CONSUMER CONVENIENCE AND THE AVAILABILITY OF RETAIL STATIONS AS A MARKET BARRIER FOR ALTERNATIVE FUEL VEHICLES

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Presentation Overview

• Introduction
  o Limited refueling availability: previous studies
• Methodology
  o Discrete Choice
  o Clustering Algorithm
• Results
  o Discrete Choice
  o Clustering Algorithm
• Conclusions
Introduction

- The availability of retail stations can be a significant barrier to the adoption of alternative fuel light-duty vehicles in household markets.
- This is especially the case during early market growth when retail stations are likely to be sparse and when vehicles are dedicated in the sense that they can only be fuelled with a new alternative fuel.
- The impact of limited availability on vehicle purchase decisions is largely a function of geographic coverage and consumer perception.
- This paper presents results from two studies that rely upon distinct methodologies to estimate the values of refueling availability:
  1) Discrete Choice
  2) Travel Time Clustering Algorithm

Previous studies of limited refueling availability (1)

- Results from a survey of diesel vehicle owners in California suggested that when 10-15% of stations provided diesel most drivers were less concerned about refuelling station coverage (Sperling and Kurani, 1987)
- This percentage was later readjusted down to 10% after more careful evaluation of the baseline number of stations in California (Nicholas, Handy et al. 2004).
- Similarly, a 1992 study by Kurani (1992) determined that most compressed natural gas (CNG) vehicle owners in New Zealand were less concerned about refuelling coverage after approximately 10% of stations in their local area provided CNG.
- Based upon results from a preference survey of Canadian drivers, Greene estimated cost penalties for reduced station coverage, concluding that coverage of greater than 20 percent of stations significantly reduces the cost barrier to purchasing a dedicated AFV (1998).
Previous studies of limited refueling availability (2)

- Melaina (2003) estimated that between 9,000 and 12,000 stations would be required to support early markets, providing sufficient coverage in both urban areas and along interstates (2003).
- Nicholas et al. (2004) employed a traffic flow model to estimate average driving times associated with different levels of coverage, concluding that coverage at 5% percent of stations would be associated with an average driving time of approximately 4 minutes for work-based commuters refuelling their vehicles in Sacramento, California (2004). This compares to an average travel time of just under 2 minutes when fuel is available at all 319 existing stations in Sacramento.
- Most studies therefore tend to confirm Kurani’s proposed 10 percent “rule of thumb” or suggest that even lower percentages could be adequate.
- However, station densities (stations per square mile) vary significantly between U.S. urban areas (Melaina and Bremson 2008), suggesting a more precise metric is needed, such as station density.

Methodology

Discrete Choice & Clustering Algorithm
**Discrete Choice Study Methodology: Survey Approach**

- The discrete choice study relies upon a series of surveys administered by NREL, PA Consulting, and Knowledge Networks between 2007 and 2009.
- Three versions of the survey were fielded, with each new version including improvements based upon results (and shortcomings) from the previous version. Data from the final survey are considered the most meaningful.
- In the final survey approximately 500 surveys were completed in four cities: Los Angeles, CA, Atlanta, GA, Minneapolis, MN, and Seattle, WA.
- Panel members in each city responded to a series of introductory questions and then to 10 hypothetical vehicle purchase decisions.
  - Panels are maintained by Knowledge Networks with in-home computers.

**Discrete Choice Study Methodology: Survey Design**

- Introductory questions acquainted the respondents with the setup of the survey, the definitions used to describe vehicle and refuelling attributes, and the maps used to represent refuelling availability.
- The maps capture three levels of refuelling availability:
  1. Short-distance trips within the respondent’s metropolitan area,
  2. Medium-distance trips within the metropolitan region (defined as the area within 150 miles of the metro area), and
  3. Long-distance trips nationwide along interstate highways connecting major cities (see Figure 2, 3, and 4).
- Introductory questions also inquired about the make, model, and year of the vehicle most recently purchased by the respondents.
- This information was used later in the survey to remind respondents—by labelling the different alternatives—that the hypothetical vehicle purchase decisions they were making were associated with a vehicle having the same attributes as their most recently purchased vehicle.
Station coverage attributes and levels

