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ABSTRACT

Understanding attitudes held by the public about the acceptability, fairness, and effectiveness of congestion pricing systems is crucial to the planning and evaluation of such systems. In this study, joint models of attitude and behavior are developed to explain how both mode choice and attitudes regarding the San Diego I-15 Congestion Pricing Project differ across the population. Results show that some personal and situational explanations of opinions and perceptions are attributable to mode choices, but other explanations are independent of behavior. With respect to linkages between attitudes and behavior, none of the models tested found any significant effects of attitude on choice; all causal links were from behavior to attitudes.

Key Words: Congestion pricing, Carpool lanes, Project evaluation, Attitudes, Discrete choice models, Attitude scales, Structural equations, Market research

OBJECTIVES AND SCOPE

Detailed information about travel behavior is important in the evaluation of transportation projects. It is extremely useful to know which groups in the population are taking advantage of the new opportunities, how much people are willing to pay to use them, and how much time they perceive that they are saving. It can be argued that 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 also vital information for planners. The analytical problem is that attitudes and behavior are mutually dependent on each other. 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 that 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 study, a joint model of attitudes and behaviour is used to provide information for evaluation of the Congestion Pricing Project in San Diego, California. The 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). A goal of the project is to reduce congestion on I-15 by taking advantage of underutilized capacity of the HOV lanes. Such a system is often referred to as 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 during their hours of operation; carpoolers continue to use the lanes without charge. Tolls vary based on the level of traffic in the Express Lanes in order to maintain an acceptable level of service for carpoolers in the Express Lanes.

The San Diego Congestion Pricing Project provides an excellent opportunity for studying transportation attitudes and behavior. It is apparently a unique example of overall public acceptance of the conversion of a limited-use free facility into a toll facility. Investigating attitudes in these circumstances is especially important to policy makers. Public (and therefore political) reluctance to support road pricing has kept it from being a widely adapted policy. However, the I-15 project has not suffered noticeably from any form of public outcry. It is useful to know how differences in travel behavior and attitudes towards the Project are related to each other and to personal and situational characteristics of the travelers in the corridor.

The social feasibility of road pricing on a broader scale has been investigated by several authors (e.g., Jones, 1994, 1998; Seale, 1993; Sheldon, Scott and Jones, 1993; 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. The specific attitudinal variables investigated here are: (1) feelings as to whether solo drivers should be allowed to pay to use the Express Lanes, (2) feelings as to whether the program is fair to carpoolers, (3) perceptions regarding whether the program is effective in reducing overall congestion on I-15, and (4) perceptions regarding the 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 personal and situational factors.

This paper is organized as follows. The presentation begins with a discussion of attitude-behavior relationships in travel demand research, in an attempt to place the present approach in the context of outstanding questions identified in previous studies. Next, the I-15 Congestion Pricing Project and its FasTrak Program are outlined, followed by a description of the source of the data for the present research. We then explore relationships between demand for FasTrak use, demand for carpooling, and attitudes regarding the HOT lanes concept and the FasTrak program. Finally, structural models are used to test the degree to which demand and attitude are functions of each other, conditional upon exogenous variables such as income, household composition, age and gender. The presentation ends with the customary summary and conclusions.

RESEARCH INTO ATTITUDES AND TRAVEL BEHAVIOR

Semantics differ across academic fields, but psychologists generally recognize three types of attitudes: (1) perceptions (or cognition), which encompass evaluative beliefs about the existence and attributes of an object or concept, (2) feelings (opinions or affective judgements) of like or dislike, and (3) conation, which encompass wishes, drives, instincts and inclinations to act purposefully (Day, 1973). The attitudes investigated here fall within the first two categories.

