Modelling the Choice of Clean Fuels and Clean Fuel Vehicles

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1. INTRODUCTION

1.1. Objectives

Reducing vehicle emissions levels is particularly important in the South Coast Air Basin of California, which includes the Los Angeles Metropolitan Area and the adjacent and interdependent Orange County, Riverside, and San Bernardino Metropolitan Areas. The climate and topography create ideal conditions for the area's infamous smog; and cars, trucks and buses contribute 88 percent of carbon monoxide emissions and about 50 percent of the ozone components: oxides of nitrogen and reactive organic gases. It is apparent that air quality can be greatly improved if gasoline-powered personal vehicles can be replaced in substantial numbers by vehicles powered by electricity or alternative fuels, such as methanol, ethanol, propane, or compressed natural gas (CNG) (see Sperling, 1988 and National Research Council, 1990, for discussions of the environmental factors associated with specific alternative fuels). While none of these alternative fuels has zero-level emissions (even electricity, if generation is taken into account), they all have lower overall emissions levels than currently available gasoline and diesel fuels; they are considered "clean" fuels for the purposes of this market research study. Personal vehicles are defined for the purposes of the study to be cars or light trucks owned or leased by private individuals.

The objective of this study is to determine the effect on personal vehicle purchase and fuel use of a few important attributes that potentially differentiate clean-fuel vehicles from conventional gasoline or diesel vehicles. By concentrating on quantitative estimation, it is intended that this study complement others aimed at qualitative assessments of the roles of information and uncertainty in consumer acceptance of clean-fuel vehicles (e.g., Turrentine and Sperling, 1991).

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1.2. Vehicle and fueling attributes studied

Clean-fuel vehicles are likely to differ from conventional-fuel vehicles in a number of important aspects involving their costs and operation. Focus group interviews were conducted and expert opinions were sought to define a set of attributes to be included as explanatory variables in the demand models developed in the study. These attributes can be divided into two subsets: generic attributes, and attributes specific to a certain type of vehicle. The generic attributes are: (1) limited availability of refueling stations, (2) limited range between refueling or recharging, (3) prices of the vehicles, (4) fuel operating costs, and (5) perceived emissions levels. Vehicle and fuel costs might be higher or lower than for comparable gasoline vehicles, depending on potential subsidies, incentives, and unknown production and distribution costs. Pollutant emissions by alternative-fuel vehicles are expected to be below the levels for gasoline vehicles, but the postulated emissions levels need to take into account potentially lower emissions from future reformulated gasoline.

In addition to being described by the five main generic attributes, there were vehicle-specific attributes for the classes of gaseous and liquid alternative-fuel vehicles and electric vehicles. For gaseous and liquid alternative fuels, an attribute distinguished (a) dedicated (alternative fuel only) vehicles and (b) multiple-fuel (gasoline and/or the alternative fuel). Multiple-fuel vehicles allow the use of gasoline when alternative fuel is unavailable, but obviously emissions reductions are compromised when gasoline is used. Multiple-fuel methanol- and ethanol-powered vehicles are known as "flexible-fuel" vehicles; gasoline and the alternative fuel can be mixed in any proportion in a single tank, and emissions levels are nonlinearly related to the proportion of gasoline in the mixture. Multiple-fuel CNG- and propane-powered vehicles are known as "dual-fuel" vehicles. They have separate tanks for gasoline and the (pressurized) alternative fuel, and the engine is readily switched to run on either fuel. LPG (propane) dual-fuel vehicles are common in Europe, particularly the Netherlands, and CNG dual-fuel vehicles can be found in Canada and New Zealand.

Different configurations of electric vehicles also were studied. One electric-vehicle attribute distinguished two performance levels: (a) future high performance electric vehicles with essentially the same performance (acceleration) as gasoline cars, and (b) low performance electric vehicles with unspecified reduced acceleration. A second vehicle-specific attribute distinguished two recharging scenarios: (a) recharge available only at home, presumably overnight, and (b) recharge available at both home and the work location.

1.3. Organization

The survey is being conducted as a multi-phase self-administered mail-back (postal) questionnaire mailed to a random sample of more than 3,000 households in the California South Coast Air Basin. The survey is comprised of three phases: (1) an initial contact and short questionnaire to recruit respondents and obtain basic information to customize the subsequent survey Phases, (2) a vehicle-choice stated-preference (SP) survey, and (3) a vehicle usage questionnaire and fuel-choice SP survey for multiple-fuel vehicles.

