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Pay to drive in my bus lane: a stated choice analysis for the proposed Lincoln Tunnel HOT lane into Manhattan

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Abstract

This paper presents the findings from a stated choice (SC) analysis conducted in the context of proposed changes to the lane system in use for the Lincoln Tunnel crossing into Manhattan. Currently, the approach road (NJ 495) to the Lincoln Tunnel has six lanes, with three in each direction. During the weekday morning peak period The Port Authority of New York and New Jersey (PANYNJ) operates a 2.5 mile exclusive bus lane (XBL) for traffic bound for Manhattan. The PANYNJ is considering creating, from existing lanes, a second XBL with the option for passenger vehicles to use it in return for an additional toll, in effect turning it into a high occupancy toll (HOT) lane. Such an approach to increase capacity and reduce congestion is unique nationally and this study looks at drivers' choices between using standard lanes, paying extra to drive on a HOT lane (the new XBL lane), switch to earlier or later departure times, or change their mode of travel. The analysis shows significant differences in the valuation of travel time savings between different population groups and also different departure time periods. The models also reveal a reluctance to change to other crossings, accept changes in departure time or switch to alternative modes.

1. Introduction

Increasing congestion in many urban and inter-urban road networks has led transport planners to increasingly rely on high occupancy vehicle (HOV) lanes in attempts to encourage drivers to share vehicles (see e.g. Kwon and Varaiya, 2008; Daganzo and Cassidy, 2008). At the same time, in some areas, the knowledge that especially certain segments of car drivers have high valuations of travel time savings has been exploited by allowing single occupancy vehicle drivers to pay a toll for using HOV lanes, turning them into high occupancy toll (HOT) lanes (see e.g. Li, 2001; Dahlgren, 2002). The present paper presents a novel application in this context, looking at allowing drivers to pay a toll for using a dedicated express bus lane on the New Jeresy approach roadway to the Lincoln Tunnel for priority access to New York City.

The Lincoln Tunnel provides a vital link between central New Jersey and midtown Manhattan. The tunnel has three tubes, each with two traffic lanes. The approach road (NJ Route 495) also has six lanes, with three in each direction. During the weekday morning peak period the Port Authority of New York and New Jersey (PANYNJ) operates a 2.5 mile exclusive bus lane (XBL) by converting one of the westbound lanes on NJ Route 495 to an eastbound lane for buses only during weekday morning peak travel hours. The XBL allows commuter buses direct access to the tunnel thereby avoiding regular peak hour traffic and significantly reducing travel time. A map of the XBL is shown in Figure 1.

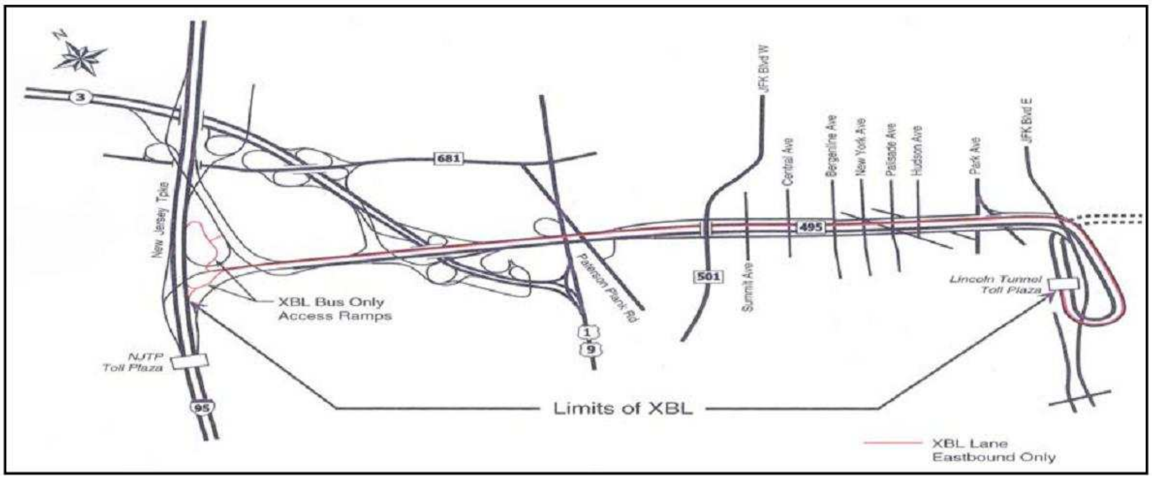


Figure 1: New Jersey Route 495 XBL (The existing 2.5 mile long exclusive bus lane)

However, with current peak hour volumes of 800 buses or more, the practical capacity of the XBL has been reached. After a review of many alternatives, the PANYNJ is assessing the feasibility of converting an eastbound general purpose lane into a second priority lane for buses and HOVs to supplement capacity of the XBL. Initially, it is unlikely that there will be sufficient demand from buses to use all of the new capacity; therefore the PANYNJ is exploring alternatives where passenger vehicles could pay an extra fee (in addition to the standard Lincoln Tunnel toll) to use the lane as a HOT lane during the morning peak.

Due to prohibitively high costs, congestion in Midtown Manhattan and environmental concerns in a non-compliant air quality area, the Lincoln Tunnel cannot be expanded by adding an additional tube with two new traffic lanes. Therefore, the PANYNJ must pursue new and unique ways to add capacity for more passenger trip within the confines of the existing Lincoln Tunnel infrastructure.

Converting an eastbound general purpose lane at the Lincoln Tunnel to a second priority access lane with the option for passenger vehicles to use it as a HOT lane is unique to the New York City metropolitan area, as well as nationally. Therefore, studies of drivers' willingness to pay an additional fee to use a priority access lane as a HOT lane at the Lincoln Tunnel are particularly important for supporting estimates of highway traffic and the potential for revenue generation.

Stated choice (SC) surveys of current Lincoln Tunnel car and commercial vehicle users, users of alternate crossings into Manhattan that compete with the Lincoln Tunnel (George Washington Bridge and Holland Tunnel), and bus riders who travel through the Lincoln Tunnel on the existing XBL, were conducted in 2007. The SC survey experiments tested alternatives that included buying in to the new HOT lane, shifting departure time earlier or later to benefit from lower fees on the new HOT lane, forming a carpool to use the proposed HOT lane at a reduced cost, switching to the improved transit services that would operate in the corridor, or diverting to an alternative travel corridor.

