #5	Lane #5 Volume	Percent	Lane Changes To Lane #4	Lane #4 Volume	Percent	Lane Changes To Lane #5	Lane #5 Volume	Percent	Lane Changes To Lane #4	Lane #4 Volume	Percent
AM Peak	7am-8am	1	1096	0.09%	2	757	0.26%	1	1281	0.08%	5	905	0.55%
	8am-9am	3	962	0.31%	3	649	0.46%	2	1084	0.18%	3	671	0.45%
AM Subtotal		**4**	**2058**	**0.19%**	**5**	**1406**	**0.36%**	**3**	**2365**	**0.13%**	**8**	**1576**	**0.51%**
Midday Peak	11am-12pm	1	488	0.20%	1	340	0.29%	1	558	0.18%	4	339	1.18%
	12pm-1pm	0	473	0.00%	1	320	0.31%	1	531	0.19%	3	322	0.93%
Midday Subtotal		**1**	**961**	**0.10%**	**2**	**660**	**0.30%**	**2**	**1089**	**0.18%**	**7**	**661**	**1.06%**
PM Peak	4pm-5pm	1	1054	0.09%	3	776	0.39%	1	1020	0.10%	1	677	0.15%
	5pm-6pm	1	1127	0.09%	4	892	0.45%	1	992	0.10%	3	692	0.43%
PM Subtotal		**2**	**2181**	**0.09%**	**7**	**1668**	**0.42%**	**2**	**2012**	**0.10%**	**4**	**1369**	**0.29%**
Saturday Peak	11am-12pm	4	515	0.78%	4	550	0.73%	0	396	0.00%	2	282	0.71%
	12pm-1pm	3	498	0.60%	5	415	1.20%	2	389	0.51%	2	283	0.71%
Saturday Subtotal		**7**	**1013**	**0.69%**	**9**	**965**	**0.93%**	**2**	**785**	**0.25%**	**4**	**565**	**0.71%**
"Before" Total		**14**	**6213**	**0.23%**	**23**	**4699**	**0.49%**	**9**	**6251**	**0.14%**	**23**	**4171**	**0.55%**
AM Peak	7am-8am	1	1099	0.09%	2	782	0.26%	1	1136	0.09%	2	769	0.26%
	8am-9am	2	985	0.20%	2	663	0.30%	1	937	0.11%	3	587	0.51%
AM Subtotal		**3**	**2084**	**0.14%**	**4**	**1445**	**0.28%**	**2**	**2073**	**0.10%**	**5**	**1356**	**0.37%**
Midday Peak	11am-12pm	1	534	0.19%	1	371	0.27%	0	453	0.00%	2	312	0.64%
	12pm-1pm	0	500	0.00%	0	330	0.00%	1	474	0.21%	0	308	0.00%
Midday Subtotal		**1**	**1034**	**0.10%**	**1**	**701**	**0.14%**	**1**	**927**	**0.11%**	**2**	**620**	**0.32%**
PM Peak	4pm-5pm	1	1016	0.10%	3	814	0.37%	1	846	0.12%	3	611	0.49%
	5pm-6pm	1	1110	0.09%	3	885	0.34%	0	874	0.00%	0	590	0.00%
PM Subtotal		**2**	**2126**	**0.09%**	**6**	**1699**	**0.35%**	**1**	**1720**	**0.06%**	**3**	**1201**	**0.25%**
Saturday Peak	11am-12pm	3	629	0.48%	3	473	0.63%	1	454	0.22%	1	273	0.37%
	12pm-1pm	3	580	0.52%	4	461	0.87%	1	509	0.20%	2	325	0.62%
Saturday Subtotal		**6**	**1209**	**0.50%**	**7**	**934**	**0.75%**	**2**	**963**	**0.21%**	**3**	**598**	**0.50%**
"After (Steady Purple)" Total		**12**	**6453**	**0.19%**	**18**	**4779**	**0.38%**	**6**	**5683**	**0.11%**	**13**	**3775**	**0.34%**
Percent Reduction				**18.1%**			**23.4%**			**26.7%**			**37.5%**
AM Peak	7am-8am	2	1140	0.18%	3	827	0.36%	2	1215	2.00%	5	884	0.57%
	8am-9am	2	964	0.21%	2	679	0.29%	1	1043	0.10%	2	729	0.27%
AM Subtotal		**4**	**2104**	**0.19%**	**5**	**1506**	**0.33%**	**3**	**2258**	**0.13%**	**7**	**1613**	**0.43%**
Midday Peak	11am-12pm	1	476	0.21%	0	315	0.00%	1	536	0.19%	3	331	0.91%
	12pm-1pm	0	509	0.00%	1	338	0.30%	0	577	0.00%	2	304	0.66%
Midday Subtotal		**1**	**985**	**0.10%**	**1**	**653**	**0.15%**	**1**	**1113**	**0.09%**	**5**	**635**	**0.79%**
PM Peak	4pm-5pm	0	1025	0.00%	4	788	0.51%	1	1048	0.10%	1	684	0.15%
	5pm-6pm	1	1182	0.08%	4	948	0.42%	0	1030	0.00%	3	715	0.42%
PM Subtotal		**1**	**2207**	**0.05%**	**8**	**1736**	**0.46%**	**1**	**2078**	**0.05%**	**4**	**1399**	**0.29%**
Saturday Peak	11am-12pm	2	533	0.38%	3	432	0.69%	0	470	0.00%	2	265	0.75%
	12pm-1pm	3	565	0.53%	3	414	0.72%	2	474	0.42%	1	301	0.33%
Saturday Subtotal		**5**	**1098**	**0.46%**	**6**	**846**	**0.71%**	**2**	**944**	**0.21%**	**3**	**566**	**0.53%**
"After (Flashing Purple)" Total		**11**	**6394**	**0.17%**	**20**	**4741**	**0.42%**	**7**	**6393**	**0.11%**	**19**	**4213**	**0.45%**
Percent Reduction				**24.3%**			**13.9%**			**24.5%**			**18.4%**

FINDINGS

The following sections describe the findings of MOE #1 that is defined as the percent of *E-ZPass*SM customers who change lanes into a dedicated *E-ZPass*SM lane from a cash paying lane.

Descriptive Observations

- The northbound and southbound "before" condition data ranges from approximately 0.3% to 1.2% for the occurrences of lane changes by *E-ZPass*SM customers to Lane #4 from Lane #3 and from 0.1% to 0.8% by *E-ZPass*SM customers to Lane #5 from Lane #6.
- The difference in percent between the total "before" and total "after-steady/solid" condition for Lane #4 is 0.11% northbound and 0.21% southbound. The percent difference in Lane #5 is 0.04% both northbound and southbound.
- The difference in percent between the total "before" and total "after-flashing" condition for Lane #4 is 0.07% northbound and 0.05% southbound. The percent difference in Lane #5 is 0.05% northbound and 0.03% southbound.
- The difference between the total "before" and total "after-steady/solid" condition in Lane #4 represents an approximate 23% northbound and 38% southbound reduction for lane changes by *E-ZPass*SM customers, and the difference in Lane #5 represents an approximate 18% northbound and 27% southbound reduction.
- The difference between the total "before" and total "after-flashing" condition in Lane #4 represents an approximate 14% northbound and 18% southbound reduction for lane changes by *E-ZPass*SM customers, and the difference in Lane #5 represents an approximate 24% reduction both northbound and southbound.

Statistical Analysis Results

- The reduction in the percent of lane changes occurring only into Lane #4, only into Lane #5,and both Lane #4 and Lane #5 are not statistically significant. The change in proportions range from 8.5 to 31.2 percent, respectively where less than 5 percent was the target.

ANALYSIS SUMMARY

The purple lights under both "steady/solid" and "flashing" operations did reduce the number of lane changes occurring close to the toll booths in Lanes #4 and #5 northbound and southbound. The reduction in lane change maneuvers corresponds to a reduction in vehicle conflicts close to the toll booths. However, because the number of *E-ZPass*SM users who were observed making the lane change maneuver is so small as a percentage of the total users (<1%), the result from a statistical perspective has been determined to be "not significant".

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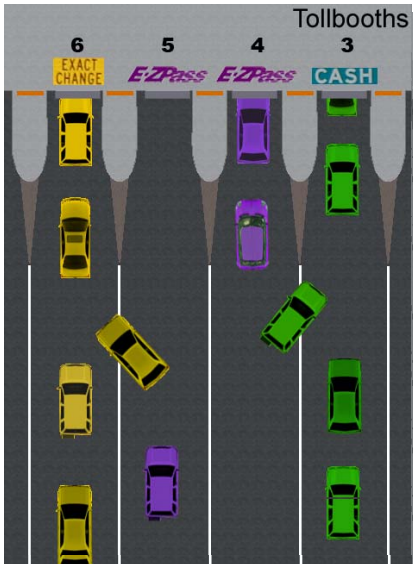
MOE #2: Lane Changes By Cash Paying Customers



This measure refers to cash-paying customers who mistakenly find themselves in a dedicated *E-ZPass*SM lane. MOE #2 data was recorded and reduced in accordance with previous methodologies used in evaluating toll lane changes for similar experiments[7]. As such, the MOE is defined as the percent of cash paying customers who change lanes out of a dedicated *E-ZPass*SM lane into a cash lane near the toll barrier (painted gore). The percent is determined based on the total number of cash paying motorists who travel through the cash paying lanes adjacent to the *E-ZPass*SM lane being observed. This evaluation focused on Cash Accepted Lane #3 and Exact Change Lane #6, which are adjacent to dedicated *E-ZPass*SM Lanes #4 and #5, respectively. Data for this MOE was recorded and reduced through manual observations.

DATA REDUCTION

Data that was reduced for MOE #2 focused on the typical weekday (Tuesday, Wednesday, or Thursday) morning (AM), midday and evening (PM) peak periods as well as the Saturday midday to capture the effects the purple lights had on both commuter (AM and PM) and arbitrary (Weekday and Saturday Midday) users of the turnpike system. Two (2) hours of data during each peak period was calculated to be required to achieve a statistical significance of 95 percent. This calculation can be found in the Appendix.

Lane change maneuvers for this measure of effectiveness were reduced from the same time periods from which data for MOE #1was collected (see page 12).

The results of the data reduction are summarized in Table 3.

FINDINGS

The discussion sections on the page following Table 3 describe the findings of MOE #2 that is defined as cash-paying customers who mistakenly find themselves in a dedicated *E-ZPass*SM lane.

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7 "Experimental Traffic Control Device Testing at Maryland Toll Plazas", published by Kittleson & Associates, Inc., Baltimore, MD, March 9, 2006

Table 3
MOE #2 – Percent Lane Changes By Cash Paying Customers

		NORTHBOUND						SOUTHBOUND					
		Exact Change Lane #6			Cash Accepted Lane #3			Exact Change Lane #6			Cash Accepted Lane #3		
Peak Period	Time	Lane Changes Out Of Lane #5	Lane #6 Volume	Percent	Lane Changes Out Of Lane #4	Lane #3 Volume	Percent	Lane Changes Out Of Lane #5	Lane #6 Volume	Percent	Lane Changes Out Of Lane #4	Lane #3 Volume	Percent
AM Peak	7am-8am	7	224	3.13%	2	252	0.79%	4	288	1.39%	7	310	2.26%
	8am-9am	4	234	1.71%	9	276	3.26%	5	278	1.80%	7	269	2.60%
AM Subtotal		**11**	**458**	**2.40%**	**11**	**528**	**2.08%**	**9**	**566**	**1.59%**	**14**	**579**	**2.42%**
Midday Peak	11am-12pm	13	221	5.88%	18	260	6.92%	7	219	3.20%	10	228	4.39%
	12pm-1pm	16	267	5.99%	7	239	2.93%	8	247	3.24%	15	239	6.28%
Midday Subtotal		**29**	**488**	**5.94%**	**25**	**499**	**5.01%**	**15**	**466**	**3.22%**	**25**	**467**	**5.35%**
PM Peak	4pm-5pm	8	329	2.43%	11	314	3.50%	18	370	4.86%	13	304	4.28%
	5pm-6pm	9	311	2.89%	13	350	3.71%	2	304	0.66%	9	302	2.98%
PM Subtotal		**17**	**640**	**2.66%**	**24**	**664**	**3.61%**	**20**	**674**	**2.97%**	**22**	**606**	**3.63%**
Saturday Peak	11am-12pm	28	626	4.47%	11	550	2.00%	21	441	4.76%	16	282	5.67%
	12pm-1pm	29	475	6.11%	19	465	4.09%	22	434	5.07%	10	264	3.79%
Saturday Subtotal		**57**	**1101**	**5.18%**	**30**	**1015**	**2.96%**	**43**	**875**	**4.91%**	**26**	**546**	**4.76%**
"Before" Total		**114**	**2687**	**4.24%**	**90**	**2706**	**3.33%**	**87**	**2581**	**3.37%**	**87**	**2198**	**3.96%**
AM Peak	7am-8am	6	265	2.26%	5	305	1.64%	4	306	1.31%	5	225	2.22%
	8am-9am	6	258	2.33%	7	284	2.46%	5	293	1.71%	6	233	2.58%
AM Subtotal		**12**	**523**	**2.29%**	**12**	**589**	**2.04%**	**9**	**599**	**1.50%**	**11**	**458**	**2.40%**
Midday Peak	11am-12pm	9	276	3.26%	13	270	4.81%	12	296	4.05%	8	247	3.24%
	12pm-1pm	8	277	2.89%	10	266	3.76%	12	331	3.63%	3	263	1.14%
Midday Subtotal		**17**	**553**	**3.07%**	**23**	**536**	**4.29%**	**24**	**627**	**3.83%**	**11**	**510**	**2.16%**
PM Peak	4pm-5pm	5	381	1.31%	12	340	3.53%	5	394	1.27%	8	310	2.58%
	5pm-6pm	5	347	1.44%	12	330	3.64%	3	381	0.79%	9	304	2.96%
PM Subtotal		**10**	**728**	**1.37%**	**24**	**670**	**3.58%**	**8**	**775**	**1.03%**	**17**	**614**	**2.77%**
Saturday Peak	11am-12pm	28	487	5.75%	11	415	2.65%	18	400	4.50%	15	323	4.64%
	12pm-1pm	19	435	4.37%	13	411	3.16%	13	397	3.27%	14	342	4.09%
Saturday Subtotal		**47**	**922**	**5.10%**	**24**	**826**	**2.91%**	**31**	**797**	**3.89%**	**29**	**665**	**4.36%**
"After (Steady Purple)" Total		**86**	**2726**	**3.15%**	**83**	**2621**	**3.17%**	**72**	**2798**	**2.57%**	**68**	**2247**	**3.03%**
Percent Reduction				**26.0%**			**4.8%**			**25.6%**			**24.1%**
AM Peak	7am-8am	4	255	1.57%	6	273	2.20%	6	275	2.00%	7	300	2.33%
	8am-9am	3	257	1.17%	5	313	1.60%	2	263	0.76%	6	275	2.18%
AM Subtotal		**7**	**512**	**1.37%**	**11**	**586**	**1.88%**	**8**	**538**	**1.49%**	**13**	**575**	**2.26%**
Midday Peak	11am-12pm	5	252	1.98%	17	263	6.46%	4	241	1.66%	10	231	4.33%
	12pm-1pm	4	257	1.56%	8	242	3.31%	3	251	1.20%	5	235	2.13%
Midday Subtotal		**9**	**509**	**1.77%**	**25**	**505**	**4.95%**	**7**	**492**	**1.42%**	**15**	**466**	**3.22%**
PM Peak	4pm-5pm	5	358	1.40%	13	279	4.66%	3	374	0.80%	14	343	4.08%
	5pm-6pm	3	348	0.86%	9	296	3.04%	3	360	0.83%	15	329	4.56%
PM Subtotal		**8**	**706**	**1.13%**	**22**	**575**	**3.83%**	**6**	**734**	**0.82%**	**29**	**672**	**4.32%**
Saturday Peak	11am-12pm	20	380	5.26%	8	370	2.16%	16	369	4.34%	15	289	5.19%
	12pm-1pm	16	383	4.18%	9	352	2.56%	16	377	4.24%	9	288	3.13%
Saturday Subtotal		**36**	**763**	**4.72%**	**17**	**722**	**2.35%**	**32**	**746**	**4.29%**	**24**	**577**	**4.16%**
"After (Flashing Purple)" Total		**60**	**2490**	**2.41%**	**75**	**2388**	**3.14%**	**53**	**2510**	**2.11%**	**81**	**2290**	**3.54%**
Percent Reduction				**43.2%**			**5.6%**			**37.4%**			**11.1%**

