Title

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by

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ABSTRACT

Understanding public attitudes concerning the acceptability, fairness, and effectiveness of congestion pricing systems is crucial to the planning and evaluation of such systems. Joint models of attitude and behavior are developed to explain how mode choice and opinions and perceptions regarding the San Diego I-15 Congestion Pricing Project differ simultaneously across the population. Results show that some demographic and socioeconomic explanations of opinions and perceptions are attributable to mode choices, but other explanations are independent of mode-choice behavior. Linking models of attitude to those of travel demand allows attitudes about future projects to be forecast together with demand.

OBJECTIVES AND SCOPE

Evaluators of transportation projects need accurate information about travel demand: For example, who is taking advantage of any new services, and who is unable or unwilling to use them? What are they paying to use these services? How much time are they saving? What adjustments are people making in their activity behavior in response to the changes caused by the project? But it is also important to have accurate information on opinions and perceptions. Knowing what people think about the usefulness, fairness, and success of new transport initiatives is vital information for planners and project evaluators. The problem is that attitudes and behavior are inter-linked. The attitudes of an individual faced with a new transport option will depend in part on whether the individual *can* take advantage of the new option, whether he or she actually *chooses to* take advantage, and the perceived benefits of the option, to the individual and to the community.

Transport planners typically use discrete choice models to understand factors affecting demand, but models of attitudes have not received similar attention. The development of models capturing the complex relationships between attitudes and choice behaviour should to be included in evaluation processes. In this paper we attempt to demonstrate how a joint model of attitudes and behaviour can be used to provide information for project evaluation.

The application involves the evaluation of responses to the Congestion Pricing Project in San Diego, California. This project allows solo drivers to pay to use a separated high-occupancy vehicle (HOV) lane facility, called the "Express Lanes," on Interstate 15 (I-15). An aim of the project is to reduce congestion on I-15 by taking advantage of underutilized capacity of the HOV lanes. Exclusive freeway lanes which are free to carpoolers but require tolls by solo drivers are often called HOT (HOV-Toll) lanes. Solo drivers wishing to pay to use the I-15 Express Lanes subscribe to a program called FasTrak, which allows them to pay to use the Express Lanes on any given trip during their hours of operation; carpoolers continue to use the lanes for free. Tolls vary dynamically to ration demand by solo drivers in order to maintain an acceptable level of service for carpoolers in the Express Lanes.

Our data are from an attitude panel survey. The panel sample is comprised of a random sample of subscribers to the program and a random sample of other users of the I-15 freeway in the vicinity of the Express Lanes, and a control sample of users of another freeway in the San Diego area.

The social feasibility of road pricing on a broader scale has been investigated by several authors (e.g., Giuliano, 1992, 1994; Jones, 1994, 1998; Seale, 1993; Sheldon, Scott and Jones, 1993; Small, 1992; Verhoef, Nijkamp and Rietveld, 1997). Here, we focus on attitudes towards one form of voluntary road pricing, and one should not expect these results to hold for area-wide implementations of mandatory charges for road use. However, results from the present research could lend insight into how certain opinions about road pricing vary across socioeconomic and demographic groups, and how differences in opinions are explained by differences in travel behavior.

We begin by presenting a model that explains demand for subscription to the FasTrak program. This is followed by joint models of attitude and behavior that explore the relationships between demand for FasTrak use and demand for carpooling and opinions and perceptions regarding the HOT lanes concept and the FasTrak program. In all cases, we specify the demand and attitudes as functions of each other and of exogenous variables such as income, household composition, age and gender. The attitudinal variables are: (1) whether solo drivers should be allowed to pay to use the Express Lanes, (2) whether the program is fair to carpoolers, (3) whether the program is effective in reducing overall congestion on I-15, and (4) the perceived safety advantage of travelling in the Express Lanes. This latter variable is explored in the hope of shedding light on that portion of demand for HOT lane use that is unexplained by time savings and observed socioeconomic and demographic variables.

Separate investigations are underway regarding FasTrak users' savings and willingness to pay. These investigations, which are still underway at the time of this writing, require integration of travel time information from traffic detectors and floating car measurements together with data from the panel survey. The overall evaluation of the San Diego Congestion Pricing Experiment also includes assessments of effects on congestion relief, land use, business impacts, media coverage, and other aspects which are beyond the scope of the research reported here; reports are available from on the FasTrak web site maintained by the San Diego Association of Governments (http://www.sandag.cog.ca.us/data_services/fastrak/).

THE FASTRAK PROJECT

The I-15 Congestion Pricing Project is a three-year demonstration which allows single-occupant vehicles to pay to use an eight-mile (13 km) stretch of two reversible HOV lanes. These HOV lanes, called the I-15 Express Lanes, are located in the northern part of the San Diego Metropolitan Area, and are separated by barriers from the main lanes. Access to the lanes is available only at the two endpoints of the facility. The lanes are operated in the southbound direction (inbound commute) from sometime before 5:30AM to after 9:00AM and in the northbound direction (outbound commute) and from before 3:00PM until after 6:30PM. The location of the Express Lanes is shown on the map of Figure 1.

The project began in December 1996 and is generating revenue for transit service improvements in the I-15 corridor. The project is described in depth J. Golob, *et al.* (1998) and Supernak, *et al.* (1999). During Phase I, known as the ExpressPass program, payment for unlimited SOV use of the HOV lanes was through purchase of passes, which were billed on a monthly basis. Phase II, known as FasTrak™, began at the end of March 1998 and will continue until December 1999. FasTrak subscribers are issued windshield-mounted transponders used for automatic vehicle identification, and there is no limit on the number of subscribers. Subscribers pay a per-trip fee, which is posted on changeable message signs upstream from the entrance to the lanes. The per-trip fee can be varied every six minutes in order to maintain free-flowing traffic conditions in the HOV lanes, representing one form of congestion pricing.

