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JOINT MODELLING OF ATTITUDES AND BEHAVIOUR IN PROJECT EVALUATION: CASE STUDY OF SINGLE-OCCUPANT VEHICLE TOLL USE OF CARPOOL LANES IN SAN DIEGO, CALIFORNIA

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INTRODUCTION

Knowing what people think about the usefulness, fairness, and success of new transport initiatives is vital information for planners and project evaluators. Methods for studying the complex relationships between attitudes and choice behaviour need to be included in evaluation processes.

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 use choice models to understand factors affecting demand, but modelling of attitudes has not received similar attention. In this paper we demonstrate how a joint model of attitudes and behaviour can be used in comprehensive project evaluation. The approach involves analysing attitude survey data using a structural equations model designed for use with discrete choice and ordinal-scale variables.

Our application involves the evaluation of responses to a project that allows solo drivers to pay a fee to use a carpool, or high-occupancy vehicle (HOV) lane facility on the Interstate 15 (I-15) Freeway in San Diego. The attitude survey is of subscribers to the program and a random sample of other freeway users. Four endogenous variables are explained as functions of each other and of exogenous variables such as income, household composition, age and gender. These endogenous variables are: (1) choice of subscription to the program, (2) mode choice of carpooling versus solo driving, (3) perception of the seriousness of the traffic congestion on the route, and (4) attitude towards allowing solo drivers to pay to save time by using the carpool lanes.

THE EXPERIMENT AND THE SURVEY

The I-15 Congestion Pricing Project

The I-15 Congestion Pricing Project is a three-year demonstration program which allows single occupant vehicles (SOVs) to pay to use an eight-mile (13 km) stretch of two reversible HOV lanes. These HOV lanes, located in the northern part of the San Diego Metropolitan Area, are separated by barriers from the main lanes, and 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 6:00AM to 9:00AM and in the northbound direction (outbound commute) and from 3:00PM to 6:30PM.

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 another paper presented at the 1998 European Transport Conference (J. Golob, *et al.,* 1998). 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. The fee was originally set at US$50 per month, but was raised to $70 per month in March 1997. The total number of ExpressPass subscribers was limited to 1,000.

Phase I ended and Phase II began at the end of March 1998 and will continue until December 1999. In Phase II, known as FasTrak™, subscribers are issued windshield-mounted transponders used for automatic vehicle identification, and there is no limit on the number of subscribers. FasTrak 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.

In the research reported here, we are concerned with the 15-month ExpressPass Phase of the Congestion Pricing Project, in which subscribers paid a flat monthly fee for SOV use of the HOV lanes.

The Evaluation Panel Survey

An independent evaluation of the Congestion Pricing Project was initiated after the project had begun in 1997, and Golob, Supernak and Golob (1998) report on the evaluation of ExpressPass Program phase of the Project. 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, and the second wave was in May and June 1998. The panel survey, which is patterned in part after a panel survey used in evaluating the original installation of the same HOV lanes (Supernak,

1991), was designed to describe and explain attitudinal and behavioural responses to the I-15 Congestion Pricing Project.

The panel sample of approximately 1,500 individuals is broken down into: 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. A partial quota sampling procedure was used to increased the number of carpoolers in non-subscriber parts of the sample. In subsequent waves of the panel, refreshment is being 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), and examples of applications are described by Giuliano and Golob (1990) and Golob, *et al.* (1997). In this paper we use the first wave of the panel as a cross-sectional data source in exploring relationships between behaviour and attitudes. For the I-15 Congestion Pricing Project, dynamic analyses await the availability of multi-wave panel data.

THE DATA

Our analysis focuses on four key endogenous variables:

(1) choice of participating in the ExpressPass Program by purchasing a monthly pass for SOV use of the HOV lanes,

(2) choice of SOV versus HOV for each respondents last commuting trip during the morning peak period, which is highly related to the first endogenous variable,

(3) perceptions of traffic conditions on the mainline lanes at the time of the last commute trip, and

(4) attitude towards the fairness of the ExpressPass Program, in terms of whether solo drivers should be allowed to use the HOV lanes for a fee.

