Precursors of Demand for Alternative-Fuel Vehicles: Results from a Survey of 2,000 Fleet Sites in California

Authors
Golob, Thomas F.
Torous, Jane
Crane, Soheila

Publication Date
1994-11-01

UCI-ITS-WP-94-10

Precursors of Demand for Alternative-Fuel Vehicles: Results from a Survey of 2,000 Fleet Sites in California

UCI-ITS-WP-94-10

Thomas F. Golob [1]
Jane Torous [1]
Soheila Crane [2]

[1] Institute of Transportation Studies
University of California, Irvine

[2] Department of Economics and
Institute of Transportation Studies
University of California, Irvine

November 1994

Institute of Transportation Studies
University of California, Irvine
Irvine, CA 92697-3600, U.S.A.
http://www.its.uci.edu

Presented at the 3rd Annual Conference and Exposition for Environmental Vehicles sponsored by the Engineering Society and Society of Automotive Engineers, Dearborn, Michigan, January 24, 1995.

UCI-ITS-WP-94-11

Precursors of Demand for Alternative-Fuel Vehicles: Results from a Survey of 2,000 Fleet Sites in California

UCI-ITS-WP-94-11

Thomas F. Golob [1]
Jane Torous [1]
Soheila Crane [2]

[1] Institute of Transportation Studies
University of California, Irvine

[2] Department of Economics and
Institute of Transportation Studies
University of California, Irvine

November 1994

Institute of Transportation Studies
University of California, Irvine
Irvine, CA 92697-3600, U.S.A.
http://www.its.uci.edu

Presented at the 3rd Annual Conference and Exposition for Environmental Vehicles sponsored by the Engineering Society and Society of Automotive Engineers, Dearborn, Michigan, January 24, 1995.

PRECURSORS OF DEMAND FOR ALTERNATIVE-FUEL VEHICLES: RESULTS FROM A SURVEY OF 2,000 FLEET SITES IN CALIFORNIA

Thomas F. Golob
Institute of Transportation Studies
University of California, Irvine

Jane Torous
Institutes of Transportation Studies
University of California, Irvine

Soheila Crane
Institute of Transportation Studies, and
Department of Economics
University of California, Irvine

ABSTRACT

This research explores factors which influence demand for light-duty alternative-fuel vehicles among commercial and governmental fleets. The data are derived from a large, comprehensive 1994 survey of more than 2,000 fleet sites in California. A model is developed to predict near-term adoption of alternative-fuel vehicles using variables in three categories: (1) fleet site characteristics, including on-site refueling, average annual miles traveled, vehicle duty cycles, and fleet size; (2) organizational decision making attributes; and (3) perceived awareness that a fleet site is subject to legislation that requires the use of alternative-fuel vehicles. This third factor, AFV mandates, is the most important, but a number of fleet site characteristics are also significant precursors of AFV demand.

PRECURSORS OF DEMAND FOR ALTERNATIVE-FUEL VEHICLES: RESULTS FROM A SURVEY OF 2,000 FLEET SITES IN CALIFORNIA

There is considerable interest in learning how fleet managers are likely to evaluate alternative-fuel vehicles (AFV's, also called clean-fuel vehicles). The ultimate question is whether or not fleets will widely adopt vehicles that run on fuels other than gasoline or diesel. The present results are a precursor to the development of a demand forecasting system for future fleet vehicle ownership and use. It is part of a broader project to develop an integrated vehicle demand forecasting system for both households and fleets (Brownstone, *et al.*, 1994).

With the onset of general clean air mandates throughout the country (cf. U.S. Dept. of Energy, 1994) and specific zero-emissions vehicle requirements in California (California Air Resources Board, 1992), it is possible that fleets will be early adopters of emerging clean-fuel technologies. Fleets might be the leading sector for several reasons: First, Incentives and mandates specific to fleets might be a major stimulus of fleet demand. Second, manufacturers might be forced to make financial concessions to fleet purchasers and lessors in order to meet mandated sales quotas. And third, the on-site refueling capabilities and mechanical expertise available at many fleet sites might be key factors in the adoption of the new technologies. Potentially, fleets could provide sufficient demand to encourage economies of scale for the manufacture of newly designed vehicles, because fleets account for about 23% of annual new-car purchases (Miaou, *et al.,* 1992, citing MVMA).

Although it is widely recognized that fleets are critical to the growth of alternative-fuel technologies, survey data needed to develop fleet demand models have been unavailable. This is 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. This 1994 California Fleet Site Survey was based on a comprehensive sample derived from motor-vehicle registration records. The survey response rate was in excess of 70%.

In this paper we explore the characteristics of fleet sites, specifically: (1) the distribution of fleets by sector, (2) the number of vehicles at sites grouped by size, (3) the availability and use of on-site refueling, (4) vehicle use and annual mileage by vehicle type, (5) fleet operators' awareness of clean fuel mandates, and (6) organizational decision making styles. Next, we build upon the descriptive results to develop a model to explain near-term AFV intentions. Many of the characteristics are shown to be predictors in this model. It is important to note that the decision to purchase an AFV within the next year or two is distinguished from other types of vehicle purchases and general fleet decisions. There are a number of constraints today that may not exist in the future, such as limited refueling and repair infrastructures, uncertainty of resale value, and general performance and reliability issues. The present study examines decision making under these constraints, and studies the characteristics of early innovation.

PREVIOUS RESEARCH

We begin by identifying contributions from previous research. Following the energy crisis of the 1970's, there was a burgeoning of interest in alternative fuel vehicles. Research from this period focuses on the ability of fleets to use low-range vehicles, and the willingness of fleet managers to trade-off factors such as mileage and operating cost (e.g., Berg, *et al.*,1984, and Hill, 1987).

In the late 1980's a new set of research priorities emerged. There was a desire to enumerate the number of fleet vehicles and how they were used at sites (e.g. Wachs,*et al.*, 1985). The interest coincides with the introduction of the Clean Air Act nationally, and the consideration of local mandates in California. Although the Census Bureau details truck inventories every five years, the report does not have sufficient detail for many fleets (Truck Inventory, 1990).

A third strand of research began in the late 1980's and continues today. There are a growing number of marketing-based studies, which are commissioned by utilities, fuel suppliers , vehicle trade associations, and others. These studies parallel the commercial introduction of a small number of electric, methanol, and compressed natural gas vehicles. Some of the studies concentrate on segments of existing or likely alternative fuel users and elicit basic operating detail, and attitudinal and opinion measures. A variety of research techniques are used, from focus groups to more large scale-surveys (e.g. Runzheimer, 1993; Macro, 1994).

Finally, there is a small, but increasingly valuable body of findings accumulating from alternative fuel vehicle fleet trials. The trials have used a variety of different vehicle vehicle-types, and test a number of different fuels, primarily methanol, compressed natural gas, and electricity (e.g. Batelle, 1994).