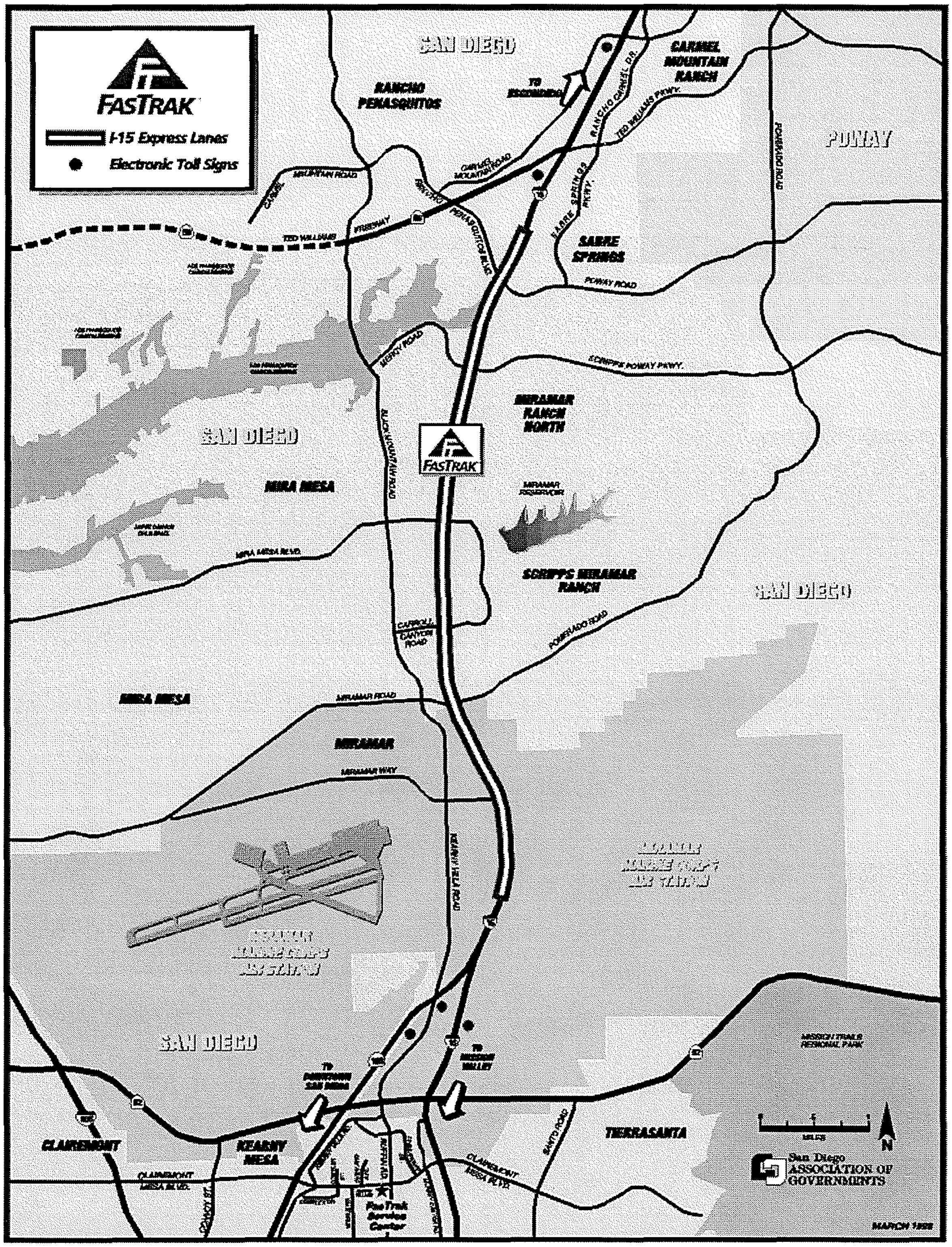

Figure 1. Location of the I-15 Express lanes north of the center of San Diego (source: www.sandag.cog.us/data_services/fastrak)

THE PANEL SURVEY

An independent evaluation of the Congestion Pricing Project was initiated after the project had begun in 1997. One data collection element of the evaluation is a panel survey conducted at six-month intervals. The first wave of the panel survey was in October 1997, the second wave in May-June 1998, the third wave in October-November, 1998, and the last two waves will be at corresponding times in May-June and October-November 1999. This survey is patterned in part after a panel survey used in evaluating the original installation of the same HOV lanes (Supernak, 1991; Golob, Kitamura and Supernak, 1997), and is designed to describe and explain attitudinal and behavioural responses to the I-15 Congestion Pricing Project.

The panel sample of about 1,500 individuals is broken down into: approximately one-third ExpressPass subscribers, former subscribers, and persons on the waiting list; one-third other I-15 commuters; and one-third commuters in another freeway corridor in the San Diego Area, used as a control group. 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 subsequent waves of the panel, refreshment was used to maintain the sample sizes in all parts of the sample. General results from analyses of the first wave of the evaluation panel are summarized in J. Golob, *et al.* (1998).

The use of panel surveys as project evaluation tools is discussed by, among others, Kitamura (1990), Richardson, *et al.* (1995), Lee-Gosselin (1997), and Paaswell (1997). The main limitation of the panel survey being used in evaluation of the I-15 Congestion Pricing Project is that it was not possible to implement a wave of the panel before the HOT lanes went into operation, because the project evaluation team and the methodology was not selected until after the Project had begun. The research reported here only uses the panel as a source of cross-sectional data for autumn 1998. Dynamic analyses await the further collection of data in spring and autumn of 1999.

DATA DESCRIPTION

There were 796 I-15 commuters with full information about morning peak-period inbound (south-bound on I-15) trips for work, work-related, or school purposes in the third wave of the panel in fall 1998. Each of these commuters made at least inbound one trip in the vicinity of the Express Lanes during the opening time of the Lanes during the week preceding the interview. (Those who were away during the week preceding the interview, or for some other reason did not commute that week, were asked to report on trips for the previous week.) These respondents were asked how many trips they made by each mode during that week. Using these data we can investigate how attitudes are related to patterns in weekly mode usage for the morning inbound trip.

