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COMMERCIAL FLEET DEMAND FOR ALTERNATIVE-FUEL VEHICLES IN CALIFORNIA*

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Abstract—Fleet demand for alternative-fuel vehicles ('AFVs' operating on fuels such as electricity, compressed natural gas, or methanol) is investigated through an analysis of a 1994 survey of 2000 fleet sites in California. This survey gathered information on site characteristics, awareness of mandates and incentives for AFV operation, and AFV purchase intentions. The survey also contained stated preference tasks in which fleet decision makers simulated fleet-replacement purchases by indicating how they would allocate their choices across a 'selector list' of hypothetical future vehicles. A discrete choice model was estimated to obtain preference tradeoffs for fuel types and other vehicle attributes. The overall tradeoff between vehicle range and vehicle capital cost in the sample was $80/mile of range, but with some variation by fleet sector. The availability (density) of off-site alternative fuel stations was important to fleet operators, indicating that fleets are willing to trade off more fuel infrastructure for changes in other attributes, e.g. increased capital or operating costs, or more limited vehicle range. Public fleets (local and county government) were the most sensitive to the capital cost of new vehicles. Along with schools, they are the only fleet sector where reduced tailpipe emission levels are a significant predictor of vehicle choice. Fleet operators in the private sector base their vehicle selection less on environmental concerns than on practical operational needs. © 1997 Elsevier Science Ltd. All rights reserved

1. OBJECTIVES AND RESEARCH CONTEXT

The potential demand for alternative-fuel vehicles (AFVs) operating on electricity, compressed natural gas, methanol, or other 'clean' fuels can be divided into residential (or personal use) demand and fleet demand. Although our preliminary results indicate that fleets with ten or more vehicles comprise only about 5% of the vehicle stock, they may still be an important source of demand for AFVs. First, there are incentives and mandates emanating from United States clean air and fuel management legislation (U.S. Department of Energy, 1994) that are intended to be direct stimulants of fleet demand. Second, manufacturers are likely to make financial concessions to fleets in order to meet low emissions vehicle sales quotas in California mandated by the California Air Resources Board. Third, the on-site refueling capabilities and mechanical expertise available at many fleet sites may increase the adoption of new fuel technologies. Finally, competitive fuel prices may make certain types of AFVs cost-effective for certain types of fleet operations.

Although it is widely believed that fleet demand will be important to the future growth of alternative-fuel vehicle technology markets, survey data suitable for developing fleet demand models have been generally unavailable before 1994 due to the difficulty of establishing a representative sample of both business and government organizations with fleet operations. The current study provides results from a large, broad-based sample of fleet sites in California.

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The paper is organized as follows: Background and previous research are summarized in Section 2, followed by a description of the 1994 survey in Section 3. Fleet site characteristics are explored in Section 4. Vehicle utilization is analyzed in Section 5. Fleet operator awareness of clean fuel mandates and their near-term AFV purchase intentions are examined in Section 6. A model of vehicle choice that provides insight into the attribute tradeoffs that fleet managers are likely to exhibit when making future vehicle acquisitions in the presence of AFVs is presented in Section 7. Finally, conclusions are drawn in Section 8.

2. BACKGROUND

Previous research on commercial fleets and their potential for adopting alternative fuel technology was initially motivated by the oil crises of the 1970s, and related concerns about reliance on oil as the primary energy source. Alternative fuel vehicles were expected to have lower range, and research focused on the ability of fleets to use these types of vehicles. Examples are Berg *et al.* (1984) and Berg (1985), which were based on a survey of 583 fleets sponsored by the Electric Power Research Institute and the Detroit Edison Company. The sample of fleets was drawn from a list compiled by Dunn and Bradstreet of fleet sites throughout the United States. A randomized survey experiment was used to test the sensitivity of expressed demand to changes in vehicle cost and daily mileage limits associated with switching to electric vehicles. The objective was to obtain an estimate of the market potential for electric vehicles while avoiding more complex and difficult issues associated with dynamics of market penetration (Hill, 1987). Some limitations of the study were: (1) reliance on a commercial list of establishments that excluded certain types of fleets, and (2) limited ability to construct appropriate sampling probabilities to ensure a representative sample. For a more detailed discussion of the sample, see Hill (1993).

Beginning in the late 1980s, the issue of commercial fleet adoption of alternative fuels re-emerged, motivated by concerns about air quality. The introduction of the Clean Air Act Amendments (U.S. Environmental Protection Agency, 1990) and the consideration of regional mandates in California (California Air Resources Board, 1992) highlighted the relative dearth of information regarding the size of various fleet vehicle populations, and how fleet vehicles are actually used. Although the US Census Bureau provides truck inventories every five years, their report falls far short of providing the detailed information needed for policy planning (U.S. Department of Commerce: Bureau of the Census, 1990). Miaou *et al.* (1992) summarize the available fleet vehicle data on composition, operating characteristics, and fueling practices on fleet vehicles, and conclude that the data are sparse and not comprehensive. Thus, there continues to be a need for fleet vehicle studies that can support air quality policy analysis and decision making.

In considering the needs of fleets and their relationship to alternative fuel technologies, a number of working hypotheses have emerged from previous studies and from our own work in this area:

1. Vehicle operating characteristics are important in fleet purchase decisions. Examples of such operating characteristics are direct cost, reliability, and job suitability. Berg (1985) and Miaou *et al.* (1992) provide some support for this hypothesis but their analyses are based on non-representative samples. Secondly, fleet demand for alternative fuels will be related to the availability of on-site refueling and on-site maintenance facilities (at least in the short term). Operating fleets using alternative fuels will require dependable support in areas where many fleets have already developed expertise. Finally, certain vehicle classes, such as vans or pickup trucks, are more likely candidates for alternative fuels because of their lower annual mileage. Berg *et al.* (1984) find some evidence supporting this hypothesis.
2. Larger fleets have a greater potential for innovation, and are more likely candidates to adopt alternative fuels. Larger numbers of vehicles allows more flexibility in re-assigning vehicles among tasks. Larger fleets are more likely to have on-site refueling and maintenance services, leading to even more flexibility in vehicle usage patterns. It is also possible that larger firms reach decisions differently from smaller firms, and are more likely to set policies that take into consideration broader social issues and/or longer term strategic concerns. Hence, they might be more willing to experiment with newer and "riskier" types

of automotive technology. Nesbitt (1993) provided some evidence supporting this notion; however, his study was based on seven focus groups and 29 one-on-one interviews. More data in this area would be desirable.

