VII.5 Discrete Choice Analysis of Consumer Preferences for Refueling Availability

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Objectives

- Quantify consumer reluctance to purchase an alternative fuel vehicle due to a lack of refueling availability.
- Compare survey results to comparable results derived from analytic models.
- Develop a general discrete choice model for major urban areas.

Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section (4.5) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Future Market Behavior

(D) Suite of Models and Tools

Contribution to Achievement of DOE Systems Analysis Milestones

This project contributed to the achievement of the following DOE milestones from the Systems Analysis section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 3:** Begin a coordinated study of market transformation analysis with H2A and Delivery Models. (1Q, 2006)

Accomplishments

- Redesigned and enhanced the discrete choice survey tool developed in Fiscal Year 2008.
- Fielded the improved survey in four metropolitan areas (Los Angeles, CA; Seattle, WA; Atlanta, GA; and Minneapolis-St. Paul, MN) and attained stated consumer preference data for refueling availability on three geographic scales: metropolitan, regional, and national (along interstates connecting major urban areas).
- Analyzed survey results and determined utility functions and associated cost penalties for limited refueling availability on an equivalent basis as the purchase price of a new vehicle.
- Quantified cost penalties associated with limited refueling availability for each geographic scale and identified general trends among each of the four metropolitan areas.

Introduction

A lack of convenient refueling availability can be a significant deterrent to household consumers considering the purchase of a hydrogen vehicle. Several studies have developed estimates of the number of stations that may be needed to satisfy the refueling availability requirements of early adopters, but only a limited number of studies have attempted to quantify the consumer value, or disincentive, associated with limited refueling availability. This study involves an analysis of consumer responses to a hypothetical vehicle purchase decision posed through a detailed survey tool. The focus of this analysis is to develop representative cost penalties associated with different levels and geographic scales (metropolitan, regional, and national) of limited refueling availability.

The coordination of station and vehicle introductions over time (and space) determines the degree of infrastructure utilization, and therefore significantly influences fuel costs. Understanding the role of consumer preferences for refueling availability in the decision to purchase a hydrogen vehicle can therefore help to inform DOE technical targets related to the cost of hydrogen fuel.

Approach

Discrete choice analysis methods are commonly employed to quantify consumer preferences for similar products with distinct attributes, such as cost, performance, and appearance. In this study, a discrete choice survey tool was used to present a representative panel of households with a hypothetical choice to purchase one of two vehicles: a conventional vehicle and an alternative fuel vehicle (AFV). In choosing which vehicle they would prefer, the respondents took into consideration quantitative descriptions of vehicle attributes such as cost and range, as well as quantitative and visual representations of different levels and geographic scales of refueling availability. In the survey, the AFV was described as being identical to the conventional gasoline vehicle in all respects except two: (1) refueling availability might be more limited, and (2) the AFV would offer significant social and environmental benefits. The AFV was not associated with any particular alternative fuel.

A series of initial screening questions collected information about the participant's driving behavior and acquainted him or her with the setup of the survey, the definitions used to describe vehicle attributes, and the maps used to represent refueling availability on three geographic scales: metropolitan, regional, and nationwide along interstate highways connecting major cities. For example, the "level 2" coverage map used for the Seattle metropolitan area is shown in Figure 1. The corresponding Seattle level 1 indicates fewer stations, level 3 indicates more stations, and the level 4 map indicates equivalent coverage as conventional gasoline stations. Similar maps were used to indicate four levels of refueling availability on regional and nationwide geographic scales. Consumer responsiveness to vehicle purchase price was used to normalize responsiveness to levels of refueling availability, allowing for the determination of cost penalties on an equivalent basis as the purchase price of a new vehicle.