There is, of course, a larger literature on the demand for alternative fuel vehicles by households, yet provocative concepts from these studies have not been applied to fleets. For example, it is not known whether there is a fleet analogy for the construct of a "green" consumer -- that is, a certain type of individual (firm) that is more environmentally conscientious in its (fleet) decision making activities. Another issue which has not been tested is the substitution and reassignment of vehicles under low-range conditions. Seemingly, fleets have a greater capacity than households to re-assign vehicles to different routes and drivers. On the other hand, issues of safety, insurance cost, and risk associated with a new technology may be more salient to fleets because of their corporate liability.

Several major findings emerge from descriptive studies of fleet demand for alternative-fuel vehicles (AFV's):

(1) *Operating characteristics are of foremost importance.* Fleet decision making is believed to be rational and based on objective criteria such as direct cost, reliability, and job suitability (Berg, 1985, Miaou *et al.*, 1992). AFV purchase intentions vary according to the availability of on-site refueling and the operational uses of the vehicles. There are also indications that certain vehicle classes, such as vans or pick-up trucks, are more likely candidates for alternative fuels because of their refueling patterns and lower annual mileage. (Berg *et al.*, 1984).

(2) In the industrial organizational literature it is believed that *larger firms and fleets are more likely to adopt innovation* than smaller ones (Mansfield,1968). Extrapolating to fleets, it may be that larger firms can reassign vehicles among drivers or can more readily adopt new operating procedures. They may also have better on-site capability, like on-site refueling and service. Another explanation is that large firms reach decisions differently: there is a characteristic of decision making that makes them more willing to experiment and "risk" new technology.

(3) The literature shows that *government and public utility fleets are currently more willing than commercial fleets to use alternative fuel vehicles.* Since many fleet studies precede important new regulations on AFV adoption, it is not known whether fleets are reacting to mandates, or to other factors. As a recent study observes (Easton Consultants, 1991), mandates will become of increasing importance to all fleets.

There are three categories of factors that appear to be key to fleet decision making about alternative fuels. First, there are a number of *fleet-specific factors* that will influence the ability to use alternative fuels such as the presence of on-site refueling, vehicle use and mileage, and vehicle type. Second, *organizational factors* also appear to be key to understanding future alternative fuel use. We do not understand why fleets that have similar characteristics, like duty cycle and mileage, make different decisions to adopt or test alternative fuels. Finally, there is recognition that *mandates and incentives* are playing an increasingly larger role in alternative fuel decisions, as the dates approach for implementing various clean-fuel regulations.

We explore the role of each of these factors, and their interactions, through a descriptive analysis of the 1994 California Fleet Survey data set.

SAMPLE SELECTION AND SURVEY DESCRIPTION

Sampling fleets reliably and systematically has been one of the most intractable problems for researchers (Hill, 1993). In this study extensive work was undertaken to develop a representative sample. Existing samples and fleet lists were examined for their completeness and deemed unacceptable. Negotiations were then made, through various state agencies, to gain access to lists of state motor vehicle registrations in California. Rigorous protocols were incorporated to ensure that individual respondents were de-identified, and that the data-set could not be used for commercial purposes.

The final sample is based upon a proportionate sample of vehicles registered to sites with 10 or more registrations. Rule-based algorithms were developed to exclude households with large numbers of registered vehicles, and to identify slight differences in registration names and addresses as likely fragments of the same fleet site. The final sample excluded fleets registered to state and federal governments, rental and leasing fleets, emergency vehicles, and fleets composed only of large trucks (>14,000 lbs. GVW). State and federal government fleets were deemed to be the subject for future research.

Following a pre-test, 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 survey was used to customized a mail survey, which had an effective response rate of 78%.

The customized follow-up mail survey was composed of three main parts:

(1) Detailed questions were asked about vehicle acquisitions and operations for the largest vehicle class at the site, and for a second vehicle class, which was assigned at random from the list of other vehicle classes (if any) operated there. The number of vehicle classes for which detailed information was elicited was restricted to two in order to reduce the survey length and minimize non-response. For each vehicle type, questions included the number of vehicles and their average annual vehicle miles traveled (VMT) by usage category, how they are maintained, and the manner in which the vehicles are disposed of and replaced.

(2) A stated preference (conjoint analysis) choice task was presented for each vehicle class. In each task, the respondent was asked to allocate future fleet acquisitions from a set of hypothetical future vehicles defined according to an experimental design. Manipulated in that design were the vehicle fuel type (gasoline or diesel, electric, compressed natural gas, and methanol) and vehicle attributes, including vehicle capital cost, operating costs, range between refueling, refueling times, and fuel availability. Results from the choice-task will be reported in future research.

(3) Extensive information was compiled on attitudes, intentions, and fleet decision making. The attitudinal questions involved importance scales for a series of AFV acquisition criteria, the likelihood of future AFV acquisition, and opinions about the future prominence, expected reliability, and safety of specific AFV fuel types.

The final sample consists of 2,711 CATI and 2,131 mail completions. This report is based on 2,023 responses that exclude 108 sites that had less than 10 vehicles in operation at the site. The excluded sites tended to be either very small companies that eluded the screening for 10 vehicles or more, or fragments of much larger organizations that were already in the sample.

Survey weighting will be based on comparisons between the survey sample and the entire fleet inventory that can be identified through processing of the complete State of California vehicle registrations file. This weighting is not available at the present time.

FLEET SITE CHARACTERISTICS

INDUSTRY SECTORS: It is not widely known how vehicles are distributed across various industries, because a random sample of business establishments does not generate a representative sample of those that operate fleets. We provide some preliminary data about businesses that operate fleets, with the caution that non-response may have varied across industry segments. Sample weighting, when available, should reduce such potential biases.

The industry classification was developed through a two-step process. First, fleet managers were asked to classify their organization in one of 12 categories and provided additional operating information. Since there were known inconsistencies, each entry was manually reviewed and cross-classified by trained coders. Using this method, only about 2% of organizations could not be classified. Definitions of the categories are self-explanatory, although businesses within service-industries were the most complex to code.

City and county government agencies account for the largest proportion of fleet sites that were contacted (14.4%), but this may also partially reflect a greater likelihood on the part of these fleet managers to participate in a University of California Study. About 60% of the fleets in the sample were in five of the thirteen sectors: government fleets (14.4%), construction and contracting (13.0%), household services and trades (12.7%), manufacturing (11.4%) and services for business (10.0%). Note that the sample excludes rental company fleets and those of federal and state government agencies.