3. Government and public utility fleets are more predisposed to adopt alternative fuels than are commercial fleets. Many more government and public utility fleets have recently adopted alternative fuels, than have commercial fleets. However, there is little available information to determine whether these fleets are reacting to legislative mandates or to other factors. Given the trend toward increased regulation of vehicle emissions levels, understanding the impact of different types of regulations and legislation on fleet behavior is becoming increasingly important.

The survey results from the California fleet study presented in this paper address these and other issues related to commercial fleet demand for alternative fuels.

3. SURVEY METHOD

The survey sample was obtained from vehicle registration data for the State of California. Rule-based algorithms were developed to exclude households with large numbers of registered vehicles, fleets registered to state and federal government agencies, rental fleets, and fleets composed only of large trucks of greater than 14,000 lb gross vehicle weight (GVW). After application of additional algorithms to identify slight differences in registration names and addresses as likely fragments of the same fleet site, the file was sorted by address to create a sequence of vehicle "fleets". The survey sample was created by selecting from those fleets in the file that had 10 or more registration records. The probability of being chosen was proportional to the number of registration records, giving an equal probability for each vehicle in the target population. This procedure assigns larger sampling probabilities to bigger fleets, in proportion to the number of vehicles registered.

A two-part survey instrument was administered to fleet operators between February and June, 1994. The response to an initial CATI (computer assisted telephone interview) was 71%, once an eligible fleet manager could be identified. Information from this interview was used to produce and send customized mail questionnaires to members of the fleet organization who were identified as the appropriate recipients of various survey questions regarding fleet operations, fleet purchasing decisions, etc. The completed mail-out questionnaires were returned either by mail or fax, and this portion of the survey had an effective response rate of 78%.

Mail questionnaires were composed of three main parts (Golob *et al.*, 1995):

1. Survey data were collected on the basis of seven different *vehicle classes* defined by body type and size (cars, minivans, full size vans, compact pickups, full size pickups, small buses, and medium duty trucks with less than 14,000 lb GVW). Detailed questions were asked about vehicle acquisitions and operations for the vehicle class with the most vehicles at the site, and for a second vehicle class, which was assigned at random from a list of the other remaining vehicle classes operated there (if any). Information was therefore collected for a maximum of two vehicle classes: the purpose of this restriction was to reduce the survey length and minimize non-response. The data collected included: number of vehicles, average annual vehicle miles traveled (VMT) by usage category, how vehicles are maintained, and the manner in which vehicles are disposed of and replaced.
2. A stated preference task (a type of conjoint analysis) was presented for each of the vehicle classes identified in part (1). In each task, a fleet decision maker was asked to simulate a fleet-replacement decision by allocating purchases over a set of three hypothetical future vehicles. Vehicle attributes were manipulated using an experimental design. Vehicles were described in terms of vehicle fuel type (gasoline, electric, compressed natural gas, and methanol), vehicle capital cost, operating costs, range between refueling, refueling times, fuel availability, cargo capacity, and emission levels.
3. Extensive information on attitudes, intentions, and fleet decision making parameters was collected. Attitudinal scale data were collected for a series of AFV acquisition criteria, AFV purchase intention, and opinions about the reliability and safety of different fuel types. We also assessed knowledge and awareness of AFV mandates.

The final sample consists of 2711 CATI and 2131 mail surveys. Most analyses are based on the 2023 responses that remain after excluding the 108 sites with fewer than 10 vehicles.

4. FLEET SITE CHARACTERISTICS

4.1. Fleet sectors

Different types of industries are likely to have different distributions of fleet vehicles due to the varying nature of their activities. However, information on these distributions is not generally known because of the difficulty in obtaining datasets for representative samples of business establishments that include information on fleet vehicles (Wachs and Levine, 1985). Some databases on commercial fleet operators are available, but information on the sample distribution is unknown. Finally, fleets in the public sector are also important, but are not addressed by many data sources. Our survey attempted to obtain a sample of fleet operators that would be as representative as possible for California, while recognizing the relative importance of fleet size when modeling purchases in future vehicle markets.

To examine the effects that might be associated with different types of organizations, we divided our sample into 12 fleet sector categories based on responses to survey questions relating to their activities — see Table 1. With respect to industrial sectors, categories were based on a simplification of SIC codes. There were also fleets from governments and schools. Tables presented in this section are based on our unweighted sample and are likely to provide the most complete and representative results to date for fleets. However, even for our sample the development of rigorous reweighting schemes to correct for various types of sampling bias is problematic, so our results may not be completely reflective of the underlying population of fleet operators.

Table 1 shows that city and county government agencies account for the largest proportion of fleet sites that were contacted (14.4%), but this may also reflect a greater willingness on the part of these fleet managers to participate in a University of California study. The five largest sectors account for about 60% of the fleets in the: government fleets (14.4%), construction and contracting (13%), household services and trades (12.7%), manufacturing (11.4%) and services for business (10%). The sample excludes rental company fleets and those of federal and state government agencies.

4.2. Fleet size

There were approx. 136,000 vehicles represented in the sample, and their distribution across sites is highly skewed towards large organizations. Although approx. 50% of the sample fleet sites had 25 vehicles or less, these sites account for only 13% of the total fleet vehicles. Half of the vehicles are located at fleet sites of 200 vehicles or more.