It is well established that there is mutual causality between attitudes and behavior in the travel context. Early attitude-behavior models focused on the causal relationship from attitudes to choice behavior, although it was generally recognized that attitudes are conditioned on past behavior (e.g., Hartgen, 1974, Recker and Golob, 1976). In contrast to these early models, Tardiff (1976) provided empirical evidence that the causal link from choice behavior to attitudes is stronger than the link from attitudes to choice behavior. Subsequent studies have shown consistently that attitudes, especially perceptions, are conditioned by choices, while at the same time, attitudes affect choices (e.g., Dobson, *et al.*, 1978; Golob and Hensher, 1998; Golob, Horowitz and Wachs, 1979; Koppleman and Pas, 1980; Lyon, 1981a, b).

In recent years, it has been popular to study attitudes and behavior using what is known as SP/RP models, with SP referring to (stated) preferences and RP referring to choice behavior (revealed preferences). In most of these models, both choice behavior and attitude in the form of preference is assumed to be a function of attitudes in the form of perceptions, with no possibility of causal links from preferences and revealed choices back to perceptions (e.g., Benjamin, *et al.,* 1998). This is at odds with evidence from previous studies, which has identified links from behavior to attitudes are at least as strong as links from attitudes to behavior. Researchers have discovered that SP and RP variables are linked in ways not explained by the unidirectional causal structure of the SP/RP models, and they have successfully compensated for this unexplained linkage by applying correction terms attributed to state dependence and serial correlation (e.g., Morikawa, 1994). Previous studies of attitude-behavior relationships indicate that these unexplained linkages in SP/RP models are due, at least in part, to missing causal links from behavior to attitudes, because choice behavior conditions perceptions, and preferences and perceptions should also affect one another.

In the present study, alternative structural equations models are evaluated to determine the model which best captures the causal relationships among the endogenous variables. Structural equation models represent a generalized modern version of the simultaneous equations methods first used by Tardiff (1976) and Dobson, *et al.* (1978) to study attitude-behavior relationships. However, here the models are estimated using a method that is tailored to ordinal attitude scales and discrete choice behavior (as in Golob and Hensher, 1998).

The need to use special estimation methods designed for discrete-choice endogenous variables has been long recognized in travel demand modeling and in attitude-behavior models in particular (e.g., Lyon, 1981a,b; Benjamin, *et al.,* 1998). However, the same consideration has not been given to attitudes as endogenous functions of personal and situational variables, and as potential endogenous functions of choice. Attitudinal variables are typically collected on discrete scales that measure either rating levels or levels of agreement with a specific statement. It is well established in psychometrics that these are ordinal, not interval, measurement scales (Coombs, 1964, 1976; Siegel, 1956; Stevens, 1946, 1951). However, with some exceptions (Benjamin, *et al.,* 1998 and Golob and Hensher, 1998), attitudinal variables are generally assumed to be interval-scaled continuous variables in attitude-behavior models (e.g., as in Bernardino and Ben-Akiva (1996) and Lyon, 1981a,b), and this must lead to biases in hypothesis testing. The method used in the present research attempts to avoid these biases.

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. The Express Lanes are barrier-separated from the main lanes, and are accessed only at the two endpoints of the facility. At the time the present data were collected, the Express Lanes were nominally open in the southbound direction (inbound commute) from 5:45AM to 9:15AM and in the northbound direction (outbound commute) from 3:00PM to 7:00PM.

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 in J. Golob, *et al.* (1998) and Supernak, *et al.* (1999). During Phase I, known as the ExpressPass program, payment for unlimited single-occupant vehicle (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.

Investigations are underway regarding FasTrak users' savings and willingness to pay to use the HOV Lanes as solo drivers (Brownstone, Golob and Kazimi, 1999, and Kazimi, Brownstone, Ghosh and Golob, 2000). The overall evaluation of the San Diego Congestion Pricing Experiment also includes assessments of congestion relief (Supernak, Golob, Kawada and Golob, 1999), land use (Supernak, Kaschade, Steffey, Kawada and Higgins, 2000), business impacts (Supernak, Steffey, Higgins, Kaschade and Kawada, 2000) and other aspects, such as media coverage (J. Golob, Supernak, Golob and Kawada, 1998).