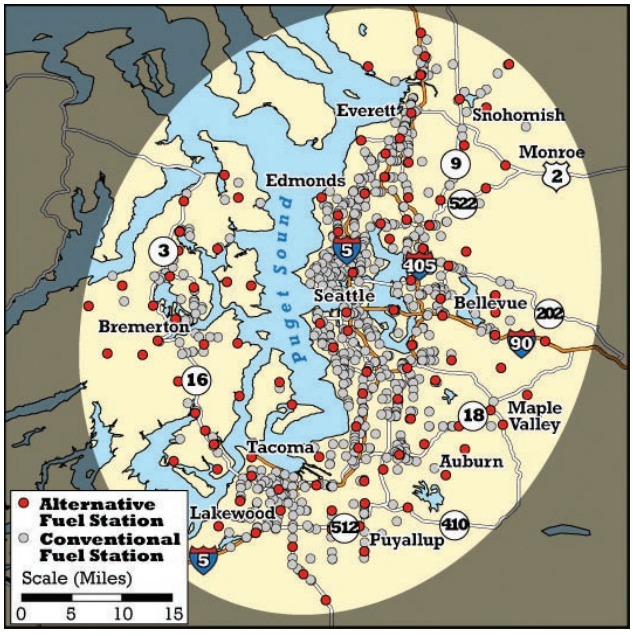

FIGURE 1. Survey Map Example: Metropolitan Coverage for Seattle, WA

Results

The 2009 survey results are an improvement over the 2008 survey results. By comparison, utility functions based upon the 2009 survey data have a moderately increased level of predictive power, include a larger number of statistically significant parameters, and provide more consistent penalty estimates within policy-relevant ranges of refueling availability. These improvements are at least partly due to the improved 2009 survey design, which included more realistic map images, a simplified set of choice task attributes (focusing on refueling coverage and vehicle purchase price), and improved sets of coverage attribute levels (e.g., metro area coverage levels 1 and 2 are more distinct, and level 1 regional coverage is changed from zero to a small number of stations). Cost penalty results associated with metropolitan area coverage are comparable to those found in other discrete choice studies [1-4], and are higher than results from analytic studies based upon "rational" economic models of consumer behavior [5,6]. The metro penalties are significantly lower than those determined from the 2008 survey, and, unlike the 2008 results, the ordering of the cost penalties does not correspond to metro area population density. A new contribution to the literature, from both the 2008 and 2009 studies, is estimation of cost penalties for regional and national geographies. The national penalties from the 2009 survey are slightly higher than those from the 2008 survey, and the regional penalties are comparable in magnitude to the 2008 results but have been captured in greater detail as a result of the improved 2009 survey.

Cost penalties associated with limited coverage on a metropolitan scale are indicated in Figure 2, where the horizontal axis indicates the percentage of existing gasoline stations in each metro area and the vertical axis is the equivalent vehicle purchase price cost penalty. Trend lines emphasize that cost penalties drop as a higher percentage of stations offer an alternative fuel. Penalties range from $1,000 to $3,000 at metro coverage levels below 5% of stations, and drop to between $500 and $2,000 near 10% of stations. Estimated penalties are less than $500 beyond 30% of stations. Figure 3 indicates cost penalties for limited regional coverage, with the horizontal axis indicating the absolute number of stations located within 150 miles of the metropolitan area. Penalties range from $2,000 to $3000 with 10 regional stations. Trend lines suggest that these penalties would drop to between $1,000 and $2,000 with

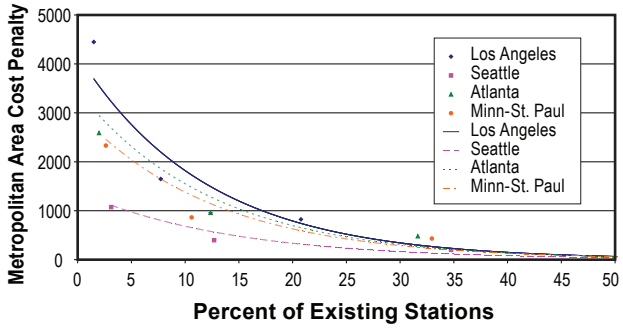

FIGURE 2. Cost Penalties For Metropolitan Coverage

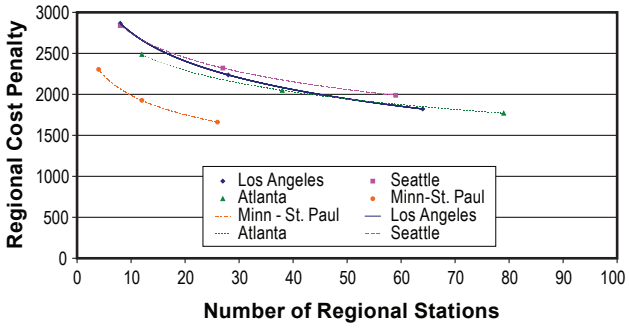

FIGURE 3. Cost Penalties For Regional Coverage

approximately 100 regional stations; a modest reduction given the absolute increase in stations. Interestingly, and somewhat surprisingly, the trend lines shown approach zero close to the estimated total number of stations in each region [7]. Penalties for limited national coverage along interstates are indicated in Figure 4, with the horizontal axis indicating the number of long-distance trips between major U.S. urban areas that would not be viable from each city. The maximum interstate coverage penalties occur when 100% of long-distance trips are not viable (right-hand side of the horizontal axis). The basis of trip numbers between cities is determined using American Travel Survey data. As was the case with analysis of the 2008 survey results, national cost penalties are relatively high, with penalties of roughly $2,500 to $5,000 associated with the last 10% of long-distance trips not covered.