This paper focuses in particular on the car segment for current Lincoln tunnel users, since this accounted for the largest share of the data collected. Here, we describe the survey approach used in this study and present estimation results for discrete choice models estimated on the resulting survey data.

The remainder of this paper is organised as follows. The following section looks briefly at our survey approach, while Section 3 discusses the actual survey questionnaire. Section 4 looks at modelling methodology, with results presented in Section 5. Finally, Section 6 presents the conclusions of the paper.

2. Survey Approach

The Lincoln Tunnel HOT Lane SC survey was designed and administered to identify the travel patterns and preferences of car drivers who could reasonably use the proposed Lincoln Tunnel HOT lane during weekday peak periods. As such, the sampling plan included peak period and shoulder period car drivers who currently use the Lincoln Tunnel in the toll direction (eastbound towards Manhattan). Peak periods were defined as 6:00–10:00 AM and 4:00–7:00 PM, with shoulder periods one hour either side of both the AM and PM peaks.

Current users of the Lincoln tunnel currently have two toll payment methods available: either they pay in cash or use an electronic toll tag, known as the E-ZPass®. To reach these two groups, two separate administration methods were developed and applied. Cash customers were handed surveys at the Lincoln Tunnel Toll Plaza, immediately prior to toll payment. Because E-ZPass customers do not stop at the Lincoln Tunnel Toll Plaza; E-ZPass customers who passed through the facility during the same time period that the cash customer surveys were handed out were mailed a survey to their E-ZPass billing address. On the basis of current Lincoln Tunnel traffic volumes and response rates achieved in prior surveys, 21,400 questionnaires were mailed to car E-ZPass holders, while 6,600 questionnaires were handed out at the Lincoln Tunnel Toll Plaza to car cash customers.

3. Survey Questionnaire

The SC survey employed a paper survey booklet that included information about the study and the concept of HOT lanes, instructions, and survey questions. Respondents who received the paper survey had the choice of completing it and mailing it back (postage-paid via Business Reply Mail) or going online to complete the survey. The actual Lincoln Tunnel car driver questionnaires consisted of four parts: context questions about each respondent's trip, stated choice trade-off questions, debrief, and demographic questions. A review of these various sections follows.

3.1. Context Questions

The survey began with a letter from the Port Authority of NY & NJ inviting respondents to complete the survey, basic survey instructions, information on the purpose of the survey, and a brief explanation of the proposed Lincoln Tunnel HOT lane.

Respondents were asked to provide details of their most recent weekday trip that they had made using the Lincoln Tunnel in the toll direction (eastbound toward Manhattan) from 5:00–11:00 AM or 3:00–8:00 PM. Respondents reported details of their trip including day of week, time of day, trip purpose, roads used, and travel frequency for the same trip purpose and other trip purposes. Respondents reported where their trip began and ended, as well as whether or not they made any stops or experienced any delay on their trip. All respondents were asked to report their total door-to-door travel time.

The next series of trip characteristic questions asked respondents to indicate how much they paid for their toll at the Lincoln Tunnel Toll Plaza, who paid the toll, and the payment method (cash or E-ZPass). Respondents who did not have an E-ZPass account provided their reasons for not having one.

All respondents were asked which tunnel or bridge they would use if they had to use a crossing other than the Lincoln Tunnel to make their trip, as well as the estimated travel time to complete their trip using this alternate crossing. Similarly, each respondent indicated which forms of transit they would use if they had to make their trip using transit, how long their trip by transit would take, and how much their transit fare would be. Respondents were also asked to provide the reason why they do not currently use transit for their trip. To conclude the trip characteristic questions, respondents reported on the flexibility of their schedule by quantifying how much earlier and how much later they could make their trip.

3.2. Stated Choice Questions

Before beginning the SC trade-off questions, respondents were presented with introductory information and reintroduced to a description of the proposed Lincoln Tunnel HOT lane. The SC section gave respondents a choice between six options:

1. Current route driving on the Lincoln Tunnel regular lanes;
2. Driving on the proposed Lincoln Tunnel HOT lane;
3. Driving earlier or later on the proposed Lincoln Tunnel HOT lane;
4. Driving in a registered carpool (three or more occupants) on the proposed Lincoln Tunnel HOT lane;
5. Driving on the next best bridge or tunnel toward Manhattan; and
6. Riding a bus on the Lincoln Tunnel Exclusive Bus Lane (XBL)

The survey presented each respondent with eight SC trade-off scenarios designed as choice experiments with these six travel options.

The specific values assigned in each SC scenario were determined by using an orthogonal experimental design. The experimental design for this survey contained thirty-two experiments, which were blocked into four groups of eight. Each group of eight experiments was randomly ordered and that order was printed in one of four versions of the paper survey. Therefore, there were four printed versions of the paper survey one of which was randomly mailed to each E-ZPass customer and handed out to each cash customer. For respondents completing the survey online, one of the four groups of experiments was randomly chosen for each respondent and the eight experiments within that group were shown to the respondent in a random order. The four groups or blocks of experiments were uniformly distributed among the respondent sample.

To increase survey realism and allow respondents to better relate to the presented choice situations, the attribute levels presented were pivoted around those currently experienced by the respondent, using the variations obtained from the experimental design. For online respondents, the calculations were performed automatically, as illustrated in Figure 2. For paper respondents, this was clearly not possible, and as a result, the calculations had to be performed by the respondents themselves, as illustrated in Figure 3. This has interesting implications in terms of respondent burden that we will return to later in the paper.