Demand for Subscription to the FasTrak Program

We assume that the choice of whether or not to become FasTrak customers is available to all of the 796 commuters who typically travel in the vicinity of the I-15 Express Lanes during the morning peak hours. A logit model of the choice of subscription to the FasTrak program was estimated for these 796 commuters, who divided into 457 (57.4%) FasTrak customers and 339 (42.6%) non-customers. The results are listed in Table 1. The survey is choice-based, so the constant (not shown) is biased. No other socioeconomic or demographic variables available in the survey adds significant explanatory power to this choice model. The two commute distance variables (distance and distance squared) should be considered together as a polynomial function.

FasTrak customers are less likely to be either less than 35 years of age or greater than 64 years of age and they are more likely to be females in this middle age group. They are more likely to be higher educated, a variable which can be viewed as a proxy for professional occupations. They are more likely to come from households with annual household incomes in excess of $80,000, and less likely to come from households with annual incomes less than $60,000. They are also more likely to come from households with either one or two household members working outside the home, as opposed to households with more than two workers or no workers.

Table 1. Logit model of choice of subscription to the FasTrak Program (N = 796 commuters interviewed in autumn of 1998)

Independent Variable	Coefficient	*z*-statistic	Probability
Age less than 35 years	-0.625	-2.80	0.0051
Age greater than 64 years	-1.623	-2.10	0.0358
Gender female and age 35 - 64	0.699	3.56	0.0004
Education beyond bachelors degree	0.561	3.05	0.0023
Household income less than $60,000	-0.727	-3.17	0.0015
Household income ≥ $80,000	0.771	4.11	0.0000
One-worker household	1.579	4.37	0.0000
Two-worker household	0.683	2.79	0.0052
One-vehicle household	-1.534	-3.64	0.0003
Household workers per vehicle	0.934	2.32	0.0202
Commute distance	-0.055	-1.53	0.1280
Commute distance squared (/1000)	1.209	2.14	0.0326
Access to I-15: Ted Williams Parkway	0.892	4.53	0.0000
Goodness of fit measures			
Initial –2 log likelihood		1085.9	
Model –2 log likelihood		926.2	
Model likelihood ratio chi-square		159.7	
Model chi-square degrees of freedom		13	
Probability		0.0000	

Subscription to FasTrak is also predicted by two spatial location variables in addition to the socioeconomic and demographic variables. Commute distance exhibits a nonlinear effect. The parabolic distance function obtains a minimum at approximately 23 miles; as a function of distance, FasTrak subscription is lowest for persons who commute 23 miles to their normal place of work or school, *ceteris paribus*. As we will see in the joint models of FasTrak and carpool demand, this is due to a corresponding peaking of carpooling at approximately this distance. The second spatial variable in the model of FasTrak subscription choice, access to I-15 via Ted Williams Parkway, is a household location factor that is unique to the I-15 Express lanes and is highly significant even in the presence of twelve other explanatory variables. At Ted Williams Parkway, just at the north end of the I-15 Express Lanes, there is access directly to the Express Lanes. Users of the Express Lanes entering at Ted Williams Parkway experience added time savings *vis-à-vis* travel in the regular lanes of I-15 by avoiding the queue at the ramps, which have ramp-metering signals. These queuing times can reach eight or nine minutes at peak periods.

Mode Demand

Each of the 976 respondents in the data used here reported making at least one weekday morning peak-period commuting trip southbound on I-15 in the vicinity of the Express lanes in a week preceding the fall 1998 panel survey interview. These respondents reported trip rates for that week for all modes, and these modes were collapsed into three: (1) solo driving using FasTrak to pay to use the I-15 Express lanes, (2) carpooling, allowing free use of the Express Lanes, and (3) toll-free solo driving in the regular lanes of I-15. The first two of these three demand variables are endogenous variables in our attitude-behavior models presented below. The third variable, demand for non-FasTrak (toll-free) solo driving, is the base in the attitude-behavior models.

Approval: Should Solo Drivers be Allowed to Pay to Use the Express Lanes?

Three opinions regarding the FasTrak program are studied here. The first of these is whether solo drivers *should* be allowed to pay to use the Express Lanes. Respondents were asked how much they agreed or disagreed with the statement "single drivers should be allowed to use the I-15 carpool lanes for a fee." Responses were collected on a four-point scale: (1) strongly agree, (2) somewhat agree, (3) somewhat disagree, and (4) strongly disagree. A cross-tabulation of this question by a four-way segmentation is shown in Figure 2. The four segments are based on the mode of each respondent's last trip: (1) FasTrak customers who paid to use the Express Lanes as solo drivers, (2) FasTrak customers who did not pay to use the Express Lanes, (3) other solo drivers who used the regular lanes and are not FasTrak customers, and (4) carpoolers who are not FasTrak customers. (A segmentation based on most commonly used mode over the past week yielded almost identical results.)