Descriptive Observations

- The northbound and southbound "before" condition data ranges from approximately 2.1% to 5.4% for the occurrences of lane changes by cash paying customers out of Lane #4 to Lane #3 and from 2.4% to 5.9% by cash paying customers to Lane #6 from Lane #5.
- The difference in percent between the total "before" and total "after-steady/solid" condition for Lane #3 is 0.16% northbound and 0.93% southbound. The percent difference in Lane #6 is 1.09% northbound and 0.80% southbound.
- The difference in percent between the total "before" and total "after-flashing" condition for Lane #3 is 0.19% northbound and 0.42% southbound. The percent difference in Lane #6 is 1.83% northbound and 1.26% southbound.
- The difference between the total "before" and total "after-steady/solid" condition in Lane #3 represents an approximate 5% northbound and 24% southbound reduction for lane changes by cash paying customers, and the difference in Lane #6 represents an approximate 26% reduction both northbound and southbound.
- The difference between the total "before" and total "after-flashing" condition in Lane #3 represents an approximate 6% northbound and 11% southbound reduction for lane changes by cash paying customers, and the difference in Lane #6 represents an approximate 43% reduction northbound and a 37% reduction southbound.

Statistical Analysis Results

- The reduction in the percent of lane changes occurring only in Lane #3 is statistically significant in the southbound direction when comparing the "before" condition to the "after-flashing" condition. Statistical significance is not reached under all other conditions both northbound and southbound.
- The reduction in the percent of lane changes occurring only in Lane #6 is statistically significant under all "after" implementation conditions.
- Combining data for Lane #3 and #6 results in a statistically significant reduction in the percent of lane changes.

ANALYSIS SUMMARY

The purple lights under both "steady/solid" and "flashing" operations did reduce the number of lane changes occurring close to the toll booths in Lanes #3 and #6 northbound and southbound, which is consistent with the results from MOE #1. The statistical significance for Lane #6 and Lane #3 and #6 combined reinforce the effectiveness of the purple lights.

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MOE #3: Percent Utilization of Dedicated *E-ZPass*SM Lanes

The NHDOT Bureau of Turnpikes provided toll lane utilization reports during the "before" and two "after" (steady/solid and flashing purple light) conditions. The toll lane utilization reports identify the number of vehicles using each toll lane during each hour of the day. Utilization reports were obtained for all traffic traveling through the Hooksett Toll Plaza by both the lane that was used as well as the payment type (cash or *E-ZPass*SM). The utilization of toll lanes during the "before", "after-steady/solid", and "after-flashing" data collection periods was compared to determine if the purple lights improved the balance of lane utilization across the lanes that accept *E-ZPass*SM.

DATA REDUCTION

Figures 12 through 17 illustrate the toll lane utilization for *E-ZPass*SM customers traveling through the Hooksett Toll Plaza both northbound and southbound, respectively, designated by the "A" and "B" following the figure number. The figures group the data according to the following conditions:

- Figure 12 – 24 Hour Weekday Toll Lane Utilization
- Figure 13 – Weekday AM Peak Hour Toll Lane Utilization
- Figure 14 – Weekday Midday Peak Hour Toll Lane Utilization
- Figure 15 – Weekday PM Peak Hour Toll Lane Utilization
- Figure 16 – 24 Hour Saturday Toll Lane Utilization
- Figure 17 – Saturday Midday Peak Hour Toll Lane Utilization

Each of the six figures consists of 4 bar graphs. When landscape oriented, the upper left bar graph summarizes the percent of total volume of *E-ZPass*SM traffic that used the joint use (cash and *E-ZPass*SM) lanes (2 and 3); noting that lanes 4 and 5 contain 100% *E-ZPass*SM users and lanes 6 and 7 contain 0% *E-ZPass*SM users (ignoring toll violations that are summarized in MOE#4). Data is shown for a total of nine days; three days each during the "before" condition, "after-steady/solid" and "after-flashing", respectively.

The other three bar graphs that make up each figure illustrate the total traffic volume in each toll lane. The green portion of each bar graph is the volume of cash-paying customers using each lane and the purple portion of each bar graph is the volume of *E-ZPass*SM customers using each toll lane.