In our modeling we also use exogenous variables constructed from survey data on each respondents age and gender, household income, and the number of drivers, workers and vehicles in the household. Our models are restricted to commuters in the I-15 corridor, and of the approximately 1,000 panel respondents in the I-15 corridor, 903 had complete data on all endogenous and exogenous variables used in the models.

Choice of ExpressPass and Choice of Mode for the Last Trip

The cross-tabulation between choice of ExpressPass and choice of mode for the last commuting trip is shown in Table 1. The few ExpressPass users who carpooled on their last commute probably did so because they needed to provide a ride for a family member or someone else on that day. The obvious interaction between these two choice variables highlights the need to treat the variables in attitude-behaviour modeling in a manner that allows mutual interdependence between the choices. Treating the two variables together as one multinomial (or nested multinomial) choice variable would mask the fact that some ExpressPass subscribers still carpool occasionally. Moreover, there is no reason to assume that the constraints affecting choice of Program subscription are identical to those affecting choice of mode for a single commute trip. The method we use is quite general in that it allows each of the two choice variables (treated as discrete-choice probit models) to freely affect the other choice, while having separate exogenous structures.

Table 1 Cross-tabulation Between ExpressPass Choice and Mode Choice

Mode choice for Last trip	Choice of subscribing to the ExpressPass Program		Row totals
	Subscribe	Not subscribe	
Solo driver	312	457	769
Carpooler	9	125	134
Column totals	321	582	903

Perceptions of Traffic Conditions

Panel respondents were asked: "Using a scale from 1 to 10, with 10 being no traffic problems at all, and 1 being bumper-to-bumper conditions, how would you rate the traffic in the regular lanes on south-bound I-15 on this day?" This variable allows us to test whether or not commuters more sensitive to traffic congestion, controlling for all socio-economic differences, choose to pay for use of the HOV lanes. A competing hypothesis is that use of the less congested HOV lanes changes how commuters perceive congestion.

The cross-tabulation between traffic perception and choice of Program subscription is shown in Figure 1. Clearly, subscribers to the ExpressPass Program have a more negative perception about traffic on the mainline (mixed-flow) of I-15 on the section parallel to the HOV lanes. Thirty-seven percent of subscribers give traffic the worst rating on the anchored ten-point scale, while only 24 percent of non-subscribers felt

traffic conditions were that bad. Statistical tests confirm a significant systematic relationship. Kendall's tau-c rank-order correlation between the dichotomous and ordinal variables is 0.22 with a *t*-statistic of 6.2 (p < .001); other types of rank-order correlation coefficients (e.g., Kendall's tau-b and Spearman's rho) yield similar results. The question is: does negative perception of traffic motivate commuters to pay for SOV use of the HOV lanes by subscribing to the ExpressPass Program, *or* do subscribers to the Program rationalize their behaviour by subconsciously or consciously adopting more negative perceptions of traffic associated with the alternative choice. One objective of our modeling is to reveal the most likely causality of this association between perception and choice.
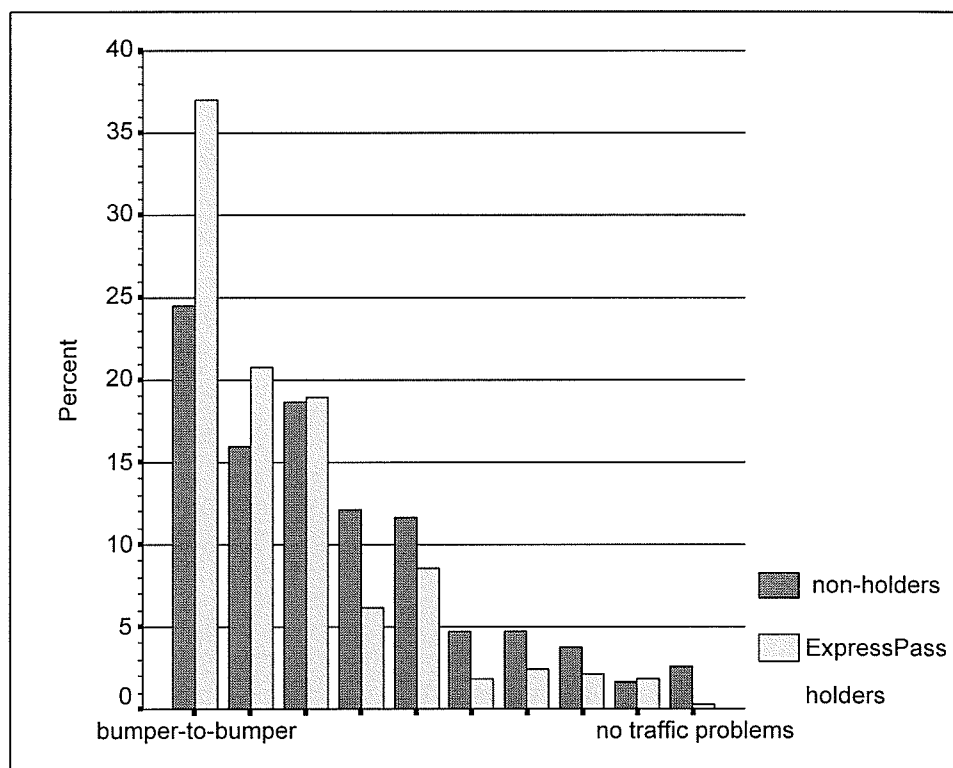