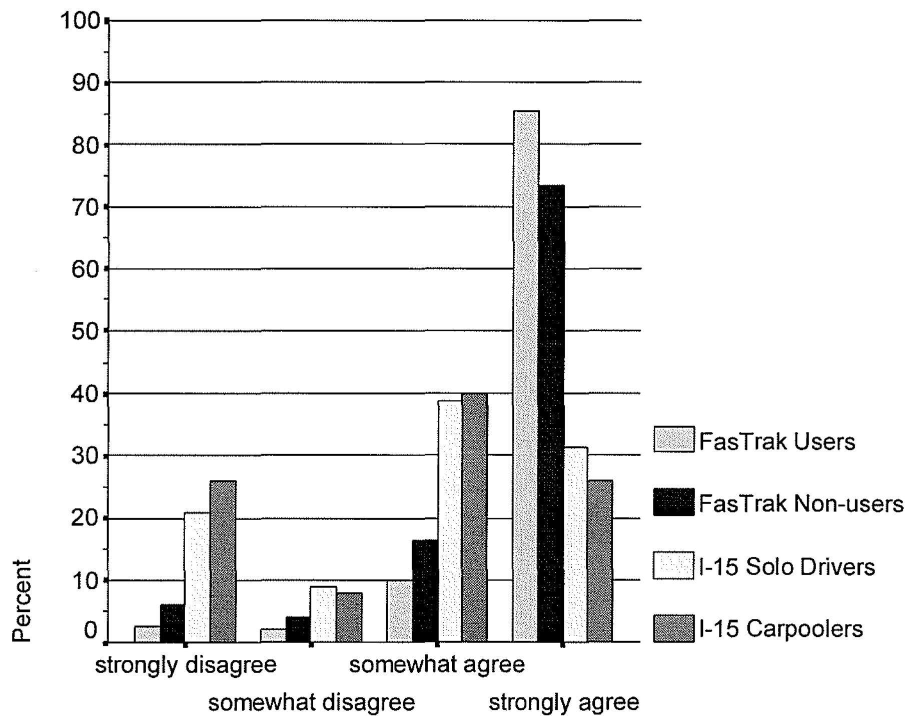

Figure 2. Agreement as to whether solo drivers should be allowed to use the I-15 carpool lanes for a fee

As expected, FasTrak customers are far more likely to hold a stronger opinion that single drivers should be able to use the I-15 Express Lanes for a fee. The chi-square for the contingency table represented by Figure 2 is 185.7 with 9 degrees of freedom ($p = 0.000$). Focusing only on the last two segments, there is no statistical difference in the attitudes of non-FasTrak solo drivers and carpoolers (chi-square = 0.70 with 3 degrees of freedom ($p = 0.873$). On the other hand, there is a significant difference in the attitudes of FasTrak users and non-users ($p = .001$ for a chi-square = 19.7 with 3 degrees of freedom). The relationship between approval and modal demand is investigated in the first attitude-behavior model presented in the Results Section.

Perceived Fairness of FasTrak to Carpoolers

The second variable is opinion concerning the fairness of the FasTrak program to carpoolers. Respondents were also asked whether they believed FasTrak was fair or unfair to travelers in the I-15 carpool lanes". Responses were collected on a dichotomous "fair" versus "unfair" scale. It is instructive to determine how explanations of this variable differ from explanations of the first attitudinal variable. The cross-tabulation of this question is graphed in Figure 3. As in the case of approval of HOT lanes, the opinions among FasTrak customers, both users and non-users on their last trips, are significantly different from those of other I-15 users (chi-square = 65.9 with 2 degrees of freedom, p = 0.000), and the opinions of non-FasTrak solo drivers and carpoolers are virtually identical. The purpose of the second attitude-behavior model presented below is to explore the causal relationships involving this attitude.

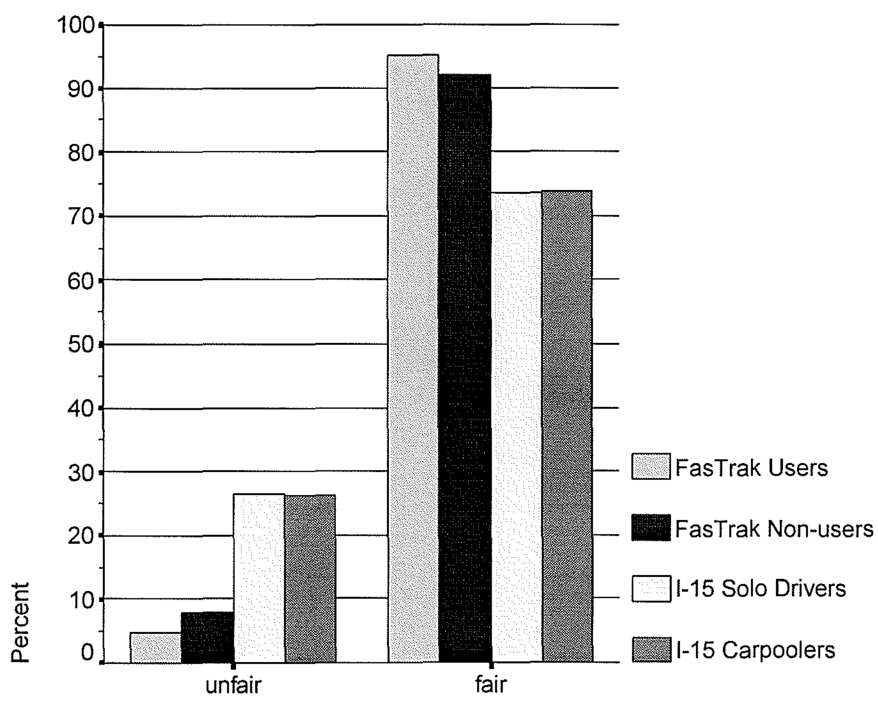

Figure 3. Whether FasTrak is fair or unfair to travelers in the I-15 carpool lanes

Perceived Effectiveness of FasTrak in Reducing Overall Congestion on I-15

The third and final variable is opinion concerning the overall effectiveness of the program. Respondents were asked whether they agreed or disagreed with the statement "FasTrak helps reduce traffic congestion overall on I-15." Responses were collected on a four-point scale. Once again, as shown in Figure 4, the perceptions of FasTrak customers are significantly different from those of non-customers; chi-square = 137.1 with 9 degrees of freedom (p = 0.000). Differences between solo drivers and carpoolers who are not FasTrak customers are not significant at the p = .05 level, but differences between FasTrak users and non-users are marginally significant. The third attitude-behavior model is designed to further explore these relationships and to pinpoint demographic differences in opinions of effectiveness.