Figure 12A – 24 Hour Weekday Northbound

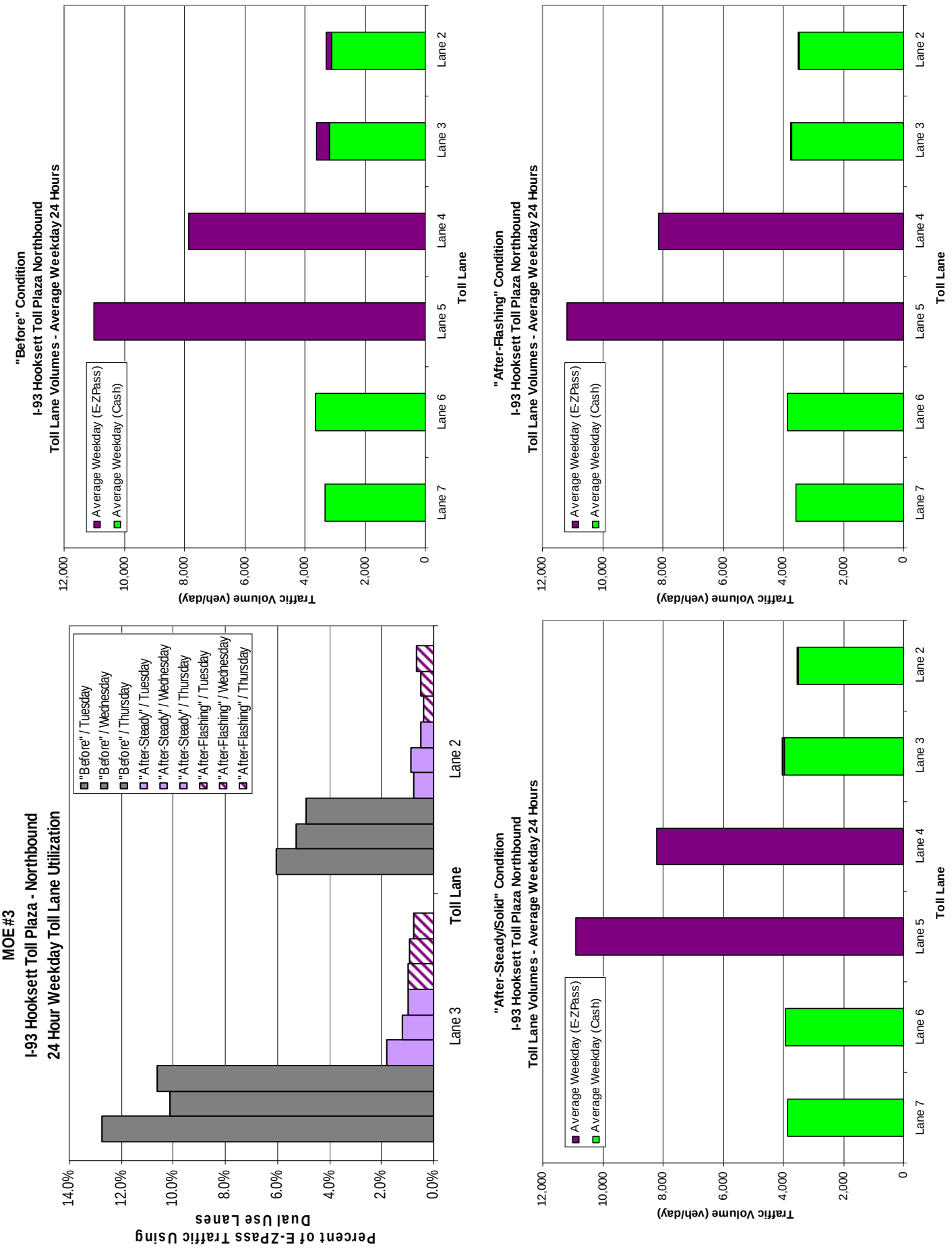


Figure 12B – 24 Hour Weekday Southbound

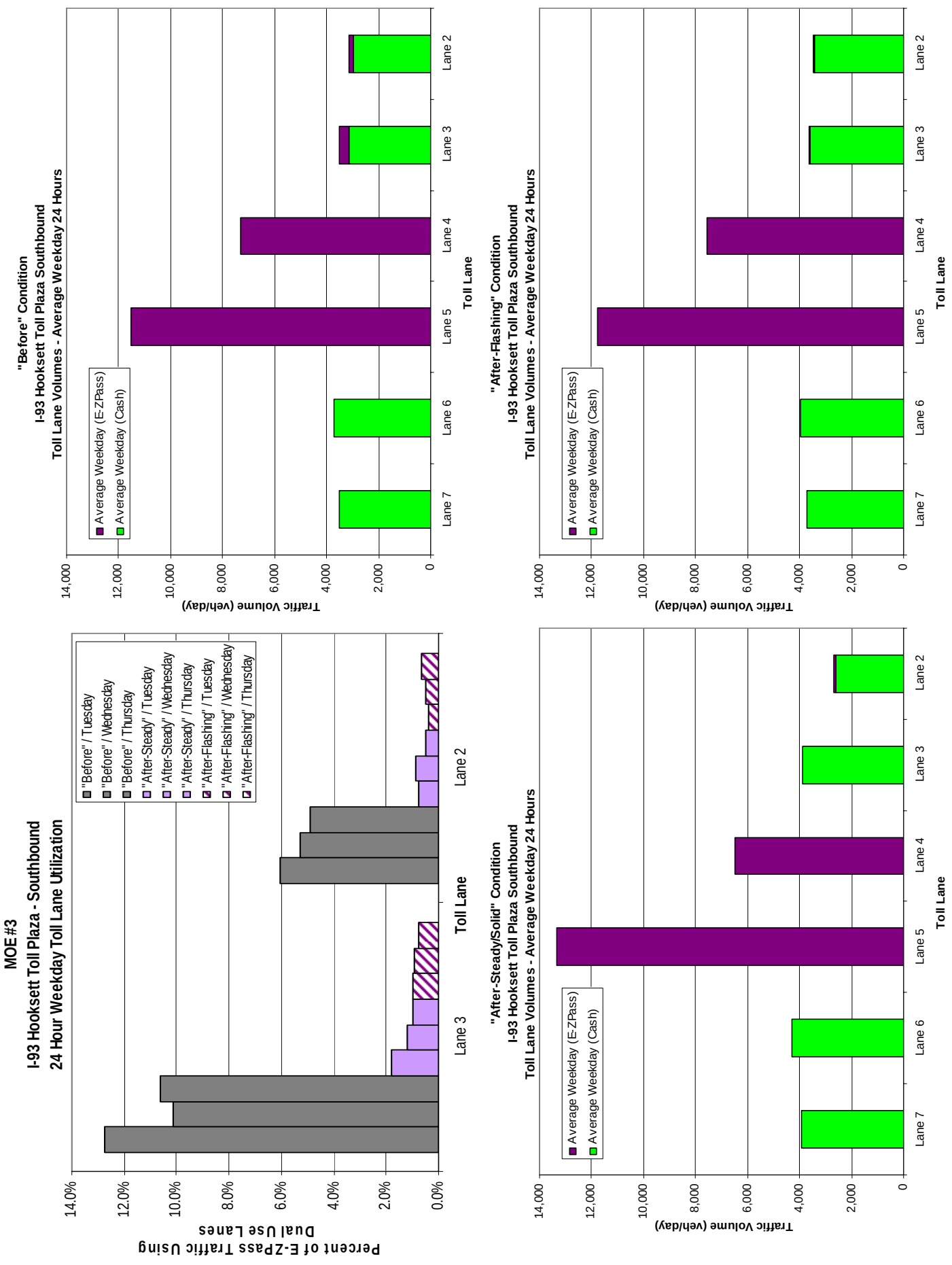


Figure 13A – Weekday AM Peak Hour Northbound

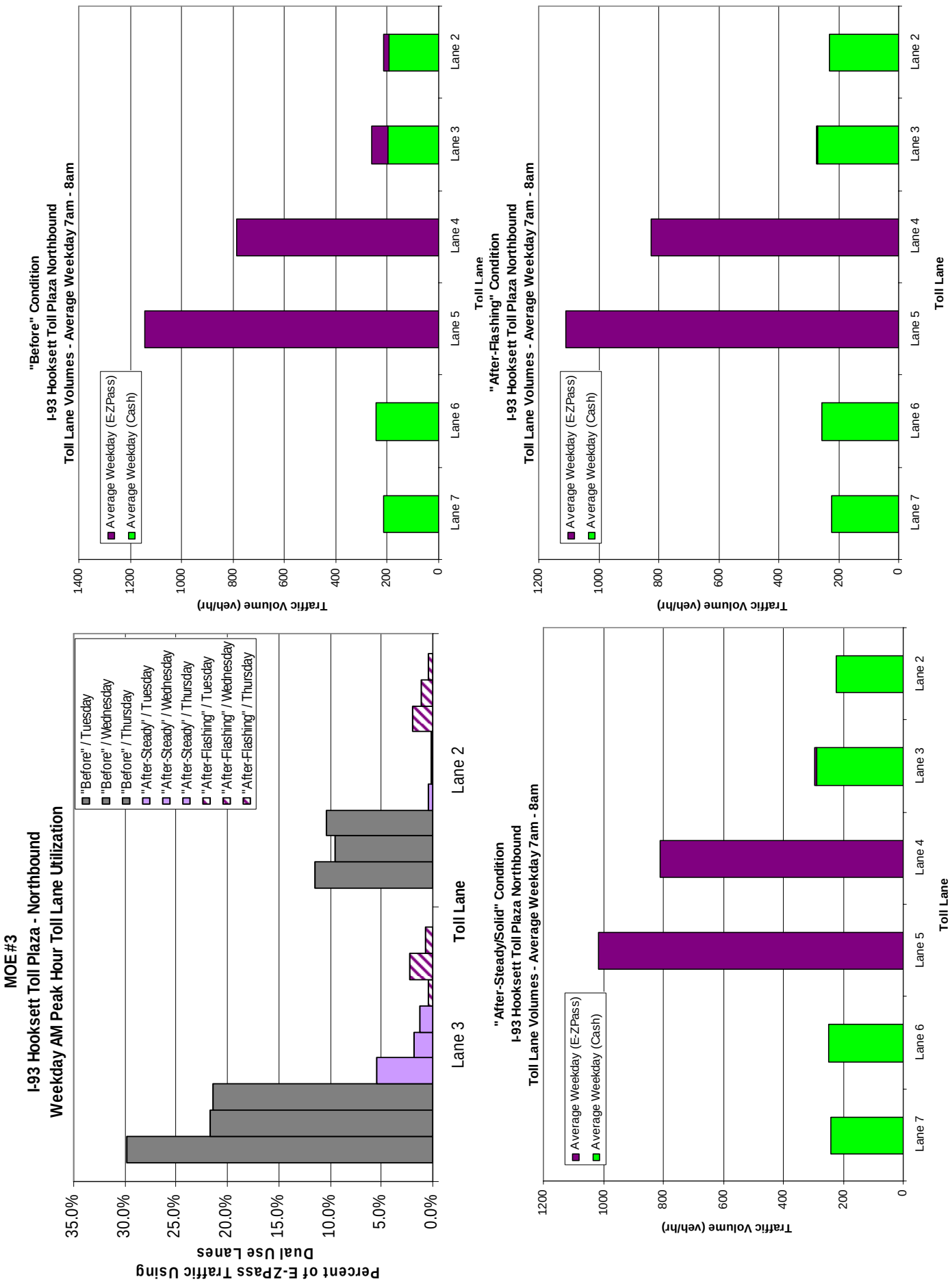


Figure 13B – Weekday AM Peak Hour Southbound

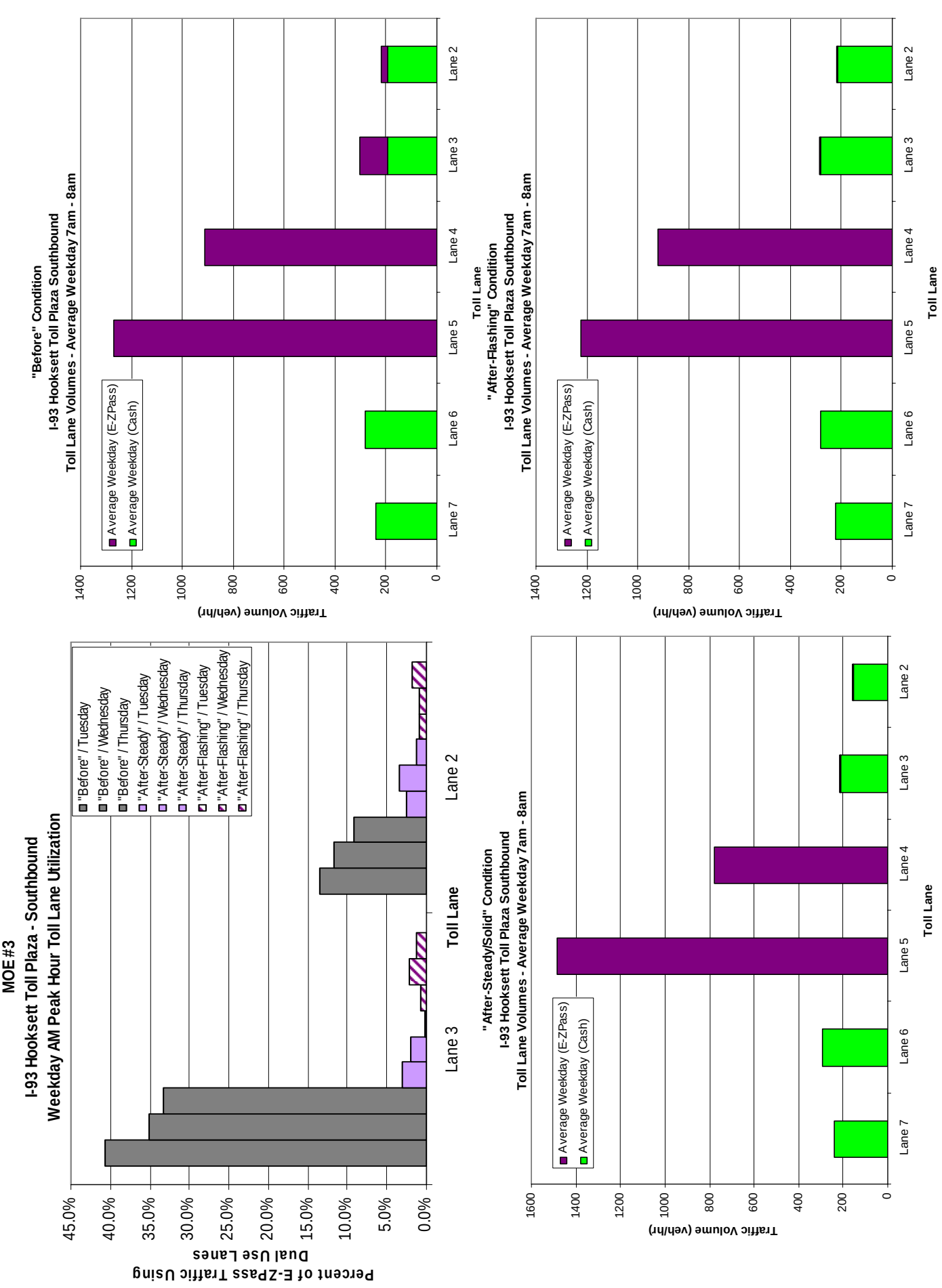


Figure 14A – Weekday Midday Peak Hour Northbound