4.3. On-site refueling and maintenance

On-site refueling capability is a major factor that might cause fleets to adopt clean fuels sooner than households. Although 44% of the overall sample has on-site refueling facilities, the use of

Table 1. Fleet survey sample (by fleet sector)

Fleet sector	Number of fleet sites	% of total	Average fleet size
Agriculture	94	4.6	28
Automotive business or service	66	3.3	22
Banking and insurance	56	2.8	44
City and county government	291	14.4	174
Construction and contracting	263	13.0	30
Household services and trades	256	12.7	30
Manufacturing	230	11.4	49
Miscellaneous industries	32	1.6	113
Retail and wholesale sales	133	6.6	37
Business and professional services	202	10.0	32
Schools (public and private)	195	9.6	65
Transportation and communications	162	8.0	109
Unknown	*43*	*2.1*	*38*

Table 2. On-site refueling capability by site organization type

Fleet sector	On-site refueling capability (%)			
	Has presently	Not now/feasible	Not feasible	Unknown
Agriculture	71	25	4	0
Automotive business or service	24	49	27	0
Banking and insurance	14	11	66	9
City and county government	76	20	4	0
Construction and contracting	41	39	17	3
Household services and trades	20	40	34	6
Manufacturing	41	33	23	3
Miscellaneous industries	28	38	28	6
Retail and wholesale sales	35	38	24	3
Business and professional services	25	32	40	4
Schools (public and private)	72	21	5	2
Transportation and communications	42	27	29	3
Total sample	43.8	30.8	22.4	2.9

such facilities varies widely. Table 2 shows how on-site refueling capabilities vary by fleet sector, according to whether: (1) they currently have on-site refueling, (2) they do not have it now, but either had central refueling in the past or indicated that it was physically possible to have on-site refueling at their location, or (3) they indicated that it was *not* possible to have central refueling.

Fleets that use on-site refueling most frequently are those in agriculture (71%), city and county government (76%) and school (72%) sectors. Fleet sites with considerably less on-site refueling include those in the construction (41%), manufacturing (41%), and transportation/communication (42%) sectors. Fleet sectors that are least likely to have on-site refueling capability are banking and insurance, and business and household services and trades. On-site refueling capability can be a positive factor in the future acceptance of AFVs, because alternative fuels might not be extensively available at service stations until the numbers of AFVs on the road justify the necessary investment in infrastructure.

4.4. On-site maintenance

In the absence of a well-developed AFV service infrastructure, adopting AFVs in the short term might require fleets to rely on their on-site service capabilities. However, the feasibility of this would depend upon cost factors, the ability to train mechanics, and procedures for obtaining parts. Forty percent of the fleet sites in our sample had the capability to service at least two different vehicle classes on-site, while 33% of the sites always contracted out for service. The remaining sites serviced only one of two vehicle classes on-site.

Table 3 lists the maintenance locations for a site's primary vehicle class and one other vehicle class they operate (if any). Fleet sites with small (shuttle) buses are most likely to perform on-site maintenance for those vehicles, while minivans are more likely to be serviced off-site. On-site maintenance is also more common for full size pick-up trucks and medium duty trucks under 14,000 lb GVW.

Table 3. Maintenance locations by vehicle class

Vehicle class	Total fleet sites	Primary maintenance location (%)		
		On-site or at another co. location	Contracted to outside garage/lessor	Other or unknown
Cars	823	42.9	44.2	8.7
Minivans	310	33.6	47.1	19.3
Full size vans	523	43.6	44.4	8.8
Compact pick-ups	560	45.5	40.2	14.3
Full size pick-ups	1019	53.9	32.2	13.9
Small buses	69	63.8	20.3	16.0
Trucks < 14,000 lb GVW	587	52.8	33.6	13.6

5. VEHICLE UTILIZATION

Because AFVs might have shorter refueling ranges and fewer refueling stations than gasoline, the utilization patterns of fleet vehicles could make them very attractive candidates for AFV replacement. Many fleet vehicles follow regular trip patterns associated with well defined duty cycles, and the daily variance in the required vehicle miles of travel (VMT) is small. In these cases, fleets with lower average VMT requirements would find AFV adoption to be more feasible. Table 4 provides the average annual VMT for each fleet sector. Fleet sites in the transportation and communication sector record the highest VMT (approx. 36,000 miles/yr/vehicle), followed by sites in the automotive sector, business services sector, and retail and wholesale trade sector. Schools record the lowest VMT (14,000 miles).

However, evaluating the feasibility of AFVs for fleets through an analysis of aggregated VMT measures is problematic. Because averages are by definition computed across a combination of multiple types of vehicles and multiple vehicle functions within a particular fleet, they do not capture the type of heterogeneity in utilization patterns that would provide the best indicator of AFV feasibility at the individual fleet level. Thus, VMT patterns for fleet vehicles should be analyzed at a greater level of detail, controlling for the effects of vehicle class, usage category, and fleet site characteristics. To augment the results from Table 4, we performed the linear regression analysis reported in Table 5. The dependent variable is annual VMT in units of 1000 miles. Fleet sector coefficients are generally consistent with the results from Table 4, but more detailed interpretations are possible from the regression. Even after conditioning on utilization category, vehicle class, and other fleet site characteristics, VMT continues to vary widely by fleet sector, with the lowest VMT reported by schools. Average VMT for government agencies is not significantly different from VMT for Banking and Insurance, while VMT for the remaining sectors are all greater than in these two sectors.

The R^2 for the regression is 0.094, indicating that there is still substantial variation in reported annual VMT across the individual fleet sites after the effects of various fleet characteristics are taken into account. However, the coefficients of many dummy variable factors are statistically significant based on their *t*-statistics, and these results indicate how these factors could affect average annual VMT. The constant of 16,420 miles provides a baseline VMT from which comparisons can be made.

VMT is negatively associated with very large site size (sites with 500 or more vehicles), supporting the contention that large organizations are better able to rotate their vehicles, or allocate them across multiple drivers. Organizations that have 20 or more fleet sites are also less likely to have a higher VMT per vehicle. However, there is a very large and significant coefficient for the variable which measures how prevalent the primary vehicle class is relative to all other vehicle classes at the site.

Fleet sites that have a limited number of vehicle classes exhibit more extensive vehicle usage, compared to fleets that have a wider variety of vehicle types. It is likely that organizations with a single vehicle type have a more specialized function (e.g. courier services). These regression results confirm that small buses log considerably more miles than other vehicle types, as do vehicles

Table 4. Average annual vehicle miles traveled for all purposes by site organization type

Fleet sector	Average annual VMT
Agriculture	22,300
Automotive business or service	28,300
Banking and insurance	18,400
City and county government	16,500
Construction and contracting	24,500
Household services and trades	22,300
Manufacturing	23,700
Miscellaneous industries	16,700
Retail and wholesale sales	27,900
Business and professional services	28,000
Schools (public and private)	14,000
Transportation and communications	36,000

used in courier services, sales calls, and transportation of people. Significant negative coefficients were found for some interactions of vehicle class and utilization category; these are potentially important fleet market segmentation variables since they correspond to segments where it may be possible to use limited range vehicles.

