Drivers' Willingness-to-Pay to Reduce Travel Time: Evidence from the San Diego I-15 Congestion Pricing Project

David Brownstone

Department of Economics
University of California
Irvine, CA 92697-5100
Tel: +1-949-824-6231
Fax: +1-949-824-2182
Email: dbrownst@uci.edu

Arindam Ghosh

Department of Economics
University of California

Thomas F. Golob

Institute of Transportation Studies
University of California

Camilla Kazimi

Department of Economics
San Diego State University

Dirk Van Amelsfort

Bureau Goudappel Coffeng
The Netherlands

June, 2002

Drivers' Willingness-to-Pay to Reduce Travel Time: Evidence from the San Diego I-15 Congestion Pricing Project

Abstract

The adoption of congestion pricing depends fundamentally upon drivers' willingness to pay to reduce travel time during the congested morning peak period. Using revealed preference data from a congestion pricing demonstration project in San Diego, we estimate that willingness to pay to reduce congested travel time is higher than previous stated preference results. Our estimate of median willingness to pay to reduce commute time is roughly $ 30 per hour, although this may be biased upward by drivers' perception that the toll facility provides safer driving conditions. Drivers also use the posted toll as an indicator of abnormal congestion and increase their usage of the toll facility when tolls are higher than normal.

Drivers' Willingness-to-Pay to Reduce Travel Time and Its Variance: Evidence from the San Diego I-15 Congestion Pricing Project

INTRODUCTION

Policy makers have been hesitant to adopt congestion pricing despite the fact that economists have been championing the cause for many decades. A fundamental question in the debate is how much drivers are willing to pay to save time by avoiding congested roadways. Most revealed preference (RP) "value of time" estimates are based upon mode choice models for the tradeoff between transit and auto travel. Small, 1992, and Wardman, 1998 provide comprehensive reviews of value-of-time studies, MVA Consultancy et. al., 1994, reviews the theoretical background and empirical studies done in U.K. summarizing value of time estimates for different modes of travel, Small et. al., 1999 review value of time studies from reducing time on congested roads, and Gonzalez, 1997, provides a review of the theory of consumer choice and its connection to value of time and mode choice modeling. It has been pointed out in the literature that value of time estimates from comparing auto travel to transit may be biased by the extent to which real differences between crowded public buses, light-rail, or private automobiles are not captured by the model.

Calfee and Winston (1998) attempt to estimate willingness to pay to reduce travel time that is specific to automobile travel, thus excluding inter-modal biases. They use stated preference data because they lacked revealed preference data for the choices involved with congestion pricing. Based on this approach, Calfee and Winston (1998) conclude that commuters have a lower valuation of time saving than previously thought.

We estimate willingness to pay to reduce median travel time specific to travel by automobile on a congested road. The approach uses revealed preference data from the I-15 congestion pricing project in San Diego. Our results indicate that willingness to pay to save time is much higher than Calfee and Winston's estimates. Our estimates are similar to Lam and Small (2001) who also use revealed preference data from another California toll facility.

We find that the median willingness to pay to reduce travel time for the population of regular morning drivers is roughly $30 per hour. This estimate explicitly controls for the variability in time savings over the month around the survey date. Variability is measured by the difference between the 90th percentile and the median time savings from using the toll facility. This measure captures the notion that drivers are concerned mostly about unexpected delays in their morning commutes. We also control for unusual congestion by including the deviation of the actual from the mean toll for the time the commuter travels the corridor, and we find that drivers are willing to pay much more to avoid unusual congestion (as evidenced by a higher than usual toll). At the time drivers need to decide whether or not to use the toll facility, they only know the distribution of time savings, tolls, and the actual toll (but not the actual time savings for the particular trip). Our choice model specification is designed to mimic the information available to the commuter.

Since the toll lanes along the I-15 are separated from the rest of the freeway, users may also benefit from improved driving conditions and safety. Willingness to pay estimates would therefore include drivers' valuation of these benefits, and may therefore be upward biased estimates of pure willingness to pay for travel time reduction. However, because all current and proposed congestion toll facilities also require separation from the main traffic lanes, we would expect these benefits to carry over to similar toll facilities.

Our models all assume that drivers do not change their departure times from home in response to changes in tolls and congestion levels. While this assumption is probably false, imposing this assumption should not bias our willingness to pay estimates since the congestion pricing scheme insures that the toll per minute of time saved is roughly constant over the morning commute period. It would be better to jointly model departure time and mode choice (as in Lam and Small, 2001), but our data are not detailed enough to support this more general model.

THE SAN DIEGO I-15 CONGESTION PRICING PROJECT

A demonstration congestion pricing project was initiated in 1996 on an 8.5 mile stretch of Interstate Route 15 in northern San Diego County. The project allows solo drivers to pay to use two underutilized reversible high occupancy vehicle (HOV) lanes, known as the “Express Lanes.” In effect, the HOV lanes become both HOV and toll lanes, sometimes referred to as HOT lanes. The corridor is northeast of the main employment centers in San Diego with pronounced unidirectional commute patterns (southbound in the morning and northbound in the evening). The Express Lanes are physically separated from the main lanes and operate in only one direction depending on whether it is morning or evening. Entry occurs at one point, and the entire length must be traversed before exiting. The Lanes are operated in the southbound direction from approximately 5:30AM to 10:00AM and in the northbound direction from 2:30PM to 7:30PM.

The demonstration project began in December 1996. During the first phase (December 1996 through March 1998), solo drivers purchased monthly passes allowing unlimited use of the Express Lanes. Carpoolers were allowed to travel for free in the Express Lanes. During the ongoing second phase (initiated in March 1998), subscribers are issued windshield-mounted transponders used for automatic vehicle identification. The second phase is referred to as FasTrak™. FasTrak user accounts are automatically debited a per-trip fee when they use their transponder. The fee is posted on changeable message signs upstream from the entrance to the lanes, and can be varied every six minutes. There is no limit on the number of subscribers to the FasTrak system. Instead, the fee is adjusted to maintain relatively free-flowing traffic conditions in the Express Lanes. Just as during the first phase, carpoolers travel for free. Almost all carpoolers use the Express Lanes when they are open. This represents a dynamic form of voluntary congestion pricing, where solo drivers can choose to pay to reduce their travel time, and the payment is generally related to the level of congestion.