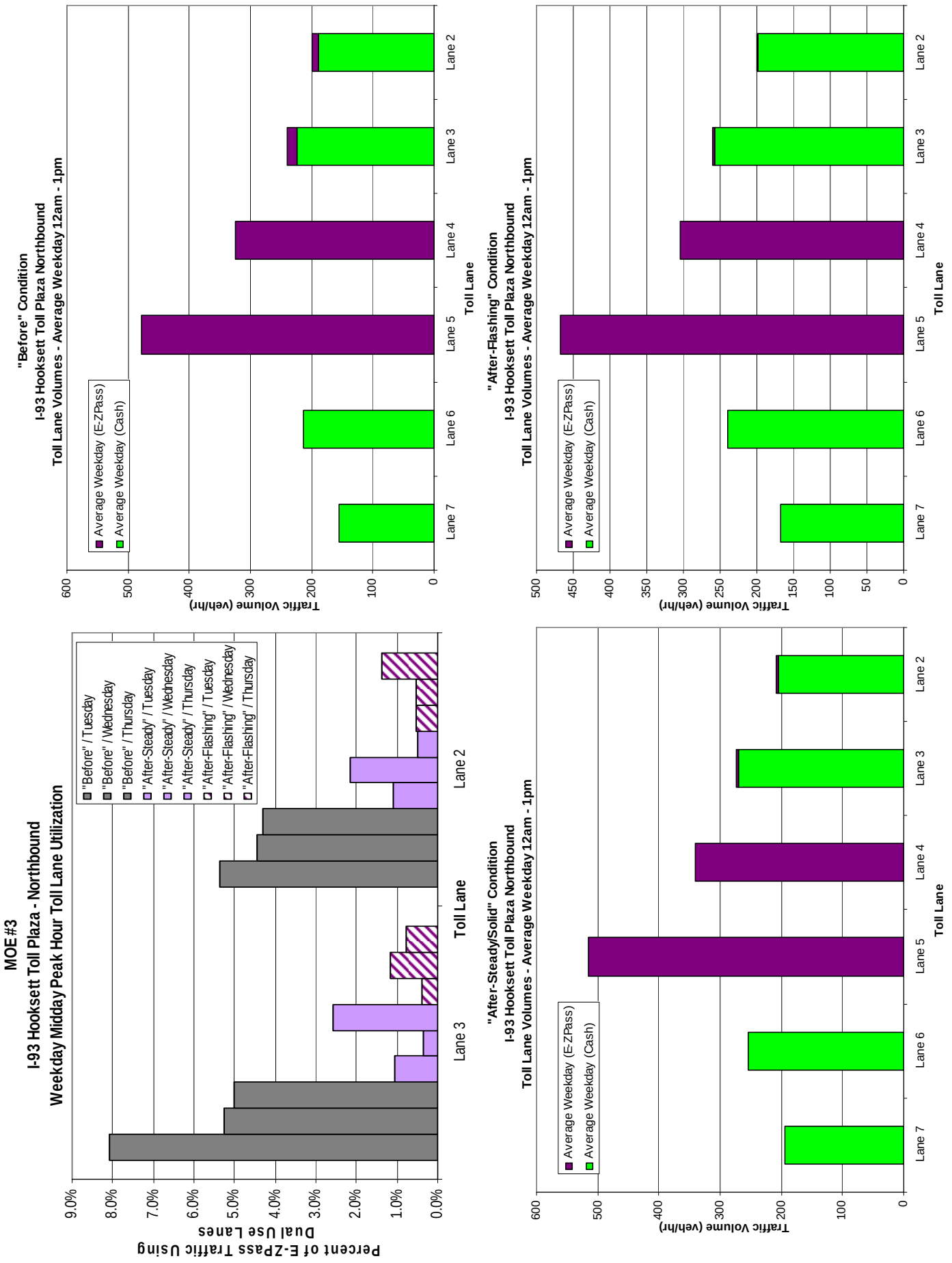


Figure 14B – Weekday Midday Peak Hour Southbound

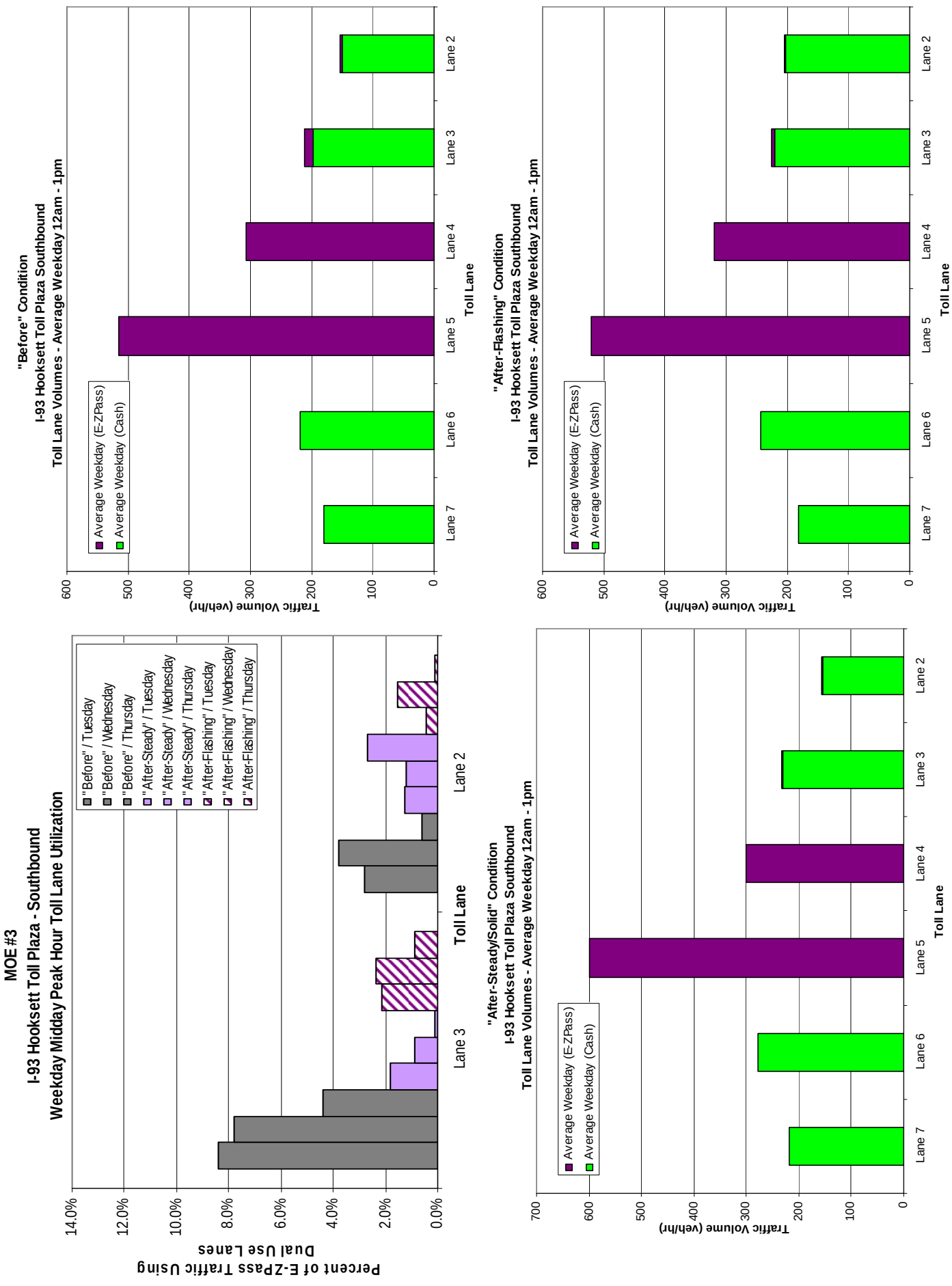


Figure 15A – Weekday PM Peak Hour Northbound

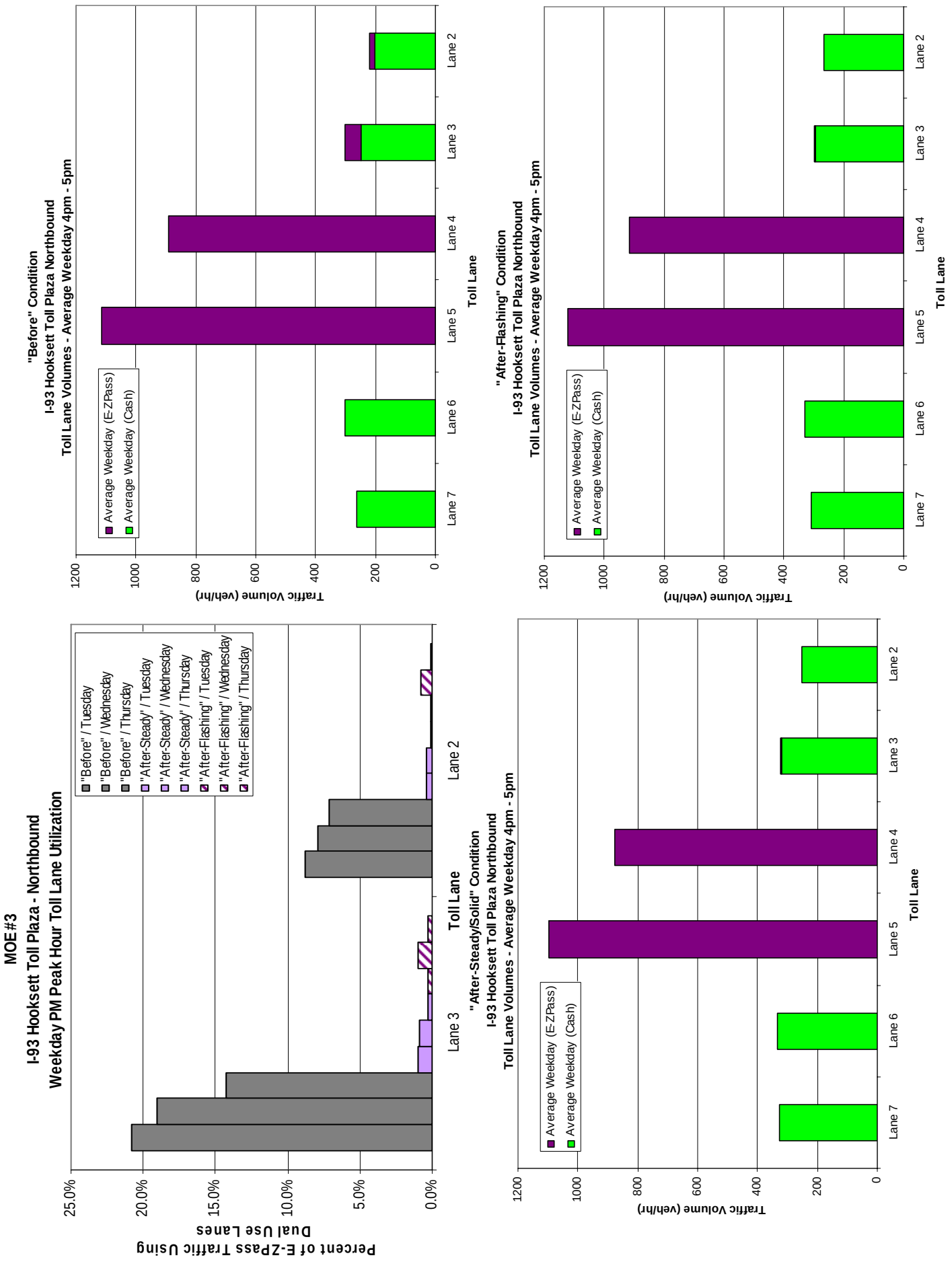
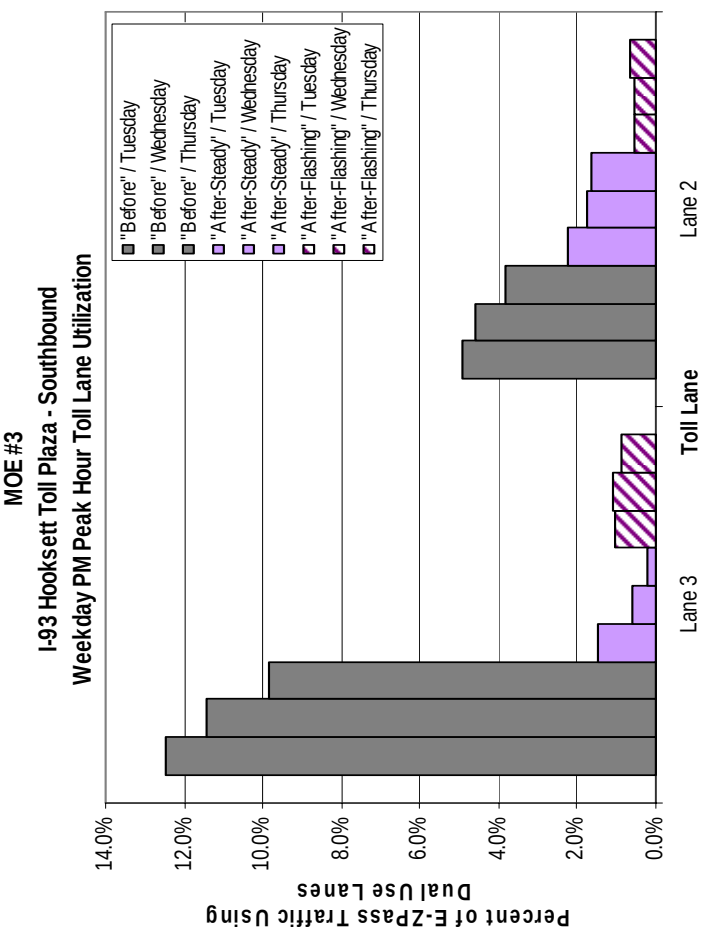
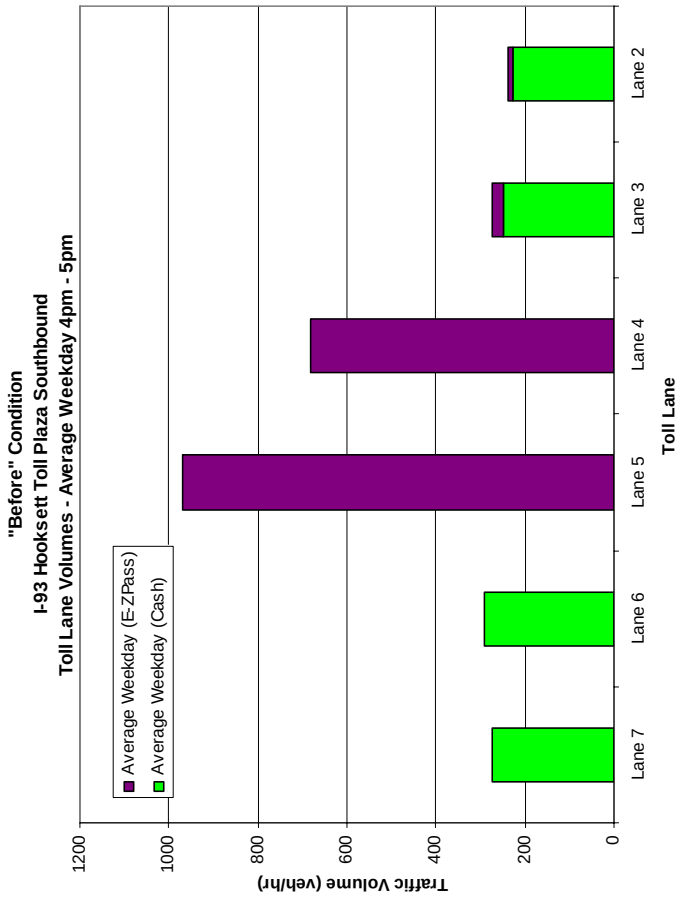
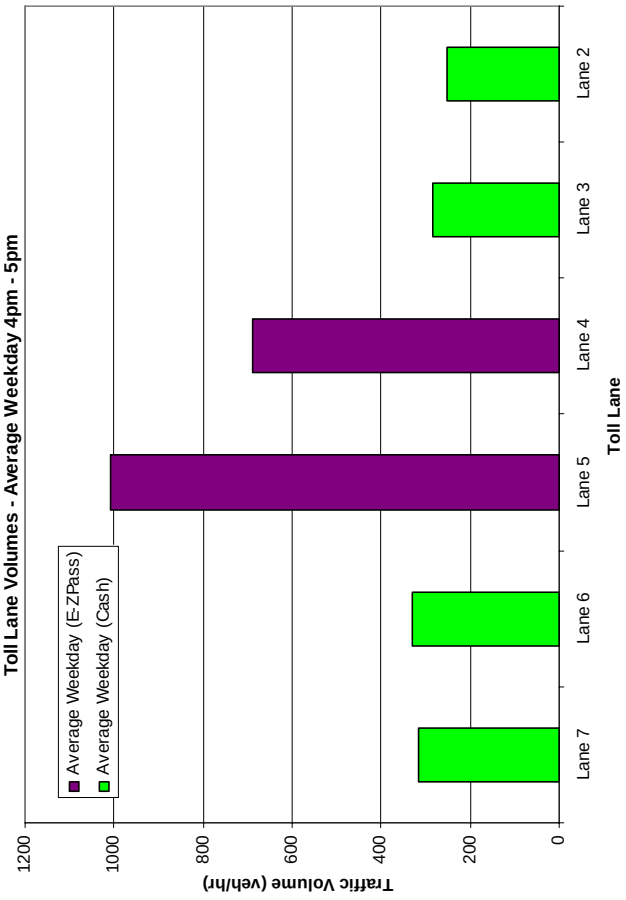


