THE NEW JERSEY TURNPIKE ROAD PRICING INITIATIVE: ANALYSIS TRAFFIC IMPACTS

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Abstract
In this paper, traffic impacts of two stages of time of day pricing program at New Jersey Turnpike were investigated. Shift in traffic between peak and off-peak periods were studied using before-after aggregate and disaggregate traffic data. Aggregate level analysis showed a shift in traffic to off-peak periods after the first stage of the program, and a shift to peak periods after the second stage; but due to lack of detailed traffic and travel time data, it was not possible to draw reliable conclusions from the aggregate analysis. Disaggregate analysis was then conducted, using traffic and travel time information for each entry-exit pair of New Jersey Turnpike between October 2002-March 2003, three months before and three months after the second stage of time of day pricing program. The vehicle-by-vehicle travel time analysis showed that travel times were not always highest during peak periods. For instance, in 2003 for almost 40% of pairs, higher travel times were observed during morning peak-shoulders. Additionally, data showed that, 53% of users preferred peak periods with lower travel times and higher tolls instead of peak-shoulders with higher travel times but lower tolls, indicating that New Jersey Turnpike users were trying to avoid congestion rather than slightly higher tolls. The paper was concluded with a detailed assessment of our results and other similar studies in terms of traffic impacts.

1. INTRODUCTION

Different forms of road pricing applications such as time of day pricing and private toll roads can be effective means of changing user behavior thus improving traffic and reducing various impacts of traffic congestion. However, success of a pricing policy requires an understanding of user behavior and possible responses to these policies. New Jersey Turnpike, one of the most heavily used roads in the country which has experienced several toll structure changes in its history can provide sufficient information regarding time of day pricing implementations. New Jersey Turnpike, is a 148 mile facility with 28 exit locations (NJTPK, 2003). The main trunk of New Jersey Turnpike runs from Deepwater, NJ in the south to Ridgefield, NJ in the north. Figure 1 shows the location of New Jersey Turnpike. The toll structure at New Jersey Turnpike is based on vehicle type, distance traveled, EZ-Pass availability and time of the day. The toll gates exist at all exits and entries and at the highway extensions towards the Hudson River. After the toll increase in 1991 until September 2000, single toll value is charged for each type of vehicle, regardless of time of day. In September 2000, EZ-Pass Technology is introduced by New Jersey Turnpike Authority (NJTPK) along with the first stage of time of day pricing program. As part of this program, different toll levels are charged to users depending on time of day and vehicle type. In January 2003, toll levels for each time period

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and vehicle type are increased as the second stage of time of day pricing program. The percent increase in the toll amount and resulting toll amounts between entry-exit pair (1,18W), are shown in Table 1 to give the reader an idea of price differentials (NJTPK, 2003).

Figure 1: Location of New Jersey Turnpike (NJTPK website, 2003)

Table 1 History of New Jersey Turnpike Congestion Pricing Implementation (NJTPK, 2003)

Toll	Passenger Cars			Tractor Trailers		
	1991	**September 2000**	**January 2003**	**1991**	**September 2000**	**January 2003**
Cash all day	70%	20% ($5.50)	17% ($6.45)	100%	13% ($20.55)	13% ($23.20)
EZ Pass peak	-	8% ($4.95)	10% ($5.45)	-	8% ($19.65)	8% ($21.20)
EZ Pass off peak	-	0%($4.60)	5 % (%4.85)	-	8% ($19.65)	8%($21.20)
EZ Pass (weekend)	-	8% ($4.95)	10 % ($5.45)	-	8 % ($19.65)	8 % ($21.20)

This study is a part of the project "Evaluation Study of the New Jersey Turnpike Authority's Value Pricing Initiative". The main focus of the project is to monitor the impacts of New Jersey Turnpike's Value Pricing Initiative both at the system wide level and at the user level. As a part of the project in this paper the impacts of time of day pricing on the traffic of the entire New Jersey Turnpike are investigated.

In Section 1 a brief literature review about similar traffic impact studies is provided. In Sections 3 and 4, data sources and details of proposed methodology are discussed, then in Sections 5, 6 and 7 seasonal factor analysis, and impacts of time of day pricing implementations at aggregate and disaggregate levels are provided, respectively. And in Section 8 disaggregate level analysis is applied to highly utilized entry-exit pairs. Finally, in the last section conclusions and discussions are presented.

