IMPACTS OF TIME OF DAY PRICING ON TRAVEL BEHAVIOR: GENERAL FINDINGS FROM THE PORT AUTHORITY OF NEW YORK AND NEW JERSEY'S INITIATIVE

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Abstract

The Port Authority of New York and New Jersey implemented a time of day pricing initiative in March 2001. This initiative provided a discount on off-peak tolls on its facilities. Peak toll rates are effective on weekdays from 6-9 AM and 4-7 PM, as well as on weekends from Noon to 8 PM. These crossings carry average daily eastbound traffic of 352,000 vehicles, or more than 126 million eastbound vehicles in 2004. This is, by far, the largest application of road pricing in the United States.

Following the implementation of the new pricing structure, the Federal Highway Administration decided to sponsor a multi-year research project aimed at studying the behavioral impacts produced by the time of day pricing initiative. The research project focuses on three main areas: user impacts, traffic impacts, and institutional analyses. This paper discusses the key findings pertaining to the impacts produced by the time of day pricing initiative on the behavior of both passenger and commercial vehicle traffic. It was found that 7.4% of passenger trips and 19.3% of truck trips (20.2% if increasing shipping charges are included) changed behavior due to the time of day pricing initiative.

1. Introduction

The concept of road pricing has been gaining support in the United States, Europe, and the Asian countries, with the recent London congestion pricing scheme as the latest and one of the most visible implementations. Although the basic fundamentals of road pricing have been known since the 1950s, after Vickrey (1961) first formulated them, the lack of adequate technologies was widely considered to be one of the factors that prevented implementation. Over the ensuing decades, these pricing concepts have come to be used by many other industries: electric utility companies charge more in peak periods, and commuter rails have long been offering peak and off-peak fares, though road pricing is still only applied to a handful of cases. Proponents argue that road pricing is the key to managing congestion in a world where experience shows that building new capacity does not solve congestion problems. Detractors point to equity issues with fare structures that may impact low income individuals, and the double taxation perception, as reasons why road pricing should not be considered. In spite of this debate, there are signs that indicate an increasing interest in road pricing as both a revenue generation and a demand management mechanism.

On January 25, 2001, the Port Authority of New York and New Jersey (PANYNJ) approved a time of day pricing initiative on its facilities with tolls that depend on time of travel (peak hours, off-peak hours and overnight), the payment technology used (cash, electronic toll collection), and the vehicle type (e.g., car, truck, bus). The new tolling policy became effective on March 25, 2001. The toll schedule before and after the implementation of time of pricing is shown in TABLE 1 for autos and trucks. A unique feature of the system is that the toll discounts are only available to users of the electronic toll collection system (E-ZPass). The PANYNJ saw the plan as a mechanism to help finance its capital budget, and as a means for reducing congestion, increasing the use of mass transit and E-ZPass, and facilitating commercial traffic management. In 2004, approximately 352,000 vehicles used the PANYNJ with a vehicle split of 91.2% autos, 6.5% trucks, and 2.3% buses. On an annual basis, in 2004, 126.6 million vehicles and 62 million interstate bus passengers used the PANYNJ crossings annually (see FIGURE 1). This is, by far, the largest application of road pricing in the United States.

The research project discussed in this paper conducted a comprehensive assessment of the impacts of the PANYNJ time of day pricing initiative on user behavior and traffic patterns. The paper is based on data collected by means of two surveys conducted to capture the behavioral changes of the two major groups of contributors to the traffic on PANYNJ facilities, i.e., passengers and commercial vehicles. This paper presents the key findings from the analysis of these surveys. For the full report, the reader is referred to Holguín-Veras et al. (2005).

The remainder of the paper is organized as follows. Section 2 briefly overviews the survey methodology used and data collected. Section 3 summarizes the key results from both the passenger survey and the commercial survey. The final section discusses the key findings.

2. The Survey Data

The passenger survey and the carrier survey were conducted using computer aided telephone interviews from June to July and November to December 2004, respectively.