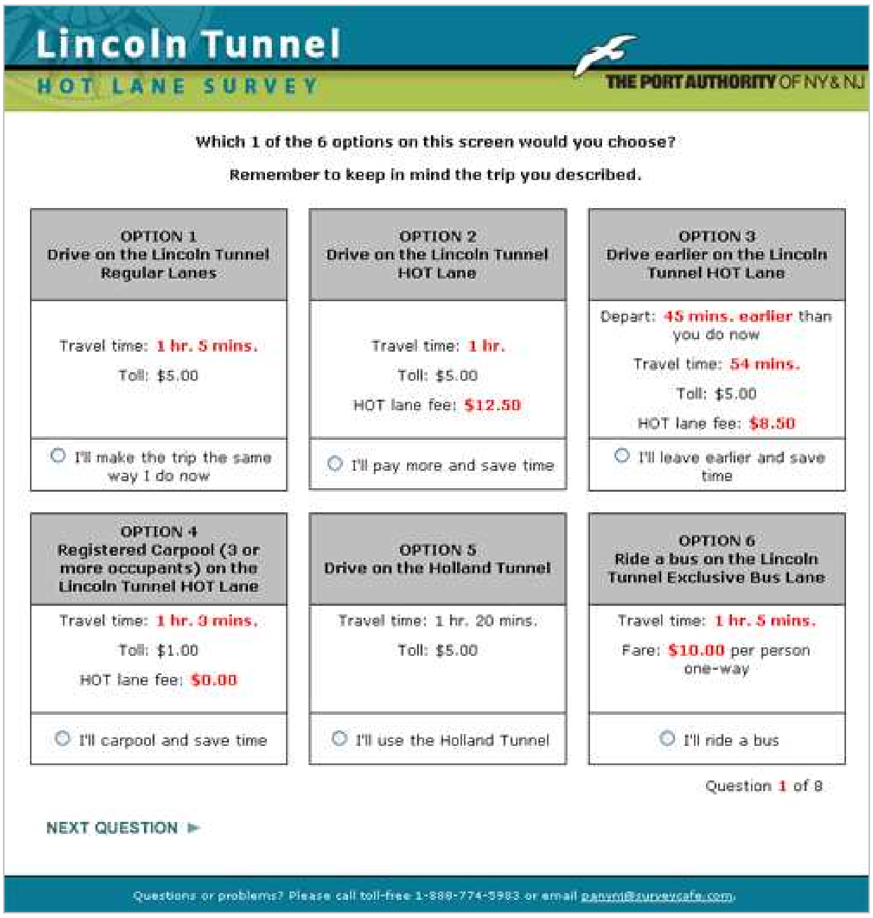
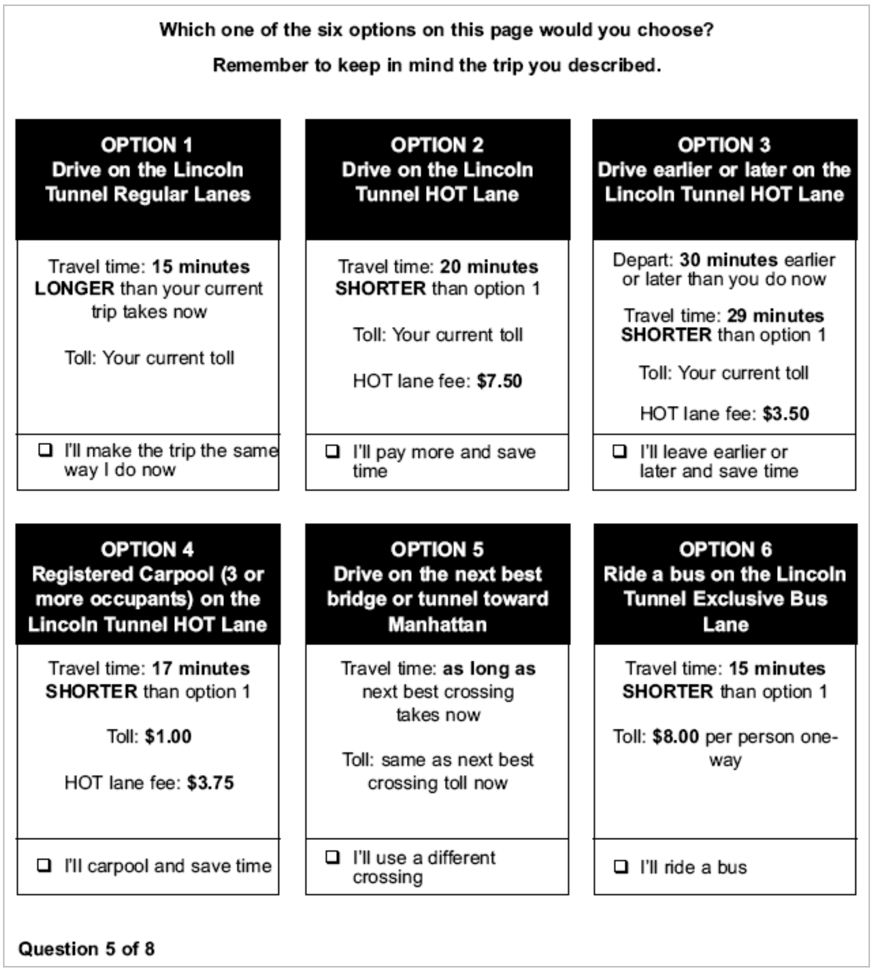


Figure 2: Lincoln Tunnel car web survey stated choice example


Which one of the six options on this page would you choose?

Remember to keep in mind the trip you described.

