Spatial Refueling Patterns of Compressed Natural Gas (CNG) Drivers in Southern California

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NSF Grant 1025313:
Spatial Refueling Patterns of Drivers of Alternative-Fuel and Conventional Vehicles
Overview

- Alternative Fuel Vehicles (AFVs) and the need for empirical data

- Previous Work:
  - Sperling & Kitamura (1986 & 1987)

- Intercept Survey
  - While Refueling
  - Fleet vs. Consumer
  - Gasoline vs. CNG
  - Time of day Controls

Honda Civic GX
Source: Honda
Research Question

- Based on observed 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 refuel a station closer to home, or one on their way between an origin and destination?
Point–Based Models

Minimize Average Weighted Distance (p-median)

Nicholas (2004)
Flow-Capturing Models

- Hodgson (1990)
- Berman, Larson, and Fouska (1992)
- Demand consists of paths, not points
- Locate $p$ facilities to capture the maximum volume of passing flows

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>12</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>D</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
</tbody>
</table>
Methodology

- **Network Analysis:**
  - ArcGIS 10, Network Analyst
  - Long-distance stops

- **Analysis Goals:**
  - Service Areas
  - Deviation Analysis
    - Shortest Path vs. Refueling Path
    - Impedance: Travel Time
  - Closest Facility to Home
  - Least Deviation Route
Anaheim - CNG Routes
Deviation Analysis
Deviation Analysis

Median Deviation (Minutes)

- Anaheim: 1.3 (GAS), 3.1 (CNG)
- Downtown LA: 2.2 (GAS), 4.7 (CNG)
- Santa Monica: 1.5 (GAS), 6.5 (CNG)
- Santa Ana: 1.9 (GAS), 5.7 (CNG)
- Burbank: 1.6 (GAS), 5.2 (CNG)
Least Deviation Analysis
## Closest to Home vs. Least Deviation

<table>
<thead>
<tr>
<th>CNG STATION</th>
<th>MEDIAN DEVIATION</th>
<th>% CLOSEST TO HOME</th>
<th>% LEAST DEVIATION</th>
<th>MEAN TRIP LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burbank</td>
<td>5.2</td>
<td>30.6</td>
<td>66.0</td>
<td>42.9</td>
</tr>
<tr>
<td>Santa Ana</td>
<td>5.7</td>
<td>30.6</td>
<td>54.0</td>
<td>12.2</td>
</tr>
<tr>
<td>Santa Monica</td>
<td>6.5</td>
<td>46.0</td>
<td>67.3</td>
<td>18.6</td>
</tr>
<tr>
<td>Downtown</td>
<td>4.7</td>
<td>24.0</td>
<td>66.7</td>
<td>30.5</td>
</tr>
<tr>
<td>Anaheim</td>
<td>3.1</td>
<td>5.8</td>
<td>58.2</td>
<td>18.9</td>
</tr>
<tr>
<td>OVERALL</td>
<td>5.3</td>
<td>27.2</td>
<td>62.2</td>
<td>25.4</td>
</tr>
</tbody>
</table>
Not Closest To Home

Least Deviation

Not Least Deviation
Not Closest To Home

Burbank Refueling Route Choices

Least Deviation

Clean Energy Burbank

Origin: School

Legend

Home Locations
CNG Stations
Route 956

Destination: Home

Glenendale

Beverly Hills
Closest To Home

Burbank Refueling Route Choices

Destination: Home

Clean Energy Burbank

Origin: Work
Not Least Deviation

Not Closest To Home

Burbank Refueling
Route Choices

Clean Energy
Burbank

Origin: School

Destination: Home

Legend
Home Locations
CNG Stations
Route 850
### Refueling Station Matrix

<table>
<thead>
<tr>
<th>CATEGORIES</th>
<th>CLOSEST TO HOME</th>
<th>NOT CLOSEST TO HOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEAST DEVIATION</td>
<td>both 58</td>
<td>least deviation 103</td>
</tr>
<tr>
<td>NOT LEAST DEVIATION</td>
<td>closest 10</td>
<td>neither 88</td>
</tr>
</tbody>
</table>
## Group Characteristics

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

**Independent samples t-test**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Least Deviation (n=103)</th>
<th>Closest to Home (n=10)</th>
<th>( p_1 )</th>
<th>( p_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation (min.)</td>
<td>( \bar{X}_1 = 4.23 )</td>
<td>( \bar{X}_2 = 7.12 )</td>
<td>2.94</td>
<td>.029**</td>
</tr>
<tr>
<td>Travel Time (min.)</td>
<td>( \bar{X}_1 = 36.73 )</td>
<td>( \bar{X}_2 = 28.08 )</td>
<td>11.36</td>
<td>.663</td>
</tr>
<tr>
<td>Trip Distance (mi.)</td>
<td>( \bar{X}_1 = 25.65 )</td>
<td>( \bar{X}_2 = 15.80 )</td>
<td>9.44</td>
<td>.623</td>
</tr>
</tbody>
</table>

\( \alpha_1 \): Equal variances assumed, \( \alpha_2 \): Equal variances not assumed. **significant at \( \alpha = 0.05 \) level
Neither?

- 88 fit into neither category
- 39 eschewed a station that fit both criteria
  - City of Glendale
  - Anaheim - Valero
- Margin of error matrix
- Flow-based models
Questions?

• **Acknowledgements:**
  - **PI:** Dr. Michael Kuby, ASU
  - Joe Schoenemann, Patrick Zweifel, Jeff Martinez, ASU
  - Mike McLean, ASU-ISSR
  - Clean Energy and Trillium

Source: California Natural Gas Vehicle Coalition

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## Reasons for Choosing Station

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>Brand loyalty</th>
<th>Convenient location</th>
<th>Low fuel price</th>
<th>No Answer</th>
<th>Right-hand turn</th>
<th>Running out of fuel</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both</td>
<td>1.7%</td>
<td>77.6%</td>
<td>13.8%</td>
<td>0%</td>
<td>0%</td>
<td>6.9%</td>
<td>58</td>
</tr>
<tr>
<td>Least Deviation</td>
<td>1.0%</td>
<td>73.8%</td>
<td>9.7%</td>
<td>0%</td>
<td>0%</td>
<td>15.5%</td>
<td>103</td>
</tr>
<tr>
<td>Closest to Home</td>
<td>0%</td>
<td>60.0%</td>
<td>10.0%</td>
<td>0%</td>
<td>0%</td>
<td>30.0%</td>
<td>10</td>
</tr>
<tr>
<td>Neither</td>
<td>2.3%</td>
<td>73.9%</td>
<td>12.5%</td>
<td>1.1%</td>
<td>1.1%</td>
<td>9.1%</td>
<td>88</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.5%</td>
<td><strong>74.1%</strong></td>
<td>11.6%</td>
<td>0.4%</td>
<td>0.4%</td>
<td>12.0%</td>
<td>259</td>
</tr>
</tbody>
</table>