For the passenger survey, the data were collected by means of a single stage random sample using random digit telephone calls. The population of interest included current and former regular users of the toll facilities. Due to the cost constraints and the inherent difficulty of finding suitable respondents from New York and other areas, the data collection focused on current and former regular users from New Jersey and Staten Island. Staten Island users were sampled because it was assumed they exhibit a different behavior, which is a consequence of: (1) living in an island, which leads to a dependence on car and toll bridges that is stronger than other users'; and (2) the frequent usage discount plan they receive by which they pay a lower rate ($2.50 per car trip) versus $4.00, $5.00 or $6.00 that other users pay. As a consequence, the sample does not necessarily represent the geographic distribution of typical bridges and tunnel users that may include thru trips originating and with destinations in other states.

The passenger survey was comprised of 505 complete observations. The data show that 467 respondents (92.5%) were current regular users, i.e., travelers who have used the PANYNJ toll facilities on regular basis (at least once a week); 38 respondents (7.5%) were former regular users who drove through the PANYNJ toll facilities on a regular basis before the time of day pricing was implemented in March 2001, but that now travel regularly by public transportation. The sample included 392 respondents (77.6%) from New Jersey, and 113 respondents from New York, specifically from Staten Island (22.4%).

The second target population was the group of commercial carriers. At first, the research team was interested in gathering data about the impacts of time of day pricing throughout the entire supply chain. Unfortunately, cost considerations suggested collecting the sample from those areas concentrating the majority of users, including private and for-hire carriers. For that reason, the sampling process focused on carriers located in New Jersey and New York; more specifically, from the New Jersey counties of Bergen, Essex, Hudson, Middlesex, Passaic and Union, and from Kings (Brooklyn) and Queens in New York. These counties were selected because previous studies determined they are significant generators, or transshipment locations, of cargoes destined to New York City (Holguín-Veras and Thorson, 2000).

The carrier survey collected 200 observations from a sample drawn from a commercial database. Of those surveyed, 182 companies (91.0%) were current regular users of the toll facilities, and 18 companies (9.0%) were former regular users (regular users before March 2001

but that became sporadic users or nonusers). Of those surveyed, 165 companies (82.5%) were located in New Jersey, while 35 companies were from New York (17.5%). This geographic breakdown was, to a great extent, the result of the inherent difficulties in finding valid respondents from the New York area, which forced the project team to increase the relative proportion of New Jersey users. From the view point of carrier type, there were 97 for-hire carriers (48.5%), i.e., companies that provide transportation services to the open market; and 103 private carriers (51.5%), those that provide transportation service exclusively to a parent or a related company. This breakdown is consistent with national statistics.

The two samples were expanded so that they represent the behavior of the entire set of trips made by passengers and carriers. This was accomplished by using the trip frequencies reported by the passengers and carriers as expansion factors for the individual observations. Unfortunately, the lack of suitable control totals, e.g., number of PANYNJ users by income levels, prevented the implementation of a formal statistical expansion process aimed at eliminating sample bias.

3. Key Findings

Different questionnaires were designed for the passenger survey and carrier survey to assess their behavioral patterns before and after the time of day pricing initiative. The passenger survey had four main sections: (1) demographics, (2) impacts of 2001 the time of day pricing initiative, (3) the respondents' most recent trip, and (4) E-ZPass usage and awareness of toll discounts. The carrier survey was comprised of sections that gathered data about: (1) company attributes, (2) impacts of the 2001 time of day pricing initiative on carrier behavior, (3) current operations and travel flexibility, and (4) E-ZPass usage and awareness of toll discounts. The key findings for both surveys are discussed next.

3.1 Results from the Passenger Survey

This section summarizes the key findings in terms of the characteristics of the interviewed passengers, the impact of the time of day pricing initiative on their behavior, their trip attributes, and their awareness of toll discounts.