The project is described in much greater depth in Golob, *et al.* (1998) and Supernak, *et al.* (1999). An independent evaluation of the project was initiated in 1997, and includes assessments of the impact on congestion, local business activity, land use, emissions, media coverage, and other areas beyond the scope of the current paper. The San Diego Association of Governments maintains a web site with a map of the lanes as well as various evaluation reports (SANDAG, 2000).

DATA DESCRIPTION

We use data collected from a panel survey of travelers who use I-15 in the vicinity of the Express Lanes during the morning period when the Express Lanes are open, together with time-specific traffic flow data obtained from loop detectors embedded in the roadway and time-specific data on FasTrak tolls.

The Panel Survey

The panel survey consists of two samples of approximately equal size: FasTrak subscribers, and other I-15 users. The panel survey was begun in autumn of 1997, during the period of monthly charges with unlimited use of the Express Lanes. The second wave of the panel was conducted in spring 1998, during the first few months of dynamic pricing. For the purposes of this analysis, we focus on the third wave of panel data, collected during the fall of 1998 (October through November). During this time period, dynamic per-trip congestion pricing was well established. The last two (fourth and fifth) waves of the panel were conducted in spring and fall, 1999.

FasTrak subscribers were picked at random from a list maintained by the billing agency, and the remaining respondents were recruited using random digit dialing of residential areas along the respective corridors. In the initial wave of the panel, a partial quota sampling procedure was used to increase the number of carpoolers in non-subscriber parts of the sample. Panel attrition was about 33% per wave for each group, and the sample was refreshed at each wave with a new random sample of FasTrak subscribers and I-15 travelers recruited using the random digit dialing of residential areas along the respective corridors. The partial quota sampling procedure implies that the resulting sample is choice-based, and weights are needed if the sample is being used to represent the population of regular I-15 corridor users. We estimated sampling weights from traffic counts carried out during the survey period. General results from descriptive analyses of the evaluation panel are summarized in Golob, *et al.* (1998) and Golob and Golob (2001).

Survey respondents were queried for detailed information about their most recent inbound trip along I-15 if that trip was made during the hours of operation of the Express Lanes and covered the portion of I-15 corresponding to the facility. By design, trip lengths must be at least eight miles long (the length of the facility). There were 684 I-15 respondents with full information on morning trips during the peak-period that were in the inbound (southbound) direction. (Approximately 6% of the respondents did not give complete answers regarding time and location of the on-ramp to the I-15 for the morning commute, resulting in their removal from the estimation sample.) Table 1 presents a summary of the individual and household demographic data for the three travel modes that we investigate: 1) solo drivers in the main lanes, 2) solo drivers using FasTrak for Express Lanes travel, and 3) carpoolers who also travel on the Express Lanes.

[Table 1 about here]

Per-Trip Dynamic Tolls

Drivers face FasTrak tolls that are a function of arrival time at the Express Lanes. The level of congestion on the Express Lanes determines the toll. Tolls are adjusted to maintain a level of service of at least “C” in the Express Lanes, which means a density of less than 27 vehicles per lane per mile (TRB, 2000). Level of service is monitored using a real-time algorithm based on Express Lanes loop detector data, augmented by video cameras. While FasTrak subscribers are provided with a profile of maximum tolls that vary by time-of-day, actual tolls may be less than the maximum tolls depending upon usage of the facility. In extreme conditions, tolls may exceed the advertised maximum tolls although this is expressly advertised as a rare occurrence (SANDAG, 2000). In practice, the Express Lanes were almost always flowing freely when the current data were collected during autumn of 1998.

Figure 1 shows the average toll by time-of-day for the months of October and November 1998 (excluding Thursday and Friday of Thanksgiving weekend). Figure 2 shows the variation in average tolls by day of week. Average tolls are remarkably similar across the week, with lowest average tolls occurring on Wednesday.

[Figure 1 about here]

[Figure 2 about here]

Based on the estimated arrival time at the Express Lanes (see next section), each survey respondent is assigned a toll price for that specific arrival time and date of travel. For respondents who choose FasTrak, this represents actual price paid. For solo drivers and those who carpool, this represents the price they would have paid had FasTrak been chosen.

Time Savings

For mode choice modeling, we need to determine possible time saving from travel on the Express Lanes, which is a function of the time to travel on the facility and the parallel main lanes. Both are a function of when drivers arrive at the facility. To determine this arrival time, we use information from the panel survey. Respondents were asked which onramp was used for the morning commute and the arrival time at that onramp. We combine these responses with time-of-day speeds along the corridor to determine arrival at the Express Lanes. Then, based upon arrival time, time savings from use of the Express Lanes is estimated using time-of-day speeds on the main lanes parallel to the facility and on the Express Lanes. Those entering I-15 at the Ted Williams Parkway onramp (at the north end of the Express Lanes) may also benefit from a special dedicated entrance to the Express Lanes that avoids a congested main-lanes on-ramp with a ramp-meter traffic signal. We estimated the time saving from using this dedicated on-ramp from floating car data and added the saving to the estimated Express lanes time saving for those who enter at Ted Williams (37 percent of the sample). Time saving is estimated for all respondents regardless of mode choice.