TABLE 1: Sample Breakdown by Industry Sector

Industry	Number of Fleet Sites	% of Total
Agriculture	94	4.6
Automotive Business or Service	66	3.3
Banking & Insurance	56	2.8
City & County Government	291	14.4
Construction & Contracting	263	13.0
Household Services and Trades	256	12.7
Manufacturing	230	11.4
Miscellaneous Industries	32	1.6
Retail & Wholesale Sales	133	6.6
Services for Business & Professional Orgs.	202	10.0
Schools (public & private)	195	9.6
Transportation & Communications	162	8.0
Unknown	*43*	*2.1*

FLEET SIZE: Fleet size is another variable that is difficult to assess from published research because previous studies have often been confined to one or two key industries. The size of the fleet is believed to be correlated with the willingness to adopt innovation, as well as the availability of on-site refueling, vehicle specialization potential, different replacement policies, and other key AFV demand factors.

The relationship of vehicle count to site size is detailed in Figures 1 and 2. There were approximately 136,000 vehicles in the sample, but their distribution across sites is highly skewed towards large organizations. While approximately 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 in fleet sites of 200 vehicles or more. This skewed distribution suggests two different approaches to alternative fuel diffusion. If the goal is to place many vehicles in service, the key may be to reach a few select organizations. If the goal is to influence many individual firms, then an effort might be concentrated on smaller fleets.

ON-SITE REFUELING AND MAINTENANCE: On-site refueling is often considered essential to AFV diffusion because it can reduce reliance upon an outside refueling infrastructure. On-site refueling is one of the essential reasons why fleets are expected to adopt clean fuels in advance of households.

FIGURE 1: Cumulative No. of Vehicles
at 2023 Fleet Sites by Site Size

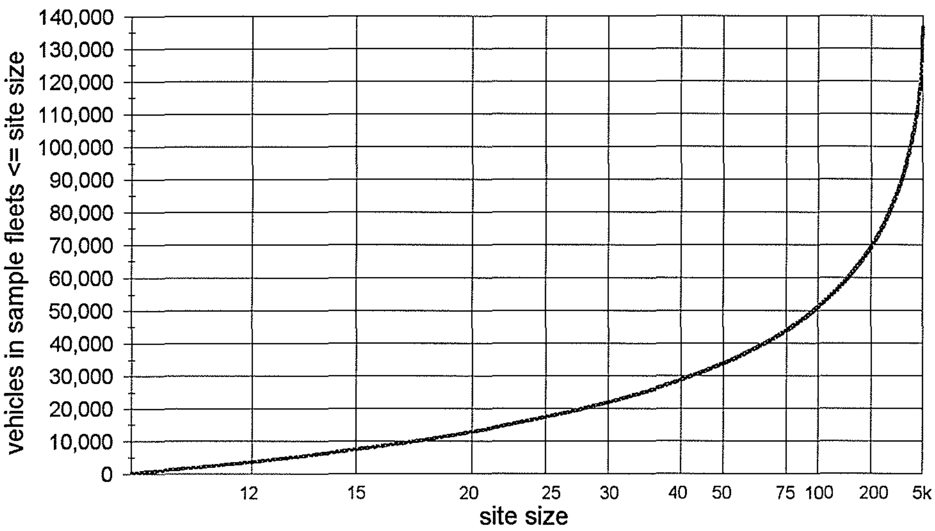
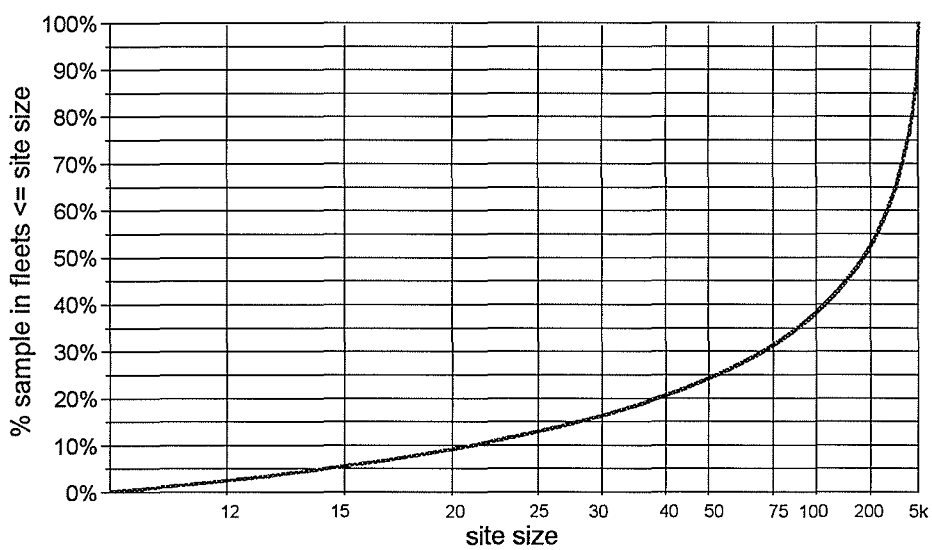


FIGURE 2: Cumulative Distribution of
Sample Fleet Vehicles by Site Size



Although 44% of the overall sample had on-site refueling facilities today, the data show that the use of such facilities varies widely. Table 2 shows a breakdown of the sites within each organizational 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. A large percentage of these respondents indicated that on-site refueling is not feasible. There are several factors that might explain this: these vehicles might be housed in smaller fleets, they may be based in dense urban areas, the vehicles might be taken home by employees at night, or the vehicles might be driven in less fixed and predictable patterns.

TABLE 2: On-Site Refueling Capability by Site Organization Type

Industry Or Organizational Classification	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 & Insurance	14	11	66	9
City & County Government	76	20	4	0
Construction & 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 & Wholesale Sales	35	38	24	3
Services for Business & Professional Orgs.	25	32	40	4
Schools (public & private)	72	21	5	2
Transportation & Communications	42	27	29	3
Total sample	43.8	30.8	22.4	2.9

ON-SITE MAINTENANCE: The ability to service and maintain vehicles on-site is often held, along with on-site refueling, to be an important characteristic for alternative fuel vehicle adoption. The absence of a wide-spread AFV service infrastructure suggests that fleets might have to rely on their on-site capabilities in the near term. However, this is dependent upon cost factors, the ability to train mechanics, and procures for obtaining replacement parts.

In the sample, 40% of the fleet sites in the sample had the capacity to service at least two different vehicle classes on-site, while 33% of the sites always contracted out for service. The remaining sites in the sample serviced only one of two vehicle types on-site (recalling that survey respondents provided detail for a maximum of two different vehicle classes).

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

TABLE 3: Maintenance Locations by Vehicle Type
Combined for Primary Vehicle Type And at Most One Other Vehicle Type

Vehicle type	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
Mini-vans	310	33.6	47.1	19.3
Full-size Vans	523	43.6	44.4	8.8
Compact Pickups	560	45.5	40.2	14.3
Full-size Pickups	1019	53.9	32.2	13.9
Small Buses	69	63.8	20.3	16.0
Trucks <14,000 lbs. GVW	587	52.8	33.6	13.6

VEHICLE UTILIZATION

Vehicle miles of travel (VMT) and other components of fleet vehicle duty cycles are commonly regarded as the most critical component of AFV feasibility. However, aggregate measures of VMT are problematic because averages typically must be computed across the combination of multiple types of vehicles and multiple vehicle functions within a particular fleet. Thus, a decomposition of VMT by vehicle type and function, controlling for fleet site characteristics, is a useful means of assessing vehicle usage requirements. We accomplish this decomposition through regression analysis, which is presented following breakdowns of aggregate VMT by the key variables.