(1) Demographics

The data indicate that the typical respondent was a middle-age white man with above average education level and household income: the average age of respondents was 43.7 years old; 63.5% were white; 58.5% were males; 79.4% received have college or higher education degrees; and had household incomes higher than the State median ($95,178 vs. $55,932 in New Jersey and $80,944 vs. $58,667 in Staten Island) (U. S. Census Bureau, 2004). These results are not surprising because experience shows that the population segment most likely to participate in telephone surveys is the group of middle aged white males with above average education level and household income.

The households captured in the survey had relatively small families with 2.5 adults, 2.3 licensed drivers and 1.1 children on average. Car ownership was highly correlated with the number of licensed drivers in the household—with an average of 2.3 passenger cars/household—with nearly 80% of the sample households having at least as many cars as licensed drivers. Their

relatively high household income and car ownership suggests that these individuals are relatively less sensitive towards small toll increases.

(2) Impacts of 2001 the Time of Day Pricing Initiative on Passenger Behavior

The passengers who have used the toll facilities more over 3 years were asked if they made any of the following changes because of time of day pricing: (1) frequency of car trips across the Hudson River, (2) use of carpools, (3) use of public transportation, (4) the number of car trips in peak or off-peak hours during weekdays or weekends, (5) the number of stops during a trip, (6) use of E-ZPass, and (7) other reported changes.

In general terms, passenger car users of the PANYNJ facilities tend to be inelastic to tolls. The data indicate that 35 out of 505 individuals (representing 6.9% of individuals and 7.4% of passenger car trips) changed behavior because of the time of day pricing initiative. The majority of the individuals who changed behavior (28 out of 35 individuals) still travel through the six PANYNJ toll facilities on a regular basis. These respondents account for 5.5% of individuals and 4.6% of passenger trips. In contrast, the remaining individuals reporting behavioral changes (7 out of 35 individuals) switched to public transportation and reduced their car trips to less than once per week. They account for 1.4% of individuals and 2.7% of passenger trips. (It is interesting to note that, when asked a follow-up question about the main reason why they switched to transit, only 2 out these 7 individuals mentioned toll costs, suggesting that there were other factors, in addition to tolls, that played a role in their mode choice decisions.)

The direct elasticities of the different demand segments with respect to the tolls were calculated (see TABLE 3). The results showed that, in all cases, the demand is inelastic with an average elasticity of -0.143, which is consistent with previous research (e.g., Burris and Pendyala, 2002; Oum et al. 1990; Cain et al., 2000). Although the different user types were found to have slightly different elasticities, the authors suggest not making much of this difference because it may be a consequence of the small sample of individuals that changed behavior. It is important to note that, when computing the elasticities, all users that changed behavior where included in the computations (not exclusively those that reduced facility usage). Furthermore, since cross-effects between the tolls at different time periods were not taken into account when computing the elasticities, it is likely that the direct elasticities were slightly overestimated because they do not take into account how lower tolls in the off-peak periods, for instance, impact the demand during the peak hours.

The majority of passengers (93.1%) did not change behavior. Lack/no flexibility and no willingness to change were the two major reasons for people not to change behavior. People did not change behavior because they had no choice or no flexibility to change (45.5%), or because they believe they should travel whenever they want to (32.4%). Other respondents felt that the toll difference was not enough to justify a change (8.8%), or it was paid by their employers (5.3%), and some said that they did not use the facilities enough in order to change (2.4%). These findings suggest that different factors were at play. First, travel constraints such as work schedules make it difficult for people to change their travel schedules. Second, the toll increase seemed to be relatively small to force changes on a sizable number of travelers.

Although the sample of individuals who changed behavior is relatively small (35 observations), which suggest caution when interpreting results, it seems clear that this group has a statistically different socio-economic profile than the group of users that did not change behavior. TABLE 4 shows the results of the statistical tests conducted to assess the significance

of the observed differences in the socio-economic characteristics. As shown, the individuals that changed behavior tend to:

- Be females, suggesting that women are more sensitive to price changes.
- Be younger than those who did not change behavior.
- Have a relative lower education level than those who did not change.
- Have fewer adults in their families.