Time-of-day speeds at several locations along I-15 were calculated from data collected by California Department of Transportation loop detectors embedded in the roadway. These point speeds were computed every six minutes of the morning commute for the months of October and November 1998. Speeds at loop detector locations are converted into speeds along the intervening segments (defined as the roadway between two loop detectors) using an algorithm that assumes that the loop detector speed at the beginning of the segment applies to the first half of the segment and point speed at the end applies to the second half of the segment (Van Grol, 1997). Since loop detectors are placed near onramps, the I-15 corridor is effectively broken into segments traveling from onramp to onramp. Speeds along the Express Lanes were measured by driving the lanes, recording start and end times, and then calculating average speed using the time differential and distance traveled. These speeds were measured every fifteen minutes of the morning peak period for five days and were found to be generally 70 miles per hour with little variation across day and time. Consequently, we assume speed on the Express Lanes to be a constant 70 miles per hour.

Time saving from Express Lanes use is estimated using two months (October and November, 1998) of speed data. The results by time of arrival at the Express lanes are summarized in Figure 3. Median time saving peaks at about seven minutes at the same time period (7:30-8:00 AM) that average tolls peak at four dollars (Figure 1). Considerable variation occurs within each half-hour time period as indicated by the divergence between median, 90th percentile, and 10th percentile time savings. Ten percent of the time, peak time savings exceed twelve minutes. To further illustrate this variance in estimated time savings, Figure 4 shows the daily distribution of time savings for the 7:30-8:00 AM time period. Figure 5 shows the additional savings from use of the Ted Williams onramp. Users of the dedicated Express Lanes onramp at Ted Williams Parkway can gain up to five minutes additional time if they choose FasTrak (toll) or carpool modes.

[Figure 3 about here]

[Figure 4 about here]

[Figure 5 about here]

Each respondent is assigned potential time saving from use of the Express Lanes based upon estimate arrival time at the facility and whether the respondent enters at the Ted Williams Parkway onramp. This time savings relative to driving in the free lanes is the same for both the FasTrak and carpool alternatives. Table 2 summarizes time saving by mode choice for the sample of survey respondents. Note that the time savings and variability differ across the groups of users because they choose different departure times. For example, solo drivers in the main lanes tend to avoid the worst peak periods. Also note that the additional time savings at the Ted Williams parkway is critical for reducing collinearity between the time savings and toll variables.

[Table 2 about here]

MODE CHOICE

Model estimation

Each traveler on the I-15 has three alternatives available during peak hours: 1) solo driving on the main lanes, 2) solo driving using FasTrak, and 3) driving with others in a carpool. We model travelers' choices with a conditional logit model where all three alternatives are available to each traveler. The simplifying assumption of a uniform choice set for all travelers is supported by data collected in the same panel survey about day-to-day variations in mode choice. These weekly mode choice data reveal that travelers who carpool the majority of the time still drive alone one or two days of the week (Golob, 2001). Specifically, of those who carpooled on their last morning, 22.5% reported solo driving on the main lanes of I-15 at least once during the previous week, and 10.6% reported solo driving using FasTrak during this same period. Of those who choose to solo drive on the main lanes for their last trip, 16.7% used FasTrak and 7.6% carpooled at least once during the previous week. Finally, of those who choose to use FasTrak for their last trip, 16.9% drove alone on the main lanes and 7.9% carpooled at least once during the previous week. Since our sample predominately contains high-income suburban workers, almost all households have at least one car per driver. This implies that no one is required to carpool due to lack of cars.

We assume that departure time from home is fixed. It is possible that travelers change their departure times in response to changes in tolls and congestion levels, but we do not have sufficient data to jointly model departure time and mode choice. Incorrectly assuming fixed departure times should not bias our willingness to pay estimates since the congestion pricing scheme insures that the toll per minute of time saved is roughly constant over the morning commute period.

Of course a traveler can only legally use FasTrak if they first obtain a transponder. We assume that any travelers who want to use FasTrak have already obtained a transponder since the toll facility had been operating for approximately one year before our survey date. We tested this assumption by fitting a Nested Logit model with the FasTrak alternative on a separate node. We were unable to reject the null hypothesis that our conditional logit model is correctly specified. We similarly tested our specification against another Nested Logit model with the carpool alternative on a separate node. We were also unable to reject our conditional logit model against this specification.

Table 3 summarizes the mode choice estimation results using unweighted maximum likelihood estimation. Since the model is estimated using a choice-based sample, the constant terms are biased and are therefore not reported. Weighted estimation was also carried out using Manski and Lerman's (1977) consistent choice-based sample estimator. This estimator, which is not fully efficient, yielded large standard errors for key parameter estimates. Therefore this paper concentrates on willingness to pay calculations that are consistently estimated using unweighted estimators since they do not depend on the alternative-specific constants.

The generic variables that vary across alternatives are: (1) toll price, (2) median time savings, (3) difference between actual and mean toll, and (4) reduction in variability of time savings from Express Lanes use. The toll variable is zero for the carpool and solo-free (solo driving in the main lanes) alternatives, and we also set it to zero for the small number of respondents who report that they did not pay for their toll charges. Time savings and reduction in variability are the same for the FasTrak and carpool alternatives, and equal to zero for the solo-free alternative. Other variables (such as gender, age, and education) are interacted with the choice-specific constants. Solo-free is defined as the base alternative. Therefore a positive coefficient on a variable in the FasTrak choice implies that FasTrak will more likely be chosen than solo driving when the variable increases (or the condition occurs in the case of dummy variables).

The generic variables are defined to mimic the information that the respondents have when they need to decide whether or not to take the Express Lanes. They know the toll they face since it is posted before the beginning of the lanes. However they do not know the exact congestion they will face on the free lanes. Since most of these morning peak-period travelers are frequent commuters, we assume that they know the distribution of time savings from Express Lanes use at the time of day they travel. This distribution is represented in our model by the median time savings and the reduction in variability due to use of the Express Lanes. The variable measuring the difference between actual and mean toll (where the mean is taken over the distribution of tolls for the time the respondent passes the entrance to the Express Lanes) captures the signalling effect of the congestion pricing scheme. A higher than average toll indicates unusually high demand for the toll facility, which is probably due to unusually high congestion in the free lanes.