Shown in Table 4 is the average annual VMT *for all functions* for the seven different vehicle classes distinguished in the survey. Small (shuttle) buses have the highest reported VMT, followed by cars, mini-vans, and then full-size (standard) vans. Compact and full-size pickups and medium-duty trucks have the lowest average annual VMT.

TABLE 4: Average Annual Vehicle Miles Traveled for All Purposes by Vehicle Type

Vehicle type	Average Annual VMT
Cars	25,400
Mini-Vans	25,000
Full-size Vans	23,600
Compact Pickups	21,000
Full Size Pickups	21,700
Small Buses	30,000
Trucks <14,000 lbs. GVW	21,900
All vehicles	*23,100*

Table 5 provides a breakdown of average annual VMT by industry sector. Fleet sites in the transportation and communication sector record the highest VMT (approximately 36,000 miles per year per 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), followed by governmental sites, miscellaneous industry sites, and those in the banking and insurance industries.

In Table 6 we examine VMT data by vehicle type and vehicle function. Although the results are interesting, there are some anomalous findings, such as the high mileage posted by pickup trucks used for sales calls, and by those trucks used to transport people. The information does show that buses are the only vehicle class that are not widely used for multiple duty-cycles. It also shows that some applications (e.g., employee-use) imply low VMT. Since the data in Table 6 are based upon several levels of averaging, the results may need to be further decomposed to be meaningful.

A more informative way to investigate the determinants of an average VMT is through a regression analysis, where the effect of a particular factor can be examined while simultaneously taking into account the potential influence of other factors. A regression model was computed to explain annual average VMT as a function of: (1) utilization category, (2) vehicle type, and (3) fleet site characteristics. The estimated regression coefficients and their *t*-statistics are listed in Table 7. The dependent variable is scaled in terms of 1,000 miles. The percent variance accounted for by the regression is 0.094.

TABLE 5: Average Annual Vehicle Miles Traveled
for All Purposes by Site Organization Type

Industry Or Organizational Classification	Average Annual VMT
Agriculture	22,300
Automotive Business or Service	28,300
Banking & Insurance	18,400
City & County Government	16,500
Construction & Contracting	24,500
Household Services and Trades	22,300
Manufacturing	23,700
Miscellaneous Industries	16,700
Retail & Wholesale Sales	27,900
Services for Business & Professional Orgs.	28,000
Schools (public & private)	14,000
Transportation & Communications	36,000

TABLE 6: Annual Average VMT and Number of Vehicles
by Vehicle Utilization Category and Vehicle Type

Vehicle Type		Utilization category							
		courier	pickup/ delivery	haul equip.	service/ mainten.	sales calls	transprt. people	employee use	all other uses
Cars	μ	35,372	30,538		22,266	27,587	25,963	17,435	21,015
	N	16	34		56	188	141	265	279
Mini-vans	μ		33,519		21,479	28,127	21,765	14,704	24,045
	N		42		48	26	51	27	56
Full-size vans	μ		29,110	25,143	20,663		22,048	23,869	15,730
	N		75	46	169		124	23	90
Compact pickups	μ		24,295	21,603	20,033	27,741	16,281	20,600	17,873
	N		74	60	230	27	32	50	102
Full-size pickups	μ		26,587	21,148	18,343	42,023	23,781	24,275	22,748
	N		109	232	460	43	62	111	243
Small buses	μ						31,622		
	N						51		
Trucks < 14k lbs, GVW	μ		25,522	19,694	15,437		39,066		24,042
	N		136	164	153		15		138
All types combined	μ	*39,185*	*27,210*	*20,890*	*18,976*	*29,843*	*24,577*	*19,550*	*21,177*
	N	*43*	*472*	*516*	*1,116*	*295*	*476*	*482*	*915*

Note: Statistics only provided for cells with at least 15 vehicles

The regression results help to highlight patterns inferred from the previous sets of tables (4, 5, and 6). The constant of 16,420 miles provides a baseline VMT from which comparison can be made. VMT varies widely by industry sector, with the lowest VMT reported by schools and the banking and insurance industry. Average VMT for government agencies is not significantly different from the constant, while VMT for the remaining sectors are all greater than this constant.

Interestingly, VMT is associated with site-size; the larger the organization, the lower the annual VMT. This helps support the construct that larger organizations are better able to rotate their vehicles, or allocate them across drivers. Organizations that have more fleet sites are also less likely to have a higher VMT. However, there is a very large and significant coefficient for the variable which measures how dominant the primary vehicle type is relative to all other vehicle types at the site. Apparently, fleets that have more limited vehicle types also make more extensive use of them, compared to fleets that have multiple vehicle types. It is likely that organizations with a single vehicle-type have a more specialized function (e.g. courier services).

The regression results in Table 7 also confirm that small buses log considerably more miles than other vehicles types, as do vehicles used in courier services, sales-calls, and transportation of people. The interaction terms, at the bottom of the table, are instructive, and improve our ability to interpret the VMT averages in Table 6. For example, fleets that use cars for sales calls average about 22,490 miles annually. This level is significantly higher than we would predict if we know singularly that the fleet relied on cars (2,000) and significantly lower than we would predict if we knew that the vehicle was used for sales calls (10,560). By subtracting the interaction term (6,490) from the sum of the constant and other coefficients, we develop a more precise picture of the VMT of cars used for sales. The regression results help to clarify the role of numerous factors, and better identify predictors of high and low usage.

AWARENESS OF AFV MANDATES

Up to this point, the analysis has focused upon objective measures of the fleet site, like the presence of on-site refueling, service capabilities, and annual VMT. In this section, we consider more behavioral measures, since these are also expected to be important predictors of AFV diffusion. We consider two factors: first, the fleet manager's perception of AFV regulation; and second, a classification scheme to describe decision making styles.