6. AFV MANDATE AWARENESS AND NEAR-TERM PURCHASE INTENTION

At the time the survey was conducted, there were several mandates affecting fleets. For example, California's Air Resources Board (CARB) required fleets of over 10 vehicles to have at least 10% of their new vehicle purchases to be low emission vehicles. At the time of the survey, CARB had also announced a likely mandate to require vehicle manufacturers selling in California to include zero emission vehicles in at least 2% of their sales (this mandate was subsequently repealed in early 1996). More generally, nationwide regulations by the Clean Air Act of 1990 and National Energy Policy Act of 1992 also affected California commercial fleets. In our survey, respondents were asked whether or not they believed that their site was subject to regulations requiring the use of AFVs. Overall, 28% believed that there was legislation requiring their organization to use AFVs. By sector, 50% of the local and county governments perceived regulation, while only 23.3% of the commercial fleet managers perceived that their site was regulated.

Table 5. Regression of average annual VMT as a function of vehicle utilization category, vehicle class, and site characteristics

	Coefficient	*t*-statistic
Constant	16.42	10.6
Fleet sector dummies (base: city and county government)		
Agriculture	5.89	3.2
Automotive business or service	7.97	3.6
Banking and insurance	−2.57	−1.0
Construction and contracting	5.72	4.3
Household services and trades	4.71	3.4
Manufacturing	2.54	1.8
Retail and wholesale sales	6.75	3.2
Business and professional services	4.50	3.1
Schools	−3.36	−2.4
Other fleet site characteristics (base: 20–119)		
Site size 10–19 (dummy)	−2.57	−3.2
Site size 120–499 (dummy)	−2.87	−2.4
Site size 500 or more (dummy)	−4.18	−1.8
Site is organization's only site in CA (dummy)	−1.41	−1.8
Organization has 20 or more sites in CA (dummy)	−5.74	−2.6
On-site refueling present (dummy)	−1.58	−2.0
Vehicle classs dummies (base: compact pickups)		
Cars	2.00	1.5
Minivans	2.75	1.8
Full size pick-ups	3.01	2.5
Small buses	12.21	4.0
Trucks < 14,000 lb GVW	3.76	2.4
Fraction of fleet that is the primary vehicle class	12.50	8.9
Utlization category dummies (base "other" uses)		
Courier	16.23	4.6
Pickup/delivery	4.68	3.2
Haul equipment	−1.98	−1.6
Service/maintenance	0.056	0.0
Sales calls	10.56	4.5
Transport people	14.45	9.0
Employee use	0.335	0.2
Utilization X type interaction dummies		
Full size pick-up X service/maintenance	−3.60	−2.0
Car X employee use	−4.23	−1.8
Truck < 14,000 lb GVW X pick-up/delivery	−4.55	−1.7
Car X sales calls	−6.49	−2.2
Truck < 14,000 lb GVW X service/maintenance	−6.98	−2.7

Table 6. Binomial probit model of belief that site is subject to AFV mandates base categories are agriculture and site size 20–29

Explanatory variable	Coefficient	*t*-statistic
Automotive business or service	−0.050	−2.40
City and county government	0.131	5.14
Construction and contracting	0.024	1.00
Household services and trades	−0.072	−3.06
Manufacturing	0.059	2.52
Retail and wholesale sales	−0.050	−2.21
Schools	0.089	3.77
Site size 10–14	−0.139	−5.99
Site size 15–19	−0.121	−5.10
Site size 30–59	0.033	1.34
Site size 60–119	0.131	5.44
Site size 120 or more	0.187	7.39
Organization has more than one site in CA	0.047	2.23
On-site refueling present (dummy)	0.129	5.46

A binomial probit model (Maddala, 1983) was estimated to explain differences in awareness of AFV regulation as a function of fleet site characteristics, the dependent variable being coded as: 0 = not aware, 1 = aware. The coefficient estimates for this probit model are listed in Table 6. The R^2 value was 0.23, computed from estimation of the residual variance. City and county government fleets were more likely to perceive that their site is subject to AFV mandates. Manufacturing organizations and schools were also more likely to perceive regulation, and other important predictors of awareness were the presence of on-site refueling, and the size of the fleet.

The propensity to purchase a clean fuel vehicle *within the next two years* was measured in the survey on a five-point scale, where the mid-point choice was 'somewhat likely'. The specific wording was: 'What is the likelihood that one or more alternative fuel vehicles will be purchased for this location within the next two years?' Reliability analysis based on comparing results with a similar question asked in the follow-up mail survey eliminated 125 respondents.

An appropriate regression method for determining differences among fleet sites in terms of stated AFV purchase intentions is the ordered-response probit model (also known as the "ordered probit model"), developed by Aitchison and Silvey (1957) and Ashford (1959). The ordered-response probit model respects the dependent variable as an ordinal scale, not requiring the tenuous assumption of equal intervals between the semantic scale points (Maddala, 1983). Results are listed in Table 7. The R^2 value was 0.22.

Larger fleets are more likely to intend to make an AFV acquisition, even after controlling for sector and on-site refueling. It is likely that size is a proxy for several factors (Golob *et al.*, 1995). First, larger firms have greater ability to absorb risk and liabilities associated with a new vehicle. Second, at an operational level, they find it easier to rotate drivers and vehicle assignments in

Table 7. Ordered-response probit model of stated intention to purchase AFVs base categories are agriculture and site size 20–29

Explanatory variable	Coefficient	*t*-statistic
Automotive business or service	−0.035	−1.58
City and county government	0.180	7.03
Construction and contracting	−0.090	−3.74
Household services and trades	−0.067	−2.82
Manufacturing	−0.061	−2.60
Retail and wholesale sales	−0.032	−1.42
Schools	−0.009	−0.39
Site size 10–14	−0.028	−1.17
Site size 15–19	−0.040	−1.67
Site size 30–59	−0.000	−0.01
Site size 60–119	0.079	3.26
Site size 120 or more	0.232	9.09
Site is organization's only site in CA	−0.041	−1.91
On-site refueling present (dummy)	0.121	5.10

order to accommodate limited range vehicles. Finally, larger firms might be more attracted to the potentially favorable publicity and image associated with use of clean fuels.