Focusing first on FasTrak choice relative to solo driving, the demographic variables are readily interpretable. Holding other attributes constant, households earning more than $100,000 are more likely to choose FasTrak over solo driving. Women, individuals between 35 and 44 years old, individuals with education beyond a bachelor's degree, and homeowners are also more likely to choose FasTrak over solo driving. FasTrak is more likely to be chosen for commute trips and for longer distance trips. The time saving effect was first estimated by separating out the effect for those making commute trips and those making non-commute trips. Since such a large proportion of our sample is making commute trips, the coefficient on time saving for this group is estimated much more precisely. Subsequent testing suggested that a constraint of equality of coefficient between commuters and non-commuters cannot be rejected. The main purposes of these non-commute trips were personal appointments and airport travel as opposed to leisure travel (which was non-existent).

When considering carpool choice as compared to solo driving, the results indicate that carpooling is more likely to be chosen than solo driving as the number of workers per vehicle increases, for longer distance trips, for non-commute trips, and when a carpool bypass onramp is available. Carpool is less likely to be chosen than solo driving by one and two-worker households as compared to households with three or more workers. When other demographic variables are included in the model, carpool choice relative to solo driving is unaffected by gender, age, education, income, and home ownership.

The coefficients of the generic variables in Table 3 are somewhat complicated to interpret due to the interaction term between reduction in variability (measured as the difference between the 90th percentile and median of the time savings distribution) and toll. This interaction term cannot be deleted from the model without significantly reducing the log likelihood and significantly increasing the standard errors of the toll and time savings coefficients. We obtained quantitatively similar results using different definitions of variability such as standard deviation. We also tried interacting the generic variables with the demographic variables, but we found no significant interactions. Time savings and reduction in variability did not vary significantly between commute and non-commute trips, so we constrain them to have the same coefficient. In general, increased time saving is associated with a higher probability of choosing carpool.

Higher tolls are associated with reduced FasTrak use *if* the reduction in variability in time saving is less than 7.21 minutes. For our sample, the median variability in time saving is just over 3 minutes. Variability is below 7.21 minutes for over ninety seven percent of our sample. Therefore, over the relevant range of reduction in variability, higher tolls are associated with reduced use of FasTrak.

We expect higher reduction in variability to be associated with increased FasTrak use. Higher reduction in variability implies that the good being purchased (e.g. time saving) is more attractive. But we find that increased reduction in variability is associated with increased use of FasTrak only *if* the toll is above $1.41. In our sample, the median toll is $1.50 and fifty two percent face a toll that is more than $1.41.

One possible explanation for the reversals of the expected variability effects for part of our sample is that the toll also provides information about upcoming congestion, and the effects of variability are conditional on mean and actual tolls in our specification. Recall that the time savings and variability measures are based on the distributions over one month since respondents cannot directly observe congestion until after they need to choose to use the Express Lanes. However they do observe the toll before they need to decide, and generally higher tolls are associated with increased congestion on the free lanes.

Drivers may therefore rationally choose to use FasTrak when tolls are higher than usual because this also signals that congestion (and therefore time savings and reduction in variability) will be higher than usual. This is empirically supported by the positive coefficient of the variable measuring the difference between actual and mean toll (Table 3). If drivers face a toll that is higher than what they normally face for that time of day, they are more likely to use FasTrak. If drivers face a lower than average toll, then they are less likely to use FasTrak. We tested our maintained assumption that drivers respond symmetrically to deviations from mean toll values and found no evidence to reject this specification.

Willingness to Pay

Willingness to pay (or value of time) is the amount of extra tolls a respondent would need to pay for a one-hour increase in time savings to keep the choice probability constant. Since the usual purpose of this calculation is to evaluate transportation network improvements, we consider a "permanent" shift in the time savings distribution where the "Actual - Mean Toll" variable is zero. For the conditional logit model in Table 3, the value of time for each respondent is computed as:

$$\frac{b\text{\_time saving}}{b\text{\_toll} + (b\text{\_toll x reduction in variability})(\text{reduction in variability for respondent})} \times (60\text{min/hour})$$

Since the value of time from the above formula varies across our sample, we use standard choice-based sampling weights[1] to make the sample represent the population

[1] We use data from traffic counts conducted during the survey period to estimate the population proportion of solo drivers on the main lanes, solo drivers using FasTrak, and carpoolers. Each sample respondent is then assigned a weight equal to this population proportion for their chosen

of regular I-15 morning travelers. Using the point estimates from the model in Table 3, we find that the median value of travel time reduction is $30/hour. The upper quartile of the distribution is $43/hour, and the lower quartile is $23/hour.

Willingness to pay estimates are often reported as a percentage of hourly wage to facilitate comparison across different studies. However, such reporting implicitly assumes a relationship between value of time and income that has not been borne out by recent surveys like Small et. al. (1999) and MVA Consultancy et. al. (1994). The other reason we do not report willingness to pay as a percentage of wage rate in this paper is because we lack information on the respondent's income. While we do have household income for a majority of the respondents, we do not know the respondent's share of that income. Furthermore, we only know household income by category, and a large percentage of those responses (over 33% for FasTrak users) are top-coded at $120,000.

Our results are much higher than the roughly $3.50 to $5.00 per hour (or 15 to 25 percent of hourly wage) obtained by Calfee and Winston (1998). Hourly wage along the I-15 corridor is higher than in the Calfee and Winston sample, but not high enough to account for the difference in value of time estimates (e.g. $30 versus $3.50). One important distinction between our study and Calfee and Winston is that we are using revealed preference data, and Calfee and Winston used data from stated preference experiments. Wardman's (2001) recent meta-analysis of British travel time valuation studies also found that stated preference studies generally yield lower values than revealed preference studies.