Figure 1   Perceptions of Regular-Lane Traffic Conditions, Broken Down by Choice of Subscription to the ExpressPass Program

There is no statistically significant relationship between perceptions of traffic conditions and mode choice (solo drivers versus carpoolers); Kendall's tau-c rank-order correlation is -.008 (with a *t*-statistic of -.30) and the chi-square statistic is 4.59 with 9 degrees-of-freedom (p = .87). However, a true causal relationship between mode choice and traffic perception might be masked by the relationship between subscription and traffic perception. If carpoolers have more negative perceptions of

traffic conditions than do solo drivers, this difference between carpoolers and solo drivers will be counteracted by the fact that many solo drivers are subscribers to the ExpressPass Program, and subscribers have more negative perceptions than non-subscribers. The test of perception versus mode choice can be conditioning on subscription choice, but this step is unnecessary, because the proposed structural model accomplishes this for all combinations of the endogenous variables.

Attitudes Towards the Concept of HOT Lanes

Respondents were later asked: "How much do you agree or disagree with the following statement: Single drivers should be allowed to use the carpool lanes for a fee?" One expects that subscribers to the ExpressPass Program would have more favorable attitudes towards the concept, and this is verified in the cross-tabulation depicted in Figure 2. (Kendall's tau-c rank-order correlation between the ordinal attitude variable and the dichotomous choice variable is -.50, with a t-statistic of -18.5.)
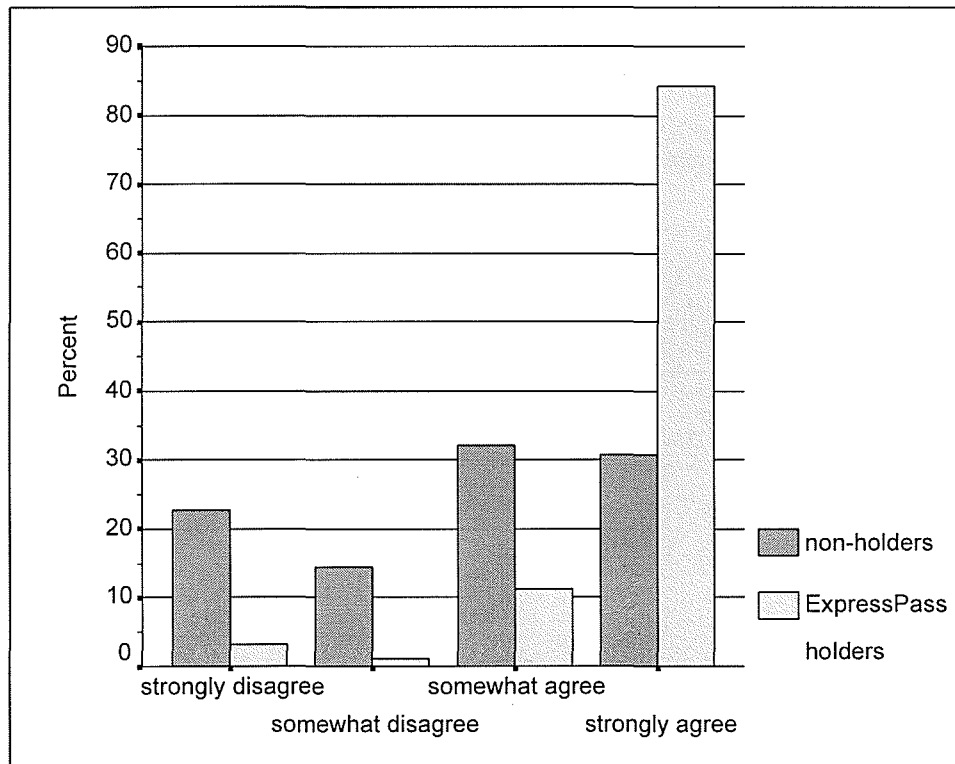