OPTION 1
Drive on the Lincoln Tunnel Regular Lanes

Travel time: **15 minutes LONGER** than your current trip takes now

Toll: Your current toll

❑ I'll make the trip the same way I do now

OPTION 2
Drive on the Lincoln Tunnel HOT Lane

Travel time: **20 minutes SHORTER** than option 1

Toll: Your current toll

HOT lane fee: **$7.50**

❑ I'll pay more and save time

OPTION 3
Drive earlier or later on the Lincoln Tunnel HOT Lane

Depart: **30 minutes** earlier or later than you do now

Travel time: **29 minutes SHORTER** than option 1

Toll: Your current toll

HOT lane fee: **$3.50**

❑ I'll leave earlier or later and save time

OPTION 4
Registered Carpool (3 or more occupants) on the Lincoln Tunnel HOT Lane

Travel time: **17 minutes SHORTER** than option 1

Toll: **$1.00**

HOT lane fee: **$3.75**

❑ I'll carpool and save time

OPTION 5
Drive on the next best bridge or tunnel toward Manhattan

Travel time: **as long as** next best crossing takes now

Toll: same as next best crossing toll now

❑ I'll use a different crossing

OPTION 6
Ride a bus on the Lincoln Tunnel Exclusive Bus Lane

Travel time: **15 minutes SHORTER** than option 1

Toll: **$8.00** per person one-way

❑ I'll ride a bus

Question 5 of 8

Figure 3: Lincoln Tunnel car paper survey stated choice example

3.3. Debrief Questions

At the conclusion of the SC scenarios, all respondents were asked a number of debrief and opinion questions. Respondents first answered how often they anticipated they would use the proposed Lincoln Tunnel HOT lane and their overall opinion of the Lincoln Tunnel HOT lane concept. Secondly, respondents were introduced to the concept of Free And Intertwined Regular (FAIR) lanes and told that, if the HOT lane were implemented, it may be possible that drivers who used the regular Lincoln Tunnel bound lanes and maintained a valid E-ZPass account for transportation services could earn credits toward free trips on the HOT lane. Thirdly, respondents indicated how often they anticipated using the proposed Lincoln Tunnel HOT lane if they could earn credits toward free trips in the HOT lane by driving in the regular lanes. The fourth debrief question asked respondents what their opinion of the Lincoln Tunnel HOT lane concept would be if it were possible to earn credits toward free trips on the HOT lane by driving in the regular purpose lanes. Lastly, respondents were asked how strongly they agreed or disagreed with four statements related to their general opinion of toll-related projects.

3.4. Demographic Questions

To conclude the questionnaire, nine demographics questions were asked to verify that the sample contained a diverse cross section of the population that would be served by the proposed Lincoln

Tunnel HOT lane. Respondents were assured that their responses would be kept confidential and that any personal information they recorded would not be shared or sold to a third party.

Respondents provided their home ZIP code, household size, number of household vehicles, gender, age, occupation, and annual income in order to attain information about the sample and to determine differences in responses among different driver segments. Respondents were also asked if they owned any electric, hybrid, or alternative fuel vehicles and their opinion on allowing these vehicles to use the proposed HOT lane for a discounted HOT lane fee.

4. Model specification

The SC data collected as part of this study were used to estimate choice models to understand likely future travel behaviour of current travellers and the likely use of a potential Lincoln Tunnel HOT lane. This section discusses model specification.

With the aim of the study described in this paper being the development of usable models for travel behaviour, we restricted ourselves to Multinomial Logit (MNL) models (McFadden, 1974). The MNL model expresses the choice probability for alternative as:

$$P = \frac{e^{V_i}}{\sum_{j=1}^{V_j} e^{V_i}}, \qquad [1]$$

where V_i is the modelled utility of alternative i, and where the assumption is made that the unobserved utility components follow a type I extreme value distribution, distributed identically and independently across alternatives and observations.

4.1. Dealing with MNL limitations

The specific assumptions about the error terms mean that the MNL model has a number of significant limitations that have increasingly led to a reliance on more advanced structures, especially by academics. However, the aim of the present paper is applied rather than methodological, and a number of steps were taken to mitigate the effects of using a more basic model structure.

Firstly, we give consideration to the fact that the analysis in this study makes use of data collected through two separate surveys, one paper-based and one web-based. Due to the differences in survey administration, and the nature of the sample that responds to each survey type (Web-based surveys often attract a different type of respondents from those of traditional CAPI or pen and paper surveys), there are potentially significant differences between the two models in the relative weight of the modelled utilities and unobserved utilities. This is potentially aggravated by the fact that in the paper survey, respondents had to work out the travel times themselves while in the web-based survey, these calculations were done automatically for the respondent.

In a methodological context, this is referred to as scale differences, with higher scale in one dataset meaning more relative weight for the modelled utilities in that dataset, manifesting itself through higher sensitivities to the explanatory variables. Not taking such scale differences into account may result in biased coefficient estimates. With this in mind, a separate analysis was conducted to investigate any scale differences between the two data sources. However, the assumption of equal scale could not be rejected as no significant differences were observed (detailed results available on request). As a result of this, the remainder of this analysis is based on the merged data with no differences in scale.

Secondly, while the MNL model does not allow for random variations in tastes across respondents, it does allow for deterministic taste heterogeneity, i.e. variations in sensitivities linked to socio-demographic information. We therefore tested for a number of different interactions, as discussed below.

Thirdly, another shortcoming of the MNL model is the assumption of independently distributed error terms across alternatives. With the present data, a case could for example be made for correlation between the different HOT lane alternatives. Here, attempts were made to estimate Nested Logit (NL) structures on the data, hence allowing for such correlations, but no conclusive evidence of significant patterns of inter-alternative correlation were observed.

Finally, another issue with the MNL model (though not limited to MNL) is that in its estimation, separate observations from the same respondent are treated as independent, and while this assumption generally leaves parameter estimates unaffected, it does tend to lead to an underestimation of the standard errors (Cirillo et al., 2000). Here, we conducted a Jackknife analysis to investigate this potential bias. Jackknife estimation is based on estimating models separately for a number of different subsamples created by drawing without replacement from the overall sample and standard errors for the overall model are calculated on the basis of the differences in results across these separate models.

4.2. Utility functions

The utility functions in a choice model determine how the estimated sensitivities of respondents interact with the explanatory variables describing the alternatives. Here, several specifications were tested using the variables included in the SC experiments, as well as trip characteristic and socio-demographic variables.

Mode specific travel time sensitivity coefficients were tested, with a common travel time coefficient for the five car alternatives and a separate coefficient for the bus alternative. While some differences in travel time sensitivity between car and bus were observed, the bus specific travel time coefficient likely captures some of the opposition to bus travel because it only applies to one alternative, and the estimated sensitivity was unrealistically high. On this basis, we reverted to a generic travel time coefficient.

Various specifications for the coefficients on travel costs were tested. Three elements of travel costs were used across the alternatives: toll, HOT lane fee, and bus fare. With the exception of the registered carpool alternative, tolls were fixed across the set of SC experiments presented to each respondent and were always the same for the Lincoln Tunnel alternatives. HOT lane fees and bus fares were varied across each respondent's experiments. A coefficient on total car cost (toll plus the HOT lane fee, if applicable) resulted in better model statistics than separate toll and HOT lane fee coefficients as the lack of variation in the tolls made it difficult to estimate a statistically significant coefficient.

We also experimented with mode-specific cost coefficients (on total car costs and bus fares). However, for the same reason outlined in the discussion on travel time coefficients, a fully generic cost coefficient (common to total costs for all alternatives) was preferred to avoid capturing opposition to bus travel in the bus fare coefficient.