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 in May-June and October-November 1999, respectively. 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, which is refreshed at each wave, 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. General results from analyses of the first wave of the evaluation panel are summarized in J. Golob, *et al.* (1998). Panel attrition and other aspects of the data from the first three waves of the panel are analyzed in Brownstone, et al. (1999).

DATA DESCRIPTION

The present analysis uses data from the third wave of panel data, collected during the fall of 1998 (October through November), when dynamic per-trip congestion pricing was well established. 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 one inbound 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 769 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. There is no correction here for the effects of the choice-based sampling on standard errors of the coefficients.

FasTrak customers are more likely to be between 35 and 64 years of age, and they are more likely to be females in this 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 are 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.

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 that has a minimum at approximately 23 miles; FasTrak subscription is lowest for persons who commute 23 miles to their normal place of work or school, *ceteris paribus*. As is later shown in the joint models of FasTrak and carpool demand, this is primarily due to a corresponding peaking of carpooling at approximately this distance. The second spatial variable in the model is access to I-15 via Ted Williams Parkway, a residential location factor that is unique to the I-15 Express lanes. 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 who enter there experience added time savings by avoiding queuing at the regular-lane ramps, which have ramp-metering signals. The queuing times at these ramps are typically substantial during the morning peak period, and in fall, 1998, the mean queuing time for the peak 15-minute period was estimated to be five minutes (Brownstone, *et al.*, 1999; Kazimi, *et al.*, 2000).

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 log likelihood		-543.0	
Model log likelihood		-463.1	
Rho-squared		0.147	
Model (–2) log likelihood ratio Chi-square		159.7	
Model chi-square degrees of freedom		13	
Probability		0.000	

Mode Choice

Each of the 976 respondents in the sample used here reported making at least one weekday morning peak-period commuting trip southbound on I-15 in the vicinity of the Express lanes during a week preceding the fall 1998 panel survey interview. These respondents were asked to report weekly trip rates for: (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 the attitude-behavior models presented below. The third variable, demand for non-FasTrak (toll-free) solo driving, is the base in the attitude-behavior models.

Table 2 presents a cross-tabulation of weekly trips by FasTrak (i.e., paying a toll to use the Express Lanes as a solo driver) and solo driving in the regular lanes of I-15, for 457 FasTrak customers. Eighty-six percent of FasTrak customers made at least one inbound FasTrak trip during the week, but only 35% of FasTrak customers made at least one non-FasTrak solo driving trip. Twenty-four percent of FasTrak customers made both FasTrak and non-FasTrak solo driving trips. The mean number of weekly inbound FasTrak trips was 2.95, plus or minus 0.17 trips (at the 95% confidence level). The mean number of weekly inbound non-FasTrak solo driving trips by FasTrak customers was 1.09 (± 0.16 trips).

Table 2. Cross-tabulation of FasTrak customers' weekly FasTrak and non-FasTrak solo driving trips

Weekly FasTrak trips	Weekly Solo driving trips in regular lanes						FasTrak totals (% of total)
	0	1	2	3	4	5	
0	12	2	4	4	4	37	63 (14%)
1	23	5	5	3	23		59 (13%)
2	35	5	5	32	2		79 (17%)
3	32	4	13				49 (11%)
4	38	12					50 (11%)
5	157						157 (34%)
Solo totals (% of total)	297 (65%)	28 (6%)	27 (6%)	39 (9%)	29 (6%)	37 (8%)	457 (100%)

Table 3 presents a similar cross-tabulation of weekly trips by FasTrak and carpooling for the 457 FasTrak customers making inbound morning peak commute trips. Only 11% of FasTrak customers made at least one carpool trip. Mixed FasTrak and carpooling trips were reported by only 8% of FasTrak customers. The mean number of weekly inbound non-FasTrak solo driving trips by FasTrak customers was 0.30 (± 0.09 trips).