Figure 2 Attitudes Towards Concept of HOT lanes
Broken Down by Choice of Subscription to the ExpressPass Program

The question, which we delegate to the structural modeling, is which is stronger: belief that solo drivers should be allowed to pay to use the HOV lanes leads to choice of paying for that privilege, or choice of paying to use the HOV lanes as a solo driver strengthens the belief in the concept? The latter direction of causality is consistent with the theory of cognitive dissonance, by which people tend to adjust their attitudes to conform with their behaviour (Festinger, 1957; Golob, *et al.*, 1979)).

There is also a significant systematic relationship between mode choice and attitude about the concept. The cross-tabulation between the two variables is shown in Figure 3, and the Kendall's tau-c rank-order correlation is -.16, with a t-statistic of – 5.94. Approximately 50% of carpoolers agree or strongly agree that solo drivers should be allowed to pay to use the HOV lanes, compared to 70% of solo drivers. Importantly, 30% of solo drivers are not in favor of the concept. While it is not surprising that solo drivers are more in favor of allowing solo drivers to pay to use the HOV lanes, the interaction between mode choice and program subscription compels us to perform a simultaneous analysis of all of the attitude and choice.
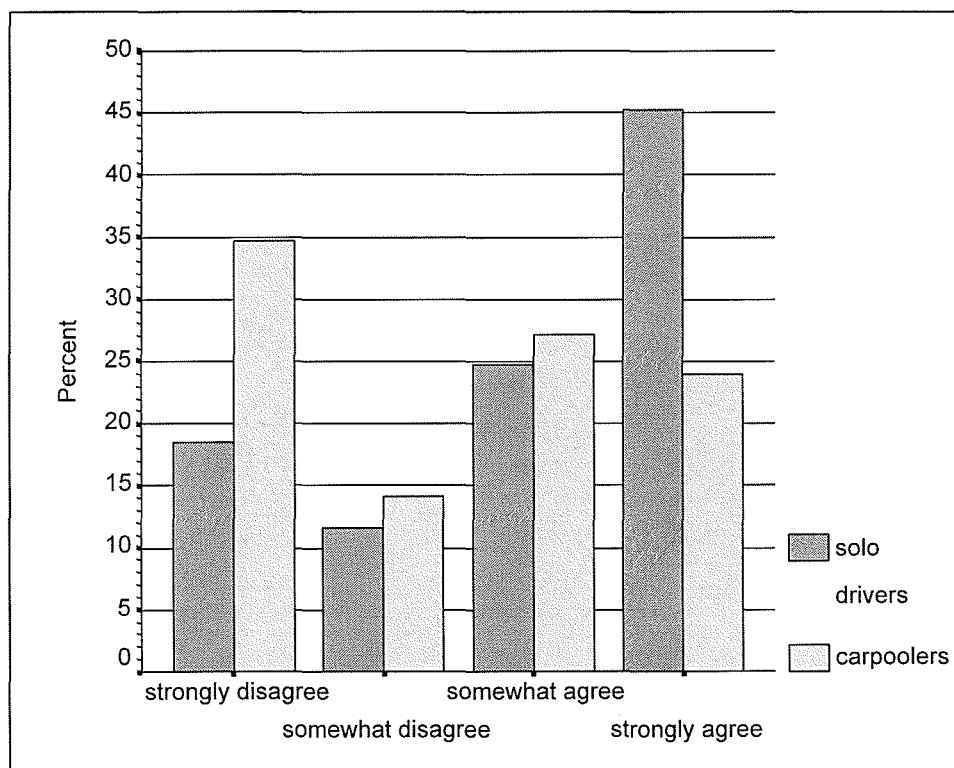