Our results are very similar to those obtained by Lam and Small (2001) from studying revealed preferences along the Route 91 toll facility linking Riverside and Orange counties in Southern California. The income of Route 91 users is somewhat lower than

---

mode divided by that mode's proportion in the sample. The weighted sample mode shares will then match the mode shares from the traffic counts.

I-15 users, and Small and Lam estimated the value of time to be between $19 and $24 per hour depending on model specification. The main difference between the Route 91 and I-15 experiments is that the Route 91 facility uses time of day pricing instead of the congestion pricing used in the I-15 experiment.

Calfee and Winston's estimates were on the very low end of the range of previous value of time estimates. Small (1992) summarizes previous results and concludes that 50 percent of gross wage rate is a reasonable estimate. Previous studies also have found that the value of time saved under congested conditions is roughly 30% higher than in uncongested conditions (see Cambridge Systematics,1977, Train, 1976, Bradley et. al., 1986, and Bates et. al., 1987). While we lack hourly wage for most of our sample, we can crudely estimate it from household income when only one household member works, assuming that worker is employed full-time (e.g. yearly household income is divided by 2,000 hours). Roughly 30 percent of our sample are single-worker households. In this case, our median value of time estimate is 88 percent of imputed hourly wage.

Drivers who pay to use FasTrak are typically avoiding heavy traffic congestion in the regular lanes of I-15, so it is not surprising that some people would pay a premium to avoid such unpleasant driving conditions. In addition, many FasTrak users and carpoolers perceive safety advantages in traveling in the Express Lanes (Golob, 2001), and the value of time includes this implicit gain in safety. Finally, avoiding traffic congestion by using FasTrak might be considered by some as a privilege granted by sufficient wealth, so that they are willing to pay to be part of an exclusive club. All of these factors combine to help explain the relatively high values of saved travel time in the specific FasTrak situation.

This study was unable to identify drivers' responses to changes in variability of the time savings distribution. We have done some preliminary work with the fifth wave of the panel survey which suggests that part of the problem is crude measurement of the time savings from using the Ted Williams Parkway. The fifth wave survey included much more extensive data collection at the Ted Williams Parkway onramp, and this improved the accuracy of the time savings measures relative to the data used in this study. When the model in Table 3 is calibrated to the fifth wave data we appear to obtain better results for the reduction in variability variable, but the values of travel time reduction are quantitatively similar to those presented in this paper.

CONCLUSIONS

Using revealed preference data, we estimate models of the choice of driving solo on a congested road and carpooling or paying to travel solo on less-congested Express Lanes. Our results indicate that those more likely to use FasTrak relative to solo driving include: (1) commuters as opposed to those traveling for personal appointments and pleasure, (2) individuals from higher income households (income of $100,000 or more), (3) women, (4) individuals between the ages of 35 and 45, (5) higher educated individuals, and (6) homeowners.

Furthermore, choice of FasTrak relative to solo driving is positively related to time savings and negatively related to price. Due to the design of the congestion pricing scheme on the I-15, tolls also signal upcoming congestion. Our results show that drivers are much less sensitive to the toll level when the toll is unusually high since this is usually associated with increased congestion ahead.

Using our mode choice model, we estimate willingness to pay to reduce travel time. We find that I-15 users have a median willingness to pay of $30 to reduce travel time by one hour. Our results based on revealed preference data are significantly higher than recent results based on stated preference data. Travelers in our corridor are relatively wealthy and, by design, have a relatively long commute (minimum commute is 8 miles).

ACKNOWLEDGEMENTS

We would like to acknowledge many helpful comments from Kenneth Small, an anonymous referee, and especially an Associate Editor. Profound thanks also go to Janusz Supernak of the Department of Civil and Environmental Engineering at San Diego State University, Jackie Golob of Jacqueline Golob Associates, and Kim Kawada of San Diego Association of Governments (SANDAG). Kathy Happersett of the Social Science Research Laboratory of San Diego State University led the team that collected the panel survey data. Some of the work presented in this paper was funded by the University of California Transportation Center. The views expressed here and any errors are the sole responsibility of the authors. The authors who are also solely responsible for any errors.

REFERENCES

Bates, J., Dix, M. and May, A., 1987. Travel time variability and its effect on time of day choice for the journey to work. Proceedings of the PTRC Summer Annual Meeting, Seminar C: Transportation Planning Methods, pp, 293-311. PTRC Education and Research Services, London.

Bradley, M., Marks, P. and Wardman, M., 1986. A summary of four studies into the value of travel time savings, Proceedings of the PTRC Summer Annual meeting, Seminar M: Transportation Planning Methods, pp. 271-285. PTRC Education and Research Services, London.

Calfee, J. and Winston, C., 1998. The value of automobile travel time: implications for congestion policy. *Journal of Public Economics,* 69: 83-102.

Cambridge Systematics, 1977. The Development of a Disaggregate Behavioral Work Mode Choice Model, Prepared for California Department of Transportation and Southern California Association of Governments, Cambridge Systematics, Inc., Cambridge, MA.

Golob, J.M. and Golob, T.F., 2001. Studying road pricing policy with panel data analysis: The San Diego I-15 HOT Lanes. In Hensher, D.A., ed., Travel Behaviour Research: The leading Edge, pp. 869-883. Pergamon, Oxford.

Golob, J. M., Supernak J., Golob, T.F. and Kawada, K. (1998). An evaluation of a high occupancy toll (HOT) lane demonstration project in San Diego, Proceedings of the European Transport Conference: Seminar C: Policy, Planning and Sustainability, Vol. 2, pp. 255-269. PTRC Education and Research Services, London.

Golob, T.F., 2001. Joint models of attitudes and behavior in the evaluation of the San Diego I-15 Congestion Pricing Project. Transportation Research – Part A 35, 495-514.

Gonzalez, R. M., 1997. The value of time: a theoretical review. Transport Reviews 17, 245-266.

Lam, T.C. and Small, K.A., 2001. The value of time and reliability: measurement from a value pricing experiment. Transportation Research – Part E 37, 213-251.