2. LITERATURE REVIEW

In most of the previous similar studies investigating the impacts of value pricing, before-after analysis along with various statistical tests are applied using aggregate traffic counts. Litman (2003) investigates the impacts of time of day pricing implication in London considering only traffic flows before and after value pricing. On the other hand, Supernak et al. (2002) and

Burris et al. (1999) investigate the impacts of time of day pricing applications on various characteristics such as: traffic flow, delay and travel time. To accomplish this goal, in each project travel time data is collected for a number of days using "floating car" method. However, due to small number of travel time runs, and variability in travel-time speeds, whether change in travel time was attributable to variable pricing could not be determined by Burris et al. (1999). Sullivan (1998) analyzes the change in traffic conditions on SR91 using traffic data collected from loop detectors before and after the opening of tolled lanes, concluding that travel times in peak hours are reduced after tolled lanes.

Traffic flow varies substantially based on hours of the day, days of the week and months of the year. Therefore, to analyze the impacts of value pricing, time-dependent factors should also be considered. Aunet (2001) defines monthly adjustment factor as the ratio between monthly average daily traffic and annual average daily traffic and represents the actual patterns of monthly traffic by inverse of the monthly adjustment factors. Begg (2003) defines monthly adjustment factors as the ratio between flow on any month and the flow on a base month. On the other hand, Cain et al. (2001) compares two periods with same six-month of traffic data from subsequent years; to minimize potential bias due to seasonal variation during before-after study of Lee County variable pricing program. During the analysis of SR-91X Lanes, Sullivan (2000) conducts two-tailed-t-tests comparing 1996, 1997 and 1998 annual average midweek traffic, concluding that there is no seasonal variation.

In none of these studies traffic, travel time and toll levels are incorporated using reliable disaggregate data, apart from one or two days of travel time data collected using "floating car" method. To understand user behavior under time of day pricing, relationship between these parameters should be investigated carefully. The objective of this paper is to investigate the changes in traffic and travel time observed at each entry-exit pair of New Jersey Turnpike before and after the time of day pricing implications considering seasonal variations. Sources of shift in traffic between peak and off-peak periods, which can be either due to toll or travel time differential are determined. To accomplish this objective, aggregate and disaggregate level before-after analyses are conducted and appropriate statistical tests are applied.

3. DATA DESCRIPTION

The extensive database used in this study, is obtained from NJTPK (2003). Aggregate level data include **(1)** Average monthly traffic for peak and off-peak periods between October – December (1998, 1999, 2000, and 2002), and between January – June (1999, 2000, 2001, and 2003), **(2)** Daily traffic for each day of May and June (2000 and 2003). Disaggregate level data include entry/exit times-locations and toll paid for each EZ-Pass vehicle for 6 months period between October 2002 and March 2003.

4. METHODOLOGY

The research methodology used to investigate New Jersey Turnpike users' behavior, their response to time of day pricing and the prevailing travel times, is composed of four parts:

1. Seasonal factor analysis to investigate time-dependent variations.
2. Before-after analysis and application statistical significance tests to determine the change in travelers' behavior during peak and off-peak periods after the toll change.

3. Analysis of the relationship between the change in traffic and travel time for different periods to better understand the reasons of shift in traffic flow.
4. Analysis of highly utilized pairs in terms changes in travel time and traffic flow.

5. ANALYSIS OF POSSIBLE SOURCES OF VARIATIONS

When traffic distribution is analyzed three kinds of variations should be considered:

(1) Factor_1: Temporal variations based on time of day, days of week and months of the year.

(2) Factor_2: Fluctuations among years for a specific time period of a day due to the changes in toll amount, travel time, or demand.

(3) Other random errors: Fluctuations due to external factors difficult to capture such as, economic growth, and sampling errors.

The statistical model of the traffic distribution can be given as follows (Walpole et al., 1998).

$$y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij} \tag{1}$$

where;

y_{ij}: Observed percent share at level i, j μ: Mean of all observations y_{ij}

α_i: Effect of Factor_1 at level i β_j: Effect of Factor_2 at level j

ε_{ij}: Random error term

To fully determine the effects of these factors on traffic, two-way ANOVA test is employed by constructing a two-factor full factorial design without replications using data sets, shown in Table 2. To reduce some part of the fluctuations (1) A.M./P.M. peak and off-peak period traffic are investigated separately, (2) Fixed toll periods and typical work days are selected, (3) Traffic flow is represented in terms of percent share with respect to total daily traffic. Percent share of each data type is calculated as the ratio of average traffic during a specific period to the average daily traffic. Therefore Factor_1 represents seasonal variation among months, and Factor_2 represents yearly changes in traffic when everything else in the system is unchanged.