Fleet sector (Table 1) is another effective predictor of near-term AFV interest. City and county government, manufacturing, and schools are the most positively inclined to acquire AFVs. Fleet operators at sites in other sectors may perceive that current AFVs will not meet their duty-cycle needs, such as heavy delivery and hauling. On-site refueling is also a significant predictor of purchase intention. Firms that have on-site refueling view it as more practical and feasible to operate AFVs, given that most alternative fuels are currently not readily available at public service stations.

The model results for near-term AFV purchase intention parallel the results from the probit model of perceived awareness of AFV mandates (Table 6), except for schools and manufacturing sectors. Government sites appear more likely to acquire AFVs, as do sites with on-site refueling, and sites with larger fleets. School fleets and manufacturers were also aware of the mandates, but the purchase intention model indicates that these fleets are unlikely to acquire AFVs in the near-term.

7. A STATED PREFERENCE VEHICLE CHOICE MODEL

7.1. *Methodology*

The mail-out portion of the survey was sent to the person who was identified in the initial CATI as being responsible for acquisition of the vehicles at the sampled fleet site. In most instances this was the same respondent that was interviewed by phone, but for some sites a different person was identified. For instance, the vehicle acquisition manager might be at a different location, e.g., the company headquarters. Complicated contact protocols were followed to establish identities and to make appropriate introductions.

Managers responsible for vehicle acquisition were asked to complete a stated preference (SP) task for each of the vehicle classes discussed in Section 3, i.e. each manager completed a maximum of two SP tasks. For each vehicle class, they were asked to imagine that they were going to replace their current vehicles by using a "selector list" of three hypothetical future vehicle types. All three hypothetical vehicles were in the same vehicle class as the current vehicles, but were varied on other attributes according to an experimental design. Vehicles were described in terms of fuel type (gasoline, electric, compressed natural gas, or methanol), vehicle capital cost, operating costs, range between refueling, refueling times, fuel availability, cargo capacity, and emission levels. The format of this task is similar to the survey instruments used in household stated choice tasks (Bunch *et al.*, 1993; Golob *et al.*, 1993), but the respondents in the fleet survey were allowed to choose varying numbers of vehicles to make up their entire fleet for each vehicle class.

The focus of the SP experiment was on new fuel types. There were four possible fuel types in the study: gasoline, electric, compressed natural gas, and methanol. In each task, three of the four possible fuel types were assigned at random. For respondents having two vehicle classes (the maximum), the fuel types were chosen so as to be different for the two tasks. This approach ensured that a respondent would be exposed to all four fuel types. In addition, this has the feature of allowing estimation and testing of models that do not assume the independence from irrelevant alternatives (IIA) assumption with respect to vehicle fuel type (Hausman and McFadden, 1984).

An experimental design was used to manipulate the values of the other 'generic' and 'fuel specific' vehicle attributes, including vehicle capital cost, operating costs, range between refueling, refueling times, and fuel availability. These design variables and their respective set of variation levels used to generate individual SP scenarios are listed in Tables 8 and 9. The specific operating characteristics of the hypothetical vehicles varied from survey to survey according to an experimental design approach (Bunch *et al.*, 1994) that makes use of orthogonal fractional factorials for generating the first alternative in the choice set, followed by a shifting procedure to generate additional choice alternatives in the choice set. Responses from stated preference tasks designed in this manner are analyzed using discrete choice models such as the multinomial logit model. "Experimental choice analysis" is becoming increasingly popular for transportation and marketing applications as an alternative to traditional conjoint analysis because the tasks are simpler and more realistic than those based on judgmental ratings or ranking tasks. A more detailed discussion of this methodology is beyond the scope of the current paper; for a review that includes references to methods and procedures, see Carson *et al.* (1994).

An example stated preference task is reproduced in Fig. 1. This represents only one of the many possible combinations of vehicle descriptions that were used in the survey. Taken together, responses on all these tasks can be pooled to estimate attribute tradeoffs for fleet purchasing decisions.

For our model estimation, the indicated number of vehicles assigned to each fuel type by the respondent was converted to a fraction of the total number of vehicles for that vehicle body type and used as a weight in a maximum likelihood estimation procedure. A weight of zero was assigned to fuel types that were not picked at all by the respondents. This procedure gives each fleet manager's responses equal weight in the estimation regardless of fleet size of number of body types chosen.

7.2. *Choice model results: generic vehicle attributes*

The multinomial conditional logit model (Maddala, 1983) effectively explained the vehicle allocation choices. This model fits the stated choice data well, with a log-likelihood (initial) = −5087.2, a log-likelihood for constants-only model = −4600.7 and a log-likelihood (model) = −4455.9 with 34 degrees of freedom and 2131 observations. This corresponds to a pseudo-R^2 of 0.12. The coefficients are listed in Table 10.

The coefficient for *capital cost* is statistically highly significant, and has the expected sign. The interaction terms involving capital cost and fleet sector dummy variables indicate that city and county government fleet sites are slightly less sensitive to the capital cost of the vehicles compared to most other sectors.

As expected, *range* was found to be an important vehicle attribute, and fleet sites where vehicles are used for transporting people have a significantly smaller coefficient for range. The ratio of the range coefficient (0.00219) to the capital cost coefficient (−0.0000265) indicates that the "tradeoff" between range and capital cost is approx. $80 per mile. In other words, for a given choice alternative, if the range is reduced by one mile, then the associated decrease in utility can be compensated for by reducing the capital cost by $80; such a tradeoff will leave the choice