Alternative specific constants (ASC) were included to capture preferences for an alternative not represented by the other attributes that describe the alternative, with the constant for the bus alternative fixed to zero and the remaining five constants estimated relative to that constant.

Interactions between the time, cost, and time shift coefficients and various trip characteristics and socio-demographics variables were tested. The following points summarise the results of these tests.

- Income: Household income was found to have a consistent negative effect on cost sensitivity only. The effect is almost linear.
- Gender: Female respondents are less sensitive than male respondents to shifting to an earlier departure time.
- Age: Age has no consistent effect on the models.
- Delay experiences: Drivers who experienced delay are less cost sensitive than those who do not currently experience delay.
- Payment by E-ZPass®: Drivers who pay by E-ZPass are more sensitive to shifting to a later departure time.
- Who pays tolls: Respondents who do not get their tolls reimbursed have a higher cost sensitivity.
- Trip frequency: Trip frequency has no consistent effect on the models.
- Earlier departure possible: Drivers with no possibility to depart earlier have lower time and cost sensitivity. Drivers who can depart earlier are less sensitive to shifting to an earlier departure time than those who have a fixed travel schedule.
- Later departure possible: Similar results to earlier departure time. Those without the ability to shift later have lower time and cost sensitivity. Drivers who can depart later are less sensitive to shifting their departure time later than those who have a fixed travel schedule.
- George Washington Bridge and Holland Tunnel auto users: Auto users of both alternate crossings showed lower travel time sensitivity. George Washington Bridge users are more cost sensitive. Holland Tunnel users are less sensitive to shifting to an earlier departure time.
- Vehicle occupancy: Respondents driving a vehicle with three or more occupants are more time sensitive than those with fewer occupants. Those driving alone showed the lowest cost sensitivity.
- Household size: Those living in single person households are more cost sensitive than those living in larger households.
- Household vehicle ownership: Respondents from households with more than one car are less time sensitive and less cost sensitive than those from single-vehicle households.
- Distance: Marginal sensitivity to time and cost decreases with increasing trip distance. As this decrease is at a similar rate for both time and cost sensitivity, distance has little impact on values of time, but does indicate that elasticity reduces with increasing distance.

The decision to retain interaction effects in the final specification was based on applicability during forecasting as well as the strength of the interaction. Two were retained, namely occupancy and income. An occupancy interaction with both time and cost coefficients is included in the final models, specified as additional time and cost coefficients for those travelling in a 3+ occupant vehicle. The income effect included in the specification is an additional linear income coefficient on cost. This is based on a lack of evidence suggesting that the effect should be non-linear.

Other effects identified above have been accommodated through segmenting the models by purpose, time of day, use of other crossings, and toll payment method.

5. Estimation results

This section presents the results of the model estimations. Given the small sample sizes for car drivers using alternative crossings, as well as for car drivers paying cash, the sample for the present paper was restricted to those respondents currently using the Lincoln tunnel and paying for their toll by E-ZPass, with results for cash respondents and users of other crossings available on request. The final sample contained 19,125 observations for car drivers. In this section, we present detailed results for one car model. We additionally present some evidence from the various segmentations undertaken for the car models.

5.1. Overall model

Coefficients were estimated for total travel time and total cost (toll plus HOT lane fee if applicable or bus fare). Additional time and cost coefficients were included for 3+ occupant vehicles to capture their additional sensitivity to travel time and cost. The total disutility associated with travel time and cost for 3+ occupant vehicles is the sum of the disutility for travel time and cost that applies to vehicles of all occupancies plus the additional disutility indicated by the extra terms specific to 3+ occupant vehicles.

A linear income coefficient on cost was also estimated to capture reducing cost sensitivity with increasing household income. The total disutility associated with cost is the sum of the disutility for cost that is common to respondents of all income levels minus a linearly increasing utility value related to household income in thousands of dollars. Coefficients were also included for the sensitivity to shifting departure time earlier (SDE) or later (SDL). Finally, alternative specific constants were included on all alternatives, with the constant for the bus alternative fixed to zero and the other constants estimated relative to that constant.

We now present the estimation results for the sample of 19,125 observations for car drivers who currently use the Lincoln tunnel and who pay their toll with an E-ZPass. Table 1 presents the results of an MNL model estimated on this sample, where we show both the standard estimation results and those obtained using a Jackknife approach with 20 subsamples.

Table 1: Detailed results for car drivers paying by E-ZPass®

Observations	19,125				
Final log likelihood	-24,306.6				
Parameters	12				
Adjusted ρ^2	0.2903				
		Standard		**Jackknife**	
Coefficient	**Units**	**est.**	**t-stat.**	**est.**	**t-stat.**
Travel Time	Minutes	-0.0306	-42.5	-0.0306	-21.47
Travel Time (3+)	Minutes	-0.0126	-6.25	-0.0123	-2.05
Cost	$ (dollars)	-0.1760	-43.3	-0.1761	-21.05
Cost (3+)	$ (dollars)	-0.0411	-5.93	-0.0393	-2.33

Cost – Income	$*inc./1000	0.0003	23.6	0.0003	13.1
SDE	Minutes	-0.0266	-15.0	-0.0266	-17.47
SDL	Minutes	-0.0238	-13.8	-0.0237	-16.02
ASC 1	(0,1)	2.6959	74.1	2.6827	36.06
ASC 2	(0,1)	2.4815	53.9	2.4785	36.81
ASC 3	(0,1)	2.2149	27.2	2.2129	31.91
ASC 4	(0,1)	-0.4245	-9.49	-0.4220	-4.18
ASC 5	(0,1)	1.0251	26.5	1.0228	12.19

As a first observation, we can see that, as expected, there are only minor differences between the standard estimates and the Jackknife estimates. On the other hand, the Jackknife runs do lead to significant changes in the standard errors, and suggest that with a few exceptions, the parameter confidence in the standard estimation was overstated. Nevertheless, all estimated parameters do remain significant at high levels of confidence.

In terms of the actual estimates, increases in travel time and cost have negative impacts on the utility of an alternative, as do increases in schedule delay, where it should be noted that the sensitivity to early departure is higher than the sensitivity to late departure, but where the differences are only very small. Respondents travelling in a carpool with three or more occupants have higher time and cost sensitivity while increases in income lead to reductions in cost sensitivity. Finally, a look at the alternative specific constants suggests that, all else being equal, there is a general reluctance to change mode or carpool; indeed, with bus being the base, all constants except for the carpool one are positive. There is also a very slight preference for the base option over the HOT lane option, a slightly stronger preference over the option involving departure time changes, and a substantial preference over the use of alternative crossings.