Table 3. Cross-tabulation of FasTrak customers' weekly FasTrak and carpool trips

FasTrak trips last week	Carpool trips last week						FasTrak totals (% of total)
	0	1	2	3	4	5	
0	49	2	1	1	2	8	63 (14%)
1	48	1	2	2	6		59 (13%)
2	66	5	1	7			79 (17%)
3	42	2	5				49 (11%)
4	45	5					50 (11%)
5	157						157 (34%)
Carpool totals (% of total)	407 (89%)	15 (3%)	9 (2%)	10 (2%)	8 (2%)	8 (2%)	457 (100%)

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

Four opinions and perceptions regarding the FasTrak program are studied here. The first of these is whether solo drivers *should* be allowed to pay to use the HOV (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 Table 4. The four segments are based on mode of the last trip: (1) FasTrak customers who paid to use the Express Lanes as solo drivers, (2) FasTrak customers who chose not to pay to use the Express Lanes (i.e., they used the regular lanes), (3) other solo drivers who used the regular lanes and are not FasTrak customers, and (3) carpoolers who are not FasTrak customers. 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.

Focusing only on the two non-FasTrak 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.

Table 4. Breakdown by segment of agreement as to whether solo drivers should be allowed to use the I-15 HOV Lanes for a fee (percentage breakdowns by segment in parentheses)

	FasTrak users		FasTrak non-users		I-15 solo drivers		I-15 carpoolers	
Strongly disagree	7	(2.2%)	8	(5.8%)	46	(18.7%)	20	(22.2%)
Somewhat disagree	1	(0.3%)	3	(2.2%)	18	(7.3%)	7	(7.8%)
Somewhat agree	28	(8.9%)	25	(18.0%)	82	(33.3%)	30	(33.3%)
Strongly agree	280	(88.6%)	103	(74.1%)	100	(40.7%)	33	(36.7%)
Chi-squared = 185.65			Degrees of freedom = 9			Probability = .000		

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 shown in Table 5.

Table 5. Breakdown by segment of responses to whether FasTrak is fair or unfair to travelers in the I-15 HOV Lanes (percentage breakdowns by segment in parentheses)

	FasTrak users		FasTrak non-users		I-15 solo drivers		I-15 carpoolers	
Unfair	15	(4.7%)	11	(8.0%)	64	(26.3%)	23	(26.1%)
Fair	302	(95.3%)	127	(92.0%)	179	(73.7%)	65	(73.9%)
Chi-squared = 66.68			Degrees of freedom = 3			Probability = .000		

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. Interestingly, while more than 90% of FasTrak customers feel that the Program is fair to carpoolers, so do more than 70% of carpoolers and non-FasTrak solo drivers, and there is no statistical difference between carpoolers and solo drivers. The purpose of the second attitude-behavior model presented below is to explore the causal relationships involving this attitude.

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

The third 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 Table 6, the perceptions of FasTrak customers are significantly different from those of non-customers. 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. FasTrak customers who are recent users of the system generally agree, either strongly or somewhat, that FasTrak helps reduce congestion. FasTrak customers who did not use FasTrak on their last trips are less likely to agree strongly that FasTrak helps reduce congestion. Both carpoolers and solo drivers who are not FasTrak customers are more skeptical of the Program's affect. Almost half of the non-customers disagree either somewhat or strongly that the Program helps reduce congestion. The third attitude-behavior model is designed to further explore these relationships and to pinpoint demographic differences in opinions of effectiveness.