Table 8. Stated choice task design variables

Generic variable	
Variable	Acronym
Capital cost of vehicle in ($)	Capital cost
Vehicle range (miles)	Refueling range
Number of refueling stations relative to gas stations (gasoline = 1)	Station density
Tailpipe emissions relative to new 1993 gasoline vehicles	Emissions
Electric — specific variables	
Operating cost with overnight recharging (cents/mile)	EV off-peak cost
Operating cost with day–time recharging (cents/mile)	EV peak cost
Number of vehicles with similar fuel type on California roads	EV penetration
Hybrid dummy (0 = battery only/1 = with gas range extender)	EV hybrid
On-site recharging time (hr)	EV on-site time
EV service station recharging time (min)	EV station time
Cargo capacity compared to gasoline vehicles	EV cargo
Compressed natural gas — specific variables	
Operating cost (cents/mile)	NGV operating cost
Number of vehicles with similar fuel type on California roads	NGV penetration
Dual fuel dummy: (0 = NGV only; 1 = can also run on gasoline)	NGV dual fuel
Cost of installing NGV slow-fill refueling on-site ($)	NGV slow-fill cost
Cost of installing NGV fast-fill refueling on-site ($)	NGV fast-fill cost
On-site slow-fill refueling time (hr)	NGV slow-fill time
On-site fast-fill refueling time (min)	NGV fast-fill time
Service station refueling time in (min)	NGV station time
Home refueling unit installation cost ($)	NGV home-fill cost
Cargo capacity compared to gasoline vehicles	NGV cargo
Methanol — specific variables	
Operating cost (cents/mile)	MV operating cost
Number of vehicles with similar fuel type on California roads	MV penetration
Cost of installing methanol refueling on-site ($)	MV on-site cost

probability unchanged. Adding 25 miles of range is equivalent to a $2000 cost premium. Certain sectors, particularly government and manufacturing sites, have a much lower dollar value for range. Fleet sites with personnel transport functions have a higher dollar value for range.

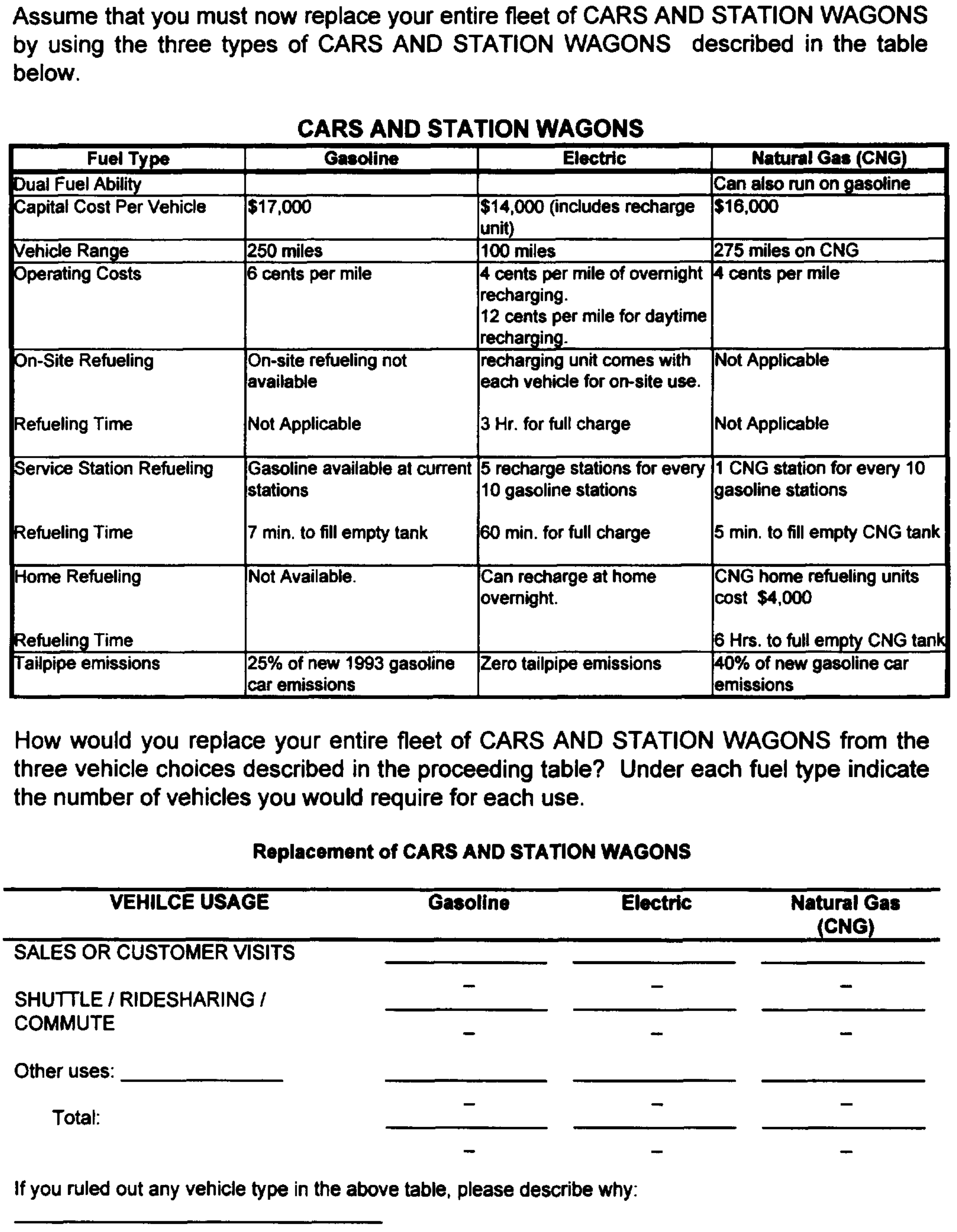
The choice model is specified with one *operating cost* variable for gasoline vehicles, compressed natural gas vehicles (NGVs) and methanol vehicles (MVs), and two operating cost variables for electric vehicles (EVs): operating cost for off-peak (night-time) recharging and operating cost for peak (day-time) recharging. All the coefficients have the correct negative sign. The non-EV operating cost and capital cost coefficients imply that fleet acquisition managers are indifferent