5.2. Segment-specific results

As a next step, we segmented the car data by purpose and also by time period, where a larger degree of disaggregation was used for commuters (six time periods) than for business travellers (three time periods) and other trip purposes (four time periods). The specific sizes for the different subsamples are shown in Table 2.

Table 2: Segmentation by departure time and trip purpose

<table>
<tr><th rowspan="2">Segment</th><th colspan="3">Trip Purpose</th></tr>
<tr><th>Commuters</th><th>Business</th><th>Other</th></tr>
<tr><td>Before 6:00 AM</td><td>1,183</td><td rowspan="3">1,842</td><td rowspan="3">788</td></tr>
<tr><td>6:00 AM–7:00 AM</td><td>2,856</td></tr>
<tr><td>7:00 AM–10:00 AM</td><td>5,440</td></tr>
<tr><td>10:00 AM–11:30 AM</td><td>693</td><td>747</td><td>793</td></tr>
<tr><td>2:30 PM–4:00 PM, After 7:00 PM</td><td>658</td><td rowspan="2">710</td><td>803</td></tr>
<tr><td>4:00 PM–7:00 PM</td><td>858</td><td>1,754</td></tr>
</table>

Here, we do not present detailed estimation results for the resulting 13 models but rather summarise the results in the form of the estimated willingness to pay for reductions in travel time and schedule delay. These values were calculated for drivers with a household income of $100,000, where this value was used given the high income of travellers using the Lincoln Tunnel in the morning peak. Table 3 shows the results for the valuation of travel time savings.

Table 3: Valuation of travel time savings by trip purpose and departure time: Current Lincoln Tunnel car users with E-ZPass paynment method

<table>
<tr><th rowspan="2">Segment</th><th colspan="3">Trip Purpose</th></tr>
<tr><th>Commuters</th><th>Business</th><th>Other</th></tr>
<tr><td>Before 6:00 AM</td><td>$20.99</td><td rowspan="3">$13.15</td><td rowspan="3">$9.21</td></tr>
<tr><td>6:00 AM–7:00 AM</td><td>$16.56</td></tr>
<tr><td>7:00 AM–10:00 AM</td><td>$15.06</td></tr>
<tr><td>10:00 AM–11:30 AM</td><td>$12.33</td><td>$10.73</td><td>$10.57</td></tr>
<tr><td>2:30 PM–4:00 PM, After 7:00 PM</td><td>$9.12</td><td rowspan="2">$10.20</td><td>$8.43</td></tr>
<tr><td>4:00 PM–7:00 PM</td><td>$19.20</td><td>$7.59</td></tr>
</table>

In general, the results show that commuters have the highest values of time amongst the trip purpose segments, followed by business travellers, and lastly those travelling for other trip purposes. While it is typical that those travelling for non-work purposes demonstrate lower values of time than work commuters or business travellers, in many corridors, business travellers have higher values of time than work commuters. However, there are several differences between the work commuters and business travellers who currently use the Lincoln Tunnel that may explain the differences in values of time in this case. As expected, most commuter trips are frequent (71% of commuters have four or more return journeys per week compared to only 14% for business trips), so commuters are in general much more familiar with the congested travel conditions on the approach to the Lincoln Tunnel at peak times. Business travellers are making slightly longer trips than commuters and are also travelling later than commuters (with a much larger proportion of business trips in the post-AM peak shoulder and very few before 7:00 AM).

Business travellers also have a slightly different employment type mix, with 22% working in a sales, office and administrative job compared to 9% of commuters and a smaller proportion (31% to 36%) working in the management, business or financial sector. Since those making commute trips through the Lincoln Tunnel are more likely to be working in senior positions, and are demonstrating their sensitivity to travel time savings by choosing to travel before congestion begins to build on the Lincoln Tunnel approach, the results showing them to have higher values of time than business travellers seem reasonable.

As discussed above, the cost sensitivity and hence the value of time was interacted with household income. Since cost sensitivity reduces as income increases, the value of time increases as income increases. Work commuters paying by E-ZPass and travelling through the Lincoln Tunnel in the AM peak and shoulder time periods were grouped into four time segments, with two periods (peak and shoulder) for PM travel (Figure 4). Those travelling earliest, before 6:00 AM, were found to have the highest values of time, following by the group travelling in the first hour of the AM peak, between 6:00 AM and 7:00 AM. A possible explanation of this is that respondents who value their time highly have moved their departure time earlier to avoid the traffic congestion found later in the morning and therefore save time. Respondents travelling in the main part of the AM peak, from 7:00 AM to 10:00 AM were found to have values of time less sensitive to income than those travelling at other times in the morning. In the afternoon, respondents travelling in the main PM peak period, between 4:00 PM and 7:00 PM were found to have a higher value of time than those travelling in the shoulder period before and after the PM peak.