Table 6. Breakdown by segment of agreement as to whether FasTrak helps reduce traffic congestion on I-15 (percentage breakdowns by segment in parentheses)

	FasTrak users	FasTrak non-users	I-15 solo drivers	I-15 carpoolers
Strongly disagree	16 (5.0%)	10 (7.2%)	65 (26.2%)	19 (21.3%)
Somewhat disagree	36 (11.4%)	24 (17.4%)	59 (23.8%)	16 (18.0%)
Somewhat agree	129 (40.7%)	62 (44.9%)	98 (39.5%)	47 (52.8%)
Strongly agree	136 (42.9%)	42 (30.4%)	26 (10.5%)	7 (7.9%)
Chi-squared = 137.06	Degrees of freedom = 9		Probability = .000	

Perceived Safety Advantage of Travelling in the Carpool Lanes

The fourth and final attitudinal variable might provide insight into why people choose to carpool or pay to use the Express Lanes as solo drivers. Respondents were asked how they would compare the safety advantage of traveling in the carpool lanes, versus traveling in the regular lanes. They were reminded that this was a question about traveling the length of the lanes, not the merge into them. Responses were collected on a five-point scale (plus "don't know") shown in Table 7.

Table 7. Breakdown by segment of perceived safety advantage of traveling in the I-15 HOV Lanes (percentage breakdowns by segment in parentheses)

	FasTrak users		FasTrak non-users		I-15 solo drivers		I-15 carpoolers	
Much less safe	2	(0.6%)	1	(0.7%)	2	(0.8%)	0	(0.0%)
Somewhat less safe	8	(2.5%)	7	(5.1%)	17	(6.9%)	2	(2.2%)
About the same	25	(7.9%)	26	(18.8%)	50	(20.4%)	10	(11.1%)
Somewhat safer	75	(23.7%)	33	(23.9%)	65	(26.5%)	29	(32.2%)
Much safer	207	(65.3%)	71	(51.4%)	111	(45.3%)	49	(54.4%)
Chi-squared = 39.28			Degrees of freedom = 12			Probability = .000		

Both FasTrak users and carpoolers are more likely to rate Express Lanes travel as being safer. The differences in attitudes among the four segments are statistically significant, and the differences between carpoolers and non-FasTrak solo drivers are marginally significant. The level of the perceived safety advantage of Express Lanes travel is related to the choice of Express Lanes travel.

MODEL SPECIFICATIONS

The objective here is to interrelate demand for FasTrak and carpooling, as measured by the weekly rates of usage, to opinions and perceptions regarding HOT lanes and the FasTrak program in particular. Four separate sets of models are developed to determine how each of the four opinions and perceptions described above is related to mode demand and how each is a function of personal and situational variables. Each of the models has three latent endogenous variables: (1) FasTrak demand, (2) carpool demand, and (3) the specific attitudinal variable under study[1]. Ordered-response probit models are used to represent each of these variables. (In one case, the attitudinal variable has only two categories, so the ordered-response probit model collapses to a binary probit model.) The thresholds and conditional probabilities are estimated using the standard maximum likelihood method (Maddala, 1983). Each model also has fourteen exogenous personal and situational variables, similar to those listed in Table 1.

[1] 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). Thus, demand for (toll-free regular lanes) solo driving is not separately identifiable and is the base against which the other two demand variables are measured.

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

$$y^* = \mathrm{B}\, y^* + \Gamma x + \zeta \tag{1}$$

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 are the elements of the B, Γ and Ψ matrices. Matrix 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:

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

The structural parameters in equation system (1) 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 the chi-square measures of model fit derived from the fitting function at its optimum value are asymptotically correct (Browne, 1984, Bollen, 1989). The 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):

$$\underset{(3\times 3)}{\mathrm{B}} = \begin{bmatrix} 0 & 0 & \beta_{13} \\ 0 & 0 & \beta_{23} \\ \beta_{31} & \beta_{32} & 0 \end{bmatrix} \tag{3}$$

These effects can also be represented as arrows in the flow diagram of Figure 1. 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 1 represents the correlation between the error terms of the two demand variables.