Table 2 Details of the Data Sets Utilized in Two-Way ANOVA

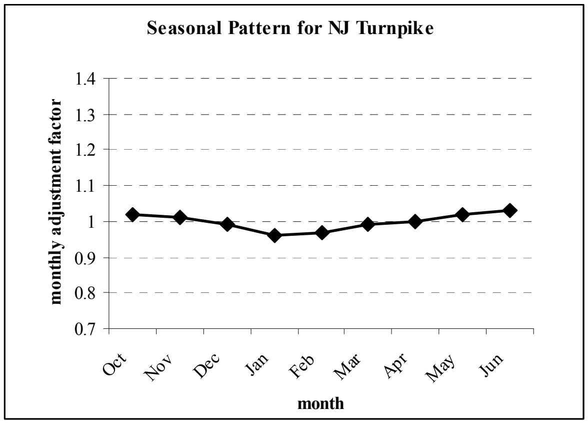
Data set	Compared Time Periods	Type of Data
Set-1	**October 1998 – June 1999**	A.M. & P.M. peak, and Off-peak percent share
	October 1999 – June 2000	A.M. & P.M. peak, and Off-peak percent share
Set-2	**October 2000 – December 2000**	A.M. & P.M. peak, and Off-peak percent share
	October 2002 – December 2002	A.M. & P.M. peak, and Off-peak percent share

From the analysis of data Set-1 it is observed that the seasonal variation among months (Factor_1) is statistically significant. On the other hand, changes in percent share of peak and off peak periods (Factor_2) are statistically insignificant before 2000. However, fluctuations among consecutive months in data Set-2 are statistically insignificant. This may be due to the fact that in data Set-2, three consecutive months which have a similar trend are compared, whereas in Set-1 a wider range of months are compared. More importantly, data Set-2 indicates that, between first and second toll increase, the change in percent shares of peak and off-peak periods is statistically significant, even if the toll amount is fixed. To fully explain this change in user behavior, traffic for peak and off-peak hours is studied in the next sections.

To further investigate fluctuations among months, monthly adjustment factors are calculated using the methodology proposed by Aunet (2001). The analysis results indicate that:

1. Traffic on December, January and February is lower compared to other months.
2. Monthly adjustment factors, shown in Figure 2, are similar to each other for consecutive months. However, they become different for months further away from each other, supporting the results obtained from ANOVA analysis.

Figure 2 Seasonal pattern for New Jersey Turnpike



6. BEFORE AND AFTER ANALYSIS AT AGGREGATE LEVEL

In this section, peak and off-peak period traffic patterns are investigated at aggregate level. Using the results obtained from Section 5, absolute and percentage shares of peak/off-peak period traffic flows are compared for same months from 1998 to 2003, separately. The aggregate level before-after analysis is done in two steps. First fluctuations in traffic among different days of the week are investigated. Then the changes in absolute and percent shares of peak/off-peak period traffic after the two stages time of day pricing implementations are analyzed.

Daily traffic flow on each day of May and June (2000 and 2003) is utilized to investigate the fluctuations among different days of the week. The results indicate that, traffic patterns are different for Monday through Thursday (14.5% of total weekly volume), Friday (17% of total weekly volume) and weekends (12.5% of total weekly volume).

Since traffic exhibits significant differences for different days of the week, in the remainder of the analysis typical work days are considered, and peak /off-peak period flows are analyzed separately. First, change in absolute demand and percentage shares is calculated. Then to determine the significance level of these changes, 1-tailed paired two-sample t-tests are conducted at 90% and 95% confidence levels (CL). Sample size for the second toll change is increased by comparing time period between October 2000–June 2001 (nine data points) and period January 2003–March 2003 (three data points), and two-sample t-test assuming unequal variances are applied. The t-tests are based on the following hypothesis (Walpole et al., 1998).

$$H_0 : (\mu_{i.})_{before} - (\mu_{i.})_{after} = 0 \qquad (2)$$
$$H_1 : (\mu_{i.})_{before} - (\mu_{i.})_{after} > 0$$

where;