Conclusions and Future Direction

Significant cost penalties appear to be associated with limited refueling availability. The results of the present study are based upon stated preferences, which are more speculative than revealed preference data. Given that revealed preference data on this issue are sparse or non-existent, the survey results attained here do improve our understanding of consumer expectations

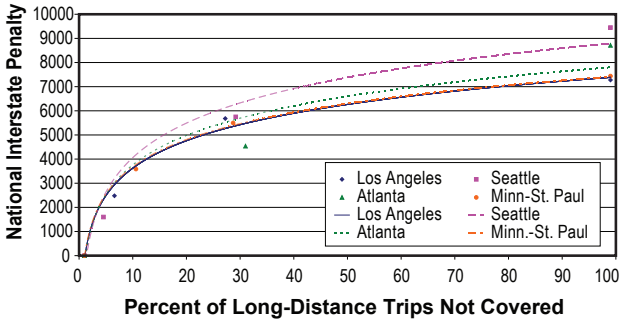

FIGURE 4. Cost Penalties For National Interstate Coverage

and perceptions of the value of refueling availability. Analysis results based upon the improved 2009 survey are consistent with the 2008 results in indicating that coverage on a regional scale (within 150 miles of the city center) and on a national scale (along interstates) appear to be as influential in the decision to purchase a vehicle as coverage within metropolitan areas. Relatively consistent trends were identified among the four cities, providing support for a generalized representation of refueling availability penalties for major urban areas. These results can be used in two potential future applications: (1) to enhance hydrogen infrastructure transition models that include a spatially detailed representations of refueling availability, and (2) to inform policies determining financial support for hydrogen vehicles and associated refueling infrastructure.

FY 2009 Publications/Presentations

1. PA Consulting Group, *Discrete Choice Analysis for Hydrogen Vehicles*. National Renewable Energy Laboratory, Golden, CO, subcontractor report. Forthcoming.

2. Melaina, M., "Hydrogen Infrastructure Analysis Highlights." Presented at the Institute of Transportation Studies, University of California Davis, May 4, 2009, Davis, CA.

3. Melaina, M., "Hydrogen Infrastructure Analysis Highlights. Presented at General Motors Powertrain," May 7, 2009, Pontiac, MI.

4. Melaina, M., "Discrete Choice Analysis of Consumer Preferences for Refueling Availability." Presented at the 2009 DOE Hydrogen Program Merit Review and Peer Evaluation Meeting, May 19, 2009, Washington, DC.

5. Melaina, M., "Estimating Cost Penalties for Limited Refueling Availability (and other related issues)." Presented at the Massachusetts Institute of Technology/Shell/Ford System Dynamics Research Workshop, June 9, 2009, Dearborn, MI.

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2. Tompkins, M.; D.S. Bunch; D.J. Santini; A.D. Vyas; D. Poyer (1998). "Determinants of Alternative Fuel Vehicle Choice in the Continental United States." *Transportation Research Record* (1641); pp. 130-138.

3. Brownstone, D.; D.S. Bunch; K. Train (2000). "Joint Mixed Logit Models of Stated and Revealed Preferences for Alternative-Fuel Vehicles." *Transportation Research Part B-Methodological* (34:5); pp. 315-338.

4. Potoglou, D.; P.S. Kanaroglou (2007). "Household Demand and Willingness to Pay for Clean Vehicles." *Transportation Research Part D* (12); pp. 264-274.

5. Greene, D. (2008). "Analysis of the Transition to Hydrogen Fuel Cell Vehicles & the Potential Hydrogen Infrastructure Requirements." Presented at the 2008 DOE Hydrogen Program Merit Review and Peer Evaluation Meeting, June 9, 2008. Washington, D.C. Available online.

6. Bremson and Melaina (2010). "Estimating Urban Refueling Availability Costs Using a Station Clustering Methodology." Forthcoming.

7. Melaina, M.; J. Bremson (2008). "Refueling Availability for Alternative Fuel Vehicle Markets: Sufficient Urban Station Coverage." *Energy Policy* 38(8): 3233-3241.