In general, 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 and sufficient condition for identification is that the rank of the matrix given by $\left[(I - \mathrm{B}) - \Gamma \right]$ 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.

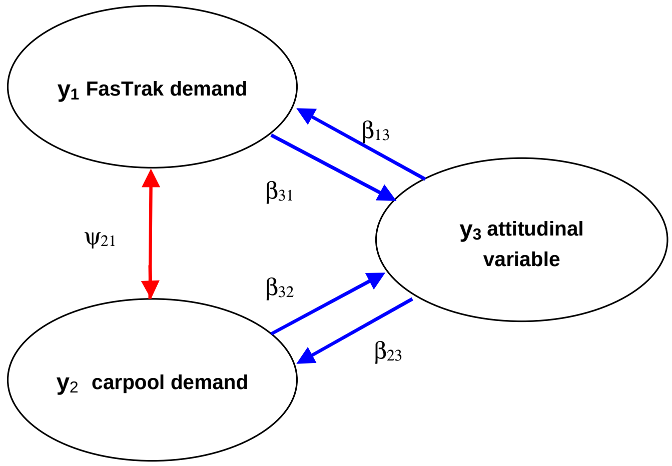

Figure 1. Flow diagram of all causal structures tested in determining the optimal models.

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 1 are zero, with the exception of link β_{31}. 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[2]. 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

[2] 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.

consistent with the theory of the reduction of cognitive dissonance, which predicts that those who engage in an activity consciously or subconsciously develop attitudes that are consistent with their behavior (Festinger, 1957; Golob, Horowitz, and Wachs, 1979). A potential reason for the lack of a no 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 (3), are listed in Table 8, 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.

Table 8. 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

Next, attempts were made to improve the optimal model by adding a second link between endogenous variables. The results are shown in Table 9. One of the models is unidentified, but the improvements implied by the other two models can be rejected. No improvements to the optimal model are statistically significant.

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 10. 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. 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.

Table 9. Potential enhancements to optimal model of choice and approval

Model	Model Fit			Improvement	
	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

Table 10. 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)

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 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 personal and situational variables are considered.

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, females in the 35-64 year age group, persons from high income households, and persons 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 the carpool lanes has a direct link from carpool demand to fairness. For this model, all coefficients in the beta matrix of definition (3) and Figure 1 are zero, with the exception of link β_{32}. The model X^2 = 9.74 with 19 degrees of freedom (p = 0.959), indicating that the model cannot be rejected at the p = .05 level. The parameter estimate for the link from carpool demand to fairness is β_{32} = -0.228, with an asymptotic 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 personal and situational variables to the attitudinal variable. These multiple exogenous effects indicate that opinions regarding effectiveness vary across the population in a manner that is not coincident with carpooling demand. The total effects on FasTrak and Carpool demand are almost identical to those listed previously in Table 10. The total effects of the exogenous variables on attitudes regarding fairness to carpoolers are listed in Table 11.

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 fairness of the Program include females younger than 35, all persons (and 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 that found for carpooling demand, with a minimum value at the mid-range of commuting distances.

Table 11. 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 any reasonable probability level.

The interpretation is that carpoolers think the program is less effective. However, the optimal model also has six significant direct exogenous effects from personal and situational 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 exogenous explanations of mode demand. The total exogenous explanations of effectiveness are listed in Table 12. 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 12. 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

Joint Model of mode Demand and Perceived safety of Express Lanes Travel

The optimal joint model of demand and perceived safety advantage has two causal links between the endogenous variables: a link from FasTrak demand to perceived safety advantage (β_{31} = 0.588, with *z*-statistic = 5.94), and a link from carpool demand to safety advantage (β_{32} = 0.470, with *z*-statistic = 4.50). The model X^2 = 22.42 with 24 degrees of freedom, corresponding to p = 0.554.