The development of the entire survey is reported here. The SP methodology is discussed in Section 2. Each of the three survey phases is described in detail. Some preliminary results from the pilot survey are presented in Section 3 to illustrate the information that is being obtained. Conclusions are drawn in Section 4, together with an outline of further research.

2. THE STATED PREFERENCE METHODOLOGY

Previous efforts to forecast demand for clean-fuel vehicles have relied on models estimated from existing market choices, or so-called "revealed preference" (RP) data (e.g., Train, 1980, 1986). Unfortunately, the variation of attributes for existing vehicles is not adequate for providing the necessary sensitivity required for forecasting and policy evaluation. In particular, attributes such as limited fuel availability, limited range, and improved (reduced) vehicle emissions for clean-fuel vehicles are likely to deviate substantially from presently existing situations (Beggs and Cardell, 1980). Predicting the influences of such attributes on choice is the principal goal of the present research. These limitations of traditional SP data motivate a stated preference (SP) approach, in which respondents are asked to express preferences for hypothetical products described in terms of their attributes. Stated preference responses can be elicited in terms of judgmental ratings or ranking tasks, or through choices made from hypothetical choice sets (Louviere, 1988). In this study, choices are made by respondents who are presented with hypothetical choice sets that contain a gasoline vehicle and clean-fuel vehicles, and discrete choice models are estimated on these data. In this way, SP data are used in a similar manner as revealed-preference (RP) data on actual market choices (Louviere and Hensher, 1983; Bates, 1988).

There have been a few SP studies involving clean-fuel vehicles, examples of which are studies of the demand for electric vehicles by Beggs, Cardell and Hausman (1981) and Calfee (1985). The present study extends the previous research in several ways. Among other things, in the present study there is a wider range of clean-fuel vehicles, a sophisticated discrete-choice experimental design is used, fuel choice is introduced for multiple-fuel vehicles, a joint SP-RP analysis is attempted to merge results concerning existing and extended attribute ranges, and there is a much larger sample size than in previous studies.

The complex SP survey tasks required to meet the objectives of this study cannot, in general, be administered as a telephone interview. The remaining alternatives are face-to-face interviews and mail surveys. Resource constraints dictated that the costs of face-to-face interviews, either at homes or central locations, would limit the attainable sample size. The vast land area of the South Coast Air Basin was a contributing factor to the high costs of face-to-face interviews, since the desired spatial distribution of the sample implied extensive interviewer travel. Survey pretesting revealed that an SP mail survey was feasible, especially if the SP choice tasks could be customized to approximate the choice sets that might actually be considered by the each respondent. Pretesting also indicated that, in order to avoid confusion and respondent fatigue, it was important to separate the vehicle choice SP and fuel choice SP for multiple-fuel vehicles. These considerations led to the SP implementation via the three-phase survey described in the remainder of this section.

2.1. Survey Phase 1: Background information

The first phase of the survey involved a recruitment letter, an incentive prize announcement, and a business-reply postcard questionnaire. It was mailed to a random sample of households in the California South Coast Air Basin. The objective was to introduce respondents to the multi-phase survey with a compelling, short recruitment letter and a simple initial survey task.

The postcard questionnaire elicited information on household size, home ownership status, number of drivers, number of vehicles owned or leased, and three characteristics of the respondent's anticipated next vehicle purchase: whether the vehicle would likely be new or used, vehicle type (in eight categories), vehicle price range (in six categories), and fuel economy range (in four categories). The household information will be used to test non-response bias and develop sampling weights (income was not asked because of its negative affect on response). The particulars concerning the respondent's anticipated next vehicle purchase were used to customize the subsequent vehicle choice phase (Phase 3 of the survey).

The pilot sample was comprised of approximately 900 households; and size of the main sample is expected to exceed 3,000 households.

2.2. Survey Phase 2: The vehicle choice SP

The second phase of the survey was divided into three parts: household socio-economic information, detailed questions about the vehicles presently owned or leased by the household, and the SP vehicle-choice tasks. The household information obtained was of the type generally used in revealed preference (RP) vehicle choice models: such as, income, household size and composition, and number of workers. These variables will be tested as segmentation criteria and as explanatory variables in the SP choice models. Some of these data can also serve in developing weights for expanding model results to the sample universe of South Coast Air Basin households.