TABLE 7: Regression of Average Annual VMT as a Function of Vehicle Utilization Category, Vehicle Type, and Site Characteristics

Explanatory Variable	Coefficient	*t*-statistic
Constant	16.42	10.6
Site type dummies		
Agriculture	5.89	3.2
Automotive Business or Service	7.97	3.6
Banking & 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 & Wholesale Sales	6.75	3.2
Services for Business & Professional Orgs.	4.50	3.1
Schools	-3.36	-2.4
Other fleet site characteristics		
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 type dummies		
Cars	2.00	1.5
Minivans	2.75	1.8
Full Size Pickups	3.01	2.5
Small Buses	12.21	4.0
Trucks <14,000 lbs. GVW	3.76	2.4
Fraction of fleet that is the primary vehicle type	12.50	8.9
Utilization category dummies		
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 Pickup X Service/Maintenance	-3.60	-2.0
Car X Employee Use	-4.23	-1.8
Truck < 14,000 lbs. GVW X Pickup/Delivery	-4.55	-1.7
Car X Sales Calls	-6.49	-2.2
Truck < 14,000 lbs. GVW X Service/Maintenance	-6.98	-2.7

There is a myriad of fleet regulation and mandates. This research did not attempt to measure which fleet sites might actually be subject to clean-fuel mandates or eligible for incentives. Instead, the survey elicited fleet operators' perceptions of whether or not their organization was subject to any regulation requiring the use of alternative-fuel vehicles. Overall, 28% of the sample believed that there was legislation requiring their organization to use alternative fuel vehicles. By sectors, 50% of the local and county governments perceived regulation, while only 23.3% of the commercial fleet managers perceived that their site was regulated.

Awareness of legislation requiring use of alternative fuel vehicles varied systematically across fleet sites in several ways. First, fleet operators at larger sites, and at sites with central refueling facilities, were more aware of such legislation. Second, there was a difference by type of fleets, as shown in Table 8.

A regression analysis was performed to explain differences in awareness of AFV regulation as a function of fleet site characteristics. Because the dependent variable is dichotomous (0 = not aware, 1 = aware), linear regressions will produce biased estimates; and bivariate logit or probit models are called for (Goldberger, 1964; Maddala, 1983). The results are shown in Table 9.

TABLE 8: Awareness of Legislation Requiring Use of Alternative-Fuel Vehicles by Site Organization Type

Industry Or Organizational Classification	% Aware of AFV Legislation
Agriculture	18.1
Automotive Business or Service	22.7
Banking & Insurance	31.5
City & County Government	50.7
Construction & Contracting	25.7
Household Services and Trades	12.6
Manufacturing	29.8
Miscellaneous Industries	12.5
Retail & Wholesale Sales	28.0
Services for Business & Professional Orgs.	18.4
Schools (public & private)	42.7
Transportation & Communications	29.6

Not surprisingly, city and county government fleets were likely to perceive that their site is subject to AFV mandates. Manufacturing organizations and schools were also somewhat likely to perceive regulation. Other important predictors of awareness were the presence of on-site refueling, and the size of the fleet, with larger fleets believing that they are more likely to be regulated.

TABLE 9: Binomial Probit Model of Belief that Site is Subject to AFV Mandates

Explanatory Variable	Coefficient	*t*-statistic
Automotive Business or Service	-0.005	-0.24
City & County Government	0.131	5.14
Construction & Contracting	0.024	1.00
Household Services and Trades	-0.072	-3.06
Manufacturing	0.059	2.52
Retail & Wholesale Sales	-0.005	-0.21
Schools	0.089	3.77
Site size 10-19	-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
Site is Organization's Only Site in CA	-0.047	-2.23
On-site Refueling Present (dummy)	0.129	5.46

ORGANIZATIONAL DECISION MAKING

Decision making is perhaps the least studied attribute of fleet sites, yet it appears to be central to AFV acquisition. A fleet-decision making typology has been proposed by Nesbitt (1993), initially based on Mintzberg's study of multiple organizations' decision situations. Nesbitt's typology is described here and the items are listed in Table 10. Because the organizational decision making variables are dichotomous, the most appropriate measure of their associations is the tetrachoric correlation coefficient, which is an estimate of the correlation in a multivariate normal distribution of the two dichotomous variables in question. A maximum likelihood method has been developed to estimate tetrachoric correlation coefficients based on probit models of each of the two variables and their cross-tabulation statistics (Kirk, 1973; Olsson, 1979).

The matrix of tetrachoric correlation coefficients between all pairs of the organizational decision making variables is shown in Table 11. Only two pair of variables are strongly associated: "Direct choice" is positively correlated with "Few choose," and "Formal rules" is positively correlated with "Costing." These relatively low correlations indicate that the variables can be studied without relying on data reduction methods; applying factor analysis would reduce the seven organizational decision making variables to five factors without substantial loss of information. Consequently, binomial probit models were computed independently for each of the seven decision making criteria to identify which fleet sites have the various decision making characteristics.

TABLE 10: Organizational Decision Making Characterizations (True/False Question)

Characterization of Organization's Decision Making	Acronym
Formal written rules specific fleet policy guide fleet decisions	Formal rules
Detailed cost analyses are used	Costing
Final choices are usually made after formally selected bids	Formal bids
Decisions are usually made with the judgment of 1 or 2 individuals without much involvement from others	Few choose
Decisions are made at the upper management level	Upper level
Very little authorization or approval is necessary	Direct choice
Decisions are made centrally at headquarters, but implemented at individual fleet sites	HQ decides

Table 11: Matrix of Tetrachoric Correlation Coefficients for the Organizational Decision Making Characteristics

	Formal rules	Costing	Formal bids	Few choose	Upper level	Direct choice
Costing	0.536					
Formal bids	0.231	0.342				
Few choose	-0.314	-0.374	-0.262			
Upper level	0.032	0.120	0.009	0.111		
Direct choice	-0.272	-0.299	-0.284	0.634	0.003	
HQ decides	0.292	0.230	0.050	-0.162	0.260	-0.073

The results from a binomial probit model point to different clusters or attributes of decision making style. Not surprisingly, the size of the organization is important with smaller firms (as measured by both total employees and vehicle count) choosing more directly and with less authorization, while larger firms require more formal rules and cost analyses.

The use of formal rules increases with the number of fleet sites, and the majority of fleet decision making appears to be "local". Only multiple fleet-sites are likely to have decision making made centrally at headquarters. Government, school, and construction industry sites all use formal bids for fleet decisions.

TABLE 12: Bivariate Probit Models of Decision Making Characteristics
(t-statistics in parentheses)