Table 9. Variable variation levels

Name	Unit	Variation level
Capital cost	$	*Cars and station wagons, minivans, full size vans, compact pickups, full size pickups*
		Electric: 14,000; 17,000; 20,000
		CNG: 14,000; 16,000; 18,000
		Methanol: 13,000; 15,000; 17,000
		Gasoline: 13,000; 15,000; 17,000
		Small and medium shuttle buses
		Electric: 80,000; 100,000; 120,000
		CNG: 40,000; 50,000; 60,000
		Methanol: 40,000; 50,000; 60,000
		Gasoline: 40,000; 50,000; 60,000
		Trucks (6000-14,000 GVW
		50,000; 60,000; 70,000
Range	miles	Electric: 60, 100, 150
		CNG: 80, 150, 275
		Methanol: 150, 200, 250
		Gasoline: 250, 300, 350
Operating cost	cents/mile	Electric vehicle cost for day charge
	cents/mile	Electric vehicle cost for overnight charge
	cents/mile	CNG, methanol, and gasoline refueling cost
On-site refueling unit cost	$	CNG slow-fill unit cost: 2000; 3000; 4000
	$	CNG fast-fill unit cost: 75,000; 100,000; 120,000
	$	Methanol on-site pump cost: 45,000; 50,000; 60,000
On-site refueling currently in place	dummy	Gasoline
		= 0 if no on-site refueling
		= 1 if currently has on-site refueling pump (from survey responses)
On-site refueling time	hr	Electric vehicle on-site recharging time: 3, 4, 6
	hr	CNG on-site slow-fill refueling time: 1, 2, 4
	min	CNG on-site fast-fill refueling time: 10, 15, 30
Service station availability relative to gasoline stations	ratio to every 10 gasoline station	Electric: 1, 2, 5
		CNG: 1, 3, 7
		Methanol: 1, 3, 7
		Gasoline: 10
Refueling time at service station	min	Electric: 20, 30, 60
	min	CNG: 5, 10, 15
	min	Methanol: 7
		Gasoline: 7
Dual fuel capability	dummy	Electric vehicle only = 0
		Electric vehicle with gasoline extender (hybrid) = 1
	dummy	CNG only = 0CNG with gasoline capability = 1
Home refueling availability		CNG: 0 = not available
		$2000 = cost of home unit
		$4000 = cost of home unit
		Electric home recharging always available for body type = cars and station wagons
Cargo capacity	relative to gasoline vehicles	Electric: 0.6; 0.7; 0.8
		CNG: 0.7; 0.8; 0.85
		Methanol: same as gasoline
Total vehicles of similar type on road in California		10,000; 50,000; 100,000
Tailpipe emissions	relative to new 1993 gasoline vehicle	Electric: zero
		CNG: 10%, 25%, 40%
		Methanol: 25%, 40%, 60%
		Gasoline: 25%; 60%; 100%

between a capital cost increase of approx. $2200 for a reduction in operating cost of $0.01 per mile. The coefficients for EV operating cost indicate that fleet managers are less sensitive to EV operating costs relative to operating costs for other fuels.

The availability of alternative fuel stations off-site was also important to fleet managers, indicating that fuel infrastructure should be an important element of policies aimed at encouraging the adoption of AFVs. However, reduced tailpipe emissions was found to be a significant predictor of vehicle choice only for the government and school sectors. This indicates that fleet operators in other sectors may be guided by economic and other practical concerns, rather than purely environmental factors, in their vehicle selections. Perhaps local government agencies and schools are the equivalent of "green" consumer in the commercial sector.



Assume that you must now replace your entire fleet of CARS AND STATION WAGONS by using the three types of CARS AND STATION WAGONS described in the table below.

CARS AND STATION WAGONS

Fuel Type	**Gasoline**	**Electric**	**Natural Gas (CNG)**
Dual Fuel Ability			Can also run on gasoline
Capital Cost Per Vehicle	$17,000	$14,000 (includes recharge unit)	$16,000
Vehicle Range	250 miles	100 miles	275 miles on CNG
Operating Costs	6 cents per mile	4 cents per mile of overnight recharging. 12 cents per mile for daytime recharging.	4 cents per mile
On-Site Refueling	On-site refueling not available	recharging unit comes with each vehicle for on-site use.	Not Applicable
Refueling Time	Not Applicable	3 Hr. for full charge	Not Applicable
Service Station Refueling	Gasoline available at current stations	5 recharge stations for every 10 gasoline stations	1 CNG station for every 10 gasoline stations
Refueling Time	7 min. to fill empty tank	60 min. for full charge	5 min. to fill empty CNG tank
Home Refueling	Not Available.	Can recharge at home overnight.	CNG home refueling units cost $4,000
Refueling Time			6 Hrs. to full empty CNG tank
Tailpipe emissions	25% of new 1993 gasoline car emissions	Zero tailpipe emissions	40% of new gasoline car emissions

How would you replace your entire fleet of CARS AND STATION WAGONS from the three vehicle choices described in the proceeding table? Under each fuel type indicate the number of vehicles you would require for each use.

Replacement of CARS AND STATION WAGONS

VEHILCE USAGE	**Gasoline**	**Electric**	**Natural Gas (CNG)**
SALES OR CUSTOMER VISITS			
SHUTTLE / RIDESHARING / COMMUTE			
Other uses: ____________			
Total:			

If you ruled out any vehicle type in the above table, please describe why:

____

Fig. 1. Example of the stated preference choice allocation survey task showing one of 64 experimental treatments.

7.3. *Choice model results: fuel-specific effects*

Even after controlling for range, capital, and operating costs, fleet managers clearly prefer gasoline vehicles over alternative fuels. Gasoline was defined to be the base fuel, and the choice-specific constants for the other three fuels are negative. However, there are many significant interaction terms involving the fuel-choice-specific constants and fleet site characteristics, indicating that there are considerable differences in preferences by market segment:

Agricultural sites have a strong aversion toward electric vehicles (EVs), as do sites operating trucks from 6000 to 14,000 lb GVW. School fleet operators are less negative about EVs, possibly due to their more intense environmental concerns. This is consistent with the awareness among school fleet operators of AFV mandates (Table 6), and the sensitivity of their choices to tailpipe emissions.

Several fleet market segments find compressed natural gas vehicles (NGVs) to be just as attractive as gasoline vehicles, based on their fuel-specific choice constants. These segments include: Large fleets with at least 120 vehicles at the surveyed site, schools, and city and county governments. It is likely that firms with larger fleets have had more exposure to NGVs, are subject to various AFV regulations, and can potentially accommodate on-site refueling. Conversely, preference for NGVs is weakest among fleets in the banking, insurance and real estate sector, potentially because of a low incidence of on-site refueling fuel (Table 2) and relatively low vehicle usage levels (Table 4). The dual-fuel capability of operating NGVs on gasoline substantially increased their acceptability. The coefficient of the dual-fuel variable implies that fleet managers are indifferent between a $11,000 increase in capital cost and adding dual-fuel capability. However, fleet managers also rated cargo space as important, so the reduction in cargo space to accommodate dual-fuel capability partially offsets the dual-fuel advantage. Finally, refueling time at a service station is also an important variable.