Manski, C.F. and Lerman, S., 1977. The estimation of choice probabilities from choice-based samples. Econometrica 45, 1977-1988.

MVA Consultancy, ITS Leeds University, TSU Oxford University, 1994. Time savings: Research into the value of time. In Layard, R. and Glaister, S., eds. Cost-Benefit Analysis, pp. 235-271. Cambridge University Press, 1994.

SANDAG, 2000. I-15 FasTrak Online. San Diego Associations of Governments http://www.sandag.cog.ca.us/data_services/fastrak/

Small, K., 1992. *Urban Transportation Economics*. Harwood Academic Publishers, New York.

Small, K. A., Noland, R., Chu, X. and Lewis, D., 1999. Valuation of Travel-Time Savings and Predictability in Congested Conditions for Highway User-Cost Estimation. National Cooperative Highway Research Program Report 431, National Academy Press, Washington, DC.

Supernak, J., Golob, J.M., Kawada, K. and Golob, T.F., 1999. San Diego's I-15 Congestion Pricing Project: Preliminary findings. Presented at Annual Meeting of Transportation Research Board, January, Washington, DC.

Train, K., 1976. Work Trip Mode Split Models: An Empirical Exploration of Estimate Sensitivity to Model and Data Specification. Working Paper No. 7602, Urban Travel Demand Forecasting Project, Institute of Transportation Studies, University of California, Berkeley.

TRB, 2000. *Highway Capacity Manual*. Transportation Research Board, National Academy Press, Washington, DC.

Van Grol, H.J.M., 1997. Evaluating the use of induction loops for travel time estimation. Presented at 8th IFAC/IFIP/IFORS Symposium on Transportation Systems, Chania, Greece, June 16-18, 1997.

Wardman, M., 1998. The value of travel time: A review of British evidence. *Journal of Transportation Economics and Policy* 32, 285-316.

Wardman, M., 2001. A review of British evidence on time and service quality valuations. *Transportation Research – Part E* 37, 91-106.

Table 1. Demographic Characteristics by Mode Choice
(In percentages except last column)

	Solo Drivers (N = 292)	FasTrak Users (N=279)	Carpoolers (N=112)	Total Number
Age of respondent:				
18-34	20.6	8.6	16.2	102
35-44	34.0	46.8	38.7	273
45-54	33.7	33. 5	29.7	225
54-64	10.3	10.8	10.8	72
65+	1.4	0.4	4.5	10
Female respondent:	34.9	47.3	44.6	284
Education of respondent				
High school	12.3	4.0	10.7	59
Some college	29.1	21.7	30.4	180
Bachelor's degree	33.9	36.1	37.5	242
Graduate work or degree	24.7	38.3	21.4	203
Reason for travel along I-15				
Work or work related	94.2	98.6	80.4	640
School	1.4	0.7	2.7	9
Non-work appointments	1.7	0.4	6.3	13
Other social reasons	2.7	0.4	9.8	20
Number of workers in household[1]				
One worker	37.7	31.5	19.62	220
Two workers	51.0	58.1	53.6	371
Three or more workers	10.3	10.0	19.6	80
Vehicles per worker[1]				
< 1 vehicle per worker	1.7	1.1	6.7	16
1 vehicle per worker	49.8	50.7	54.8	348
> 1 vehicle per worker	45.7	45.0	36.5	300
Household Income				
$20,000 or less	1.5	0	2.9	8
$20,000 to $40,000	7.1	2.5	7.7	36
$40,000 to $80,000	44.9	25.8	45.2	254
$80,000 to $120,000	31.5	38.1	37.5	240
$120,000 or more	15.0	33.6	6.7	145
Household owns home	78.42	92.1	85.7	582

Table 2. Time Savings Associated with Express Lanes Use (In minutes)

	Median Time Savings	Quartile Range of Time Savings (25^{th}% to 75^{th}%)	Median Variability (90^{th}% - 50^{th}%) Time Savings
Solo in main lanes	4.49	1.63 to 7.14	3.06
Solo using FasTrak	5.98	3.14 to 10.07	3.59
Carpool users	5.87	3.08 to 10.01	3.33

Table 3. Logit Choice Model

(N = 684 I-15 morning travelers interviewed in autumn of 1998)

Independent Variable	Coefficient	Std. Error	z-statistic
Choice of FasTrak Relative to Solo Driving in Main Lanes			
Household income beyond $100,000	0.542	0.130	4.165
Household income less than $40,000	-0.712	0.495	-1.438
Gender female	0.627	0.178	3.521
Age between 35 and 45	0.516	0.175	2.940
Education beyond bachelor's degree	0.708	0.190	3.722
Homeowner	0.799	0.285	2.801
Distance from home to destination (miles)	0.022	0.010	2.211
Commute trip (includes trips to work or school)	1.701	0.789	2.157
Choice of Carpool Relative to Solo Driving in Main Lanes			
Number of workers per vehicle in household	0.893	0.374	2.389
Distance from home to destination (miles)	0.119	0.057	2.097
Squared distance from home to destination	-0.001	0.001	-1.444
Single worker household	-1.090	0.356	-3.058
Two worker household	-0.657	0.291	-2.262
Commute trip (include trips to work or school)	-1.710	0.438	-3.908
Enter I-15 using a carpool bypass onramp	0.504	0.278	1.814
Generic Variables			
Median time savings from Express Lanes (min.)	0.216	0.044	4.916
FasTrak Toll ($/trip)	-0.764	0.219	-3.495
Reduction in Variability of time savings from use of Express Lanes measured as the difference between 90th percentile and median time savings	-0.149	0.072	-2.071
Reduction in Variability of time savings interacted with toll	0.106	0.035	3.066
Actual - Mean Toll	0.636	0.248	2.567

Goodness of fit measures

Initial – log likelihood (all parameters equal zero)	-694.869
Model – log likelihood	-606.594