Exogenous variable	Endogenous variable						
	Formal rules	Cost-ing	Formal bids	Few choose	Upper level	Direct choice	HQ decides
Automotive Business or Service	**-0.068**	-0.023	**-0.047**	0.022	0.032	-0.006	-0.039
	(-2.95)	(-0.99)	**(-2.03)**	(1.01)	(1.36)	(-0.26)	(-1.66)
City & County Government	0.016	-0.052	**0.215**	**-0.234**	**-0.111**	**-0.205**	-0.044
	(0.59)	(-1.92)	**(7.94)**	**(-9.13)**	**(-4.06)**	**(-7.81)**	(-1.60)
Construction & Contracting	**-0.115**	**-0.079**	**0.053**	**0.095**	0.009	-0.003	**-0.096**
	(-4.57)	**(-3.10)**	**(2.09)**	**(3.98)**	(0.33)	(-0.11)	**(-3.76)**
Household Services and Trades	**-0.096**	**-0.105**	**0.05**	**0.065**	0.005	-0.03	**-0.128**
	(-3.80)	**(-4.10)**	**(1.97)**	**(2.72)**	(0.20)	(-1.21)	**(-5.00)**
Manufacturing	**-0.079**	**-0.08**	**0.075**	-0.004	0.03	**-0.054**	-0.01
	(-3.19)	**(-3.18)**	**(3.00)**	(-0.18)	(1.18)	**(-2.22)**	(-0.39)
Retail & Wholesale Sales	**-0.054**	**-0.072**	0.008	-0.005	-0.037	0.012	-0.011
	(-2.26)	**(-3.00)**	(0.33)	(-0.22)	(-1.53)	(0.51)	(-0.45)
Schools	0.004	-0.048	**0.178**	**-0.177**	**-0.071**	**-0.209**	-0.048
	(0.15)	(-1.88)	**(7.05)**	**(-7.39)**	**(-2.77)**	**(-8.54)**	(-1.90)
Site Size 10-19	-0.037	-0.01	0.005	0.039	**-0.053**	**0.08**	**-0.076**
	(-1.50)	(-0.41)	(0.22)	(1.64)	**(-2.10)**	**(3.29)**	**(-3.02)**
Site Size 15-19	**-0.073**	**-0.104**	-0.001	0.023	0.031	**0.093**	**-0.069**
	(-2.88)	**(-4.09)**	(-0.03)	(0.97)	(1.23)	**(3.80)**	**-2.72)**
Site Size 30-59	**0.058**	**0.087**	**0.059**	**-0.058**	0.046	-0.024	0.022
	(2.23)	**(3.33)**	**(2.26)**	**(-2.34)**	(1.76)	(-0.96)	(0.84)
Site Size 60-119	**0.128**	**0.107**	0.013	**-0.111**	-0.021	-0.047	0.044
	(5.01)	**(4.15)**	(0.50)	**(-4.59)**	(-0.82)	(-1.90)	(1.69)
Site Size 120 or More	**0.117**	**0.113**	-0.005	**-0.104**	**-0.124**	**-0.076**	**0.079**
	(4.34)	**(4.16)**	(-0.17)	**(-4.08)**	**(-4.54)**	**(-2.92)**	**(2.89)**
Site is Organization's Only Site in CA	**-0.099**	(-0.04)	**-0.078**	**0.099**	-0.013	**0.106**	**-0.102**
	(-4.38)	(-1.66)	**(-3.45)**	**(4.61)**	(-0.55)	**(4.79)**	**(-4.43)**
On-site Refueling Present (dummy)	**0.094**	-0.01	0.043	0.021	0.017	0.014	**-0.112**
	(-3.73)	(-0.38)	1.723	0.881	(0.68)	(0.57)	**(-4.41)**
R^2	.082	.062	.079	.172	.053	.128	.056

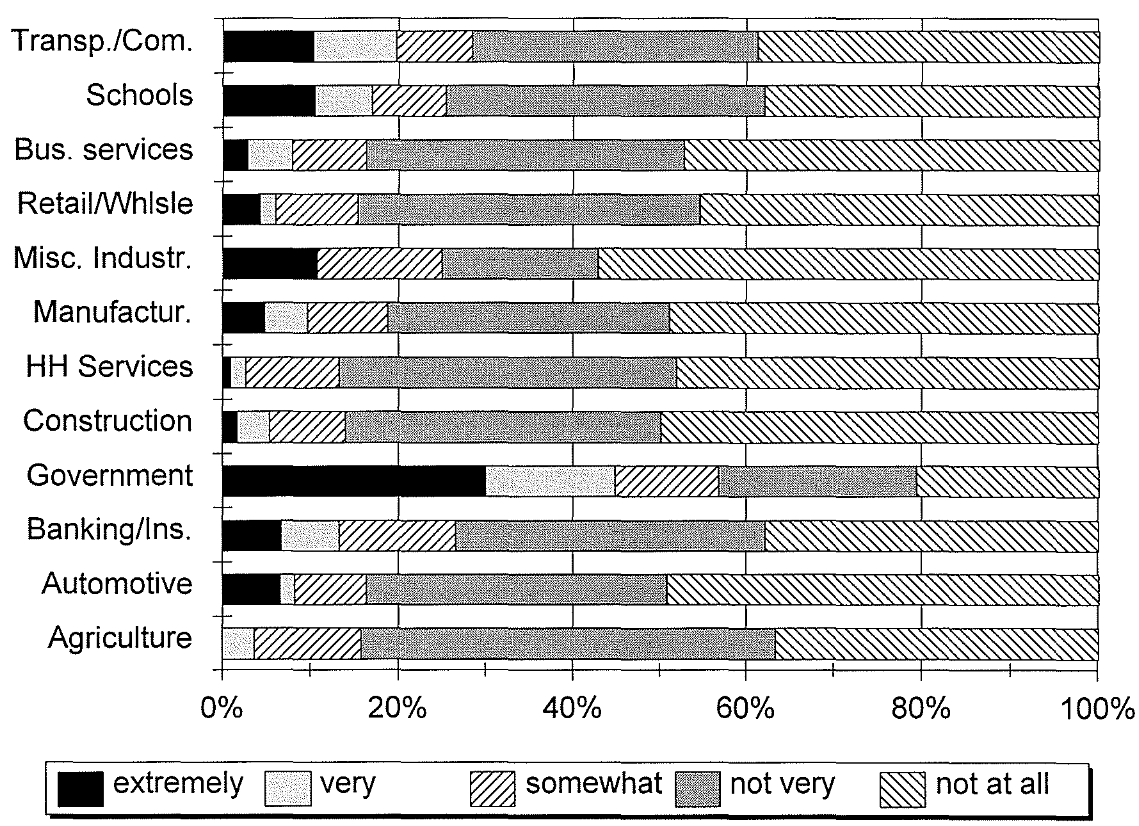
Clearly, more exploration of fleet decision making styles is of descriptive interest. But understanding of these styles may or may not help explain how organizations with fleets will make decisions under new and untested circumstances, such as AFV acquisition in the presence of incentives and mandates.

ANTICIPATED NEAR-TERM PURCHASE OF AFV's

In this section, we apply some of the descriptive information about fleet operations, and fleet decision making to develop a model of *near-term* fleet acquisitions. Specifically, we use a multivariate ordered probit model to explore the interaction between the site-specific measures and the behavioral factors, and to describe the attributes associated with near-term acquisition of an alternative fuel vehicle. The multivariate approach is distinctly superior to the examination of variables independently.

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.