Figure 15B – Weekday PM Peak Hour Southbound







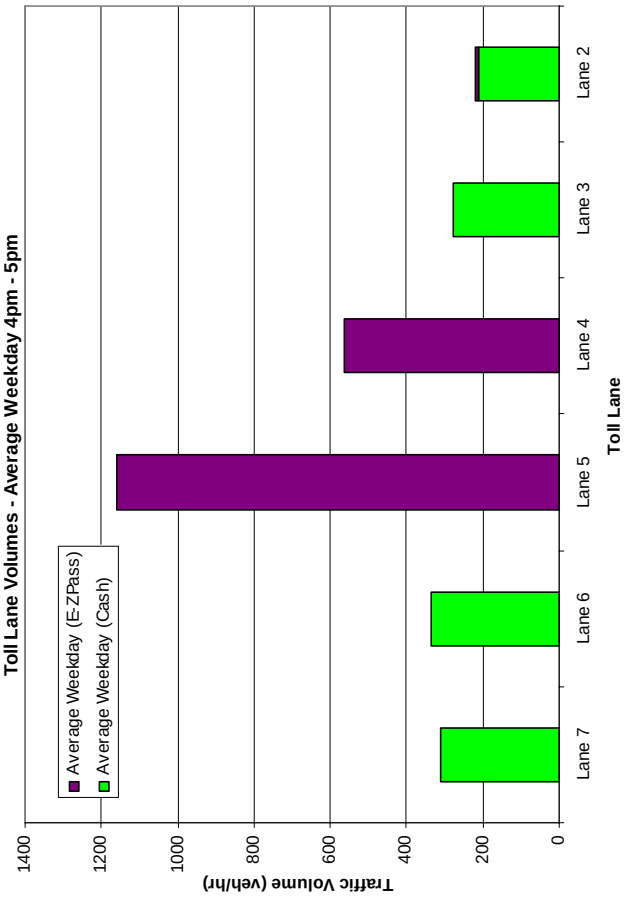


Figure 16A – 24 Hour Saturday Northbound

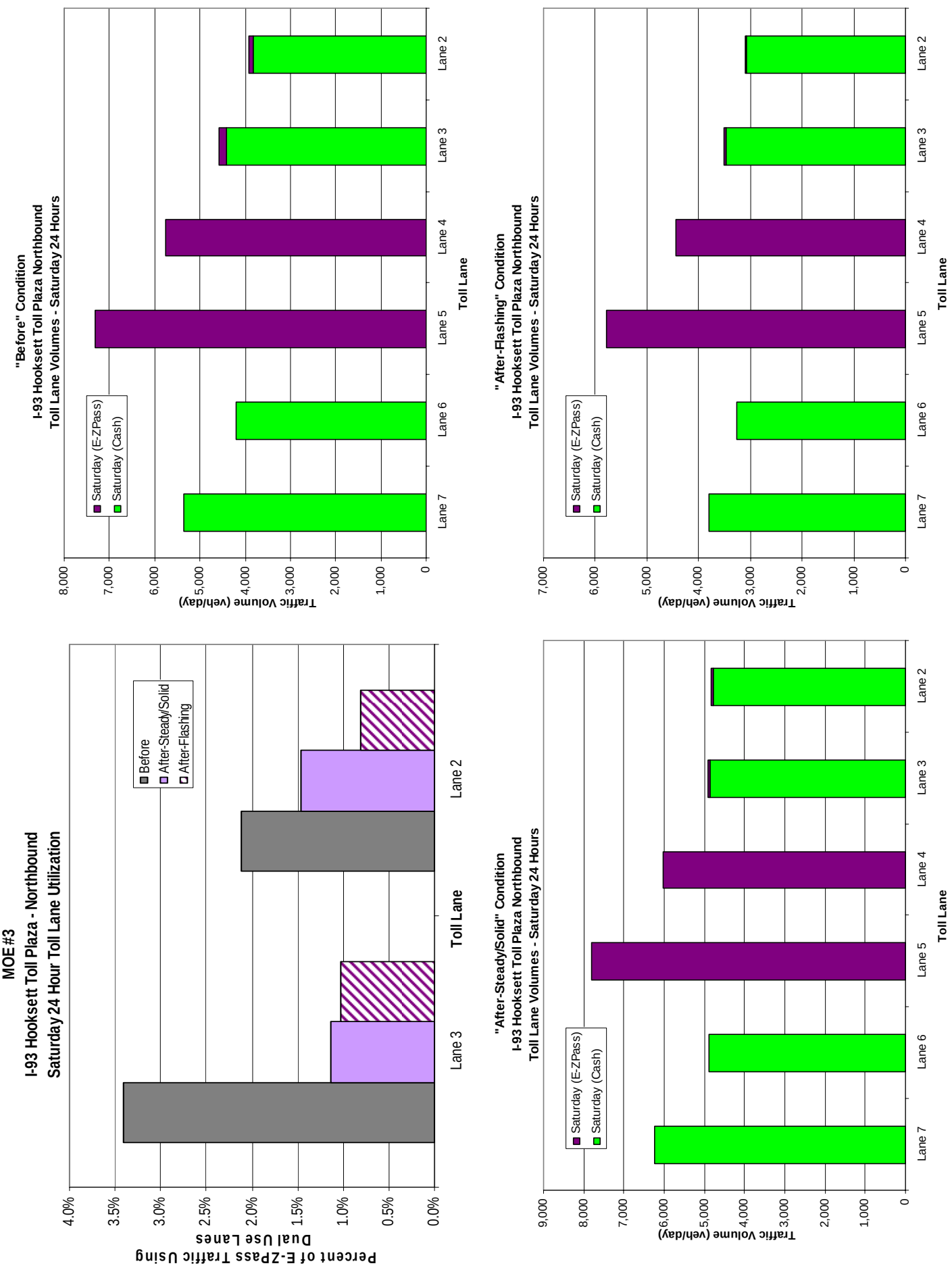


Figure 16B – 24 Hour Saturday Southbound

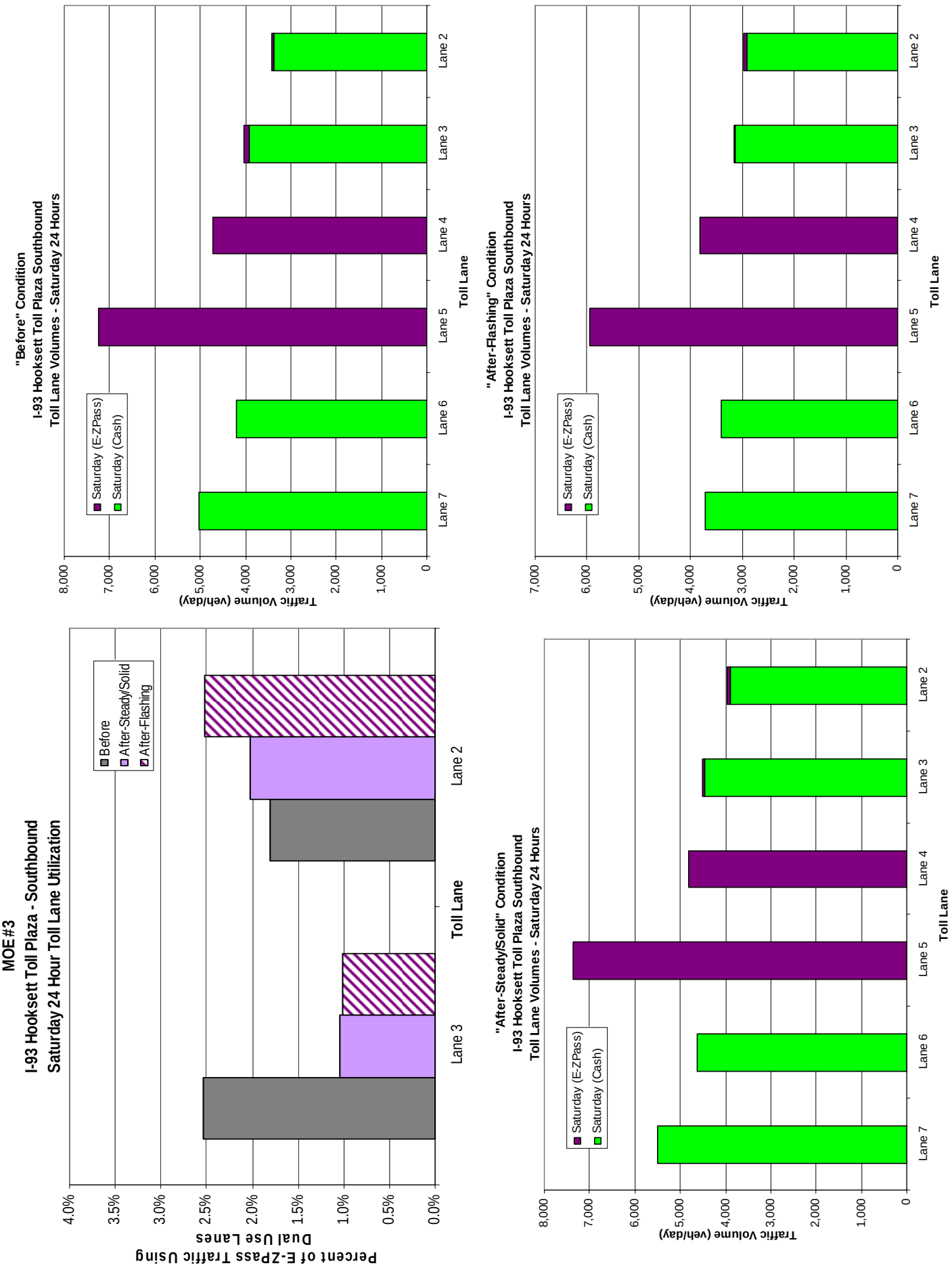


Figure 17A – Saturday Midday Peak Hour Northbound

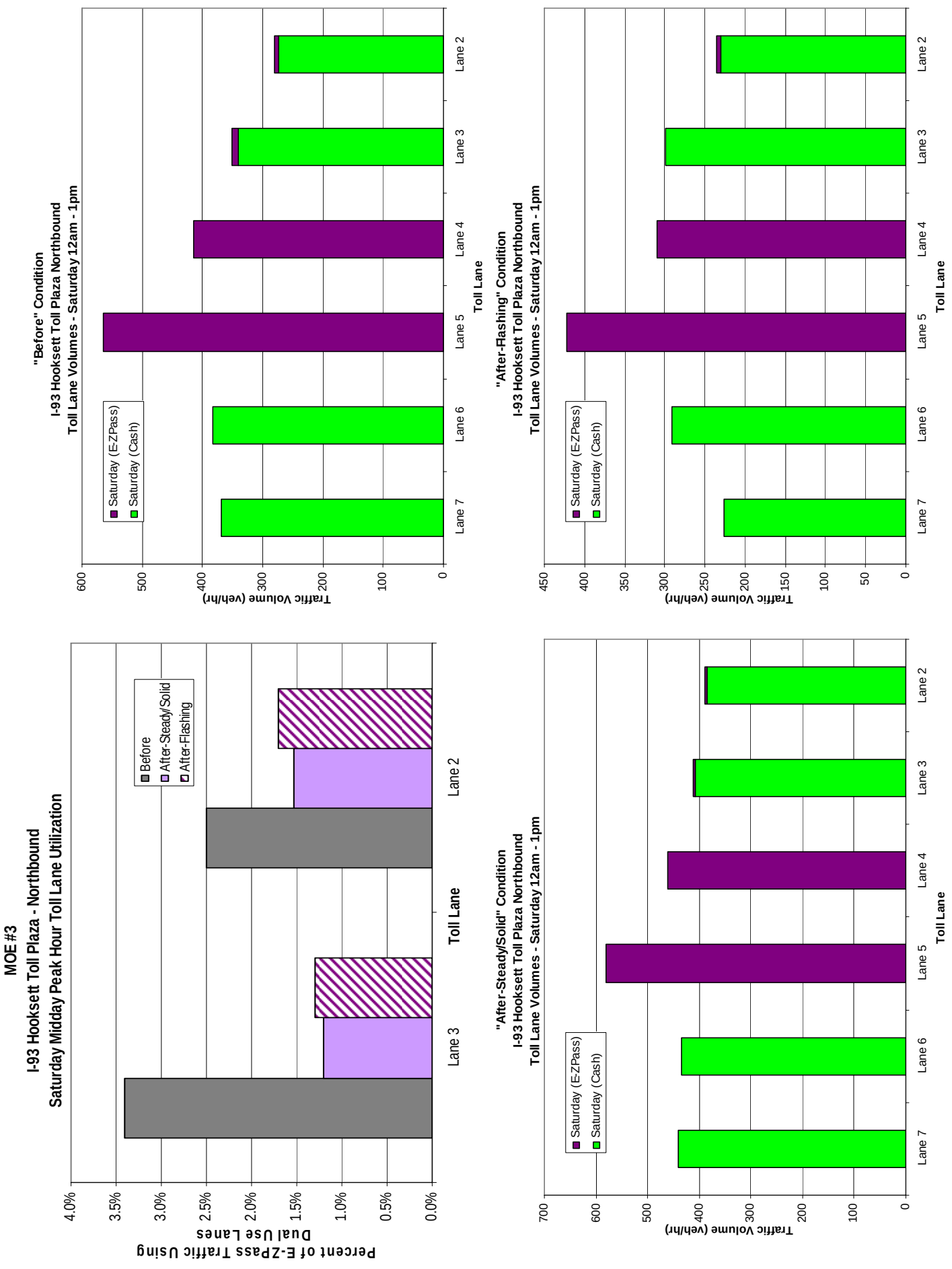
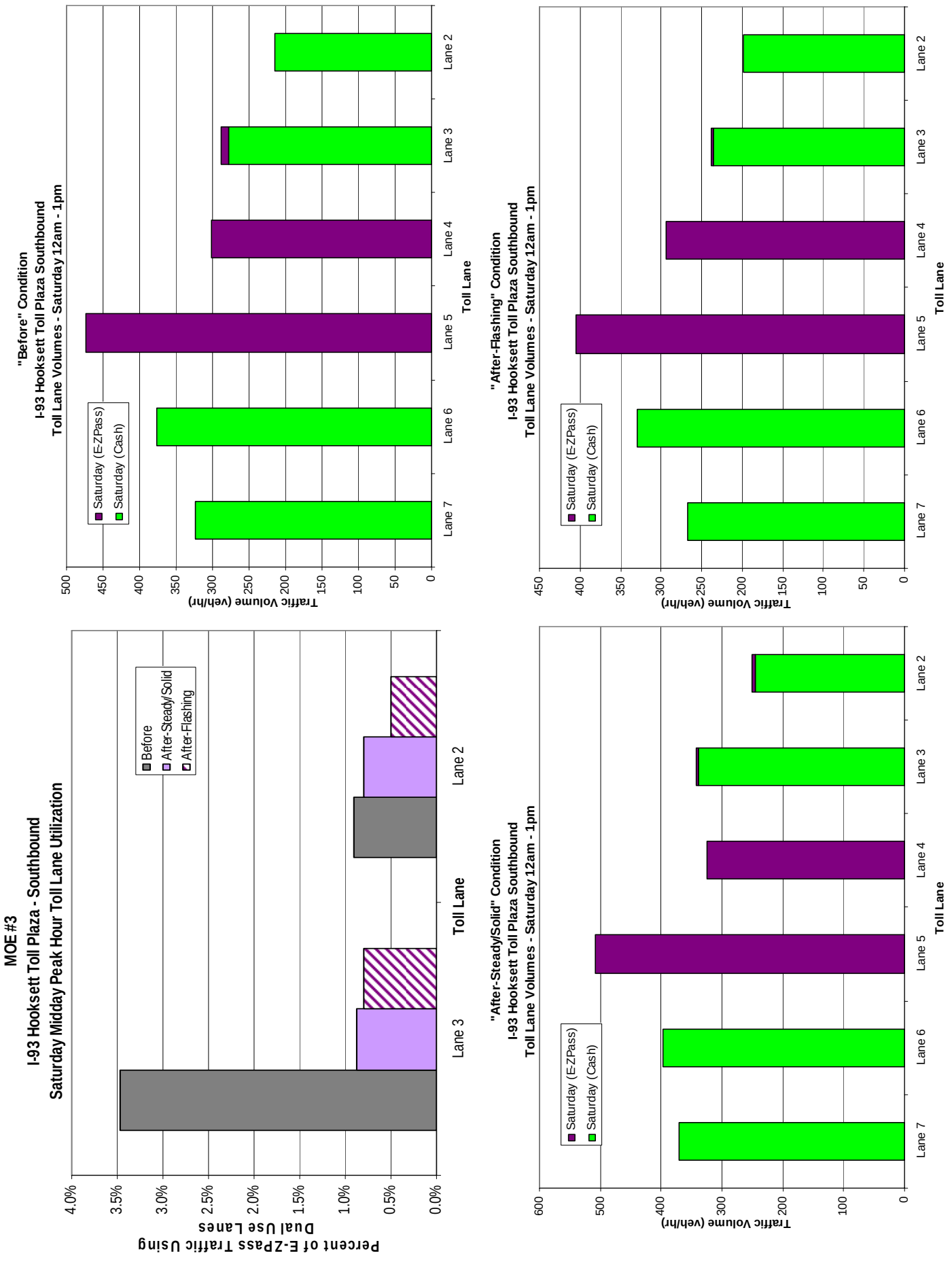


Figure 17B – Saturday Midday Peak Hour Southbound



FINDINGS

The following sections describe the findings of MOE #3 that is defined as utilization given the number of vehicles using each toll lane during each hour of the day.