It is also interesting to notice that the individuals who changed behavior tend to adopt multiple combinations of strategies to respond to time of day pricing. Most of the respondents who changed behavior reported multiple changes, frequently involving three or more, e.g., changes in car trip frequency plus change of transportation mode plus other reactions. The most important two-dimension combinations include: decreasing car trips plus increasing transit trips plus … (2.5%), increasing transit trips plus increasing/starting carpooling plus … (1.8%), and increasing the transit trips plus switching to E-ZPass plus … (1.2%). Only a small proportion of people who changed their number of trips in weekdays switched their trips from peak hours to off-peak hours simultaneously (1.2%). Also, a group of people decreased their car trips in both weekday peak and off-peak periods (1.0%). It is obvious that this pattern of time of travel switch is more significant during weekdays than during weekends. The most frequently cited changes were a: shift towards public transportation (4.2%), reduction in the car trips frequency (3.0%), reduction in the weekday peak trips (2.9%), increase in the weekday off-peak trips (2.2%), shift towards carpooling (1.9%), and shift towards E-ZPass (1.5%).

(3) The Respondents' Most Recent Trip

The passenger survey collected data about the characteristics of current and former regular users' most recent trips. It was found that 61.5% of current regular users' most recent car trips were made for work purposes, either commuting to work (46.3%) or traveling as part of their jobs (15.2%). Meanwhile, work related trips accounted for even higher percent of the most recent transit trips (83.8%) made by former regular users.

The survey also asked their time and day of travel. The majority of the most recent car and transit trips were made during weekdays: 77.5% of the most recent car trips and 93.8% of the most recent transit trips. Peak-hour trips were found the dominant trip group. Using the PANYNJ's definitions of peak periods (i.e., weekdays 6-9 AM and 4-7 PM, weekends noon-8 PM), it was found that 54.1% of current regular users drove through toll booths in the peak periods with 33.9% traveling during the weekday AM peak trips, followed by weekday PM peak trips (13.0%) and weekend peak trips (7.1%). Approximately 85% of former regular users' most recent transit trips were made during the peak periods. Weekday AM peak trips account for 80.7%, followed by weekend peak trips (3.6%) and weekday PM peak trips (0.7%).

Further analysis on the relationship between trip purpose and time of travel shows that the vast majority of work related trips were made during peak hours. About two-thirds of work related car trips (63.4%) were made during peak periods, especially weekday AM peak hours. Most of work related transit trips (91%) were made during peak periods.

The survey asked the respondents about their time of travel flexibility, in terms of departure flexibility (how earlier or later they were willing to depart from the origin and still meet their travel constraints) and arrival flexibility (how earlier or later they were willing to arrive at the destination and still meet their travel constraints). **TABLE 2** shows the average

flexibility windows. Work related trips have less than 20 minute travel flexibility on average, which reflect the difficulties for passengers to shift their time of travel.

TABLE 2 shows a number of interesting features. In general, it confirms the asymmetric nature of time of travel flexibility because in all cases respondents have more flexibility to arrive and depart earlier than later. It also highlights that the perceived flexibility for work trips is almost the same regardless of mode, which may be a consequence of the reliable transit service in New York City during the peak hours. For recreation/shopping trips, the average flexibility values when using transit are much higher than the values corresponding to passenger car, which may be a consequence of the relatively larger availability of parking during the times at which recreation activities take place (the off-peak hours).

(4) E-ZPass Usage and Awareness of Toll Discounts

Passengers reported high usage of E-ZPass though low awareness of toll discounts: 78.3% of respondents said that they currently have E-ZPass tags; though 62.7% knew about some kind of discount, only 17.0% knew about the time of day pricing discount (20.8% among E-ZPass users). Moreover, the majority of E-ZPass users did not know the exact amount of tolls they paid for their most recent trips. Only 16.7% of E-ZPass users correctly reported the amount, compared to 58.1% of cash users who reported tolls correctly. The likely reason is that since E-ZPass users pay their toll bills every month by credit card they may not necessarily know the actual amount of tolls paid every time they use the facilities. Low awareness of toll discounts, especially of the time of day pricing initiative, is bound to diminish the ability of the time of day pricing in balancing traffic throughout the day. Needless to say, it is quite ironic that electronic toll collection—widely considered to be the enabler of modern road pricing—seems to mask the price signals that are so crucial to the success of road pricing.