FIGURE 3: Likelihood of Alternative-Fuel Vehicles Being Purchased for Use at the Fleet site by type of Fleet Site



The stated likelihood that alternative fuel vehicles will be purchased for use at the fleet site is independently related to several fleet site characteristics. As expected, larger fleets are more likely to state such an intention, as are fleets with central refueling facilities. Also, certain types of fleets have a different levels of expectancy, as shown in Figure 3. Almost 30% of operators of city and county government fleets stated that AFV purchase in the next two years was extremely likely, followed by about 10% for school, transportation and communications, and miscellaneous industry fleets. Conversely, more than 80% of the operators at seven fleet site types stated that it was either"not at all likely" or "very unlikely" that AFV's would be purchased for their sites. These seven fleet types are: household services and trades, construction and contracting, retail and wholesale, agriculture, business services, automotive sales and services, and manufacturing.

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 13.

TABLE 13: Ordered-Response Probit Model of Stated Intention to Purchase Alternative-Fuel Vehicles

Explanatory Variable	Coefficient	*t*-statistic
Automotive Business or Service	-0.035	-1.58
City & County Government	0.180	7.03
Construction & Contracting	-0.090	-3.74
Household Services and Trades	-0.067	-2.82
Manufacturing	-0.061	-2.60
Retail & Wholesale Sales	-0.032	-1.42
Schools	-0.009	-0.39
Site size 10-19	-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

The model results in Table 13 closely parallel the results from the probit model of perceived awareness of AFV mandates (cf. Table 8). Specifically, government sites appear more likely to acquire alternative-fuel vehicles, as do sites with on-site refueling, and sites with larger fleets. In the previous analysis, school fleets and manufacturers were aware of the mandates, but in the model of Table 13 we see that these fleets indicate that they are unlikely to acquire AFV's in the near-term.

To test the efficacy of firm decision making characteristics, a second ordered-response probit model was computed with the decision making characteristics defined in Table 10 as additional independent variables. Because decision making styles distinguish many larger fleet sites, it was thought that these variables might help explain why larger fleets are more likely to purchase AFV's. The model results are listed in Table 14.

TABLE 14: Ordered-Response Probit Model of Stated Intention to Purchase Alternative-Fuel Vehicles as a Function of Fleet Characteristics and Organizational Decision Making Characteristics

Explanatory Variable	Coefficient	*t*-statistic
Automotive Business or Service	-0.023	-1.07
City & County Government	**0.167**	**6.34**
Construction & Contracting	**-0.069**	**-2.92**
Household Services and Trades	-0.031	-1.30
Manufacturing	**-0.057**	**-2.47**
Retail & Wholesale Sales	-0.024	-1.07
Schools	-0.003	-0.12
Site Size 10-19	-0.014	-0.63
Site Size 15-19	-0.023	-1.00
Site Size 30-59	-0.010	-0.40
Site Size 60-119	**0.056**	**2.36**
Site Size 120 or more	**0.206**	**8.15**
Site is Organization's Only Site in CA	-0.034	-1.60
On-site Refueling Present (dummy)	**0.126**	**5.36**
Formal written rules guide fleet decisions	0.026	1.00
Detailed cost analyses are used	0.050	1.86
Final choices made after formally selected bids	-0.023	-1.01
Decisions with the judgment of 1 or 2 individuals	**-0.067**	**-2.30**
Decisions are made at the upper management level	-0.004	-0.19
Very little authorization or approval is necessary	-0.010	-0.38
Decisions are made centrally at headquarters	**0.047**	**2.05**

Only two of the seven decision making variables are statistically significant in explaining AFV purchase intention: "decisions with the judgment of 1 or 2 individuals" (-) and "decisions are made centrally at headquarters" (+). In addition,"detailed cost analyses are used" was marginally significant (+). These results imply that the decision to acquire alternative fuel vehicles is likely to be made remotely from the fleet site, by coordination among a number of individuals and departments, or by a central staff. The need for upper management decisions might also reflect the perceived uncertainty and non-routine nature of a new AFV purchase. Larger organizations may be more able to adopt innovation.

Finally, Table 15 reveals what happens when awareness of AFV mandates is added to the set of independent variables explaining near-term AFV purchase intention: it is a powerful predictor of intended purchase. Fleet sites with operators that *believe* that they are subject to mandates are far more likely to say that they will acquire alternative-fuel vehicles in the near term. The specter of regulation might be different in the short-term because fleet managers who are acquiring vehicles might judge the current technology to be "pre-market", less reliable, and more uncertain in resale-value. Therefore, it is primarily firms that perceive regulation who may choose to acquire this technology in the near-term.

Contingent on awareness of AFV mandates, none of the decision making variables are significant in explaining AFV purchase intention. However, the results listed in Table 15 identify other characteristics that are associated with the near-term interest in AFV vehicles. Larger fleets continue to be more likely to make an AFV acquisition, even when differences in decision making styles and awareness of AFV mandates are taken into account. It is likely that size is a proxy for several factors: First, larger firms have greater ability to absorb risk and liabilities associated with a new vehicle. Second, on an operational level, they may have greater ability to rotate drivers and vehicle assignments in order to accommodate limited range vehicles. Finally, at an organizational level, larger firms may also be more attracted to the favorable publicity and image associated with use of clean fuels.

Fleet sector also continues to be a significant predictor of near-term AFV interest, even in the presence of awareness of mandates. City and county government fleets are the only sector that is positively inclined to acquire AFV's. Two other sectors, manufacturing and construction, display an opposite tendency of not intending to acquire AFVs. Fleet operators at sites in these sectors may perceive that current AFVs will not meet their duty-cycle needs, such as heavy delivery and hauling. Operational factors might also explain why on-site refueling is a significant predictor of purchase-intention. Firms that have on-site refueling view it as more practical and feasible to operate alternative-fuel vehicles, given the absence of an outside refueling infrastructure.

TABLE 15: Ordered-Response Probit Model of Stated Intention to Purchase Alternative-Fuel Vehicles as a Function of Fleet Characteristics, Organizational Decision Making Characteristics, and Awareness of AFV Mandates

Explanatory Variable	Coefficient	*t*-statistic
Automotive Business or Service	-0.029	-1.46
City & County Government	**0.122**	**4.90**
Construction & Contracting	**-0.087**	**-3.88**
Household Services and Trades	-0.016	-0.73
Manufacturing	**-0.081**	**-3.72**
Retail & Wholesale Sales	-0.026	-1.27
Schools	-0.036	-1.58
Site Size 10-19	0.033	1.55
Site Size 15-19	0.017	0.77
Site Size 30-59	-0.014	-0.62
Site Size 60-119	0.021	0.92
Site Size 120 or more	**0.155**	**6.46**
Site is Organization's Only Site in CA	-0.018	-0.92
On-site Refueling Present (dummy)	**0.083**	**3.75**
Formal written rules guide fleet decisions	0.028	1.14
Detailed cost analyses are used	0.012	0.47
Final choices made after formally selected bids	-0.008	-0.35
Decisions the judgment of 1 or 2 individuals	-0.032	-1.16
Decisions are made at the upper management level	0.030	1.41
Very little authorization or approval is necessary	-0.022	-0.84
Decisions are made centrally at headquarters	0.039	1.80
Aware that site is subject to AFV mandates	**0.348**	**15.54**

SUMMARY AND DIRECTIONS FOR FUTURE RESEARCH

This study began by identifying three different types of information that are critical to our understanding of alternative fuel decisions. We observed the need to enumerate *fleet-specific factors*, such as on-site refueling, site size, and vehicle utilization. We also noted the importance of *organizational factors* associated with decision making, and recognized the growing importance of *mandates and incentives.*

Our research has investigated these three issues, and described their interaction in a single model which attempts to explain the intention to purchase alternative-fuel vehicles in the near term (Table 15). Results demonstrate that AFV adoption is clearly being spurred by public policy. However, several fleet-specific factors also help explain AFV acquisition, namely on-site refueling, fleet size, and industry sector. There was less support for the construct that *organizational-factors*, by themselves, have an influence on near-term demand for alternative-fuel vehicles.