Figure 3 Attitudes Towards Concept of HOT Lanes, Broken Down by Mode Choice

METHODOLOGY

Our models deal with four endogenous variables – (1) choice of paying for the privilege of using the HOV lanes as a solo driver, (2) mode choice, (3) perception of traffic, and (4) attitude towards allowing solo drivers to pay for use of the lanes – and nine exogenous variables: (1) gender, (2) age less than 35, (3) age > 54, (4) household workers per vehicle, (5) household drivers per vehicle, (6) household income < $40,000, (7) income $40,000-$60,000, (8) income > $100,000, and (9) ownership versus rental of residence. Structural equations models are employed to simultaneously model the causal relationships among pairs of these four endogenous variables and between each of the four endogenous variables and the nine exogenous variables. Structural equation models (SEMs) are simultaneous equations which are specified in terms of direct causal links between variable pairs, with the additional capabilities of specifying latent variables and covariance structures for errors in equations and errors in measurement (Bollen, 1989). SEMs are similar to path analysis models in that they can be used to test hypotheses of causality among endogenous variables in the presence of exogenous influences, but SEMs can be specified with both recursive and non-recursive (feed-back) causal structures.

The SEM estimation method we use allows us to treat the two endogenous choice variables as freely interrelated discrete choices, and the perception and attitude variables as ordinal scales. The method is described in Golob and Hensher (1998) and Golob, *et al.*, (1997). Briefly, three distinct stages are involved in estimating model parameters, their variances and overall model fit:

(1) Binary (binomial) probit models are computed for the two discrete choice endogenous variables, and ordered-response probit models are computed for the two ordinal variables. These provide normal-distribution thresholds and conditional probabilities.

(2) Correlation matrices are computed using maximum likelihood methods based on the results of the first stage. The correlations between the latent choice variables are known as tetrachoric correlations, while those involving the ordinal endogenous variables are known as polychoric correlations.

(3) Using the variance analysis method know as asymptotically distribution free) weighted least squares (ADF-WLS), the structural parameters and their asymptotic standard errors are estimated, together with goodness of fit measures for the entire equation system. These estimates can be shown to be unbiased under very general assumptions about the distributions of the data.

The difficulty in using SEMs involves testing competing hypotheses of direct causal effects. SEMs with radically different causal structures often give similar results in

terms of goodness-of-fit measures (Stelzl, 1986; Hayduk, 1996). In our application we are guided by theory that limits the combinations of endogenous variable causal structures to a reasonable number. We also adopt the approach of holding the structure of the exogenous regression effects constant when comparing alternative endogenous structures, and the extensive exogenous structure enables us to identify most endogenous causal structures, as verified by the order conditions for model identification (Bollen, 1989).

RESULTS

A series of structural equations models was estimated using LISREL8 with PRELIS2 software (Jöreskog and Sörbom, 1993). In determining the optimal model, we were particularly guided by results for nine models, and the likelihood ratio chi-square goodness-of-fit results for these models are listed in Table 2. The probability value, determined by comparing the model chi-square derived from the ADF-WLS fitting function to the model degrees of freedom, is the probability of obtaining a chi-square value that large if the model is correct. If that probability is greater than the predetermined critical value of 0.05, we cannot reject the hypothesis that the model is correct at the 95% confidence interval.

Model 1 in Table 2 contains every significant exogenous effect, but no causal structure among the endogenous variables; this model can be rejected at the $p = .05$ level. Model 2 has the same exogenous structure, but adds reciprocal causal links between the two choice variables. While this model can still be rejected at the $p = .05$ level, the improvement in model chi-square for these two nested models is 335.51, which is highly significant. Similarly, a significant improvement in model fit is obtained by adding a direct effect from choice of ExpressPass Program subscription to attitude towards allowing solo drivers to pay to use the HOV lanes (Model 3). Even more improvement is obtained by reversing the link from attitude to choice (Model 4). Model 5 has links in both directions between choice of Pass and attitudes towards the concept, and the two links are about equal in magnitude and significance. Our conclusion is that there is reciprocal causality between these two variables.