3.2 Results from the Carrier Survey

The objective of the carrier survey was to quantify the changes following the time of day pricing initiative. The following subsections discuss the key findings. For a more detailed analysis, the reader is referred to Holguín-Veras et al. (2006).

(1) Company Attributes

The interviewed carriers were classified into current regular users and former regular users depending on whether they currently dispatch trucks between New York City and New Jersey using the PANYNJ toll facilities on a regular basis, i.e., at least once a week. For analyses purposes, the carriers were further classified as for-hire or private carriers depending on whether or not they provide transportation services to the open market, or exclusively to a parent or related company. In general, current regular users tend to:

- Provide Less Than Truckload (LTL) or Full Truckload (FTL) services: the majority of current regular users do LTL services (54.1%) or FTL (34.6%). Other services mentioned include intermodal (11.1%), drayage (4.2%), or marine containers (1.0%).
- Operate medium to large fleets: The average fleet size is 53.9 trucks, and the most significant group of current regular users (34.9%) owns more than 50 trucks.
- Own more large size trucks (trailers/semi-trailers) than small size trucks (two, three/four axle trucks): trailers/semi-trailers are the equipment types more frequently owned by current regular users (88%), followed by two-axle trucks (58.7%) and then

three/four axle trucks (55.3%). Moreover, the average number of trailers/semi-trailers owned by current regular users is 38.0 trucks while the average numbers of two-axle trucks and three/four axle trucks owned were 10.3 trucks and 4.6 trucks separately.

- Work in New Jersey and New York, not venturing far from the Mid-Atlantic region: the majority of shipments tend to be originated at the states where these companies are located. 71.1% of shipments made by current regular users originate in New Jersey and 8.5% in New York. Current regular users tend not to venture far from the Mid-Atlantic region. Therefore, the four large states of the Mid-Atlantic region, New York State (45.7%), New Jersey (17.8%), Pennsylvania (8.1%) and Connecticut (6.3%), represent the major destinations of most shipments for current users.

Among current regular users, for-hire carriers and private carriers exhibit some differences in company attributes. For-hire carriers tend to be larger than private carriers (67.3 vs. 31.0 trucks). In terms of the fleet composition, private carriers are more likely to own smaller-size trucks (i.e., two/three/four axle trucks), while for-hire carriers tend to own larger truck combinations, i.e., trailers/semi-trailers. For-hire carriers employ more interstate truck drivers and have slightly more interstate truck drivers per truck than private carriers (51.1 drivers versus 13.0 drivers for private carriers; and 0.8 drivers/truck versus 0.6 drivers/truck for private carriers), which indicates their predominantly interstate focus.

(2) Impacts of the 2001 Time of Day Pricing Initiative on Carrier Behavior

The carriers who have used the toll facilities over 3 years were asked if they made any of the following changes because of the time of day pricing initiative: (1) trip frequency between New York and New Jersey, (2) the number of stops during a tour, (3) time of day going east through the toll booths, (4) travel time of a round-trip tour, (5) the typical shipment size, (6) shipment charges, (7) the typical load of the truck's cargo capacity, (8) the types of vehicles used in the fleet, (9)the delivery routes, and (10) other reported changes.

The data indicate that 36 carriers (20.2% of truck trips) changed behavior (increasing shipping charges was considered a behavioral change) because of the time of day pricing initiative. Excluding increases in shipping charges as a behavioral change, the percentage of the traffic that changed behavior becomes 19.3%. This includes 31 current regular users that changed behavior in different ways though still continuing to use the PANYNJ facilities (15.5% of carriers and 17.7% of truck trips); and 5 former regular users who cited tolls as the key reason to stop using the facilities (2.5% of carriers and 2.5% of truck trips). Two out these five carriers reported tolls as the key reason for stopping using the facilities; while the remaining three cited toll costs as a contributing factor to the overall high costs that forced them to change their business patterns. Since former regular users were not asked questions about behavioral changes, the analysis focuses only on current regular users.