Five SP choice sets such as the one shown in Figure 1 are contained in each Phase 2 questionnaire. Each choice set consisted of three vehicles: one gasoline vehicle and two alternative-fuel vehicles, the vehicles being described on the basis of the attributes outlined in Section 1. Respondents are asked which one of the three hypothetical vehicles they prefer, then answer additional questions concerning whether or not they would replace an existing vehicle if their first choice was available. The respondents were randomly divided into two groups; one was presented with choice sets that contained one electric vehicle, and the other with choice sets without an electric vehicle. This design allows testing of the effects on choices of including or excluding hypothetical vehicles with greater attribute differences compared to existing vehicles.

The specific experimental design was chosen as a compromise among various competing objectives. The framework of three vehicles per choice set retained the possibility of estimating models which do not necessarily rely on the assumption of independence from irrelevant alternatives. This format required that levels be chosen for 6 or 7 attributes per

On this and the following four pages, we are asking you to choose from among three hypothetical new vehicles.

Suppose that you were considering purchasing a New minivan and the following three vehicles were available:

	Vehicle "A"	Vehicle "B"	Vehicle "C"
Fuel type	Gasoline only	Alternative fuel only	Alternative fuel and/or gasoline
Level of pollution relative to 1991 cars	85% of today's levels	40% of today's levels	40% of today's levels
Fuel cost	6 cents/mile	6 cents/mile	6 cents/mile
Fuel availability	Gasoline available at all stations	All stations have alternative fuel	All stations have alternative fuel
Purchase price	$21,000	$19,000	$17,000
Range in miles between refuelings	300 miles	150 miles	150 miles

13. Given these choices, which vehicle would you choose?
☐ Vehicle "A" ☐ Vehicle "B" ☐ Vehicle "C"

14. If your first choice was not available, which would be your second choice?
☐ Vehicle "A" ☐ Vehicle "B" ☐ Vehicle "C"

15. Would you actually replace one of your current vehicles with your first choice?
☐ Yes ☐ No
↓

If not, would you purchase your first choice as an additional vehicle for the household? ☐ Yes ☐ No

Figure 1: Vehicle choice survey question (example)

Some future vehicles might be able to run on *both* gasoline and an alternative fuel, such as methanol, ethanol, propane, or compressed natural gas. Owners of these vehicles could decide which fuel to use each time they refueled. Fuels might differ in price and in their emissions levels. They might also differ in how far you can drive on a tankful because some fuels are less dense. The alternative fuels might not be available at all service stations.

Suppose you owned a multiple-fuel two-door coupe that ran on both gasoline and an alternative fuel. For each of the four hypothetical situations below, please indicate which fuel you would most likely choose on a regular basis. Assume that you get 32 miles per gallon with both fuels.

SITUATION 1:

	The alternative fuel:	Gasoline:
Price per gallon:	$1.75	$1.25
Availability:	2 out of every 3 stations have the alternative fuel	All stations have gasoline
Range on a full tank:	150 miles	300 miles
Pollution relative to 1991 cars:	60 % of today's levels	85 % of today's levels
I would regularly refuel with:	☐ The alternative fuel	☐ Gasoline

SITUATION 2:

	The alternative fuel:	Gasoline:
Price per gallon:	$1.75	$ .75
Availability:	1 out of every 10 stations have the alternative fuel	All stations have gasoline
Range on a full tank:	200 miles	300 miles
Pollution relative to 1991 cars:	10 % of today's levels	40 % of today's levels
I would regularly refuel with:	☐ The alternative fuel	☐ Gasoline

Figure 2: Fuel type choice survey question (example)

vehicle per choice set. In most cases four levels per attribute were used to cover the range of interest, and to provide for estimation of nonlinear effects. The basic design used to produce the variation in attribute levels was an orthogonal main effects plan for a 4^{21} factorial in 64 runs.

The SP survey tasks were completely personalized, being individually printed using a specifically designed software package that read the experimental design file and the data from an the Phase 1 survey. Each respondent received five of the 64 different experimental design treatments. The design levels of the vehicle price and fuel cost attributes were centered about the midpoints of the category values reported by the respondents in Phase 1, and all hypothetical vehicles were described to be the type that the respondent indicated he or she would next purchase. The order of the attributes in the questionnaire was randomized during printing to eliminate possible bias.