Descriptive Observations

- The data shows a lower percentage of *E-ZPass*SM customers in joint-use Cash/ *E-ZPass*SM Lanes #2 and #3 during both the "after" conditions in both the northbound and southbound directions when compared to the "before" condition with the exception of southbound, total daily traffic on Saturday.
- The data shows a lower percentage of *E-ZPass*SM customers in joint-use Cash/ *E-ZPass*SM Lanes #2 and #3 in the "after-flashing" condition in both the northbound and southbound directions when comparing the "after-steady/solid" to the "after-flashing" conditions.
- The data shows a steady increase in the percent of *E-ZPass*SM customers traveling through *E-ZPass*SM only Lanes #4 and #5 during both "after" conditions.

Statistical Analysis Results

A detailed discussion on the results of the statistical analysis under each alternative can be found in the Appendix. The following are general conclusions:

- Statistically significant changes in traffic volumes only occurred across all toll lanes simultaneously when evaluating the weekday 24-hour time periods.
- A statistically significant decrease in *E-ZPass*SM customers occurred in Lane #2 and #3 in both the northbound and southbound directions during both the "after" conditions when compared to the "before" condition. The only time period statistical significance was not noted for these two lanes was the Saturday Midday peak hour.
- A statistically significant increase in *E-ZPass*SM customers occurred in Lane #5 in the southbound direction during both the "after" conditions when compared to the "before" condition during the weekday 24-hour, AM and PM peak hours.

ANALYSIS SUMMARY

The statistical tests of proportions related to MOE #3 suggest that lane utilization changes at a statistically significant level occur when considering all 24 hours on a weekday. There is preliminary evidence that lane volumes in *E-ZPass*SM Toll Lanes #4 and #5 increased after installation of the purple lights. Preliminary evidence also suggests a lower percentage of *E-ZPass*SM customers using joint-use Cash/ *E-ZPass*SM Lanes #2 and #3 with the implementation of purple lights as wayfinding devices. The shift in lane utilization indicates that *E-ZPass*SM customers previously using the right-side of the toll plaza are now recognizing, finding and using the dedicated centrally located *E-ZPass*SM lanes.

■

MOE #4: Percent of Toll Violations

Violations in dedicated *E-ZPass*SM lanes were identified from reports provided by the NHDOT Bureau of Turnpikes. A toll violation is when a vehicle goes through the toll plaza and no toll is paid with either cash or electronic transaction. Toll violations are the result of both confused and aggressive drivers. Confused drivers unintentionally enter the dedicated *E-ZPass*SM lane and fail to exit prior to the tollbooth. Aggressive drivers are defined as those without *E-ZPass*SM who enter a dedicated *E-ZPass*SM lane and do not exit prior to the tollbooths and intended to violate the tolls. It is noted that the violations that were recorded and provided for data reduction may not be "true violations" by definition. An event recorded as a violation may have been attributed to an erroneous data reading from the *E-ZPass*SM equipment or attributed to some other factor. Nevertheless, the data that is summarized as follows reflects a consistent comparison between the four conditions.

DATA REDUCTION

Figures 18 and 19 compare the percent of toll violations in each lane "before" and "after" the installation of the purple lights under both "after" conditions.

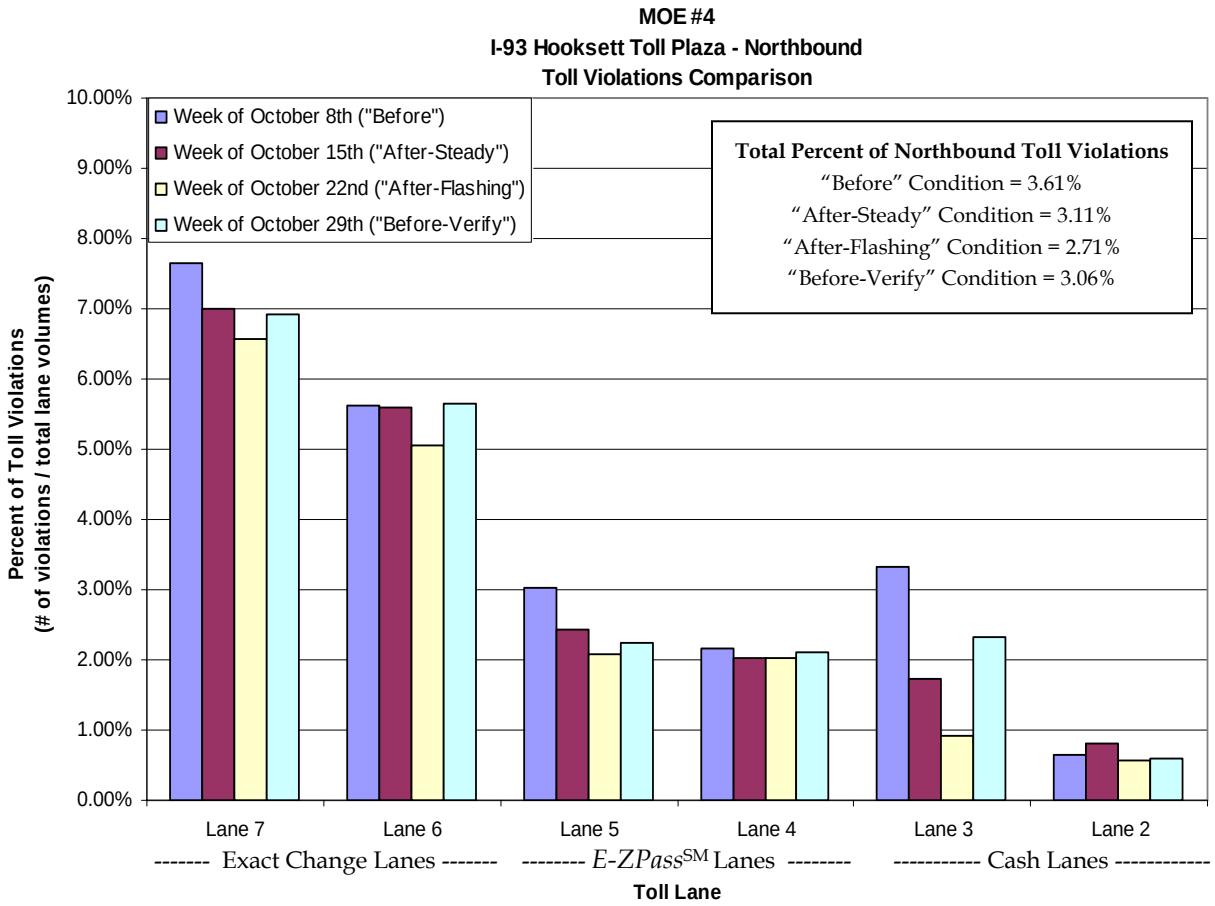


Figure 18 – Northbound Toll Violations Comparison

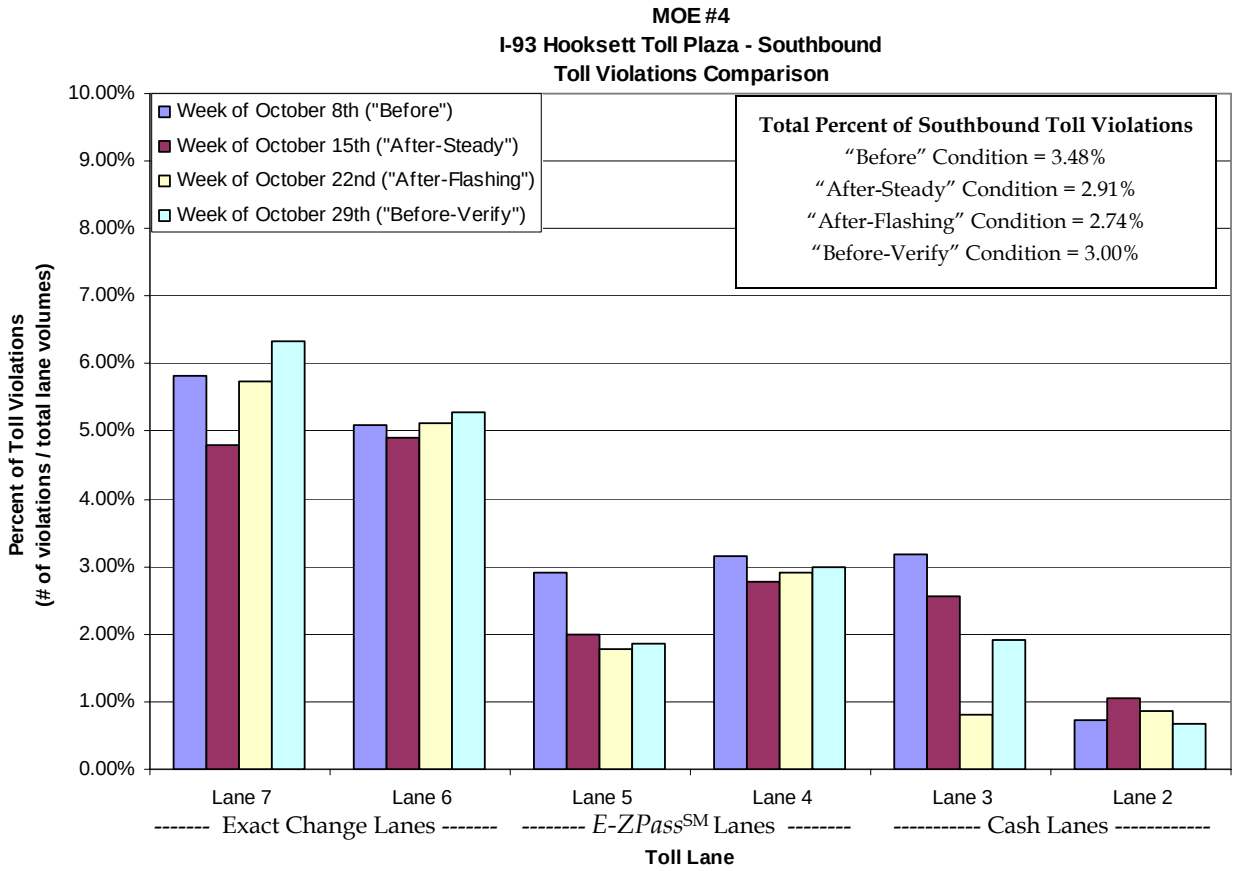


Figure 19 – Southbound Toll Violations Comparison

FINDINGS

Descriptive Observations

- The total percent of violations for the I-93 Hooksett toll plaza in the northbound direction decreased from the 3.61% "before" condition to 3.11% during the "after-steady/solid" condition to the 2.71% during the "after-flashing" condition. The "before" condition was "verified" following the purple light experiment and the number of violations increased to 3.06%.
- The total percent of violations for the I-93 Hooksett toll plaza in the southbound direction decreased from the 3.48% "before" condition to 2.91% during the "after-steady/solid" condition to the 2.74% during the "after-flashing" condition. The "before" condition was "verified" following the purple light experiment and the number of violations increased to 3.00%.

Statistical Analysis Results

- A comparison of the "before" and "after-steady/solid" condition data shows a statistically significant decrease in both the northbound and southbound directions in the percent of toll violations in Lanes #3, #4, #5 and #7. The percent of toll violations also decreased in Lane #6 but not to a statistically significant level.

- The comparison of the "before" and "after-steady/solid" condition data shows an increase in the percent of toll violations in the northbound and southbound directions in Lane #2 but not to a statistically significant level.
- A comparison of the "before" and "after-flashing" condition data shows a statistically significant decrease in both the northbound and southbound directions in the percent of toll violations in Lanes #3, #4, and #5. The percent of toll violations also decreased in Lanes #6 and #7 but not to a statistically significant level.
- The comparison of the "before" and "after-flashing" condition data shows an increase in the percent of toll violations in the southbound direction in Lane #2 but not to a statistically significant level. A decrease in the percent of toll violations in the northbound direction in Lane #2 was noted, but not to a statistically significant level.

ANALYSIS SUMMARY

The overall percentage of toll violations occurring in both the northbound and southbound directions showed a decrease in the number of violations across all toll lanes except Manual Change Lane #2 with the installation of the purple lights. All but one of these lanes (Exact Change Lane #6) showed statistical significance in the reduction in the number of violations. When the purple lights were turned off following the experiment, it was noted that the number of toll violations increased to a level greater than at any time when the purple light experiment was being conducted, but not to the level immediately preceding the purple light experiment.

3

Customer Survey

A survey was conducted among *E-ZPass*SM customers to gather information about a users' perspective on the deployment of the purple lights at the Hooksett Toll Plaza and the perceived effectiveness. Two forms of data collection techniques were used to gather information from the survey. The first method involved asking a user to fill out a paper questionnaire made available by the NHDOT at the *E-ZPass*SM Customer Service Center located onsite at the Hooksett Toll Plaza and both Hooksett Rest Areas located 2 miles north of the Hooksett Toll Plaza. The second method involved internet access to an online version of the survey. *E-ZPass*SM customers were informed of the opportunity to complete the survey by several methods of media exchange. These methods included the following:

- Verbal notification from October 16, 2006 to October 28, 2006 by NHDOT staff tending to the *E-ZPass*SM Customer Service Center and both Hooksett Rest Areas.
- A Formal News Release (posted on October 13, 2006) by the NHDOT describing the experiment. The news release was subsequently conveyed to the public through local newspaper (Union Leader, Nashua Telegraph, and Concord Monitor) and television (WMUR-TV) reports.
- NHDOT *E-ZPass*SM website link to the online version of the survey. The link was posted to the NHDOT/ *E-ZPass*SM website on October 16, 2006 (see www.nh.gov/dot/bureaus/turnpikes/ezpass).

The media releases relative to the *E-ZPass*SM customer survey can be found in the Appendix.