Models 6 and 7 in Table 2 represent alternative causality for the correlation between choice of subscription to the ExpressPass program and perception of traffic conditions. Model 6 with the link from perception of traffic conditions to choice is marginally better than Model 7, in which the link is from choice to perception. The superiority of the structure of Model 6 is confirmed in Model 8, which contains links in both directions. In Model 8, which represents essentially no improvement over Model 6, the coefficient associated with the link from choice to perception is very small and insignificant, compared to the link from perception to choice. Finally, results for the saturated Model 9 show that adding of the last eight links between

pairs of endogenous variables is not justified in terms of improved model fit versus Model 6 (the difference in chi-square being 1.54, with 6 degree of freedom, which is not statistically significant at the 95% confidence level).

Table 2: Comparison of Models based on Alternative Causal Structures among the Endogenous Variables, with the same Exogenous Variable Structure

Endogenous variable structure	Chi-square	Degrees of freedom	Probability
1. Null: no links from any endogenous variable to any other endogenous variable	480.65	16	0.000
2. Choice linkages only: reciprocal effects between the two choice variables	145.14	14	0.000
3. Previous model plus direct causal effect from Pass choice to attitude towards concept	10.82	13	0.626
4. Alternative to previous model: link from attitude towards concept to choice of Pass	9.95	13	0.698
5. Links in both directions between choice of Pass and attitudes towards concept	9.47	12	0.663
6. Previous model plus link from traffic perception to choice of Pass	1.86	11	0.999
7. Alternative to previous model: link from choice of Pass to traffic perception	4.24	11	0.962
8. Links in both directions between choice of Pass and traffic perception	1.85	10	0.997
9. Saturated: links in both direction between all pairs of variables	0.32	4	0.989

Our conclusion is that Model 6 of Table 1 captures the best causal structure among the endogenous variables. There are five direct causal links between the four endogenous variables:

(1) Choice of subscription to the ExpressPass Program and choice of mode for the last trip are interrelated, with causality in both directions. The signs of the two direct effects indicate that ExpressPass subscribers choose to solo drive to a greater degree than predicted by all other effects; and

(2) those who choose to carpool are less likely to subscribe to the ExpressPass program, *ceteris paribus*. This latter direct effect quantifies the degree to

which carpooling is *not* affected by allowing solo drivers to pay to use the HOV lanes.

(3) Persons who think that solo drivers should be allowed to pay to use the HOV lanes are more likely to choose to subscribe to the ExpressPass program, , *ceteris paribus*.

(4) Choice of ExpressPass subscription also leads to a more positive attitude towards allowing solo drivers to pay for use of the HOV lanes, *ceteris paribus*, which is a manifestation of cognitive dissonance (Festinger, 1957).

(5) Finally, persons who hold more negative perceptions of traffic conditions on the mainline lanes are more likely to choose to subscribe to the ExpressPass Program. The significance of this effect shows that there are differences in sensitivity to traffic congestion that are not explained by common socio-demographic characteristics.

In each of the models listed in Table 2, many of the effects of the exogenous variables are not significant at the p = .05 level, because a common exogenous structure was used that was the union of all effects which were significant in at least one of the models being compared. Consequently, the model with the best endogenous structure, model 6, has several insignificant exogenous links that can be removed without adversely affecting the model's explanatory power. An optimal model was estimated by sequentially removing the most insignificant exogenous regression effects from the model listed in Table 2 and stopping when all remaining exogenous effects are significant at the p = .05 level, and no excluded effects would be significant if added to the model. The optimal model has a chi-square goodness-of-fit value of 10.36 with 23 degrees of freedom, corresponding to a probability value of 0.989; the model cannot be rejected at the p = .05 level.