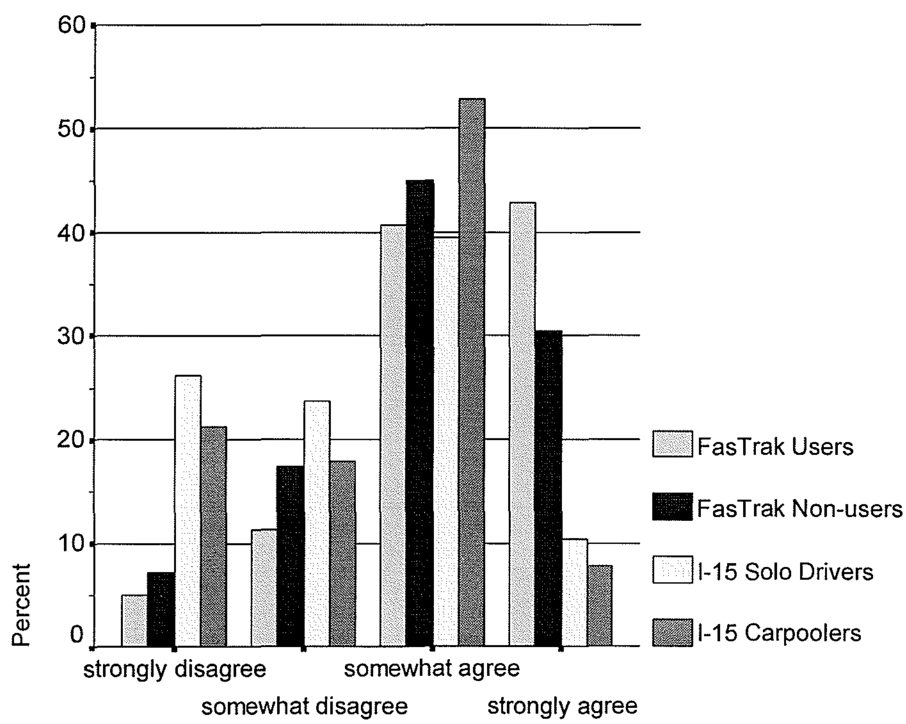

Figure 4. Agreement as to whether FasTrak helps reduce traffic congestion overall on I-15

METHODOLOGY

The objective of our attitude-behavior models is to interrelate demand for FasTrak and carpooling, as measured by these weekly rates, to opinions and perceptions regarding HOT lanes and the FasTrak program in particular. In so doing, we will also estimate demand function in terms of commuter socioeconomic and demographic variables. It is well established that opinions and perceptions can be conditioned by travel choices, but attitudes can also affect choices (e.g., Golob, Horowitz and Wachs, 1979). The task is to identify the strengths of the causal relationships in both directions and select the model or models which best capture the causal relationships among the endogenous variables.

We present four separate sets of models to determine how each of the three opinions and perceptions described above is related to mode demand and how each is a function of demographic and socioeconomic characteristics of I-15 commuters. Every one of the models has three latent endogenous variables: (1) FasTrak demand, (2) carpool demand, and (3) the specific attitudinal variable under study. Demand for (toll-free regular lanes) solo driving is not separately identifiable and is essentially the base against which the other two demand variables are measured, because for the vast majority of the sample of commuters, the sum of the three demands (FasTrak plus carpool plus solo driving) is a constant (five morning peak period trips per week). Treating all variables as ordinal allows us to avoid biases in estimation attributed to non-normally distributed variables, as discussed below. Each model also has fourteen exogenous variables, similar to those listed in Table 1.

Each model can be defined in terms of a system of simultaneous equations called a structural equations model:

$$y^* = B y^* + \Gamma x + \zeta \qquad (1)$$

where y^* is (3 by 1) column vector of three latent endogenous variables, x is a (14 by 1) vector of exogenous variables, and ζ is a (3 by 1) vector of errors in equations. The variance-covariance matrix of these errors is defined as Ψ. The structural parameters to be estimated in each model are the elements of the B, Γ and Ψ matrices. B in Equation 1 is a (3 by 3) matrix of direct effects between pairs of endogenous variables, Γ is a (3 by 14) matrix of regression effects of the fourteen exogenous variables on the three endogenous variables, and Ψ is a (3 by 3) symmetric matrix of error-term variances and covariances.

The total effects of the exogenous variables on the endogenous variables (the reduced-form equations) are given by solving Equation system 1 in terms of x alone, assuming that matrix (I - B) is non singular:

$$y^* = (\mathrm{I} - \mathrm{B})^{-1}\,\Gamma\, x \qquad (2)$$

The first two latent endogenous variables are normal probabilities of weekly demand for FasTrak and carpooling, respectively. These models assume that we observe a specific number of weekly trips $y = k$ (where $0 \le k \le 5$) if and only if the unobserved latent variable lies within a specific range defined by two thresholds: $\alpha_k < y^* \le \alpha_{k+1}$ where $\alpha_0 < \alpha_1 \ldots < \alpha_6$, and $\alpha_0 = -\infty$ and $\alpha_6 = \infty$. We use probit models to define the probability of observing category j for observed variable y, conditional on the vector of exogenous variables (x):

$$P(y = k \mid x) = P(\alpha_k < y^* \le \alpha_{k+1}) = \Phi(\alpha_{k+1} - \omega' x) - \Phi(\alpha_k - \omega' x) \qquad (3)$$

Here Φ denotes the standard cumulative normal distribution function and ω is a vector of reduced-form regression coefficients defining the conditional mean. The α and ω parameters are estimated using maximum likelihood (Maddala, 1983). The third variable in each model is a latent variable representing a similar ordered-probit model of one of the attitudinal variables described above in the Data Description Section.

The structural parameters are estimated using the arbitrary distribution function, weighted least squares (ADF-WLS) method. This method, which has become standard for structural equation models with ordinal-scale endogenous variables, is described in Golob (1998). The method produces unbiased parameter estimates which have asymptotically correct standard errors and yields asymptotically correct chi-square measures of model goodness of fit (Browne, 1984, Bollen, 1989). And our sample size is sufficient to satisfy the asymptotic assumptions.

The optimal causal structure for each model is determined by comparing models with alternative causal structures involving the endogenous variables. The possible links are the four non-zero elements in the last row and column of the beta matrix of equation (1):

$$\underset{(3\times3)}{B} = \begin{bmatrix} 0 & 0 & \beta_{13} \\ 0 & 0 & \beta_{23} \\ \beta_{31} & \beta_{32} & 0 \end{bmatrix} \quad (4)$$

These effects can also be represented as arrows in the flow diagram of Figure 5. Each element in matrix (3) corresponds to an arrow that points from the column variable to the row variable. The two-headed arrow in Figure 5 represents the potentially significant correlation between the error terms of the two demand variables.