2.3. Survey Phase 3: the fuel choice SP

The third and last phase of the survey had two main parts: detailed descriptions of usage for each of (up to three of) the household's present vehicles, and the fuel-choice SP task. The questions about the present vehicles can be used to estimate inferred shifts in usage between household vehicles, if a limited range vehicle (such as an electrically powered vehicle) is forecasted as replacing an existing vehicle. The underlying relationships between vehicle characteristics and usage patterns are yet to be developed and are beyond the scope of the research reported here.

In the fuel choice SP task, as shown in Figure 2, respondents are told: "Some future vehicles might be able to run on *both* gasoline and an alternative fuel, such as methanol, ethanol, propane, or compressed natural gas. Owners of these vehicles could decide which fuel to use each time they refueled. Fuels might differ in price and in their emissions levels. They might also differ in how far you can drive on a tankful because some fuels are less dense. The alternative fuels might not be available at all service stations." For each of four hypothetical situations, respondents are then asked to choose which fuel they would most likely choose on a regular basis. In each of the four situations, the alternative fuel and gasoline choices are each described in terms of four attributes manipulated according to an experimental design similar to that used in the vehicle choice SP. The four attributes are: price per (equivalent) gallon (four levels for both fuels), availability (where gasoline is always defined to be available at all stations, and the alternative fuel has four levels of limited availability), range on a tankful (four different levels for each of the two fuels), and pollution (four different levels for each of the two fuels).

There are 64 experimental design treatments; with four SP task replications per survey, resulting in 16 survey versions on the basis of attribute values. The order of the attributes is once again randomized for each respondent, and the vehicle type and fuel economy of each respondent's anticipated next purchase (from the Phase 1 data) is reproduced on this Phase 3 survey to keep the choices in perspective.

3. PRELIMINARY RESULTS

The response rate for the Phase 1 pilot sample was approximately 34 percent. More than 67 percent of Phase 1 respondents successfully returned Phase 2 surveys as well, yielding an effective Phase 2 response rate of about 22 percent. The Phase 3 response thus far is at least 65 percent of the Phase 2 sample. These are similar to response rates experienced in many other mail surveys, indicating that the complexity of the Phase 2 and 3 surveys did not have an adverse effect on the response rate.

The model results reported below are preliminary, based on the simplest multinomial discrete choice models applied to the small pilot sample. Results of more detailed analyses of the full data set will be reported in future papers.

3.1. A model of vehicle type choice

An initial analysis was accomplished using the Phase 2 pilot data. These data represent the choices of 173 individuals, 88 of whom responded to the survey version containing an electric vehicle in each choice set, and 85 of whom responded to the version containing only gasoline and alternative-fuel vehicles. The repeated choices indicated by each respondent are treated initially as independent choices, leading to a total sample size of 850 choice observations.

Results from a multinomial logit model estimated on the pilot data are displayed in Table 1. Given in the table are the coefficient estimates and associated t-values. The overall model represents a significant explanation of choice, as indicated by the likelihood-ratio chi-square statistics. The coefficient estimates for the attribute levels in each model are generally significant and theoretically supportable. For example, purchase price, fuel price, a dummy variable for slower acceleration, and vehicle emission levels all have negative coefficients, indicating that higher levels of these factors have negative influences on vehicle demand. Range and fuel availability, on the other hand, have anticipated positive coefficients. The results are very encouraging as they lend strong support to the survey design, particularly the selection of the levels of vehicle attributes used in designing the choice sets.

The coefficient estimates of purchase price and fuel price obtained from the SP data are quite comparable to those by Train (1986) that are based on RP data. Purchase price and fuel price are the only two variables that are common between the two models. Train's purchase price coefficient is -0.171 for two-vehicle households with annual incomes greater than $20,000, which best represent the SP sample of this present study. The SP estimate in Table 1, -0.167, is virtually identical to Train's RP estimate. Train's operating cost coefficient is -0.330, while the SP estimate in Table 1 is -0.214. This discrepancy, however, may be due to the large standard error associated with Train's estimate (which is not significant with a t-statistic value of 1.35). Considering that over a decade has elapsed between the two surveys, the similarity between the SP and RP coefficient estimates is noteworthy, and lends strong support to the SP data of the present study.