The estimated direct effects of the endogenous variables on one another are shown in the flow diagram of Figure 4. As all effects estimated using our method are based on correlations, the effects are standardized and can be directly compared in terms of magnitude without worrying about the scales of the variables. (In a recursive model, the standardized effects are equivalent to partial correlations, but this is not true in non-recursive models such as those under investigation; Stelzl, 1986). The total effects of the endogenous variables on one another, which are computed according to the formulas (3) through (6) in Golob and Hensher (1998), are listed in Table 3. Total effects represent the accumulation of direct effects via all paths, direct or indirect, that link a causal variable with a variable that it influences in any way. The positive total effects of the two choice variables on themselves are the result of the (non-recursive) reciprocal negative direct effects linking the two variables. These indicate that the choices are self-reinforcing. (The total effects of each choice on itself are identical because they are not separately identifiable.)
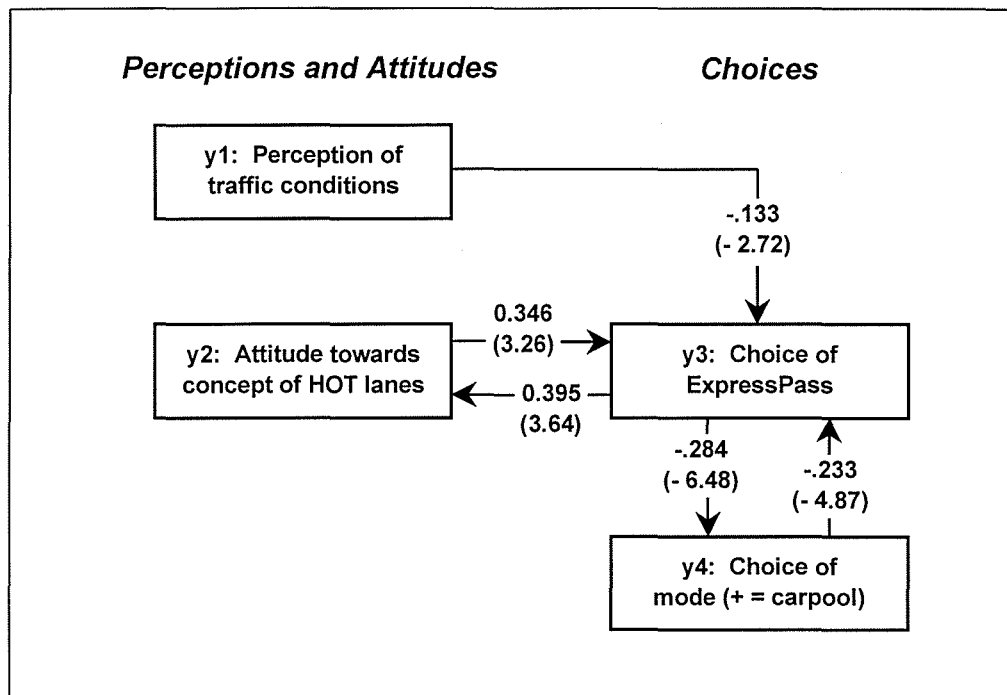
Figure 4 Estimated Direct Causal Effects Between Endogenous Variables in the Optimal Model (asymptotic z-statistics in parentheses)

Table 3 Total Effects of the Endogenous Variables on One Another in the Optimal Model (asymptotic *z*-statistics in parenthesis)

Influenced Endogenous Variable	Influencing Endogenous variable			
	Perception of traffic conditions	Choice of ExpressPass	Choice of mode	Attitude towards concept
Perception of traffic conditions				
Choice of ExpressPass	-.167 (-2.80)	0.254 (7.81)	-.292 (-4.88)	0.434 (3.18)
Choice of mode	0.047 (2.81)	-.356 (-6.25)	0.083 (5.63)	-.123 (-2.66)
Attitude towards concept of HOT lanes	-.066 (-2.19)	0.496 (3.54)	-.115 (-2.51)	0.172 (5.12)

The total effects of the exogenous variables are given in Table 4. These total effects are often referred to as the coefficients of the reduced-form equations, in which the

effects of the endogenous variables on one another are "solved out" and each endogenous variable is expressed as a function only of the exogenous variables. The total effects can be interpreted for each endogenous variable as follows:

(1) Perceptions of traffic conditions on the regular lanes of the freeway is not well explained by the exogenous variables. Only gender and age less than 35 have significant total effects; Females have more a negative perception of traffic conditions than do males. Younger persons have a more positive perception, perhaps due to the fact that they have witnessed less increase in time in traffic congestion.