$\mu_{i.}$ = mean percent share of period *i*, *i*=1, 2, 3 (1=A.M.-peak, 2=P.M.-peak, 3=Off-peak)

Results for aggregate level before after analysis are represented in Table 3. After the first toll increase and introduction of EZ-Pass, from October 1998 to March 2001, peak-period traffic increased at a lower rate compared to off-peak period traffic, supporting the results obtained from Kraft (2003). Additionally, peak traffic percent share decreased, while percent share of off-peak traffic increased after first toll increase. On the other hand, between 2001 and 2003, trend in rate of increase of traffic is reversed. More importantly, unlike the first toll increase, from year 2001 to 2003, the percent share of peak period traffic increased while percent share of off-peak traffic decreased. These changes are statistically significant at 90% and 95% CL.

Table 3 Aggregate level before and after analysis results

Change	Morning peak	Afternoon Peak	Off-Peak
1st too change (Oct 98 – June 99) & (Oct 00 – June 01)			
Absolute Demand	6% increase	4% increase	10% increase
Percentage Share	2% decrease*	3.8% decrease**	2% increase**
Statistical Significance	Yes	Yes	Yes
2nd toll change (Oct 00 – June 01) & (Jan 03 – Mar 03)			
Absolute Demand	14% increase	8% increase	4% increase
Percentage Share	16% increase***	15% increase***	7% decrease***
Statistical Significance	Yes	Yes	Yes

*$t_{critical}$= 1.4 (90% CL), **$t_{critical}$= 1.86(95% CL), ***$t_{critical}$= 2.35 (95% CL)

In summary, New Jersey Turnpike users' response to second toll increase is different from the response to the first toll increase. Between time periods after the first toll increase and the second toll increase, there is a significant increase in the percent share of peak period traffic. Therefore, given the small differential between peak and off-peak tolls, it is likely that change in percent share of peak and off-peak periods can be due to higher travel times rather than the toll differential. Since travel time data for these time periods was not available, aggregate level analysis could not determine a reliable relationship between shift in traffic and congestion levels. In order to better identify source of the changes in traffic, disaggregate level analysis is conducted using vehicle-by-vehicle information obtained from NJTPK (2003).

7. DISAGGREGATE LEVEL BEFORE AND AFTER ANALYSIS

In this section, vehicle-by-vehicle EZ-Pass traffic data, between October 2002 and March 2003, is analyzed. This period involves the second phase of the time of day pricing program. The database contains entry-exit locations, times and toll amount but does not contain any other vehicle data to ensure the privacy of users.

While conducting disaggregate analysis, the traffic between entry-exit pairs, and travel times corresponding to that specific traffic for each hour of the day are investigated. As presented in Section 4, monthly fluctuations between two consecutive month are negligible compared to fluctuations between months further away from each other. Thus, to minimize the error due to seasonal variations and to incorporate the changes in traffic independent of toll increase, analysis is conducted by utilizing consecutive months and percentage values. Since traffic pattern for weekdays, Fridays and weekends are different, traffic and travel time values are investigated separately for each day type. Each day is divided into 8 sub-periods for weekdays and Fridays in order to analyze the shift between peak periods and peak shoulders:

1. Pre-peak period (6:00A.M.–7:00A.M. and 15:30P.M.–16:30P.M.)

2. Peak-1 period (7:00A.M.–8:00A.M. and 16:30P.M.–17:30P.M.)
3. Peak-2 period (8:00A.M.–9:00A.M. and 17:30P.M.–18:30 P.M.)
4. Post-peak period (9:00A.M –10:00 A.M. and 18:30P.M.–19:30P.M.)

On the other hand, for weekends, since toll value is same for the whole day, each day is divided into 2 sub-periods:

1. Period-1 (12:00A.M.–12:00P.M.)
2. Period-2 (12:00P.M.–12:00A.M.)

For each month and day type, total traffic and average travel time between each entry-exit pair are constructed. Some of the clusters are too small to be statistically significant and are not needed to be included in the analysis. Therefore, EZ-Pass database is further clustered to develop clusters of vehicles that are large enough to be statistically significant. Pairs satisfying at least one of the following two criteria are included in the final set. Data set determined based on two criteria, represents approximately 80% of total flow observed on sub-periods.