As noted earlier, only the results of the SP pilot survey are available for this paper, on which only limited model specifications have been tested thus far. Nonetheless, the indications gained appear to warrant further interpretation of the estimation results. The discussion below contains inferences about consumers' valuations of clean fuel vehicle attributes based upon the results so far available. The preliminary nature of the discussion, however, must be kept in mind.

The relative coefficient estimates for purchase price and fuel price indicate that a reduction in fuel cost by one cent per mile is equivalent to a reduction in vehicle purchase price by $1,280. Assuming no discount rate, this implies that the respondents estimated the life-time use of a vehicle at 128,000 miles, a reasonable value for a new vehicle.

Table 1: Multinomial logit vehicle-choice model results for the pilot sample

Attribute	coeff.	t-value
Purchase price ($ * 1000)	-.167	-6.0
Fuel price (ct/mile)	-.214	-9.1
Range (miles * 100)	1.01	12.4
Pollution level (frac. of 1991 gasoline cars)	-1.96	-7.4
Fuel availability (frac. of stations)	1.09	4.9
Low acceleration (electric only)	-.898	-3.6
Charge at work and home (electric only)	-.166	0.7
VEHICLE-TYPE CONSTANTS		
Dedicated alternative fuel vehicle	.388	2.1
Dual alternative fuel/gasoline vehicle	.949	5.2
Dedicated electric vehicle	.267	1.0
Hybrid electric/gasoline vehicle	.103	0.4
Respondents / Choice observations	173 / 850	
Likelihood with 0 coefficients	-933.8	($Rho^2(0)=.193$)
Likelihood with constants only	-922.6	($Rho^2(C)=.183$)
Likelihood with all coefficients	-753.9	

The coefficient estimates suggest negative effects of limited range, limited fuel availability, and low acceleration on the demand for clean fuel vehicles. Suppose the lower energy content of an alternative fuel leads to a reduction of the range between refueling by 100 miles. The coefficient estimates imply that this would be equivalent to an increase in purchase price by approximately $6,000, or, the limited range can be compensated for by lowering the purchase price by $6,000. Similarly, low acceleration of an electric vehicle would be equivalent to a purchase price increase by $5,400; the availability of clean fuel at on average one out of two stations (availability of 0.5) would be equivalent to a $3,300 increase in purchase price.

These deficiencies can be compensated for by the improved pollution level offered by a clean fuel vehicle. For a 25% reduction in pollution, the consumer would be willing to accept a decrease in range of approximately 50 miles; a decrease in fuel availability of about 45%; or a fuel price increase of 2.3 cents per mile.

The estimated alternative-specific constants are positive and significant for the alternative-fuel vehicle types. This reveals that the respondents exhibit strong preferences toward clean-fuel vehicles if they are otherwise identical to the gasoline vehicle. Within this category, dual-fuel vehicles are preferred over dedicated alternative-fuel vehicles. On the other hand, the alternative-specific constants are positive but not significant for electric vehicles. The choice model results provide no indication that hybrid electric/gasoline vehicles are preferred over dedicated electric vehicles. Neither is the ability to recharge at the work location viewed as an added advantage. It is possible that more sophisticated choice models applied to the larger, main survey sample will establish positive values for these electric vehicle enhancements, but the respondents in the pilot sample marginally prefer electric vehicles *ceteris paribus*, and this preference is not amplified by dual-fuel capabilities or non-home recharging capabilities.

3.2. A model of fuel type-choice

The estimation results for a binary fuel type choice model are summarized in Table 2. The model is based on the pilot sample of 118 individuals who responded to the Phase 3 survey, resulting in a data set containing 471 stated choice observations.

Quite notable are the similarities between the vehicle type choice model (Table 1) and the fuel type choice model (Table 2) in the coefficient estimates for range, pollution level and fuel availability. Evidently, the relative valuations of these three attributes are quite similar between vehicle type choice and fuel type choice. The alternative fuel constant is positive but not very significant, indicating that consumers would be not strongly prefer alternative fuels to gasoline if their attributes were identical.