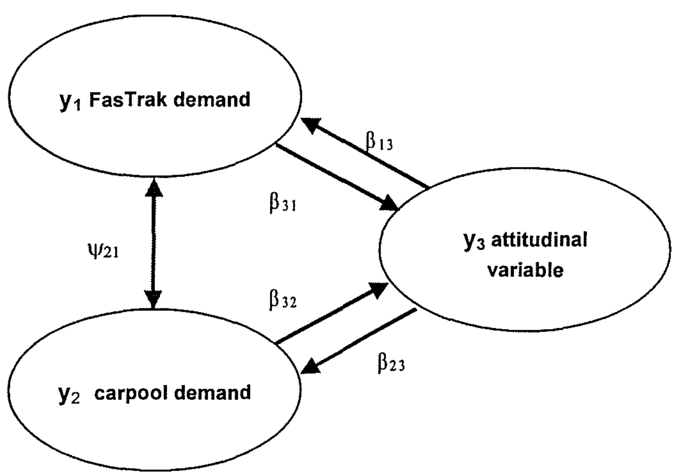

Figure 5. Flow diagram of all causal structures tested in determining the optimal models

However, not all of these links can be estimated simultaneously because the model might not be identified, depending upon the structure of the remaining parameter matrices in Equation system 1. A necessary condition for identification is that the free parameters in matrix B must be chosen such that $(\mathrm{I} - \mathrm{B})$ is non-singular, where I denotes the identity matrix. A necessary and sufficient condition for identification is that the rank of the matrix given by

$$C = \left[(\mathrm{I} - \mathrm{B}) \middle| -\Gamma\right] \tag{5}$$

must be equal to two (one less than number of endogenous variables). Because of the large number of exogenous variables, these identity restrictions do not adversely affect the searches for optimal models.

RESULTS

Joint Model of Mode Demand and Approval

The optimal model for demand and attitude towards whether solo drivers *should* be allowed to use the Express Lanes for a fee has one direct causal link from FasTrak demand to approval. That is, all coefficients in the beta matrix of definition (3) and Figure (5) are zero, with the exception of link β_{31}. The causal structure represented by the optimal model is depicted in Figure 6.

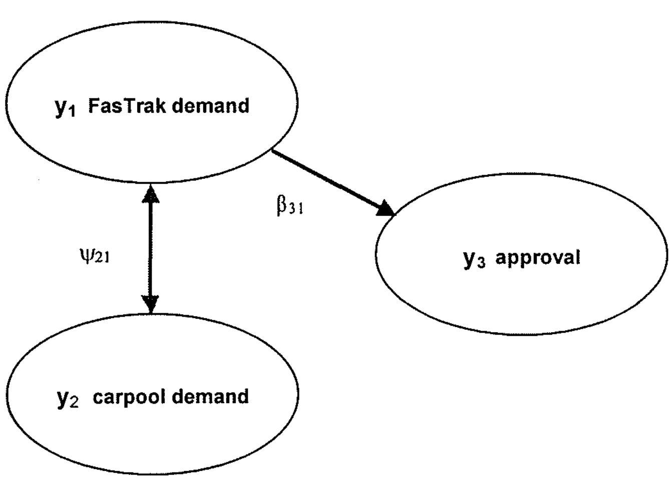

Figure 6. Flow diagram of causal structure of optimal model of demand and approval

The model chi-square, calculated from the minimized objective function, is 10.66 with 27 degree-of-freedom, corresponding to a probability of 0.998. The model cannot be rejected at any reasonable confidence level[1]. The estimate for β_{31} is 0.911, with an asymptotic *z*-statistic of 13.26 (p = 0.000).

This model implies that those who make heavier use of FasTrak are more likely to approve of the HOT lanes program, but carpoolers are not significantly different from solo drivers in their attitudes towards approval. The link from FasTrak demand is consistent with cognitive dissonance, which predicts that those who engage in an activity consciously or subconsciously develop attitudes that are consistent with their behavior, a phenomena explored in the travel demand modeling by Golob, *et al.* (1979). A potential reason for the lack of a link from carpooling to approval is that carpoolers also often drive alone, and they might wish to have available the option to pay to use the Express lanes as solo drivers. The lack of significant links from approval to either demand variable indicates that there is no evidence that usage of FasTrak is influenced by attitudes concerning approval of the HOT Lanes concept.

The determination of the optimal model is as follows. The goodness of fit statistics for the four possible alternative models with a single link between endogenous variables (i.e., one non-zero element in the beta matrix of Definition 4) are listed in Table 2, along with the base model with no links between endogenous variables. The base model can be rejected at the p = .05 level, having a chi-square value of 310.29 with 28 degrees of freedom, corresponding to p = .000. Every one of the single-link models can also be rejected at the p = .05 level, with the exception of the optimal model, which has a chi-square value of 10.66 with 27 degrees of freedom.

Next, attempts were made to improve the optimal model by adding a second link between endogenous variables. The results are shown in Table 3. One of the models

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[1] The logic of this test of overall fit is opposite to that in usual test of parameter significance. The null hypothesis is that the constraints implied by the model are valid. The probability is that of obtaining a chi-square value larger than the value obtained if the null hypothesis is correct. That is, probability values > α indicate that the differences between the model-implied covariance matrix and the observed covariance matrix are small enough to be due to sampling variations, at the (100- α)% confidence level.

is unidentified, but the improvements implied by the other two models can be rejected according to tests of nested hypotheses. No improvements to the optimal model are statistically significant.

