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Poster A03

On the Way or Around the Corner?

Observed Refueling Choices of Alternative Fuel Vehicle Drivers in Southern California

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Introduction

Many challenges remain for commercializing alternative fuel vehicles (AFVs) for consumers. Academics and stakeholders in both public and private sectors cite the lack of a refueling infrastructure as the key barrier to AFV adoption (Melendez 2006). AFV refueling infrastructure build-out is a substantial investment, both economically and politically. Thus, automobile manufacturers are hesitant to produce more AFVs without a robust refueling infrastructure, and fueling stations owners are reluctant to build more facilities without a substantial population of vehicles. This mutual hesitancy is the so-called "chicken and egg problem."

To overcome these barriers and construct an effective refueling station infrastructure, an understanding of AFV driving and refueling behavior is important. We update the landmark 1986 and 1987 studies by Kitamura and Sperling, interviewing 259 drivers of compressed natural gas (CNG) vehicles at five stations in Southern California. Based on observed refueling behavior of CNG drivers in Southern California, what do early adopters of AFVs consider to be **convenient locations for refueling**? Specifically, **when faced with a choice**, do drivers choose the station closest to home or one requiring the least deviation?

These results can help analysts select appropriate optimal facility location models when siting AFV refueling facilities. Models are generally either **point-based** models (e.g., p-median, max cover), or **path-based** (flow-intercepting, flow-refueling). Point-based models would prove more appropriate for early station placement in metropolitan areas if CNG drivers tend to refuel close to home. Refueling along the way between stops regardless of proximity to home points towards using flow-based models.

Survey

Why Los Angeles?

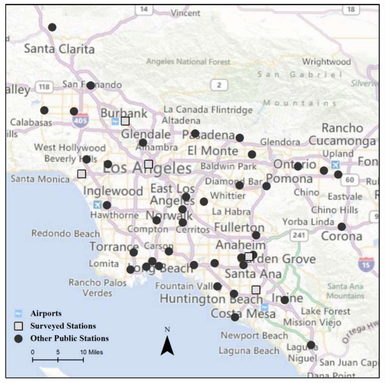
- Public refueling stations – Clean Energy / Trillium
- Commuter incentives
- Polycentric, many land uses
- Honda Civic GX

Intercept methodology, stratified by time of day, n=259.

Questions focused on:

- Socio-demographic information
- Other vehicles in household
- Reasons for owning an AFV
- Reasons for refueling at that particular station
- Stops immediately before / after station
- Home location

Publicly Available CNG Stations



Methodology

Using ArcGIS 10 and Network Analyst

- Least travel-time path between each driver's previous and next stops
- Least travel-time path from previous stop to station to next stop
- **Deviations**
- **Closest Facility Analysis**
  - Travel time between home and *closest* CNG refueling facility
  - Diagnostic for recommending point-based models
- **Least Deviation Analysis**
  - Travel time from previous stop to *all stations* to next stop
  - Diagnostic for recommending flow-based models

Deviation Example

Categorize drivers into 2x2 matrix – did they choose a station that was closest to home or minimized detour? Neither? Both? Then categorize marginal cases, conduct t-tests between independent station choice groups to explore key population differences

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Results

Table 1. Deviation, Closest Facility, and Least Deviation

CNG STATION	MEDIAN DEVIATION (minutes)	% CLOSE TO HOME	% LEAST DEVIATION	MEAN TRIP LENGTH (miles)
Burbank	5.2	30.6	66.0	42.9
Santa Ana	5.7	30.6	54.0	12.2
Santa Monica	6.5	46.0	67.3	18.6
Downtown	4.7	24.0	66.7	30.5
Anaheim	3.1	5.8	58.2	18.9
OVERALL	5.3	27.2	62.2	25.4

Table 2. Categorization of refueling station selection

CATEGORIES	Closest to Home	Not Closest to Home
Least Deviation	"both" 59	"least deviation" 102
Not Least Deviation	"closest" 10	"neither" 88

Table 3. Marginal cases of 2x2 classification, by rank

RANK	Closest to Home	2nd Closest to Home	3rd Closest to Home	4th or More Closest	TOTALS
Least Deviation	"Both" 59	36	"Least Deviation" 15	51	161
2nd Least Deviation	"Closest to Home" 8	13	"Neither" 3	13	37
3rd Least Deviation	2	4	7	8	21
4th or Greater Deviation	0	2	4	34	40
TOTALS	69	55	29	106	259

Although trip lengths varied across the 5 stations, CNG drivers show a consistent willingness to detour 3-6 minutes from their shortest paths to refuel (Table 1). At all 5 stations, less than half of surveyed drivers refueled at the station closest to home, while more than half chose the station on their path of least deviation. As these classifications are not independent, we isolated the choice groups in order to compare the revealed refueling preferences of those that refueled closest to their home vs. those that minimized their detour.