Attribute	coeff.	t-value
Fuel price (ct/mile)	-.585	-9.1
Range (miles * 100)	1.07	7.6
Pollution level (frac. of 1991 gasoline cars)	-1.96	-4.3
Fuel availability (frac. of stations)	1.23	2.9
Alternative fuel constant	.343	1.2
Respondents / Choice observations	118 / 471	
Likelihood with 0 coefficients	-326.5	($Rho^2(0)=.381$)
Likelihood with constant only	-316.4	($Rho^2(C)=.361$)
Likelihood with all coefficients	-202.1	

Table 2: Binary logit fuel type choice model results for the pilot sample

The fuel price coefficients, however, are quite different between the two models. Individuals' valuations of fuel price, relative to their valuations of range, pollution and fuel availability, are much higher for fuel type choice than for vehicle type choice. The results suggest that consumers' long term vehicle type choice may be more strongly influenced by range, pollution and fuel availability, while short term fuel type choice may be dominated by fuel price considerations. (Estimates of logit coefficients are influenced by the variances of the error terms associated with the respective alternatives. As these variances are not observed, only relative coefficient values can be estimated. Thus, the similarity in the absolute values between Tables 1 and 2 may be due to coincidence). Although the generality of these results must be further examined through more rigorous analysis on the full survey data, the results here offer initial insights into consumers' preferences toward clean fuel vehicles and clean fuels.

4. CONCLUSIONS AND DIRECTIONS FOR FURTHER RESEARCH

The SP survey has generated data that are likely to prove valuable in forecasting demand for clean fuels and clean-fuel vehicles. The survey response rates are acceptable, and the initial vehicle choice and fuel choice models yield statistically significant and theoretically supportable results. These results allow estimation of the relative effects on demand of: purchase price, fuel price, fuel availability, vehicle range, and pollutant emission on vehicle and fuel demand, as well as the influences of many vehicle type-specific attributes, such as the dual-fuel option. The results are very encouraging as they lend strong support to the survey design. In particular, the results indicate that the levels of vehicle and fuel attributes used in designing the choice sets are appropriate and meaningful.

Further research is underway or anticipated along several lines. First, competing modelling assumptions will be tested by applying several different choice models to the main sample data; the models to be examined include multinomial probit and nested logit. Second, the Phase 2 and 3 surveys elicited repeated choices from each respondent, and error component models will be used to account for differences in preference across individuals. Third, joint estimation of vehicle choice and fuel choice data (from survey Phases 2 and 3) will be pursued. Finally, the results of this SP analysis will be used to generate a more comprehensive model for car ownership and usage forecasting. This will be done by combining coefficients from both the SP model and an RP model estimated from vehicle make/model/vintage market choice and annual usage data. The coefficients for clean-fuel vehicle attributes, which are only available from the SP model, will be combined with those of conventional vehicle attributes, such as trunk space and vehicle-class choice-specific constants.

REFERENCES

Bates, J. (1988). Econometric issues in SP analysis. *Journal of Transport Economics and Policy, 12: 59-70.*

Beggs, S. and S. Cardell (1980). Choice of smallest car by multi-vehicle households and the demand for electric vehicles. *Transportation Research, 14A: 389-404.*

Beggs, S., S. Cardell and J. Hausman (1980). Assessing the potential demand for electric cars. *Journal of Econometrics, 16: 1-19.*

Calfee, J.E. (1985). Estimating the demand for electric automobiles using fully disaggregated probabilistic choice analysis. *Transportation Research, 19B: 287-302.*

Louviere, J. (1988). Conjoint analysis modeling of stated preferences: A review of theory, methods, recent developments and external validity. *Journal of Transport Economics and Policy, 12: 93-120.*

Louviere, J. and D.A. Hensher (1983). Using discrete choice models with experimental design data to forecast consumer demand for a unique cultural event. *Journal of Consumer Research, 10: 348-361.*

National Research Council, U.S. (1990). *Fuels to Drive Our Future.* National Academy Press, Washington, DC, USA.

Sperling, D. (1988). *New Transportation Fuels: A Strategic Approach to Technological Change.* University of California Press, Berkeley, CA, USA.

Train, K. (1980). The potential market for non-gasoline-powered vehicles. *Transportation Research, 14A: 405-414.*

Train, K. (1986). *Qualitative choice Analysis.* MIT Press, Cambridge, MA, USA.

Turrentine, T. and D. Sperling (1991). The development of the alternative fueled vehicles market: Its impact on consumer decision processes. Presented at 6th International Conference on Travel Behavior, Quebec City, Canada, May 22-24.