Note: all variables are dummy (0-1) variables unless otherwise noted

Figure captions

Figure 1. FasTrak Tolls for October and November, 1998

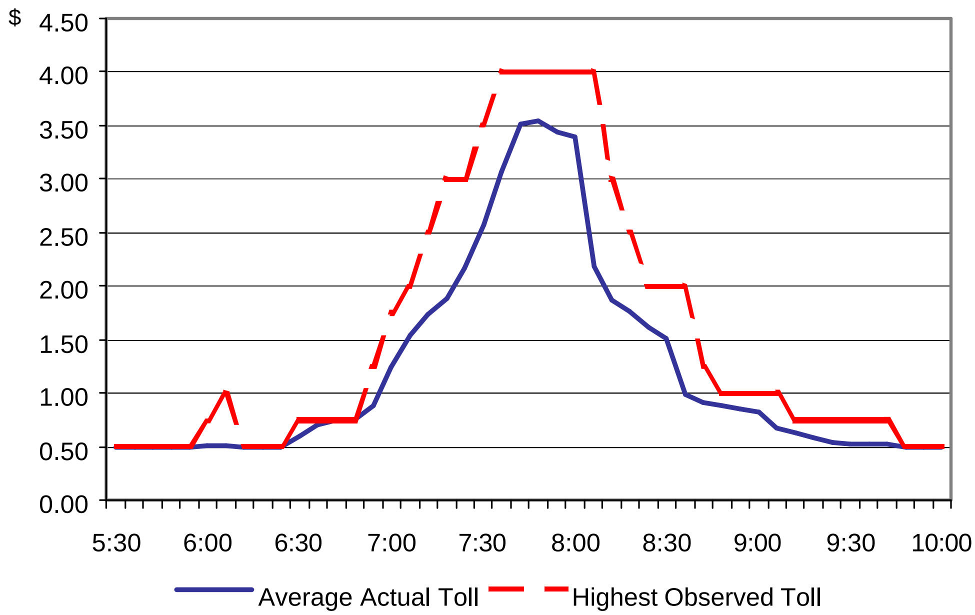
Figure 2. FasTrak Tolls by Day-of-Week for October and November, 1998

Figure 3. Time Savings Associated with Express Lanes Use (October – November, 1998)

Figure 4. Day-to-Day Variation in Average Time Savings for Express Lanes for Lane Arrivals from 7:31 to 8:00 AM (October – November, 1998)

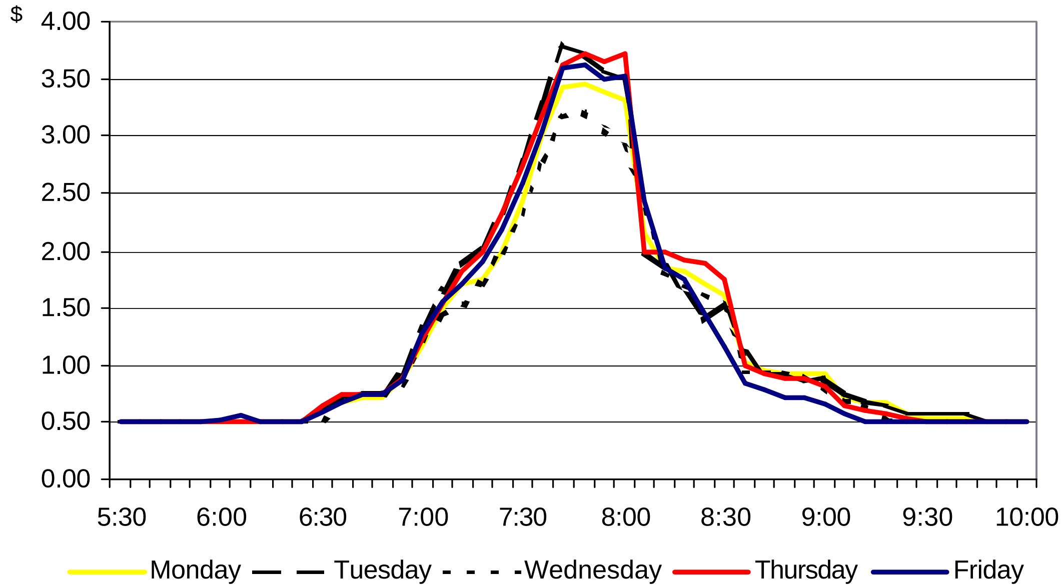
Figure 5. Time Savings Associated with Use of Ted Williams Bypass On-ramp (October – November, 1998)

Figure 1



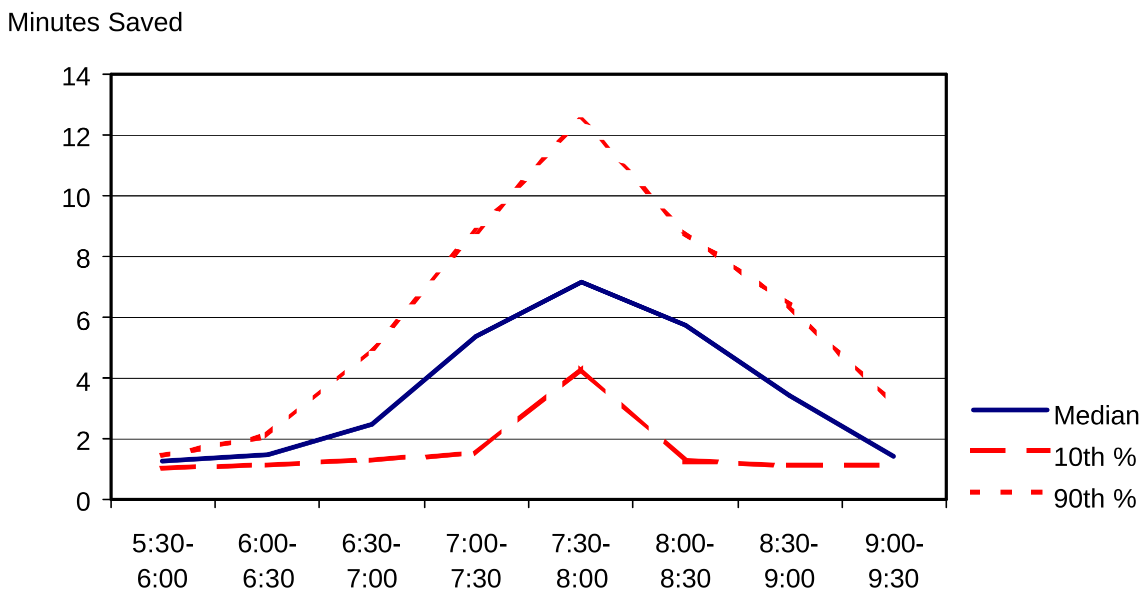
$
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
5:30
6:00
6:30
7:00
7:30
8:00
8:30
9:00
9:30
10:00
Average Actual Toll
Highest Observed Toll