List of Questions

The questions asked of *E-ZPass*SM customers in both the paper format and online survey are listed as follows:

1. Which direction were you traveling when you first noticed the purple lights?
    - North, towards Concord, NH
    - South, towards Salem, NH / Boston, MA

2. What type of vehicle were you driving?

- o Motorcycle
- o Passenger Car
- o Van, Pick-up, Light Duty Truck or SUV
- o Bus or RV
- o Truck over 5T GVW

3a. Did you use a dedicated *E-ZPass* SM lane?

- o Yes
- o No

3b. If you used an *E-ZPass* SM lane, which lane did you use?

- o Left (Lane 5)
- o Right (Lane 4)
- o I Don't Remember

4a. What lighting condition best describes the time-of-day when you first noticed the purple lights?

- o Daylight / 8AM-5PM
- o Twilight / Early Morning or Late Evening
- o Nighttime

4b. What condition best describes the weather when you first noticed the purple lights?

- o Clear
- o Cloudy and Overcast
- o Rain
- o Fog

5a. Did you notice the roadway signs in advance of the Hooksett Toll Plaza that advised you to look for the purple lights?

- o Yes
- o No

5b. If you did not notice the advanced roadway signs, did you understand what the purple lights meant?

- o Yes, I understood what the lights meant without seeing the advanced signs.
- o No, I did not understand what the lights meant having not seen the advanced signs.
- o I saw the advanced roadway signs and therefore understood what the purple lights meant.

6. What state of operation were the purple lights in when you first noticed them?

- o Solid Purple

- Flashing Purple

7. Did you use the purple lights to guide your vehicle into a dedicated *E-ZPass* SM toll lane?

   - Yes
   - No

8. Do you think the purple lights were helpful?

   - Yes
   - No

9. What suggestions for improvement do you have (Open Ended)?

Survey Results

A total of 219 customers participated in the survey. The majority (152) of the responses were obtained over the internet through the online survey. The breakdown of the responses by venue is shown below.

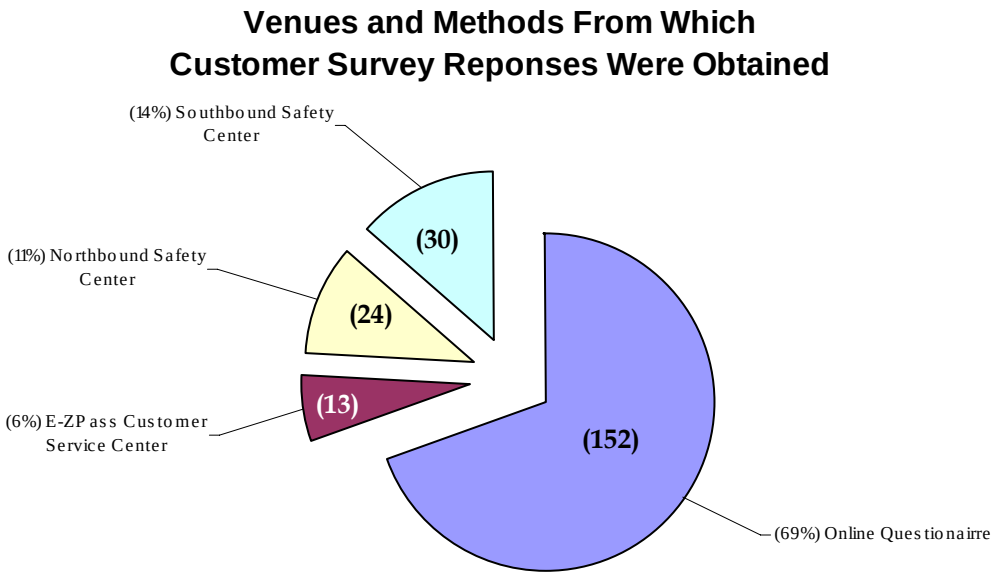


Figure 20 – Customer Survey Breakdown

Question #1 was used to identify the users of the Hooksett Toll Plaza by direction of travel given the unique geometrics presented by each approach, noting that the northbound approach has a crest vertical curve that limits drivers' ground level view of the tolls until they are within a thousand feet of the plaza. As such, it is likely that the purple lights will aid in northbound wayfinding (with sight limitations) more than the southbound approach in which drivers can see the toll plaza in excess of a ½ mile. Of the 219 customers, 135 (62%) of the respondents were traveling northbound and 84 (38%) of the respondents were traveling southbound.

The responses from Questions #2, #3a, #3b, and #8 are summarized in the pie charts (Figures 21 and 22) on the following pages based on the respondent direction of travel.

Figure 21 - NORTHBOUND APPROACH SURVEY RESULTS

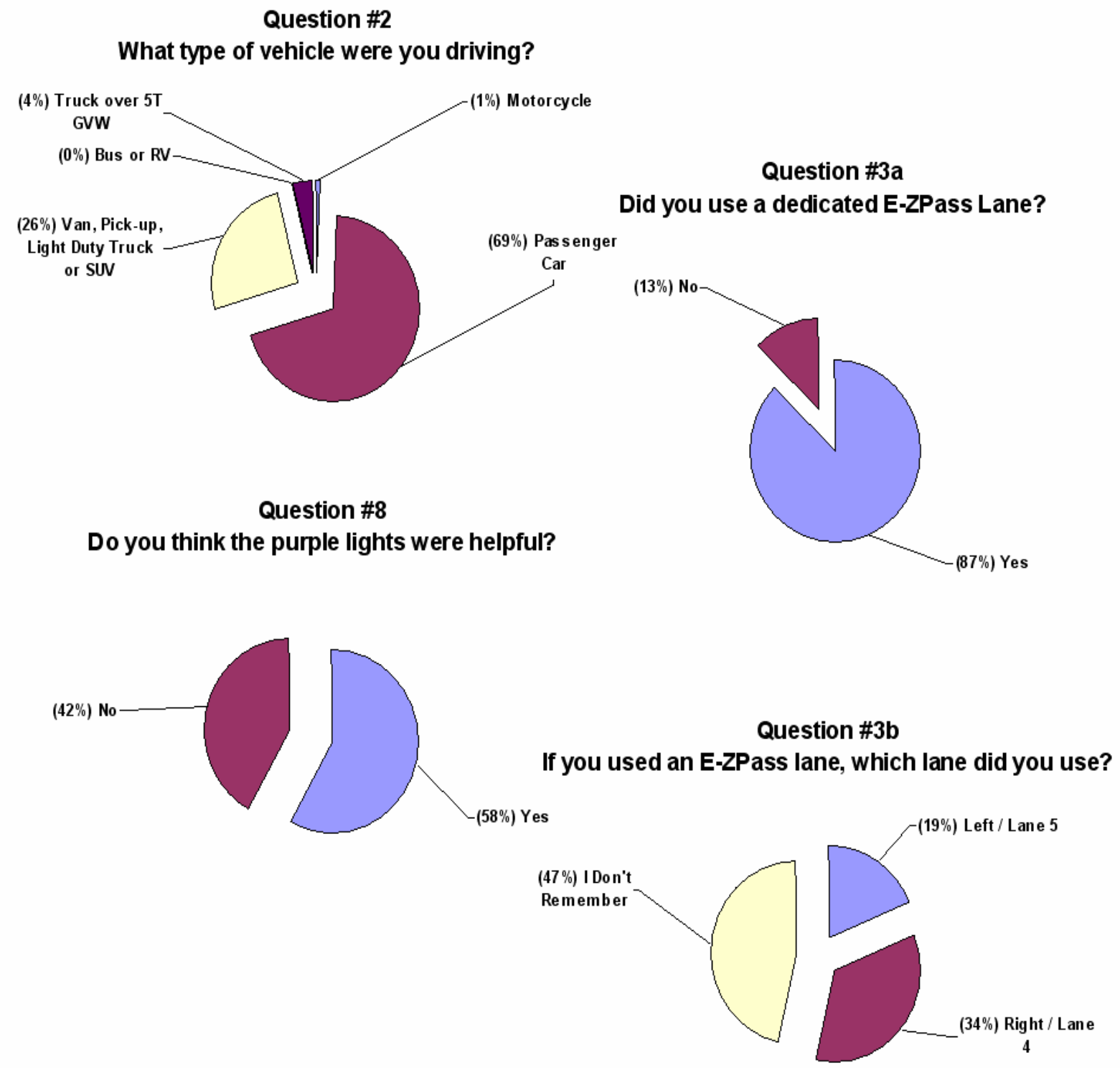
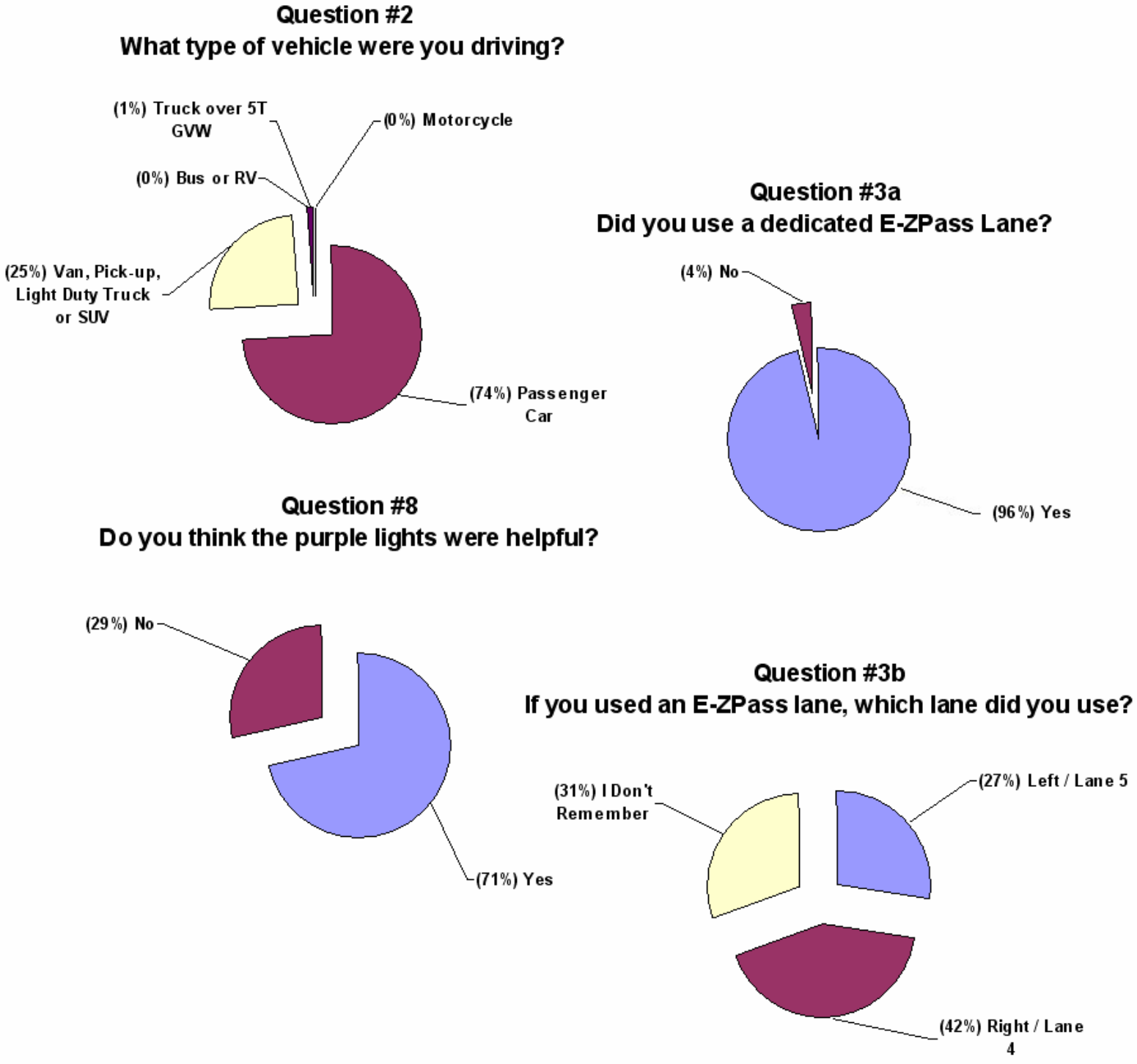


Figure 22 - SOUTHBOUND APPROACH SURVEY RESULTS



As shown in the responses to Questions #2, #3a, #3b, nearly all of the respondents (97%) drove passenger a car, van, pickup truck, or an SUV and the vast majority (92%) of the respondents used a dedicated *E-ZPass*SM lane. It is interesting to note that contrary to what was expected, the northbound respondents did not find the purple lights to be more helpful than the southbound respondents, who as previously stated, can more easily see the large existing overhead lane use signs from a distance. Some of the addition comments (Question #9) from the northbound motorists indicated that large trucks in combination with the vertical curve blocked their view of the purple lights leading to them to respond that the lights were not useful. These customers noted that they would have found the purple lights more helpful if they were mounted higher.