Criteria 1: Determine the exit location, forming at least 10% of total daily traffic generated from a specific entry location. If all entry-exit pairs were analyzed, percent changes at pairs with low traffic would be quite high even if absolute magnitudes of these changes are not important enough to affect overall traffic.

Criteria 2: Determine entry-exit pairs, which have at least 100 veh/hr of traffic flow during sub-periods. This amount is approximately 10% of hourly traffic between an entry-exit pair during pre-specified sub-period. This criterion determines the pairs that are highly utilized only during specified sub-periods. These pairs are responsible for most of the traffic during specific sub-periods even if they do not satisfy the first criterion.

After cleaning the data set, the main goal is to construct "before and after conditions" at New Jersey Turnpike and compare them. Before and after conditions are constructed based on traffic and travel times patterns observed before and after time of day pricing implementation. To achieve the above goal, disaggregate level analysis is conducted in two parts.

- The time period where highest traffic flow is observed between an entry-exit pair
- The time period where highest travel time is observed between an entry-exit pair

The analysis results can be represented in three distinct time periods:

October – November, November –December, 2002 (Before Period): This period is the base period and it represents basic traffic patterns at New Jersey Turnpike. Summary of the findings are as follows:

- The most important observation during this time period is that for almost 50% of the pairs highest traffic flow between an entry-exit pair is observed at peak periods with less travel time compared to peak shoulders.
- For 25% of the pairs traffic flow between an entry-exit pair is maximum at peak shoulders that have less travel times than peak periods.
- For 10% of the pairs, highest traffic flow is observed at periods with highest travel time. These pairs either have travel time more than 15 minutes or provide more than 10% gain in travel time when a shift to another period occurs.

- At almost 35% of the pairs there is a change in traffic for sub-periods with highest travel time; such that for 67% of the pairs where traffic flow has changed, traffic flow at sub-periods with highest travel time decreased.
- Almost 65% of changes in departure time are to or within peak periods.

December – January, January – February, 2003 (Transition Period just after the second toll increase): This is the transition period due to the new year, new tolls, and other seasonal factors. In fact, the travel patterns observed during this transition period are slightly different than the base period. Summary of the findings are as follows:

- Proportion of pairs for which the traffic flow is maximum at periods with less travel time is reduced to 45%, and 23% for peak periods and off-peak period, respectively.
- The pairs having highest traffic at periods with highest travel time increased to 18%.
- Pairs experiencing a change in traffic flow at periods with highest travel time increased to 42%, for 65% of which traffic flow at sub-periods with highest travel time decreased.

February – March 2003 (Stable period after the second toll increase): During this period a return to the base period conditions is observed. Only differences between traffic conditions before and after the toll increase are as follows.

- On February-March 2003 the percentage of pairs with highest traffic at peak periods but less travel time than peak shoulders increased to 53% after the toll increase.
- The percentage of pairs with highest traffic at peak shoulders but less travel time than peak periods decreased to 20% after the toll increase. This means that users of New Jersey Turnpike return to their traveling routine irrespective of the changes due to the second phase of time of day pricing program.

A similar pattern is observed for weekends, apart from the fact that, on weekends sample size is smaller, smaller percent of travelers try to minimize their travel time and number of travelers who prefer not to change their periods is slightly more compared to weekdays. The reason for these slight differences between weekdays and weekends can be due to the fact that traffic flow on weekends is almost 25% lower than weekday traffic, and most of the travelers do not have a strict departure time constraints since most of the trips are not work related. Results show that, most users prefer peak periods with lower travel times and higher tolls rather than peak-shoulders with higher travel times but lower tolls, indicating that users are trying to avoid congestion instead of slightly higher tolls. Besides, toll increase on January 2003 did not have serious impact on traffic. Apart from some fluctuations on January and February, traffic conditions are similar before and after the toll change. Only difference is that, after the toll increase; on February-March 2003 percent of pairs with highest traffic at peak periods but less travel time than peak shoulders increased. However, percent of pairs with highest traffic at peak shoulders but less travel time than peak periods decreased. Since this difference is counterintuitive under time of day pricing, it cannot be attributed to toll increase; it can only be explained by travel time differences between peaks and peak shoulders.

8. ANALYSIS OF HIGHLY UTILIZED ENTRY-EXIT PAIRS

After the disaggregate level analysis of the overall behavior observed at New Jersey Turnpike, in this section highly utilized four entry-exit pairs are selected. A similar analysis conducted in

Section 7 is done. For each month first the time periods with highest traffic flow and travel times are determined, and the change in the locations of these time periods are analyzed.