Figure 2



$
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
5:30
6:00
6:30
7:00
7:30
8:00
8:30
9:00
9:30
10:00
Monday
Tuesday
Wednesday
Thursday
Friday

Figure 3



Minutes Saved
14
12
10
8
6
4
2
0
5:30-6:00
6:00-6:30
6:30-7:00
7:00-7:30
7:30-8:00
8:00-8:30
8:30-9:00
9:00-9:30
Median
10th %
90th %

Figure 4

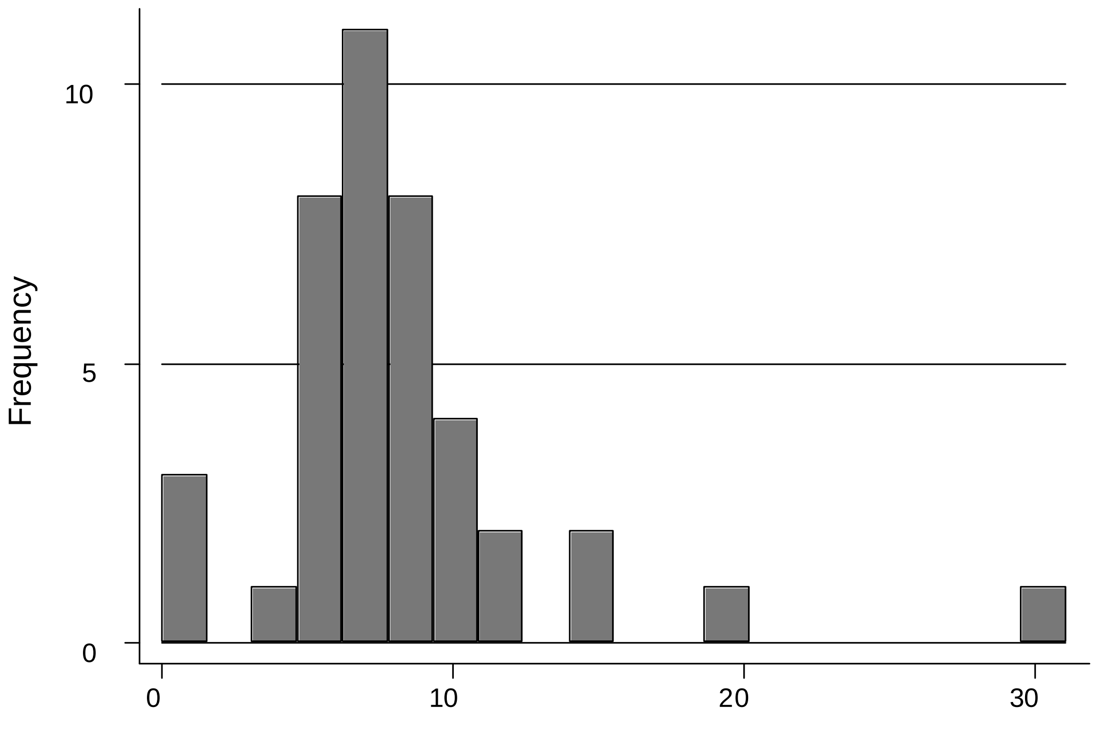
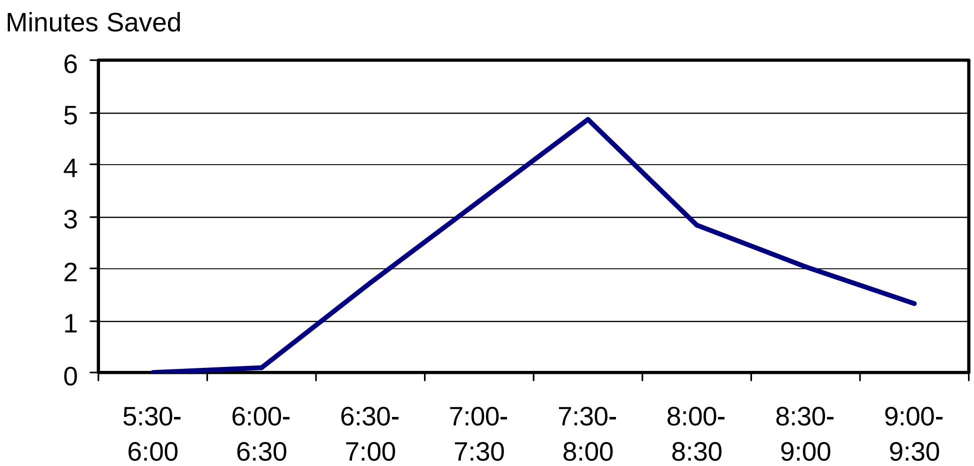


Figure 5


Minutes Saved
6
5
4
3
2
1
0
5:30-6:00
6:00-6:30
6:30-7:00
7:00-7:30
7:30-8:00
8:00-8:30
8:30-9:00
9:00-9:30