The study has provided a broad set of results to enhance our knowledge about alternative fuel use in fleets. The descriptive data might help us appreciate that city and county government fleets, for example, are willing to adopt the innovation. We observed the highest level of on-site refueling among county and government fleets (Table 2) and these same fleets had the lowest average annual VMT (Tables 5 & 6). County and local government fleets are known to have a broad mix of vehicle types which is also associated with lower VMT (Table 7) since the vehicles may be dedicated to fewer uses. Thus, the descriptive data point to strong operational factors, as well as regulatory ones, that favor near-term AFV penetration within this sector. While the diffusion of this changed vehicle technology by the government sector seems entirely reasonable from the *fleet specific-factors*, there is clearly need for further study. It is curious that the government sector can adopt this change in vehicle technology more rapidly than other organizations, since the *organization factors* (Table 11) characterized its decision making as formal, rule bound, and requiring levels of authorization. This tendency might be explained by the strong influence of perceived mandates and incentives.

Demand for alternative-fuel vehicles might also be stimulated by the concentration of fleet vehicles in large fleet sites (Figures 1 & 2) because larger fleet sites as more likely to acquire alternative fuel vehicles. These large fleets are probably already testing alternative fuel vehicles, and they anticipate that they will continue to do so.

Research underway is aimed at combining the descriptive results illustrated here with data from the stated choice sections of the 1994 California Fleet Site Survey to estimate an AFV demand model.

ACKNOWLEDGMENTS

This research is extracted in part from a project sponsored by Southern California Edison Company, in cooperation with the California Energy Commission and Pacific Gas and Electric Company. The authors first wish to thank our co-investigators on the project -- David Brownstone and Lyn Long of the University of California, Irvine; David Bunch and Ryuichi Kitamura of the University of California, Davis; and Mark Bradley of the Hague Consulting Group -- all of whom have all contributed enormously to the work described in this paper. In addition, Ernest Morales, Richard Rice, and Debbie Brodt of Southern California Edison Co., and Gary Occhiuzzo and Mike Jaske of the California Energy Commission have worked diligently on behalf of the project. None of these kind people or their organizations are responsible for any errors or for the views expressed here.

REFERENCES

Aitchison, J. and S. Silvey (1957). The generalization of probit analysis to the case of multiple responses. *Biometrika*, 44: 131-140.

Ashford, J.R. (1959). An approach to the analysis of data for semi-quantal responses in biological response. *Biometrics*, 15: 573-581.

Batelle (1994). Vehicle Exhaust Emissions -- Early Mileage Results. Clean Fuel Demonstration Project, Statistical Analysis Report No. 4. Prepared for South Coast Air Quality Management District and other agencies by Batelle Memorial Institute, Columbus OH.

Berg, M., M. Converse, D. Hill (1984). Electric Vehicles in Commercial Sector Applications: A Study of Market Potential and Vehicle Requirements. Prepared for the Detroit Edison Company by the Institute for Social Research, University of Michigan.

Berg, M (1985). The potential market for electric vehicles: results from a national survey of commercial fleet operators. *Transportation Research Record,* 1049.

Brownstone, D. , D.S. Bunch and T. F. Golob (1994). A demand forecasting system for clean-fuel vehicles. Presented at the OECD International Conference, Towards Clean Transport: Fuel Efficient and Clean Motor Vehicles, Mexico City, March .

California Air Resources Board (1992). Approval of motor vehicle pollution control devices (new vehicles). *Title 13, Div. 3, Chapt. 1, Art. 2, California Code of Regulations.*

Easton Consultants, Inc (1991). Natural Gas Vehicle Fleet Market Study. Unpublished report prepared for the American Gas Association and the Natural Gas Vehicle Coalition.

Goldberger, A.S. (1964). *Econometric Theory.* Wiley, New York.

Hill, D. (1987). Derived demand estimation with survey experiments: Commercial electric vehicles. *The Review of Economics and Statistics,* 69: 277-285.

Hill, D. (1993). Demand for Commercial Electric Vehicles: A Regional Pilot for a National Survey. Unpublished manuscript, Survey Research Institute, University of Toledo.

Kirk, D.D. (1973). On the numerical approximation of the bivariate normal (tetrachoric) correlation coefficient. Psychometrika, 38: 259-268.

Macro International (1992). NGV Market Assessment. Unpublished Report, conducted for the New England Gas Association.

Madalla, G. S. (1983). *Limited-Dependent and Qualitative Variables in Econometrics.* Cambridge University Press, Cambridge.

Mansfield, E. (1968). *Industrial Research and Technological Innovation: An Economic Analysis.* New York, W.W. Norton and Co.

Miaou, S., P. Hu, J. Young (1992). Fleet Vehicles in the United States: Composition, Operating Characteristics, and Fueling Practices. Paper prepared by Oak Ridge National Laboratory for U.S. Department of Energy. ORNL-6717.

Nesbitt, K. (1993). What Can Alternative Fuel Mandates for Fleets Really Accomplish? Paper presented at the conference, Transportation and Energy: Strategies for a Sustainable Transportation System, Asilomar Conference Center, Pacific Grove, CA, August 22-25.

Olsson, U. (1979). Maximum likelihood estimation of the polychoric correlation coefficient. *Psychometrika*, 44: 443-460.

Runzheimer International (1993). *Business Fleet Refueling Assessment: Final Report.* Conducted by Runzheimer International Ltd, Northbrook, IL, for the Gas Research Institute.

Truck Inventory and Use Survey (1990). U.S. Department of Commerce: Bureau of the Census. U.S. Government Printing Office. Washington, DC.

U.S. Department of Energy (1994). Taking an Alternative Route. prepared by Argonne National Laboratory Energy Systems and Decision Information Systems Division.

Wachs, M. and Levine, N. (1985). Vehicle Fleets in the South Coast Air Basin: Results of a Survey Performed for the SCAQMD. Urban Innovations Group, Los Angeles.