When drivers refueled at a CNG station that is either the closest station to home or the least-deviation station – *but not both* – they selected the latter by an order of magnitude: **102:10** (Table 2). There were 59 drivers who could refuel at a station that meets both criteria and therefore did not have to choose. More interesting, however, are the 88 drivers who chose a station that fits neither criteria.

Table 3 analyzes the marginal cases to see how close drivers came to *almost* selecting a station that was almost closest-to-home or almost least-deviation. Among the 10 who stopped at the station closest to home over the least-deviation station, it was the 2nd-shortest detour for 80%. The same is not true for the 102 who refueled at their least-detour station: 50% of them filled up at a station that was not even 3rd closest to home. Among the 88 drivers who optimized neither criteria, 29 chose the station with the 2nd shortest detour vs. 19 who chose the 2nd closest to home.

Table 4. Summary statistics for independent groups

POPULATION CHARACTERISTIC	BOTH (n=58)	LEAST DEVIATION (n=103)	CLOSEST TO HOME (n=10)	NEITHER (n=88)
% Employed	89	98	90	93
%Male	65.5	61.2	30	60.2
% Home-Anchored	79.3	75.7	60	77.3
% Work-Anchored	60.3	72.8	40	65.9
Average Age	37.5	38.6	38.2	39.8
Most Freq. Tank Level	1/8	1/4	1/8	1/4
Median Trip Distance	6.75 miles	15.18 miles	13.68 miles	21.68 miles
Median Deviation	5.55 min	3.4 min	6.6 min	11.1 min

Summary statistics (Table 4) show little variation across groups. Gender has the most dramatic difference, where the "closest" groups is 70% female. This same group also have the lowest percentage of work-related trips. Group size, however, is very small (n=10).

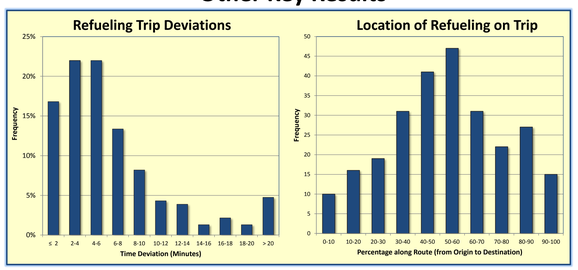
For the two groups that refueled at a station that met only one criteria, t-tests show that deviations differed significantly, but trip length and travel time were not (Table 5). This eliminates the explanation that those who minimize deviations are taking longer trips than those refueling close to home.

Table 5. Difference of means tests: choice groups

ATTRIBUTE	LEAST DEVIATION (n=103)		CLOSEST TO HOME (n=10)			
	$\bar{x}_1$	σ_1	$\bar{x}_2$	σ_2	p_1	p_2
Deviation (minutes)	4.23	4.01	7.12	2.94	.029*	.014*
Travel Time (minutes)	36.73	62.18	28.08	11.36	.663	.227
Trip Distance (miles)	25.65	62.97	15.80	9.44	.623	.156

α_1: Equal variances assumed, α_2: Equal variances not assumed. *significant at α = .05 level

Other Key Results



Closest to Home vs. Least Deviation

Example of refueling routes from origin at work (1), to destination at home (2), where driver is faced with a choice between a CNG refueling station that requires the least deviation from the shortest travel time path (Burbank) or is closest to home (Glendale).

Conclusion and Implications

When no CNG station exists that is both closest to home and most on their way, **ten times as many** drivers refueled at the station that minimized deviation as opposed to the one closest to home.

An additional 88 chose a station that fit neither absolute classification, but many of these drivers were closer to minimizing detour than to refueling closest to home.

Trip distances and travel time were **not** significantly different between the choice groups: those who refueled closest to their home cannot be explained merely by inherently shorter trips.

This empirical evidence suggests that **flow-based location models** may be more appropriate for early infrastructure planning of AFV refueling station locations, rather than point-based models.

Based on these results, we suggest that **the initial wave of AFV refueling stations should be focused along frequently traveled paths of drivers**, such as home-work commute routes.

Related analyses underway (not shown here): (1) Comparison of CNG and gasoline driver refueling; (2) Survey of commercial drivers refueling at another fleet's station; (3) Similar survey of EV public recharging in Phoenix. Other geographies should be examined for consistency.

References

Kitamura, R., Sperling, D., 1987. Refueling Behavior of Automobile Drivers. *Transportation Research A*, 21A (3) 235-245.

Melendez, M., 2006. Transitioning to a hydrogen future: learning from the alternative fuels experience, Technical Report No. NREL/TP-540-39423.

Sperling, D., Kitamura, R., 1986. Refueling and New Fuels: An Exploratory Analysis. *Transportation Research A*, 20A (1) 15-23.