(2) Persons who choose to subscribe to the ExpressPass Program for the privilege of using the HOV lanes as solo drivers tend to be middle aged (36 through 53 years of age), and come from households that are more likely to own their residences, have higher incomes, and relatively more vehicles per worker and per driver. The strongest variable is the age less than 35, which is negatively related to subscription choice.

(3) Carpoolers, on the other hand, are more likely to be female, younger or older, and come from households that tend to be renting, with lower household incomes and with fewer vehicles per driver and per worker.

(4) Positive attitudes towards allowing solo drivers to pay for use of the HOV lanes are more likely to be held by middle aged persons who come from households with higher incomes and relatively more vehicles.

The R^2 values for the endogenous variables, established through estimation of the error-term variances (Golob, et al., 1997), are 0.08 for traffic perception, 0.62 for choice of subscription, 0.30 for mode choice, and 0.41 for attitude towards the concept of HOT lanes. The relatively low R^2 for traffic perception is due in part to the fact that it is not well explained by either the exogenous or the endogenous variables.

CONCLUSIONS

Transport projects, whether they are demonstrations or permanent installations, need to be evaluated in a way that monitors the attitudes and perceptions, as well as the behaviour of affected individuals. Attitudinal panel surveys are extremely useful in collecting data before, during and after infrastructure or service changes are invoked. However, we have demonstrated that it is possible to identify project influences on perceptions, attitudes, and behavior when only one wave of a panel is available. The method of structural equation modeling was used to determine which groups in the population choose to participate in an innovative road pricing experiment, and how the attitudes of affected groups were inter-linked with their behaviour and perceptions.

Table 4 Total Effects of the Exogenous Variables in the Optimal Model
(asymptotic z-statistics in parenthesis)

Exogenous Variable	Perception of traffic conditions	Choice of ExpressPass	Choice of mode	Attitude towards concept
	Endogenous variable			
Gender (+ = female)	-.218 (-3.78)		0.047 (3.02)	
Age < 35 years	0.183 (2.53)	-.178 (-11.7)	0.050 (6.39)	-.070 (-3.26)
Age > 54 years		-.059 (-4.15)	0.107 (7.58)	-.099 (-2.53)
Workers per vehicle		-.025 (-3.35)	0.092 (4.31)	-.010 (-2.23)
Drivers per vehicle		-.038 (-4.26)	0.140 (6.08)	-.015 (-2.43)
Income < $40,000		-.112 (-8.63)	0.032 (4.83)	-.044 (-3.33)
Income $40-60,000		-.141 (-9.47)	0.040 (5.14)	-.056 (-3.27)
Income > $100,000		0.197 (11.07)	-.148 (-14.08)	0.209 5.85
Owns versus rents		0.137 (8.28)	-.039 (-5.80)	0.054 3.17

Results show strong evidence of mutually causality between choice behaviour and attitudes. Attitudes influence choice, but choice also conditions attitudes. A consequence for the I-15 Congestion Pricing Project is that support for the project will grow as the number of subscribers grows, providing that the benefits of subscription can be maintained.

It is now common practice in transport demand modeling to use "sated preference" (SP) data on survey respondents' choices among hypothetical alternatives to extend the forecasting capability of choice models based on observed, or "revealed preference" (RP) data. However, we have provided evidence that suggests that attitudes towards future choices will depend upon all relevant choice experiences of the respondents. Model using stated preference data are likely to yield biased

results if it is assumed that causality is only in the direction of stated preferences affecting choices. For example, in an SP survey aimed at soliciting commuters' responses to improved bus service, current bus users will likely respond more positively to the scenarios that are more favorable to bus, while current car users will respond in the opposite direction. SP responses will depend on choice experiences, and a simultaneous attitude-behavior causal structure is called for when modeling stated preference data.

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