The average direct elasticity of the truck-trip demand with respect to the tolls was calculated. The demand is inelastic with average elasticities equal to -0.428 if all the carriers that changed behavior are included; and -0.220 if only the trips made by those that changed are taken into account. Same as passenger-car demand's elasticity, it is likely that the direct elasticity are overestimated because they do not take into account the cross effects.

As before, statistical testing was conducted to assess the significance of the differences in the company attributes between the carriers that changed behavior and those that did not change. TABLE 6 shows the results. In general, the carriers that changed behavior tend to: (1) focus on

full truck load (FTL) service; (2) employ less interstate truck drivers than the companies that did not change; and, (3) work in the areas outside of New Jersey and New York.

These results seem conceptually correct because the segment of the trucking industry that changed behavior (FTL trucking companies going thru the New York City area en route to other destinations) is the segment that has more alternatives at their disposal. In contrast, local delivery trucks traveling between New Jersey and New York City simply do not have any alternative, other than changing time of travel that, as discussed before, require the consent from receivers that, for the most part, do not have any incentive to switch to the off-peak hours.

The survey asked those carriers that did not change behavior why they did not make any changes. In general, their inelastic behavior is explained by the major delivery constraints they face, or because they felt that the toll increases were not high enough to warrant changes in their operational patterns. The most significant reason cited is that they *do not have a choice* (75.3%): they felt that either they *can not change schedule due to the customers' requirements* (68.9%) or *they must use the quickest route* (6.4%). This indicates that their customers, most probably receivers, determine time of travel decisions. Other reasons include *the travel cost (including tolls) is paid by someone else* (19.8%), *price difference not all that much/can afford it* (2.0%). A very small proportion of the carriers seem to be off-peak users since 0.4% said there was no change in the toll cost for off-peak travel.

The carriers that changed behavior adopted multiple combinations of strategies to deal with time of day pricing. These include: decreasing the truck trips through the toll booths plus passing the additional costs generated by the toll changes to their customers plus …. (6.1% of current regular users), changing routes plus increasing shipment charges plus …(other changes)... (5.5%), decreasing truck trips plus changing routes plus …(other changes)... (4.1%), combinations between switching business to other areas and increasing shipment charges plus …(other changes)... (2.4%), decreasing their truck trips through the toll facilities plus …(other changes)... (2.4%), or changing their delivery routes plus …(other changes)... (2.4%); and switching to E-ZPass and simultaneously either decreasing truck trips (2.2%) or increasing shipment charges (2.1%). Overall, the behavioral changes most frequently cited are: switching to or increasing the usage of E-ZPass (10.4%), increasing shipment charges (9.0%), reducing truck trips (6.2%), and changing their routes to avoid toll facilities (6.2%). Changing the time of travel to the off-peak hours was found to be a really minor strategy, only 0.5% of current regular users shifted to off-peak periods because of the time of day pricing.

(3) Current Operations and Travel Flexibility

On average, a typical tour made by current regular users took 409 minutes with an average of 13.0 stops per tour. The companies reported that they make 6.4 truck trips per day. Current regular users carry various types of commodities. The most significant cargo types delivered by these carriers include: household goods/various (25.0%), textiles/clothing (22.4%), food (20.2%), and machinery (14.6%) among others. The average load factor for current regular users is 85.2%. The relatively high values of the load factor suggest the reported values correspond to the values for trucks leaving the home base.

The analysis of the breakdown of trips by time of day indicates that about 68.4% of truck trips are made during peak hours (6-9 AM and 4-7 PM on weekdays, noon-8 PM on weekends). When asked about reasons why trucks travel on this schedule as opposed to other times of day, 61.6% of current regular users said *customer requirements dictate schedule*, which confirms the

key role played by cargoes' receivers in setting the delivery times. Only 3.5% said *the toll is cheaper* which indicates the minor role of toll cost in determining carriers' time of travel choices.