Table 2. Alternative Joint models of demand and approval

Model	Model Fit			Improvement in fit versus base	
	X^2	d-o-f	p	ΔX^2	Δd-o-f
Base: no links between demands and approval	310.29	28	.000		
Only link from FasTrak demand to approval	10.66	27	.998	299.63	1
Only link from carpool demand to approval	110.18	27	.000	200.11	1
Only link from approval to FasTrak demand	49.63	27	.005	260.66	1
Only link from approval to carpool demand	146.78	27	.000	163.51	1

Table 3. Potential enhancements to optimal model of choice and approval

Model	Model Fit			Improvement in fit	
	X^2	d-o-f	p	ΔX^2	Δd-o-f
Base: link from FasTrak demand to approval	10.66	27	.998		
Add link from carpool demand to approval	10.65	26	.997	0.01	1
Add link from approval to FasTrak demand		(not identified)			
Add link from approval to carpool demand	10.13	26	.998	0.53	1

For the optimal model, the estimated total effects of the exogenous variables on each of the three endogenous variables, given by Equation 2, are listed in Table 4. Because there are no links from endogenous variable to the two demand variables, these total effects on the two demand variables are identical to the direct effects, which are the elements of the gamma matrix in Equation 1. However the total effects on approval include the direct effects on FasTrak demand channeled through the link from FasTrak demand to approval. All effects are standardized, because the estimation is performed by matching the model-replicated covariances to the observed correlation matrix. The missing total effects in Table 4 represent structural zeros, where there is no possible path from an exogenous variable to the endogenous variable.

The total effects reveal that demand for usage of FasTrak is similar to demand for subscription to FasTrak (Table 1), with the following exceptions. FasTrak subscription is relatively lower among households with annual incomes less than $60,000, but there is no significant relationship between FasTrak usage and this income group. Also, the high income dummy variable is only marginally significant at the p = .05 level. This indicates that, while household income and FasTrak subscription are strongly related, household income and FasTrak usage are less strongly related, *ceteris paribus*. Similarly, FasTrak subscription rates are higher among higher educated commuters and among commuters from two-worker households, but these variables are not significant in explaining FasTrak usage when the other demographic and socioeconomic variables are considered.

Table 4. Total effects of the exogenous variables – Joint model of demand and approval (asymptotic z-statistics in parentheses)

Exogenous variable	FasTrak demand	Carpool demand	Approval (+ = approve)
Age less than 35 years	-0.089 (-1.77)		-0.004 (-0.11)
Age greater than 64 years	**-0.049 (-4.94)**	**0.067 (7.90)**	**-0.045 (-5.63)**
Gender female			
Gender female and age 35 – 64	**0.085 (2.21)**		**0.078 (2.24)**
Education beyond bachelors degree		**-0.109 (-2.63)**	
Household income less than $60,000			
Household income ≥ $80,000	**0.112 (2.04)**	-0.062 (-1.47)	**0.102 (2.06)**
One-worker household	**0.081 (2.00)**	**-0.190 (-2.83)**	**0.074 (2.09)**
Two-worker household		-0.120 (-1.76)	
One-vehicle household	**-0.109 (-2.59)**		**-0.100 (-2.73)**
Household workers per vehicle		**0.154 (3.95)**	
Commute distance		**0.465 (3.68)**	
Commute distance squared		**-0.381 (-3.45)**	
Access to I-15: Ted Williams Pkwy.	**0.108 (1.52)**	**0.247 (5.06)**	0.098 (1.56)

Highly educated persons exhibit less carpool demand, but they are not significantly different from their counterparts in terms of FasTrak demand. Likewise, commuters from households with lower numbers of vehicles per worker have a higher level of carpool demand, but again this characteristic does not explain differences in FasTrak demand. Finally, there is a significant convex nonlinear distance function for carpool demand, but no significant distance effects on FasTrak demand. For I-15 commuters traveling past the Express Lanes, carpool demand obtains a maximum at a commuting distance of approximately 31 miles, *ceteris paribus*.

In terms of demographic differences in attitudes towards approval of the Program, females in the 35-64 year age group, commuters from high income households, and those from one-worker households show higher levels of approval. Older persons and those from one-vehicle households show lower levels of approval. Our model indicates that all of these differences in attitudes are due to differences in FasTrak demand for these segments.

Joint Model of Mode Demand and Fairness

The optimal joint model of demand and opinion about the fairness of the FasTrak program to travelers in carpoolers has a direct link from carpool demand to fairness. The model X^2 = 9.74 with 19 degrees of freedom, corresponding to p = 0.959; the model cannot be rejected at the p = .05 level. The flow diagram implied by the optimal model is shown in Figure 7. The parameter estimate for the link from carpool demand to fairness is β_{32} = -0.228, with *z*-statistic = -5.02.

The interpretation is that carpoolers think the program is less fair to them. There is no significant relationship between attitude regarding fairness and FasTrak usage. However, the optimal model also has nine significant direct exogenous effects from socioeconomic and demographic variables to the attitudinal variable. These multiple exogenous effects indicate that opinions regarding effectiveness vary substantially across the population in a manner that is not coincident with socioeconomic and demographic explanations of carpooling demand.

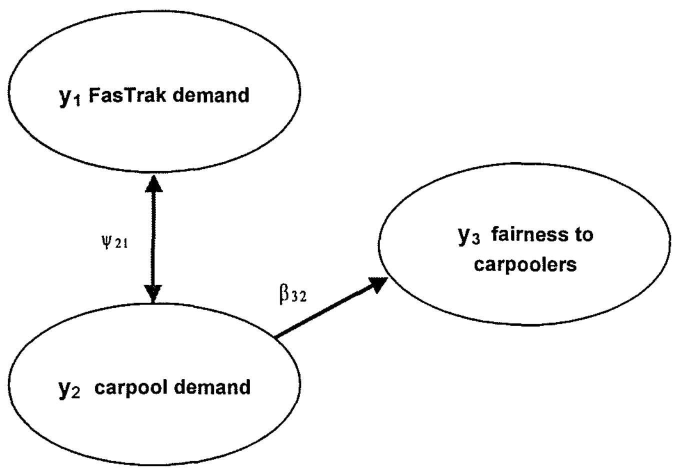

Figure 7. Flow diagram of causal structure of optimal model of demand and fairness

The total effects of the exogenous variables on attitudes toward fairness of the Program to carpoolers are listed in Table 5. The total effects on FasTrak and Carpool demand are almost identical to those listed previously in Table 4. The two segments with the strongest favorable attitudes towards the FasTrak Program are females aged 35-64 and all commuters less than 35 years of age. In addition, higher educated respondents, those from both lower and higher income households, and commuters from one-worker households are more likely to maintain an opinion of fairness to carpoolers. On the other hand, segments with less favorable attitudes towards the Program's fairness include females younger than 35, persons, females particularly, older than 64, persons from one-vehicle households, and persons from households with more workers per vehicle. Regarding spatial location factors, commuters who use the Ted Williams Parkway access to I-15 are more likely to think that the Program is fair, and opinions of fairness first decrease then increase with commute distance. This distance effect is similar to the distance effect on carpooling demand; opinions about fairness are minimum at a mid-range commuting distance.