<table>
<thead>
<tr>
<th>#</th>
<th>Attribute</th>
<th>Variables for Utility Function</th>
<th>Description for Consumer</th>
<th>Units</th>
<th>Number of Levels</th>
<th>Levels (for consumer description)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Metro Area Coverage</td>
<td>MAC</td>
<td>Average Distance to the nearest Metro Area Refueling Station</td>
<td>miles</td>
<td>4</td>
<td>2.7 / 1.1 / 0.6 / 0.1</td>
</tr>
<tr>
<td>2</td>
<td>Medium Distance Coverage</td>
<td>MDC</td>
<td>Number of stations within 100 mile of the metro area</td>
<td>ln(#number of stations)</td>
<td>4</td>
<td>Varies by market: 4 to 12; 12 to 28; 28 to 79; 2,400 to 8,300</td>
</tr>
<tr>
<td>3</td>
<td>No Long Distance Coverage Level 1</td>
<td>LDC,1</td>
<td>Long Distance Trips that are Possible</td>
<td>true/false</td>
<td>2</td>
<td>No destinations beyond 150 miles</td>
</tr>
<tr>
<td>4</td>
<td>Long Distance Coverage – Level 2</td>
<td>LDC,2</td>
<td>Long Distance Trips that are Possible</td>
<td>true/false</td>
<td>2</td>
<td>Nearby cities</td>
</tr>
<tr>
<td>5</td>
<td>Long Distance Coverage – Level 3</td>
<td>LDC,3</td>
<td>Long Distance Trips that are Possible</td>
<td>true/false</td>
<td>2</td>
<td>Regional cities</td>
</tr>
<tr>
<td>6</td>
<td>Long Distance Coverage – Level 4</td>
<td>LDC,4</td>
<td>Long Distance Trips that are Possible</td>
<td>true/false</td>
<td>2</td>
<td>Same as conventional vehicles</td>
</tr>
<tr>
<td>7</td>
<td>Vehicle Purchase Price</td>
<td>VPP</td>
<td>Vehicle purchase price</td>
<td>$1000/vehicle</td>
<td>5</td>
<td>&lt;35%, &lt;15%, 0%, +15%, +35%</td>
</tr>
</tbody>
</table>

The vehicle attributes varied between choices, according to a discrete choice algorithm developed by Zwerina, Huber, and Kuhfeld (2005). The algorithm employs a search strategy to generate balanced, efficient designs for choice experiments where multiple choices are presented.
Discrete Choice Survey: Screenshot #2 – Regional Maps and Metrics

Number of stations within 150 miles of the metro area
[Number of stations in the region within 150 miles of the metro area. With an alternative fuel vehicle, all trips within this region would be possible, but some destinations would require advance planning.]

Discrete Choice Survey: Screenshot #3 – Long distance (interstate) Coverage

Long Distance Trips that are Possible
[Long distance trips are trips outside the 150-mile radius surrounding the metro area where you live. Some long distance trips will not be possible with the alternative fuel vehicle due to limited station coverage along interstate routes.]
Discrete Choice Survey: Screenshot #4 – Fuel Cost, Benefits, Purchase Price

**Fuel Cost**
[This is the amount per month you spend to put fuel in the vehicle.]

<table>
<thead>
<tr>
<th>Same as your INSERT MAKE/MODEL</th>
<th>Same as your INSERT MAKE/MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Other Attributes</strong></td>
<td></td>
</tr>
<tr>
<td>Same as your INSERT MAKE/MODEL</td>
<td></td>
</tr>
<tr>
<td><strong>Virtually NO oil used or imported</strong></td>
<td>[The alternative fuel is not gasoline or diesel, and virtually no oil is used or imported to produce the alternative fuel.]</td>
</tr>
<tr>
<td><strong>No smog emissions</strong></td>
<td>[Zero smog-causing emissions (which affect local air quality) are emitted from the alternative fuel vehicle.]</td>
</tr>
<tr>
<td><strong>50% fewer Greenhouse Gas emissions</strong></td>
<td>[Greenhouse gas emissions (which contribute to global warming) from the alternative fuel vehicle are reduced by 50%.]</td>
</tr>
</tbody>
</table>

**Purchase Price**
[This is the "net price" of the vehicle and already takes into account possible tax incentives or credits.]