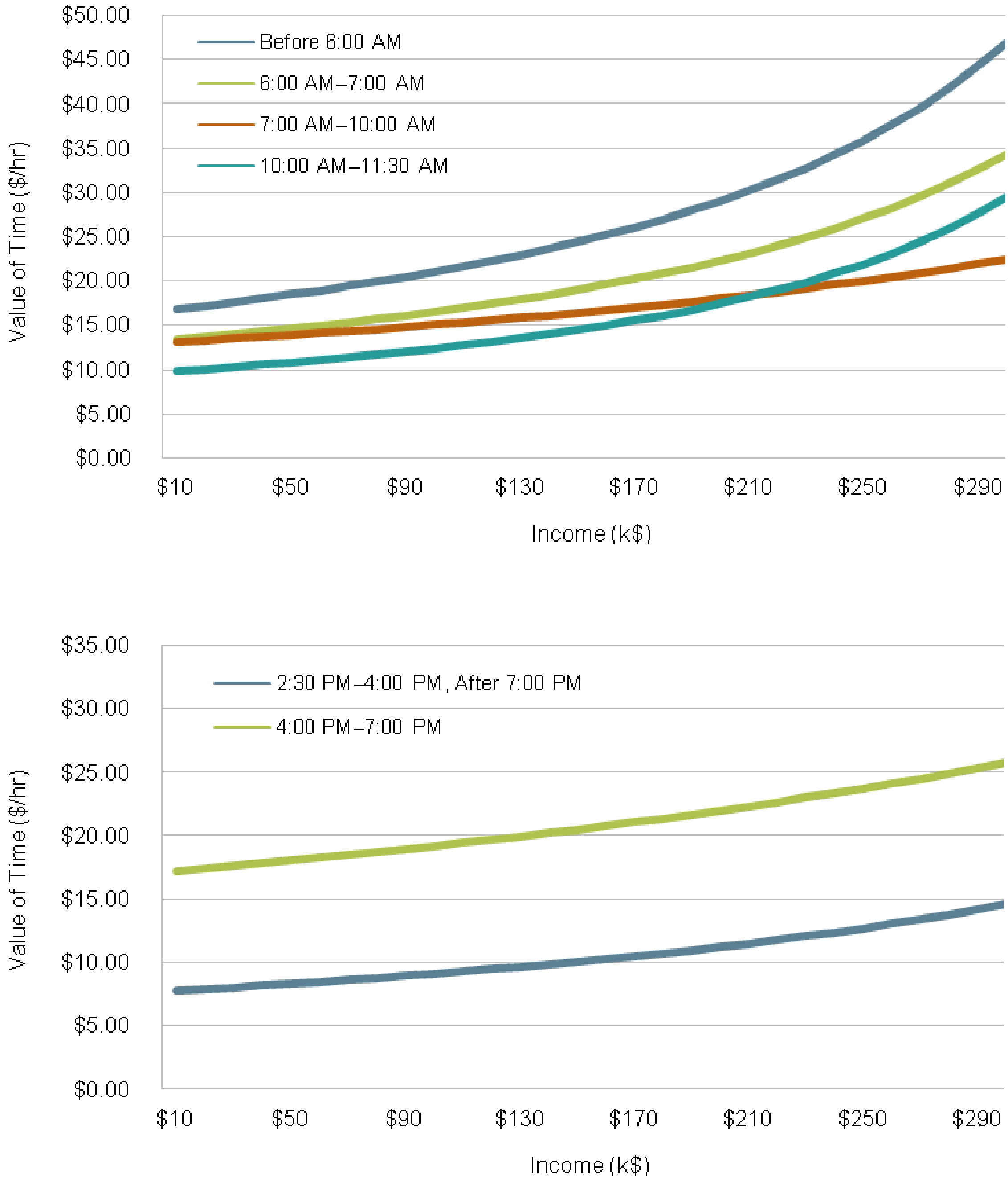


Figure 4: Valuation of travel time savings for commuters as a function of income and departure time

Early morning business travellers using the Lincoln Tunnel in a car and paying by E-ZPass were found to have slightly higher values of time than business travellers using the tunnel later in the day (Figure 5).

Figure 5: Valuation of travel time savings for business travellers as a function of income and departure time

Relatively small differences in values of time are apparent for other trip purpose travellers using the Lincoln Tunnel and paying by E-ZPass by time of day, especially at lower income levels. For higher income travellers, values of time reach $20.00 per hour for those travelling in the AM peak and AM shoulders compared to $15.00 for those travelling in the afternoon (Figure 6).

Figure 6: Valuation of travel time savings for other trip purposes as a function of income and departure time

Valuations of the willingness to shift departure time can be calculated in a similar way to willingness to pay for travel time savings (value of time). In our models, a time shift coefficient has been estimated in units of minutes, which provides a per minute disutility for shifting departure time. From this, we can calculate the monetary penalty associated with shifts in departure time. This gives us an indication of what savings in cost or corresponding changes in travel time would be required to make a shift in departure time acceptable.

Table 4 shows mean values for shifts to earlier or later departure times, estimated at a household income of $100,000. Among commuters travelling in the morning, those travelling in the main part of the AM peak (7:00–10:00 AM) would require the largest toll or travel time savings to shift to an earlier departure time, indicating that a significant proportion are travelling during that time period because they have relatively inflexible travel schedules.

The values for willingness to shift to an earlier departure time should be interpreted with care. The AM peak (7:00–10:00 AM) Lincoln Tunnel E-ZPass segment has a value of time of $15.06 per hour and a valuation to avoid early departure of $15.31 per hour. This means that, in order for an AM peak E-ZPass customer to consider travelling one hour earlier equal (in terms of utility) to travelling at their preferred departure time, travelling one hour earlier must realise them $15.31 worth of travel savings, either in tolls, travel time, or some combination of both tolls and travel time.

For example, if travelling an hour earlier gave a travel time of exactly one hour faster, this would equate to $15.06 worth of travel savings (as the value of time is $15.06 per hour for AM peak E-ZPass drivers). If in addition, the toll was 25 cents lower at the earlier time, which would give the full $15.31 needed for travelling one hour earlier to be considered of equal disutility to travelling at their preferred departure time.

In terms of travelling later, those commuters travelling in the early morning (before 7:00 AM) would require smaller toll or travel time savings to travel later than to shift even earlier than they travel already. Among the morning commuters, those travelling in the main part of the AM peak (7:00–10:00 AM) again have the highest values.

Table 4: Mean values for willingness to pay to avoid shifting to earlier or later departure times for car models ($/hour)

<table>
<tr><th rowspan="2"></th><th rowspan="2">Segment</th><th colspan="3">Trip Purpose</th></tr>
<tr><th>Commuters</th><th>Business</th><th>Other</th></tr>
<tr><th rowspan="6">Earlier departure</th><td>Before 6:00 AM</td><td>$11.70</td><td rowspan="3">$12.54</td><td rowspan="3">$7.22</td></tr>
<tr><td>6:00 AM–7:00 AM</td><td>$9.63</td></tr>
<tr><td>7:00 AM–10:00 AM</td><td>$15.31</td></tr>
<tr><td>10:00 AM–11:30 AM</td><td>$12.24</td><td>$7.05</td><td>$6.24</td></tr>
<tr><td>2:30 PM–4:00 PM, After 7:00 PM</td><td>$1.82 *</td><td rowspan="2">$7.81</td><td>$7.43</td></tr>
<tr><td>4:00 PM–7:00 PM</td><td>$16.13</td><td>$8.97</td></tr>
<tr><td></td><td colspan="4"></td></tr>
</table>

Later departure	Before 6:00 AM	$8.13	$9.79	$8.53
	6:00 AM–7:00 AM	$4.15		
	7:00 AM–10:00 AM	$14.18		
	10:00 AM–11:30 AM	$12.99	$8.38	$9.09
	2:30 PM–4:00 PM, After 7:00 PM	$1.82 *	$8.27	$8.75
	4:00 PM–7:00 PM	$11.88		$7.79
	* Departure time shift coefficient is not significantly different from zero			

As explained above, car cost sensitivity was interacted with household income. Since cost sensitivity reduces as income increases, the value of toll savings required to shift departure time also increases as income increases.