Table 5. Total effects of the exogenous variables on opinions of fairness of FasTrak to carpoolers

Exogenous variable	Total effect	z-statistic
Age less than 35 years	**0.287**	**20.14**
Age greater than 64 years	**-0.082**	**-21.09**
Gender female	**-0.104**	**-5.31**
Gender female and age 35 – 64	**0.301**	**13.74**
Education beyond bachelors degree	**0.025**	**2.07**
Household income less than $60,000	**0.083**	**4.60**
Household income ≥ $80,000	**0.113**	**5.53**
One-worker household	**0.039**	**2.10**
Two-worker household	0.020	1.67
One-vehicle household	**-0.102**	**-6.52**
Household workers per vehicle	**-0.023**	**-2.66**
Commute distance	**-0.093**	**-2.35**
Commute distance squared (/1000)	**0.080**	**2.34**
Access to I-15 is Ted Williams Parkway	**0.153**	**4.15**

Joint model of Mode Demand and Effectiveness

The optimal joint model of demand and attitude regarding effectiveness of the FasTrak program has a single causal link from carpool demand to perceived program effectiveness (β_{32} = -0.242, with *z*-statistic = -2.44). The model X^2 = 16.95 with 21 degrees of freedom, corresponding to p = 0.714; the model cannot be rejected at the *p* = .05 level. The flow diagram of the causal structure is identical to that of the previous model (Figure 6).

The interpretation is that carpoolers think the program is less effective than do either solo drivers or FasTrak users. However, the optimal model also has six significant direct exogenous effects from socioeconomic and demographic variables to the attitudinal variable, indicating that opinion regarding effectiveness of the Program are variable across the population in a manner that is not entirely coincident with socioeconomic and demographic explanations of mode demand.

The total exogenous explanations of effectiveness are listed in Table 6. More highly educated commuters are more likely to perceive that the Program is effective in reducing overall congestion on I-15. The opposite perception is more likely to be held by commuters who are younger than 35 and older than 64, by persons from one-vehicle households and from households with higher numbers of workers per vehicle. The perception of effectiveness also decreases with commute distance.

Table 6. Total effects of the exogenous variables on opinion regarding project effectiveness in reducing congestion on I-15

Exogenous variable	Total effect	z-statistic
Age less than 35 years	**-0.083**	**-2.61**
Age greater than 64 years	**-0.109**	**-11.73**
Gender female		
Gender female and age 35 - 64		
Education beyond bachelors degree	**0.128**	**2.35**
Household income less than $60,000		
Household income ≥ $80,000	0.007	0.59
One-worker household	0.038	1.87
Two-worker household	-0.052	-1.39
One-vehicle household	**-0.088**	**-2.61**
Household workers per vehicle	**-0.030**	**-2.08**
Commute distance	**-0.117**	**-1.99**
Commute distance squared (/1000)	0.094	1.94
Access to I-15 is Ted Williams Parkway	0.112	1.63

SUMMARY AND CONCLUSIONS

Attitude-behavior models were found that unambiguously related weekly mode choice to attitudes concerning the FasTrak Program, while simultaneously capturing demographic and socioeconomic influences. The results concerning the linkages between FasTrak demand, carpool demand and each of three attitudes is as follows.

> FasTrak usage positively shapes attitude towards **approval** that solo drivers should be allowed to pay to use the Express Lanes. However, there is no relationship between carpool demand and approval; carpoolers and solo drivers are equally likely to approve of HOT lanes.
>
> Carpool use negatively shapes attitude towards **fairness to carpoolers** of allowing solo drivers use the Express Lanes. There is no relationship between FasTrak demand and attitude concerning fairness.
>
> Carpool use also negatively shapes perception of **effectiveness** of the project. There is no relationship between FasTrak demand and perceived effectiveness.

The effects of demographic and socioeconomic variables on each of the dependent variables is summarized in Table 7. Attitudes towards fairness of the HOT lanes to carpoolers has the greatest number of significant explanatory variables.

Table 7. Statistically significant exogenous total effects on all of the endogenous variables (p = .05 level for one-tailed tests)

Exogenous variable	FasTrak demand	Carpool demand	Approval	Fairness	Effective-ness
Age less than 35 years				Positive	Negative
Age greater than 64 years	Negative	Positive	Negative	Negative	Negative
Gender female				Negative	
Gender female & age 35 – 64	Positive		Positive	Positive	
Education beyond bachelors		Negative		Positive	Positive
Household income < $60,000				Positive	
Household income ≥ $80,000	Positive		Positive	Positive	
One-worker household	Positive	Negative	Positive	Positive	
One-vehicle household	Negative		Negative	Negative	Negative
Household workers / vehicle		Positive		Negative	Negative
Commute distance function		Convex		Concave	Concave
Access to I-15at Ted Williams Pkwy.	Positive	Positive		Positive	

All major transportation projects should include assessment of equity and fairness to various population groups, and the overriding importance of these considerations for congestion pricing has been articulated by several authors (e.g., Giuliano, 1995, Jones, 1998, Lo and Hickman, 1997). The future of road pricing might well rest with public attitudes concerning the acceptability, fairness, and effectiveness of such systems. Here we have attempted to explain how attitudes toward one such project differ across the population, while simultaneously taking into account differences in travel behavior across the population. Hopefully, results such as these can be used to predict acceptance of new systems in concert with conventional demand modeling.

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