Table 10. Conditional logit model of vehicle allocation choice

Explanatory variable	Coefficient	*t*-statistic
Capital cost and fleet sectors = agriculture, automotive business or services, banking and insurance, household services, retail and wholesale sales, business and professional services, schools, or transportation and communication	−0.0000265	−4.78
Capital cost and fleet sector = city and county gov.	−0.0000235	−2.12
Capital cost and fleet sector = construction	−0.0000143	−1.31
Capital cost and fleet sector = manufacturing	−0.0000239	−1.88
Range and utilization category = all except transport people	0.00219	6.39
Range and utilization category = transport people	0.00152	2.77
Station density	0.213	2.27
Operating cost (NGV, methanol, gasoline)	−0.0583	−4.91
Emissions and fleet sector = city/county gov. or = school	−0.409	−2.70
NGV dual fuel	0.294	3.59
EV off-peak cost	−0.0129	−0.41
EV peak cost	−0.0162	−1.62
Gasoline on-site refueling available	0.267	3.49
EV on-site refueling time (hr)	−0.0688	−1.66
EV station time	−0.00468	−1.57
NGV station time	−0.0253	−2.49
Cargo capacity (EV and NGV)	0.147	1.31
EV constant	−0.895	−2.51
EV constant and vehicle class = compact pick up	0.289	2.14
EV constant and utilization category = transport people	0.484	3.39
EV constant and vehicle class = trucks = < 14,000# GVW	−0.395	−2.47
EV constant and utilization cat. = service/maintenance	0.349	3.23
EV constant and fleet sector = schools	0.769	4.16
EV constant and fleet sector = agriculture	−0.632	−1.82
NGV constant	−0.363	−2.43
NGV constant and fleet site size > = 120 vehicles	0.424	3.04
NGV constant and fleet sector = city and county gov.	0.297	2.34
NGV constant and fleet sector = schools	0.439	2.71
NGV constant and fleet sector = retail and wholesale	−0.261	−1.49
NGV constant and fleet sector = banking, ins., real est.	−0.754	−1.95
MV constant	−0.261	−2.95
MV constant and fleet sector = schools	−0.297	−1.70
MV constant and fleet sector = transport. and comm.	−0.268	−1.65
MV constant and fleet sector = agriculture	0.342	1.84

Methanol is the least unattractive of the non-gasoline fuels, as indicated by comparing the fuel-specific choice constants. Many fleet managers are familiar with methanol, and some methanol vehicles are available today. Because all methanol vehicles presented in the stated preference tasks were flexible-fuel, they can also operate on gasoline, which is clearly a preferable attribute. However, preference for methanol vehicles is significantly lower for both school and transportation and communication fleets. In the case of schools, this could reflect a common concern about safety. In contrast, the agricultural sector was more predisposed towards methanol than other sectors. There are several plausible explanations for this, including similarities (and possible confusion) between methanol and ethanol, the ease of conversion between gasoline and methanol, and geographic differences in air quality.

8. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

This investigation has provided new information on preferences for electric and other AFVs from among a wide spectrum of fleet managers. These preferences should be important to governmental policy planners and vehicle manufacturers, because fleet demand is a critical component in US Federal clean air and energy legislation and California mandates for electric and low emissions vehicles. The survey used a complex contact protocol and multiple-stage interview process in order to collect responses from the most appropriate managers in the organization, depending on whether they were responsible for fleet operations, vehicle acquisition decisions, or in some cases, both.

The descriptive analysis pinpointed vehicle utilization as a significant parameter. Although the average fleet annual vehicle miles of travel (VMT) across all fleet sites was 16,420 miles, there was substantial variation across fleet sectors, from a high of 36,000 miles by fleets in the transportation and communications sector, to a low of 14,000 miles by schools. VMT further varies by vehicle class, indicating that fleet operations are highly differentiated. This differentiation was also apparent in fleet managers' awareness of alternative-fuel mandates and their plans for near-term purchases of AFVs.

The stated preference model results also showed that there were major differences in preferences for fuel types among fleet market segments. For example, schools were less negative toward electric vehicles and compressed NGVs, but more negative toward methanol vehicles, relative to the other sectors. There were also substantial differences among fleet market segments in terms of preference tradeoffs for other vehicle attributes. For all fleets on average, the tradeoff between range and capital cost is approx. $80 per mile. The availability of alternative fuel stations off-site was important to fleet managers, indicating that fleets are willing to trade off improved fuel infrastructure for changes in other vehicle attributes. For example, the model coefficients imply that higher capital or operating costs, or smaller vehicle range, can be compensated for by a larger number of alternative fuel service stations. However, reduced tailpipe emissions were found to be a significant predictor of vehicle choice only for the government and school sectors. We found no indication that private fleet operators' vehicle selections are directly influenced by this environmental factor.

The stated preference model provides a basis for forecasting fleets' demand for AFVs. Producing such forecasts requires development of weights to expand the survey sample to represent the entire fleet population. Registration files of the California Department of Motor Vehicles are currently being used to develop these weights. Preliminary results show that for the six county greater Los Angeles region there are approx. 10 million household vehicles, and 430,000 fleet vehicles operated by organizations of the type covered in this report. This suggests that these types of fleets must purchase a disproportionate number of AFVs if they are to be important contributors to meeting clean fuel mandates.

Once the vehicle registration files are processed, we can get more information about our sample fleets' current vehicle holdings. In particular we can get the make, model, and vintage of each vehicle in the fleet. This information can be used to more closely link the fleets' stated preferences to their revealed preferences as evidenced by their past vehicle purchases. Eventually these data could be used to jointly estimate stated and revealed preference models similar to our household models (Brownstone *et al.*, 1994).

We plan to follow all of the sample's fleet vehicles between two "snapshots" of the registration file taken one year apart. This will allow a better measure of the fleets' vehicle replacement policies.

In particular, we will be able to see which fleets purchase new or used vehicles. This information is critical for forecasting the short-run dynamics of fleet purchase behavior.

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