The results for the location of periods with highest traffic and travel times for A.M. period are represented in Table 4. For none of the pairs highest travel time and highest traffic flow occur at the same period, apart from January and February 2003. More importantly, although highest traffic flow is observed at the same period and usually at peak periods, periods with highest travel time show differences among the months and it is usually observed at peak shoulders.

Table 4 Changes in the location of highest traffic and travel time for selected pairs, A.M. period

entry-exit pair	sub-period	oct	nov	dec	jan	feb	mar
11-13A	**highest travel time**	peak2	peak2	peak1	peak1	peak2	peak1
	highest traffic flow	peak1	peak1	peak1	peak1	pre	peak1
14-16E	**highest travel time**	peak2	peak2	peak1	post	peak2	post
	highest traffic flow	pre	pre	pre	pre	pre	pre
18W-14	**highest travel time**	post	pre	post	pre	peak2	pre
	highest traffic flow	peak1	peak1	peak1	peak1	peak1	peak1
18W-16W	**highest travel time**	pre	post	pre	post	post	pre
	highest traffic flow	peak2	peak2	peak2	peak2	peak2	peak2

Next, statistical tests are applied to compare the changes in the amount of highest traffic flow and travel times. While applying significance test a similar hypothesis shown in Equation (2) is assumed and 1-tailed paired two-sample t-tests are conducted at 95% CL. The analysis conducted for the change in the amount of highest traffic flow and travel time indicates that;

- For all pairs traffic flow at periods with highest travel time is lower compared to amount of traffic at periods with highest traffic. Travel times at highest traffic periods are lower.
- For most of the pairs the traffic flow at periods with highest travel time is decreasing.
- For most of the cases amount of change is statistically in significant at 95% CL, indicating that toll increase on January 2003 did not have serious impact on traffic flows.

Table 5 Results of the t-test for the selected periods, morning period

entry-exit pair	t-test results	period with highest travel time				period with highest traffic flow			
		traffic flow		travel time		traffic flow		travel time	
		before	after	before	after	before	after	before	after
11-13A	Mean	453.667	378.667	22.171	13.308	514.000	520.000	19.276	13.165
	t Stat	0.728		2.584		-0.345		**3.024**	
	t-critical	2.132		2.920		2.353		**2.132**	
14-16E	Mean	471.000	430.000	11.095	17.038	562.333	605.000	9.041	12.032
	t Stat	0.555		-1.801		**-2.202**		-0.758	
	t-critical	2.920		2.920		**2.132**		2.920	
18W-14	Mean	369.000	346.000	19.254	16.925	560.333	502.667	15.770	14.391
	t Stat	0.529		0.533		0.574		0.421	
	t-critical	2.132		2.132		2.132		2.353	
18W-16W	Mean	262.333	313.000	9.822	5.507	608.000	560.667	4.042	2.817
	t Stat	-0.698		1.379		0.378		2.205	
	t-critical	2.353		2.353		2.353		2.353	

9. CONCLUSION

The purpose of this paper is to gain insights into the user behavior as response to time of day pricing and travel time fluctuations using reliable and accurate data sources. Among two different levels of analysis, results indicate that disaggregate level analysis provides more accurate and reliable results compared to aggregate level analysis, and help to better understand the user behavior under value pricing. The details of the obtained results can be summarized as follows:

1. Traffic flow on winter months is lower compared to traffic on summer months. Besides, traffic flows are different among different portions of a week namely, Monday through Thursday, Friday, and weekends. ANOVA tests show highest share for Fridays and lowest share for weekends.
2. Aggregate level analysis conducted for the first stage of time of day pricing implementation indicate that, rate of increase of peak period traffic flow is lower than rate of increase of off-peak period percent share. Moreover, after the first toll increase percent share of peak period traffic flow reduced, whereas percent share of off-peak period increased. However after two years, between 2001 and 2003, trend in traffic is reversed. The peak period traffic flow increased at a higher rate compared to off-peak period traffic flow resulting an increase in peak period traffic percent share and a reduction in off-peak period traffic percent share. 1-tailed t-tests conducted for both time of day pricing implementations indicate that, these changes are statistically significant. These changes among two stages of time of day pricing implementation can be due to the first stage of the time of day pricing program which might have encouraged commuters to shift to peak shoulders and in turn increased travel times during these periods. However, due to lack of detailed traffic and travel time data at aggregate level, it is not possible to pinpoint the exact reason of this change in traffic.
3. From the disaggregate level analysis it is observed that on weekdays and Fridays, before the toll increase for almost 75% of entry-exit pairs, highest traffic flow is observed at periods with less travel time. Whereas for 10% of pairs traffic is maximum at periods with highest travel time. After the toll increase on January 2003, between January and February, the percentage of pairs for which traffic is maximum at periods with less travel time**,** are dropped to 68%. And percentage of pairs for which the traffic is maximum at periods with highest travel time increased to 18%. However, on March 2003, the corresponding percentage values starts to come back to values observed before the toll increase. These results indicate that most of the users choose to stay in periods with less travel time, and the second toll increase did not have serious impact on New Jersey Turnpike traffic patterns apart from some fluctuations.
4. A similar pattern is observed for weekends, apart from the fact that, on weekends sample size is smaller, smaller percent of travelers try to minimize their travel time and number of travelers who prefer not to change their periods is slightly more compared to weekdays. The reason for these slight differences can be due to the fact that traffic on weekends is almost 25% lower than weekday traffic, and most of the travelers do not have strict departure time constraints since most of the trips are not work related.
5. The disaggregate level analysis conducted for highly utilized entry-exit pairs show that for almost all pairs highest traffic flow is observed at peak periods and show no change through out the time period. On the other hand location of periods with highest travel

time fluctuates among months and usually observed at peak shoulders. Besides for none of the entry-exit pairs highest travel time and highest traffic flow occur at the same time period, apart from transition period, January and February 2003.

6. The before and after analysis applied for these highly utilized entry-exit pairs show that, the traffic flow at periods with highest travel time is much less compared to the amount of traffic at periods with highest traffic flow. And travel times at periods with highest traffic flow are lower. For most of the pairs the traffic flow at periods with highest travel time is decreasing. However, for most of the cases the amount of change is statistically insignificant at 95% CL, indicating that the toll increase on January 2003 did not have serious impact on the traffic flows.
7. Overall, the disaggregate level analysis, indicate that commuters at New Jersey Turnpike respond more to congestion (lower travel times) than slightly higher tolls. More specifically, most of the users prefer peak periods with less travel times and higher tolls instead of peak shoulders with higher travel times but less toll.
8. In some empirical studies (Litman, 2003; Supernak et al., 2002, Burris et al., 1999, Sullivan 1999) investigating the impacts of variable pricing on traffic using traffic counts, highest traffic is observed during mid-peak periods, where the toll is higher and shift in traffic is always from mid-peak hours to peak shoulders. Unlike these studies, traffic at New Jersey Turnpike is more uniformly distributed between mid-peak and peak shoulders. Thus, highest traffic is not always observed at mid-peak hours
9. Same studies conclude that discount tolls reduce peak-period traffic and this reduction in traffic leads to reduced travel times during peak periods. However, toll differences between peak and off-peak periods at NJTPK are quite small. Given these facility specific traffic conditions and small toll differences shown in Table 1, travel time differences between different periods are found to have more effect than toll differences on user behavior. This was an important finding specific to this study.
10. All of the aforementioned empirical studies also emphasized that lack of reliable travel time data had a negative and limiting effect on reliable statistical assessments of travel time changes due to variable pricing implications. Thus, these studies conclude that individual and combined impact of toll and travel time differences on user behavior cannot be determined properly without reliable travel time data. The same problem is encountered in this study too when it is attempted to understand the change in traffic using aggregate data. However, disaggregate data enabled the research team to partially overcome this problem and to explain some of the reasons behind the change in traffic before and after the time of day pricing implementation. Thus, in order to fully understand the user response to time of day pricing implementations, disaggregate data which include detailed traffic, travel time and toll amount information at the same time is necessary.

Based on these conclusions, future research will attempt to develop an analytical demand function representing the relationship between cost namely, travel time and tolls, and demand. This demand function will be used to calculate the price elasticities for different sub-periods. Based on the same demand function relative effects of value of time and tolls on user behavior can also be studied. Finally, these results will be compared with the results which will be obtained from detailed traveler surveys being conducted by RPI/Rutgers research team.

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