Similar to car users, about three-quarters of carriers (74.2%) reported that they did not have any time of travel flexibility in terms of arrival flexibility. For those that reported some arrival flexibility (25.8%), the average early arrival flexibility and late arrival flexibility were 37.3 minutes and 48.8 minutes respectively (see TABLE 5). The time of travel flexibility data indicate that for-hire carriers are more constrained by the schedules and, as a result, have much less flexibility than private carriers. This is a consequence of the outsourcing of transportation, by which the shippers and receivers transfer this responsibility to for-hire carriers, which in turn have to deal with the challenge of dealing with congestion. Therefore, for-hire carriers are less sensitive to tolls because of the reluctance of their customers (receivers) to relax their delivery schedules. Private carriers, by virtue of transporting cargoes for a parent or a related company, find a more understanding environment in which both shippers and receivers are more willing to accommodate the carriers for the benefit of the entire operation.

(4) E-ZPass Usage and Awareness of Toll Discounts

Similar to passengers, the interviewed carriers were dominated by E-ZPass users. 90.3% of current regular users currently use E-ZPass to travel through the PANYNJ toll facilities. However, current regular users were not fully aware of available toll discounts. Among all current regular users, only 25.4% knew about off-peak or non-rush hour use discounts.

The comparison between E-ZPass and cash users indicates that E-ZPass users seem to have poorer awareness of toll discounts even though they are using E-ZPass. 25.7% of E-ZPass users knew about off-peak or non-rush hour use discount in contrast to 37.9% of cash users.

4. Conclusion

This paper has outlined a set of conclusions of interest to the road pricing community. According to the survey results, 7.4% of passenger trips and 19.3% of truck trips (20.2% if the carriers that only increased shipment charges are included) changed behavior due to the time of day pricing initiative.

The direct elasticities of passenger car demand with respect to tolls indicate that, as expected, demand is inelastic with elasticity values in the range of -0.1 to -0.24. These values are similar to the ones computed in previous studies.

The analyses of the passenger data suggest that individuals who changed behavior were more likely to: be female, younger; have a relative lower education level, and have relatively smaller families with fewer adults than those who did not change. These individuals adopted combinations of various strategies to deal with time of day pricing. Most of the respondents that changed behavior reported multiple changes, frequently involving three or more, e.g., changes in car trip frequency plus change of transportation mode plus other reactions. The top three combinations include: decreasing car trips plus increasing transit trips plus … (2.5%), increasing transit trips plus increasing/starting carpooling plus … (1.8%), and increasing the transit trips plus switching to E-ZPass plus … (1.2%).

The carriers that changed behavior tend to: focus on full truck load (FTL) service; employ less interstate truck drivers than the carriers that did not change behavior; and be more likely to venture in areas outside of New Jersey and New York. This suggests that the more

elastic industry segment to tolls is the group of relatively smaller FTL operators doing long distance trucking. Among other things, this is the segment that has more alternative routes at their disposal. However, since only a fraction of long distance trucking companies were included in the sample (i.e., those that at one step in the supply chain stop in New Jersey) this finding may imply that the percentage of trucking companies that did change behavior is larger than estimated in this paper.

As in the passenger case, the carriers employ combinations of multiple strategies to deal with time of day pricing. The top three most significant ones involve: decreasing the truck trips through the toll booths plus passing the additional costs generated by the toll changes to their customers plus … (6.1% of current regular users), changing routes plus increasing charges plus … (5.5%), and decreasing truck trips plus changing routes plus … (4.1%). The fact that the most frequently cited change is increasing shipment charges to their customers (most likely receivers) suggests that, in order to fully understand the broad impacts of road pricing on freight traffic, more research is needed to specifically find out how receivers reacted to the shipment charge increases enacted by the carriers. Only then, the road pricing community would begin to develop a full understanding on the broad impacts of pricing on the behavior of the commercial sector.