<table>
<thead>
<tr>
<th>$XXXXX</th>
<th>$XXXXX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle you are MOST likely to purchase</strong></td>
<td></td>
</tr>
<tr>
<td>Gasoline Vehicle (Similar to INSERT MAKE/MODEL)</td>
<td>Alternative Fuel Vehicle (Similar to INSERT MAKE/MODEL)</td>
</tr>
</tbody>
</table>

Metro Coverage for Seattle

In earlier versions respondents had difficulty distinguishing between 2 & 3.
Regional Coverage for LA.

Regional baseline is based upon Melaina & Bremson 2008

Long-distance (interstate) coverage for L.A.
Methodology: Travel Time Clustering Algorithm

- A clustering algorithm is applied to data on existing gasoline station locations and average fuel dispensing volumes (gallons per month).
- This data was acquired from MPSI for over 100 U.S. urban areas, and includes all stations within each urban area.
- The clustering algorithm involves identifying the two stations in closest proximity to each other and then collapsing the smaller station into the larger station, resulting in a new fuel volume (the sum of the two previous volumes) being dispensed from the original location of the larger station.
- When applied iteratively, this algorithm produces a series of theoretical station networks that dispense the same total volume of fuel through a successively smaller number of stations.
- As more and more stations are eliminated, the network approaches uniform geographic coverage while maintaining variation in station sizes that reflect the intensity of local fuel demand.

Average additional distance traveled

- If station A is eliminated from the network, we assume that drivers would begin their diversion from their normal driving routines from the same location, but would now drive to station B rather than station A.
- If actual diversion locations are randomly distributed within the circle (some closer to B than location A and some further) they would tend to average each other out to the distance $r$.
- Distance $r$ was multiplied by 1.27 to attain a rectilinear “driving” distance $d$. 

Station A Elimination Example
Cost of diversion: weight function ($/mile)

\[ \text{Cost} = d \times w_A \]

- Time cost (TC) = $15/hr
- Vehicle miles traveled (VMT) = 15000 miles/year
- Vehicle range (RNG) = 300 miles
- Ave. speed (MPH) = 25 mph
- These assumptions give a result of $30/mile for \( w_A \)
- The present value (at the time of vehicle purchase) of the total cost of all refueling diversions is determined using a 10% discount rate over a four-year vehicle ownership period.

\[ w_A = \frac{TC \times VMT}{MPH \times RNG} \]

where
\( w_A \) is the weight function ($/mile)
TC is the average time cost ($/hr) for drivers
MPH is the average network speed (mph)
VMT is the annual vehicle mile travelled
RNG is the range (mi.) of the AFV

The result is an estimated cost for a Rational Actor with accurate knowledge of likely future diversion times.

Results

Discrete Choice & Clustering Algorithm
Discrete choice results: Metro area coverage

- Penalties are estimated using result for the Vehicle Purchase Price coefficient (Greene 2001)
- Logit model results (solid shapes) are considered the best fit

Discrete choice results: Regional coverage

- Original fit from PA (shaded shapes) is considered the best fit
Discrete choice results: Interstate coverage

- Penalty expressed as % of long-distance trips not covered
- Basis determined using ATS data for trips between cities

Clustering Algorithm Results

- Degree of clustering is the fraction of original stations remaining
- Algorithm was run for all cities (FULL) as well as for larger cities with >1000 stations (LRG)
- There is only a slight divergence between averages for the two at 0.25-1.0% coverage
- These results can be compared to the Metro Area discrete choice results
Comparing results at the metro level

- Cluster results are significantly lower than discrete choice results
- Extremes between L.A. and Minneapolis suggest a difference on the order of $1000-$2000 (bottom right)
- This difference may be interpreted as the perceived penalty incurred on top of an estimate of a “rational” penalty

Conclusions

- Consumers have high expectations for refueling availability
  - Perceived cost penalties ranging from $3,500 to $12,000 for the sum of medium and long-distance trips
  - Perceived cost penalty ranging from $750 to $4,000 for metro area coverage
  - Penalties for long-distance interstate coverage are particularly high
- The lack of refueling availability for dedicated alternative fuel vehicles can impose a market barrier on the same order as the estimated cost differential between conventional and advanced vehicles
  - Would apply for hybrid CNGVs (with sufficient range) or hydrogen fuel cell electric vehicles (range goals have been met)
- Improving consumer awareness of station coverage could help reduce this barrier for early adopters
  - Perhaps using information technologies made available before the time of purchase, onboard vehicles or otherwise
Questions?

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References