■

Summary Results to Questions #4a and #4b

When further reviewing the survey results, it was found that lighting and weather conditions (Question #4a and #4b) had a direct bearing on how a respondent answered Question #8 (whether the purple lights were helpful or not), regardless of whether the motorist was traveling northbound or southbound. The following bar graphs in Figures 23 and 24 shows the percent of respondents who found the purple lights helpful based on the indicated lighting (time of day) and weather condition:

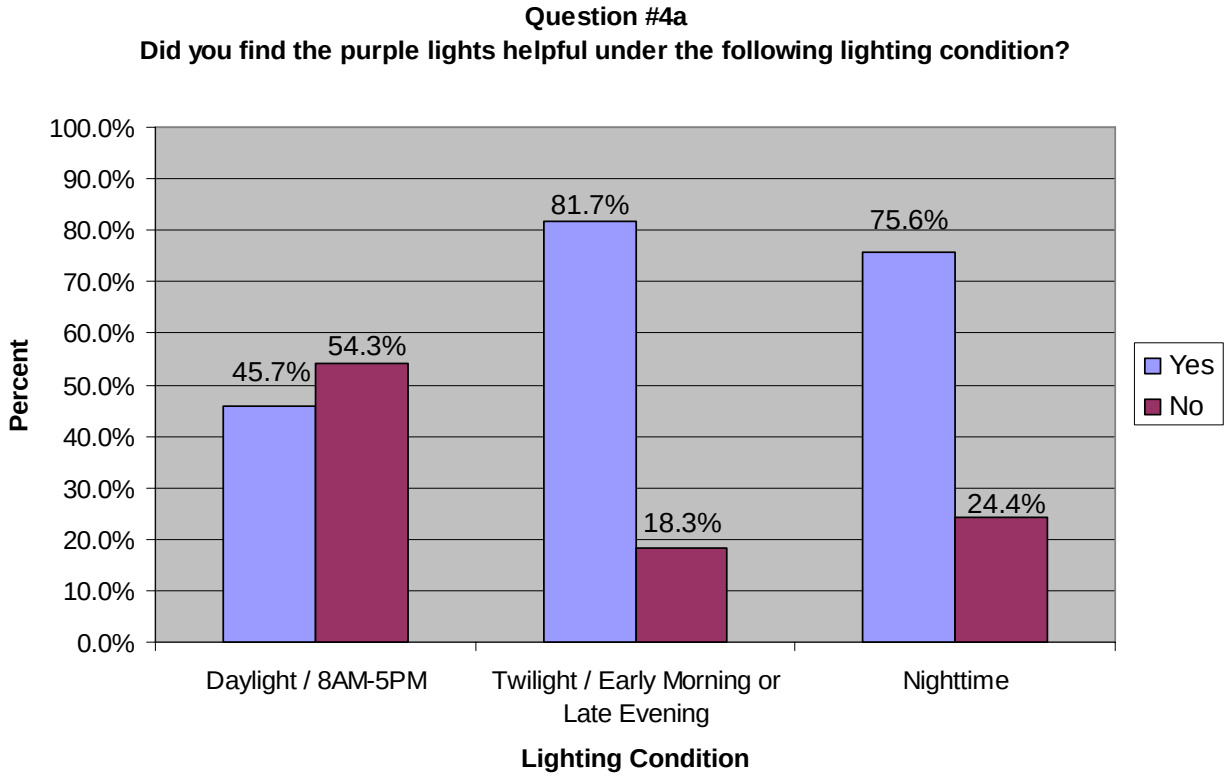


Figure 23 – Purple Light Approval Rating Based on Lighting (Time of Day) Conditions

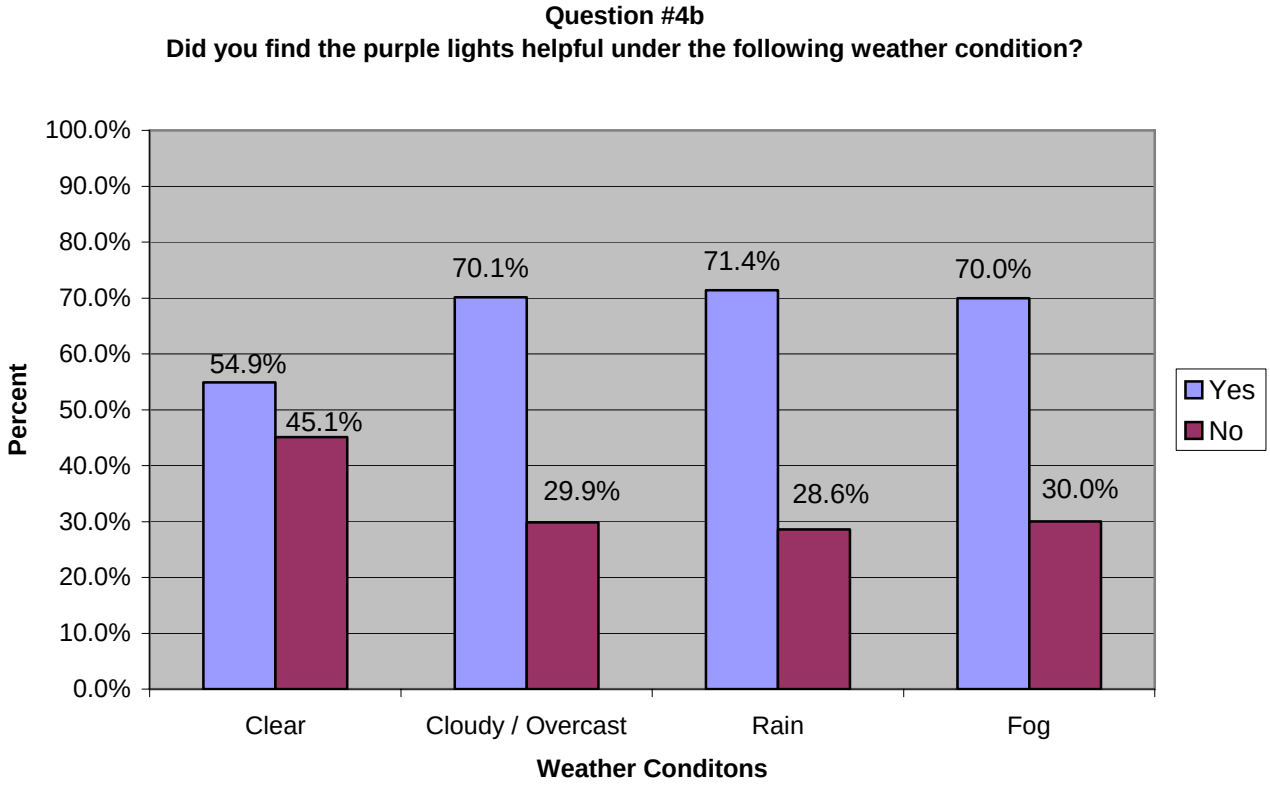


Figure 24 – Purple Light Approval Rating Based on Weather Conditions

As shown in the Figure 23 and 24, nearly half of the respondents did not find the purple lights helpful in the daytime under clear conditions. However, under poorer lighting (twilight, overcast or nighttime) conditions or during inclement weather (rain or fog), the number of respondents who found the purple lights useful increased by nearly 25% to approximately 3 out of 4 users.

■

Summary Results to Questions #5a through #8

Questions #5a, #5b, #7, and #8 directly correspond to the effectiveness of the purple light experiment based on the respondents answer to Question #6 asking whether the purple light was in a flashing or steady (solid) state of operation, noting that 171 (78%) of the customers took the survey during steady (solid) operations.

Tables 4 and 5 summarize the survey results based on whether the purple light was steady or flashing, respectively. Table 6 summarizes the combined results of Questions #5 through #8.

Table 4
E-ZPass[SM] Customer Survey Results With A Steady (Solid) Purple Light

	Q. #5a: Did you notice the roadway signs in advance of the Toll Plaza that advised you to look for the purple lights?		Q. #5b: If you did not notice the advanced roadway signs, did you understand what the purple lights meant?		Q. # 7: Did you use the purple lights to guide your vehicle into a dedicated *E-ZPass* [SM] toll lane?		Q. # 8: Do you think the purple lights were helpful?	
	Yes	No	Yes	No	Yes	No	Yes	No
Northbound	40	61	42	19	46	55	58	43
Southbound	32	38	32	6	42	28	49	21
Total	72	99	74	25	88	83	107	64
Percent	42%	58%	75%	25%	51%	49%	63%	37%

Table 5
E-ZPass[SM] Customer Survey Results With A Flashing Purple Light

	Q. #5a: Did you notice the roadway signs in advance of the Toll Plaza that advised you to look for the purple lights?		Q. #5b: If you did not notice the advanced roadway signs, did you understand what the purple lights meant?		Q. # 7: Did you use the purple lights to guide your vehicle into a dedicated *E-ZPass* [SM] toll lane?		Q. # 8: Do you think the purple lights were helpful?	
	Yes	No	Yes	No	Yes	No	Yes	No
Northbound	12	22	14	8	15	19	21	13
Southbound	9	5	3	2	9	5	11	3
Total	21	27	17	10	24	24	32	16
Percent	44%	56%	63%	37%	50%	50%	67%	33%

Table 6
Combined *E-ZPass*[SM] Customer Survey Results

	Q. #5a: Did you notice the roadway signs in advance of the Toll Plaza that advised you to look for the purple lights?		Q. #5b: If you did not notice the advanced roadway signs, did you understand what the purple lights meant?		Q. # 7: Did you use the purple lights to guide your vehicle into a dedicated *E-ZPass* [SM] toll lane?		Q. # 8: Do you think the purple lights were helpful?	
	Yes	No	Yes	No	Yes	No	Yes	No
Northbound	52	83	56	27	61	74	79	56
Southbound	41	43	35	8	51	33	60	24
Total	93	126	91	35	112	107	139	80
Percent	42%	58%	72%	28%	51%	49%	63%	37%

As shown in Tables 4, 5 and 6 and generally independent of direction, the majority of motorists did not see the roadway signs in advance of the Toll Plaza that advised *E-ZPass*SM customers to look for the purple lights as wayfinding devices to the dedicated *E-ZPass*SM lanes. However, even though the majority of the *E-ZPass*SM users did not see the advanced signs, they understood what the purple lights meant.

While, just over half (51%) of *E-ZPass*SM customers actually used the purple lights to guide their vehicle into a dedicated *E-ZPass*SM lane, nearly two-thirds (63%) of the respondents to the survey thought that the purple lights were helpful. Under poorer lighting (twilight, overcast or nighttime) conditions or during inclement (rain or fog) weather, these percentages increase to 70% of the *E-ZPass*SM customers using the purple lights to guide their vehicles into one of the dedicated *E-ZPass*SM lanes, and nearly 80% of *E-ZPass*SM customers believing that the purple lights were helpful.

■

Summary Results to Question #9

Question #9 was open-ended and gave the opportunity for *E-ZPass*SM customers to provide suggestions for improving not only the purple lights, but also toll plaza operations in general. Of the 219 total respondents to the survey, 160 (73%) left additional comments. Each of the written responses can be found in the Appendix. Listed below are the most frequent suggestions and comments that were gathered in response to Question #9:

- Move the *E-ZPass*SM lanes to the outer lanes (47 respondents);
- The purple lights are too dim in full daylight (45 respondents);
- Yes, the purple lights are a great idea (25 respondents);
- Use the purple lights in flashing mode (12 respondents);
- The purple lights are not a good idea (8 respondents);
- The purple lights look red causing some confusion (7 respondents);
- Add some kind of back plate to the purple lights (6 respondents);
- Use the purple lights in steady/solid mode (6 respondents);
- Improve the advanced signs (4 respondents); and
- Use the "wig-wag" flashing mode implemented in the northbound direction as opposed to the simultaneous flashing mode used in the southbound direction (3 respondents).

4

Findings and Recommendations

The New Hampshire Department of Transportation (NHDOT) has undertaken a project using experimental purple lights as traffic control devices that are intended to improve wayfinding for *E-ZPass*SM customers. Vanasse Hangen Brustlin, Inc. (VHB) was retained to monitor and evaluate the effectiveness of the purple lights and summarize the results of the experiment.

A statistical analysis test called the "test of proportions" was used to evaluate each of four applicable measures of effectiveness (MOE's) to determine if changes in results are "statistically significant". Statistical significance indicates that the purple lights had a true effect on the performance measure when comparing the "before" and "after-steady/solid" or "after-flashing" conditions. In addition, statistical significance indicates whether any observed difference in the "before" and two "after" data conditions was or was not likely due to chance. In this experiment, statistical significance means there is a 95 percent probability that if the same experiment was repeated, the same result would occur.

The statistical analyses of the MOE's indicate the purple lights have statistically changed driver behavior in the following respects:

- Reduced the occurrence of cash paying customers traveling in and thus changing lanes from dedicated *E-ZPass*SM lanes into the adjacent cash lanes near the toll booths with the implementation of either a 'steady/solid" or "flashing" purple light;

- Reduced the percentage of *E-ZPass*SM customers in Cash Lanes (#2 and #3) that also accept *E-ZPass*SM transactions with the implementation of either a 'steady/solid" or "flashing" purple light;

- Reduced the number of toll violations in Lanes #3, #4, #5, and #7 with the implementation of a "steady/solid" purple light as a wayfinding device; and

- Reduced the number of toll violations[8] in Lanes #3, #4, and #5 with the implementation of a "flashing" purple light as a wayfinding device.

In addition to statistical analyses, a field and online customer survey was conducted. The results of the survey reveal that the purple lights were well received by *E-ZPass*SM customers who use the I-93 Hooksett Tolls. Based on the survey, 51% of the *E-ZPass*SM customers used the purple lights to guide their vehicles into one of the dedicated *E-ZPass*SM lanes and 67% of *E-ZPass*SM customers believed that the purple lights were helpful. Of interest, under poorer lighting (twilight, overcast or nighttime) conditions or during inclement (rain or fog) weather these percentages increase to 70% of the *E-ZPass*SM customers using the purple lights to guide their vehicles into one of the dedicated *E-ZPass*SM lanes and nearly 80% of *E-ZPass*SM customers believing that the purple lights were helpful. Finally, of those *E-ZPass*SM customers who found the purple light helpful, 67% stated a preference to the purple light in "flashing" mode as opposed to the "steady/solid" purple mode.

The findings discussed above are based on data collected within a four week period in October 2006. As drivers become more accustomed to the purple lights the performance may change over time. The changes in driver behavior that were observed and those found to be statistically significant were small changes in the percent of drivers that use the tolls. The purple lights were not observed to cause any negative impacts to toll plaza operations or safety.

To maximize the effective use of lights as a wayfinding device and to increase customer satisfaction, the following modifications are recommended for further testing:

- Test the effectiveness of flashing yellow lights as opposed to flashing purple,
- Install back plates on the overhead signal housing to aid in visibility;
- If purple lights are used, increase the intensity of the light emitting diodes to increase visibility during full day light conditions; if this is not feasible, consider installing a photocell that activates the purple lights only under diminished lighting conditions;
- Implement a "wig-wag" flashing mode in the light display as opposed to a steady/solid mode to aide in the visibility of the lights.

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8 It is noted that the violations that were recorded and provided for data reduction may not be "true violations" by definition. An event recorded as a violation may have been attributed to an erroneous data reading from the *E-ZPass*SM equipment or attributed to some other factor. Nevertheless, the data that is summarized as follows reflects a consistent comparison between the four conditions.

- Fabricate larger advanced signs and mount them on overhead sign structures as opposed to the smaller advanced signs that were post mounted across from one another within the guard-railed median and adjacent to the paved shoulder.