Figure 7 compares the willingness to pay for avoiding shifts in departure time for the AM peak auto commuters paying by E-ZPass on the Lincoln Tunnel. The shapes of the curves are similar to those for values of time, with higher valuations at the highest income levels. As before, respondents travelling in the main part of the AM peak, (7:00–10:00 AM) show the smallest variation across the range of household incomes. As noted above, those travelling in the early morning, before 7:00 AM, require smaller toll or travel time savings to travel later than to shift even earlier than they currently travel.

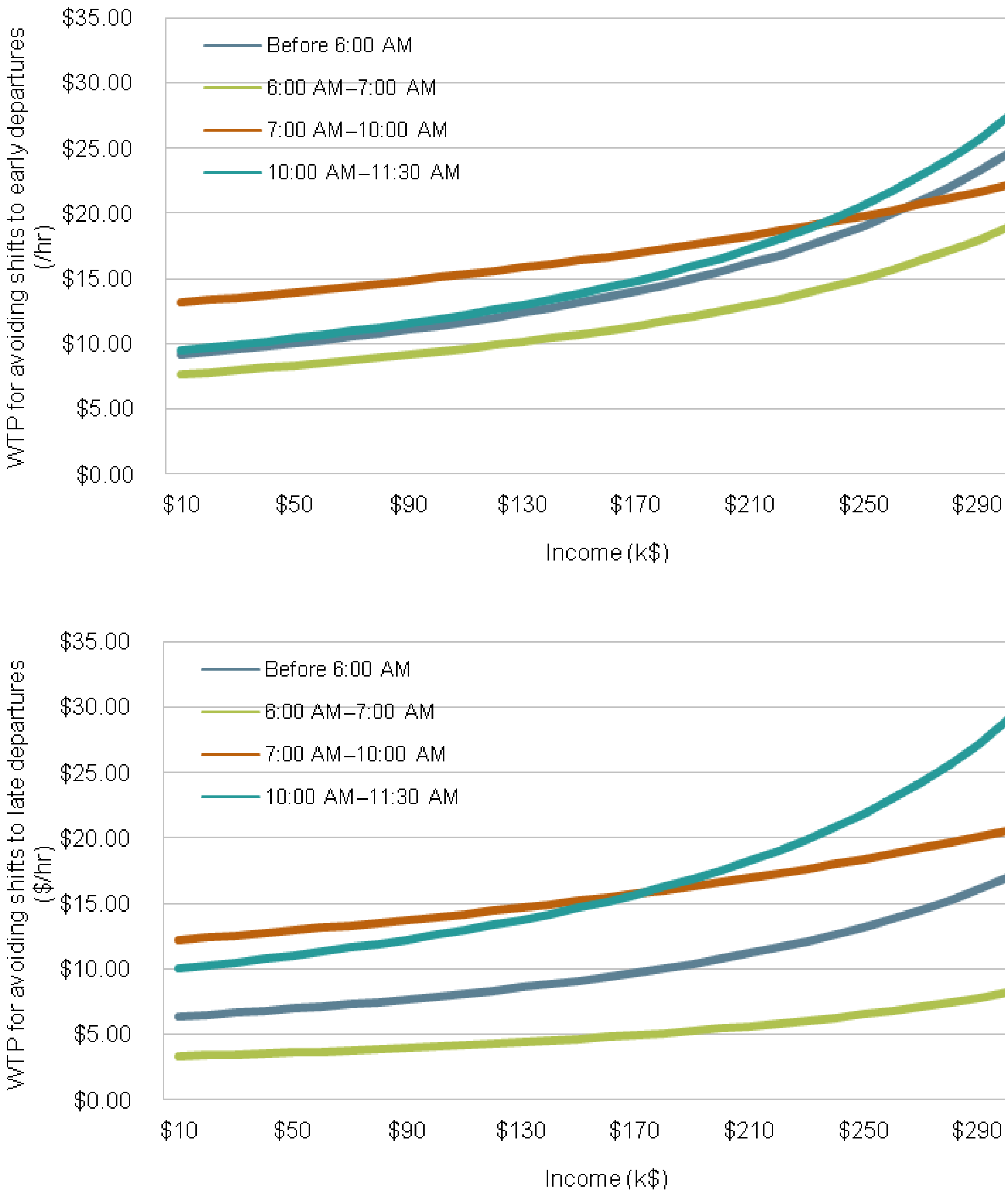


Figure 7: Willingness to pay for commuters to avoid shifts to earlier or later departure times ($/hour) for AM Time Period Segments

6. Summary and conclusions

This paper has summarised the findings of a study looking at potential driver behaviour after the introduction of a new lane system for the New Jersey approach roadway leading to the Lincoln Tunnel crossing into Manhattan. What sets this paper apart from the many other stated choice studies of driver behaviour in toll road settings is the specific context, namely the plan to allow car drivers to pay extra to drive on a new expresses bus lane, which would be created by converting a current general pupose lane for priority treatment. This creates a further segmentation of the different options available to drivers, with additional time savings in return for a higher toll.

In the SC survey undertaken for this study, respondents were consequently faced with a choice between various options that involved paying a fee for using faster lanes, changing their departure time, travelling on alternative crossings and changing mode.

The results of this discrete choice analysis show that, all else being equal, there is a general reluctance to changing mode or departure time, forming a new carpool, or using an alternative crossing. Additionally, the study has shown significant variations in sensitivities across different population groups (e.g. different income groups and trip purpose). The variation in the valuation of travel time savings across respondents is an indication that specific sub-segments will be more likely than others to pay the extra fee for using the proposed HOT lane. The actual uptake will depend on the fee in operation, where the differences in valuations by time of day are also likely to play a role.

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