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LIST OF FIGURES AND TABLES

FIGURE 1 Six PANYNJ Toll Facilities of Interest

TABLE 1 Toll Rates Before and After the Time of Day Pricing Initiative

Type of vehicle	Passenger cars		Trucks	
	Before	After	Before	After
Cash peak	$4.00 / car	$6.00 / car	$4.00 / axle	$6.00 / axle
Cash off-peak	$4.00 / car	$6.00 / car	$4.00 / axle	$6.00 / axle
E-ZPass peak	$3.60 / car	$5.00 / car	$3.60 / axle	$6.00 / axle
E-ZPass off-peak	$3.60 / car	$4.00 / car	$3.60 / axle	$5.00 / axle
E-ZPass overnight			$3.60 / axle	$3.50 / axle

Note: (1) Tolls are collected in the eastbound (New York bound) direction only;
(2) Peak hours mean 6-9 AM and 4-7 PM on weekdays and 12 noon-8 PM on weekends; overnight for trucks ranges from midnight to 6 AM on weekdays; others are off-peak hours.

TABLE 2 Time of Travel Flexibility Reported by Passengers (Minutes)

Mean (minutes)	Trip Purpose					
	Work related		Recreation/shopping		Others	
	Car trip	Transit trip	Car trip	Transit trip	Car trip	Transit trip
Earlier departure	19.0	17.9	16.4	30.6	16.2	15.6
Later departure	14.7	14.9	13.8	24.1	14.4	15.6
Earlier arrival	20.4	18.3	16.0	32.6	24.2	19.5
Later arrival	12.3	9.1	12.3	23.6	9.7	8.3

TABLE 3 Elasticity of demand with respect to tolls (passengers)

User type	Time of travel	% of changes in toll rates	% of changes in demand (1)	Elasticity of demand with respect to tolls
Cash users	Peak hours	50.0%	-11.1%	-0.222
	Off-peak hours	50.0%	-5.7%	-0.113
E-ZPass users	Peak hours	38.9%	-4.8%	-0.122
	Off-peak hours	11.1%	-2.7%	-0.240
Average for all users		33.0%	-4.7%	-0.143

Note: (1) It includes all users that changed behavior in one way or another (not limited to those that only changed facility usage).

TABLE 4 Comparison of Socio-Economic Characteristics (Passenger Survey)

Variable	Changed behavior	Did not change	Statistically significant at the 5% level?	Test used
% of Females	57.6%	40.2%	Yes	Normal test for sample proportion
Mean age	38.3 years	45.2 years	Yes	Normal test for sample mean
% of individuals with or above four-year college education	38.6%	56.1%	Yes	Normal test for sample proportion
Mean Income	97,443	101,600	No	Normal test for sample mean
Median Income	95,178	80,944	Not conducted	No test available
Family structure				
Number of adults (mean)	2.1	2.5	Yes	Normal test for sample mean
Number of children (mean)	1.2	1.1	No	Normal test for sample mean

TABLE 5 Time of Travel Flexibility by Carrier Type (Minutes)

Carriers	Early Arrival Flexibility	Late Arrival Flexibility
Among the 25.8% of carriers that have time of travel flexibility:		
For-Hire Carriers	23.7	26.1
Private Carriers	55.1	79.0
All Current Users	37.3	48.8

TABLE 6 Comparison of Company Attributes (Carrier Survey)

Variable	Changed behavior	Did not change	Statistically significant at 5% level?	Test used
% of FTL operators	73.6%	25.3%	Yes	Normal test for sample proportion
Fleet size (mean)	51.6 trucks	54.5 trucks	No	Normal test for sample mean
Interstate drivers (mean)	34.2 drivers	39.3 drivers	Yes	Normal test for sample mean
% of carriers transporting shipments with origins other than New Jersey and New York	28.0%	9.9%	Yes	Normal test for sample proportion
% of carriers transporting shipments with destinations other than the Mid-Atlantic region	30.4%	16.2%	Yes	Normal test for sample proportion