The interpretation is that those using the Express Lanes, both carpoolers and FasTrak users, perceive a greater safety advantage in using the Lanes. This is consistent with the theory of cognitive dissonance (Golob, *et al.,* 1979), but it might also be attributed to experience. There is no evidence that commuters who desire safer travel choose to use the Express Lanes by either carpooling or as FasTrak customers, because we can find no significant links from perceived safety to either demand variable.

The estimated total exogenous effects on the perceived safety advantage of traveling in the Express Lanes are listed in Table 13. The most important explanatory variable is commute distance, which exhibits a convex function with a maximum at mid-range commuting distance. Commuters who access I-15 at Ted Williams parkway perceive a greater safety advantage. These spatial effects are consistent with higher levels of Express Lanes usage, either by carpooling or by FasTrak. The only other significant demographic differences in perceived safety involve gender combined with age: females less than 35 and females over 64 perceive less of a safety advantage for Express Lanes travel. None of the other exogenous effects are significant at the $p = .05$ level.

The joint attitude-behavior model postulates that the lack of personal and situational effects on perceived safety of Express Lanes travel is due to the canceling of effects channeled through the two demand variables. For example, commuters from one-worker households are more likely to use FasTrak but less likely to carpool (Table 7). Thus, because both carpoolers and FasTrak users perceive a greater safety advantage, positive and negative effects from one-worker households are combined in the calculating total effects on perceived safety.

Table 13. Total effects of the exogenous variables on perceptions of the safety advantage of driving in the Express Lanes

Exogenous variable	Total effect	z-statistic
Age less than 35 years	-0.051	-1.93
Age greater than 64 years	-0.008	-1.21
Gender female	-0.101	-2.71
Gender female and age 35 - 64	0.084	2.39
Education beyond bachelors degree	-0.052	-1.92
Household income less than $60,000		
Household income ≥ $80,000	-0.097	-1.83
One-worker household	-0.038	-0.84
Two-worker household	-0.030	-1.06
One-vehicle household	-0.035	-1.20
Household workers per vehicle	-0.028	-0.60
Commute distance	0.198	2.63
Commute distance squared (/1000)	-0.158	-2.47
Access to I-15 is Ted Williams Parkway	0.179	2.24

SUMMARY AND CONCLUSIONS

Four attitude-behavior models were found that relate demand for FasTrak and demand for carpooling to attitudes concerning the FasTrak Program. Each of these models was optimal, in that it unambiguously outperformed any other model linking the variable in question.

The results concerning the linkages between FasTrak demand, carpool demand and each of the four attitudes is as follows.

> FasTrak use positively shapes attitude towards approval. However, there is no relationship between carpool demand and approval.
>
> Carpool use negatively shapes attitude towards fairness to carpoolers. There is no relationship between FasTrak demand and attitude concerning fairness of FasTrak to carpoolers.
>
> Carpool use negatively shapes perception of effectiveness. There is no relationship between FasTrak demand and perceived effectiveness.
>
> Both FasTrak demand and carpool demand positively shape perceptions of safety advantage. Users of the Express Lanes perceive a greater safety advantage in their use.

The explanation of attitudes in terms of personal and situational variables is summarized in Table 14. Attitudes towards fairness of the HOT lanes to carpoolers exhibits the greatest number of significant explanatory variables, while perceptions of the safety advantage of traveling in the Express Lanes has the least number of significant explanatory variables.

Evaluations of all transportation projects should include assessment of equity and fairness to various population groups (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. The analyses presented here attempt to explain how attitudes toward one such project differ across the population, while simultaneously taking into account differences in travel behavior across the population. These results can be used to predict acceptance of new systems in concert with conventional demand modeling.

Table 14. 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	Safety advantage
Age less than 35 years				Positive	Negative	
Age greater than 64 years	Negative	Positive	Negative	Negative	Negative	
Gender female				Negative		Negative
Gender female & age 35 – 64	Positive		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	Convex
Access at Ted Williams Pkwy.	Positive	Positive		Positive		Positive

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