Siting Strategies for Early H2 Refueling Infrastructure in California: Learning from the Gasoline Experience

Michael Nicholas
Institute of Transportation Studies
University of California, Davis
May 14, 2013

This presentation does not contain any proprietary, confidential, or otherwise restricted information
Overview

Timeline
(NextSTEPS program)

• Start: Jan. 1, 2011
• End: Dec 31, 2014
• 50% Complete

Budget

• Total project funding
  – DOE share: $240 K (4 years)
  – Contractor share: $ 0
• Funding received FY12: $60K
• Funding for FY13: $60K

Barriers

• Barriers addressed (from MYPP)
  – Future Market Behavior
  – Inconsistent Data, Assumptions and Guidelines
  – Insufficient Suite of Models and Tools
• Goal Addressed::
  – Provide analysis to support hydrogen and fuel network development

Partners

• The work was conducted at UC Davis under the NextSTEPS research consortium, which has 23 government and industry sponsors, including USDOE
• UC Davis manages NextSTEPS (see supplemental slides)
**OVERALL PROJECT GOAL:** Determine the minimum number of stations necessary for the maximum number of customers to reduce investment necessary.

<table>
<thead>
<tr>
<th>DOE BARRIERS</th>
<th>AN 031 PROJECT GOALS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Future Market Behavior</strong></td>
<td>Analyze strategies for early H2 fueling station placement, numbers and network development, to enable fuel accessibility for initial rollout of H2 fuel cell passenger cars.</td>
</tr>
<tr>
<td><strong>Inconsistent Data Assumptions and Guidelines</strong></td>
<td>Develop an understanding of refueling behavior and apply to early stations strategies for deployment.</td>
</tr>
<tr>
<td><strong>Insufficient Suite of Models and Tools</strong></td>
<td>Conduct case studies for California, utilizing GIS-based analysis for station siting and convenience from the perspective of consumers.</td>
</tr>
</tbody>
</table>
Project Overview

Analysis Framework
- Gasoline station locations
- Surveys
- Traffic flows
- Population
- Income
- New car buying habits

Models and Tools
- ArcGIS
- Nearest Facility (p-median)
- Census variables

Studies and Analysis
- Station Siting
- Station Sizing
- Market analysis
- Refueling Behavior

Outputs and Deliverables
- Cluster strategy
- Refueling behavior
- Market assessment with siting
SPATIAL DESIGN FOR EARLY H2 FCV ROLLOUTS

H2 INFRASTRUCTURE SHOULD OFFER

COVERAGE: enough stations, located to provide fuel accessibility for early vehicles
CAPACITY: meet H2 demand as FCV fleet grows
COORDINATE FCV PLACEMENT + H2 INFRASTRUCTURE BUILD-OUT, GEOGRAPHICALLY AND OVER TIME

Finding: Station distribution and size is a function of fuel price, vehicle price, and distance to station.

“Cluster Strategy” geographically dispersed clusters (2-3 stations per cluster) in a metro region can be tied together with connector stations such that relatively few stations can provide adequate coverage in an early network.

Large new stations may take time to reach full utilization due to normal vehicle buying habits.
A Refueling Network is made up of “Anchor” and “Network” stations

- Local anchor stations are most likely a prerequisite for vehicle purchase
- Connector stations provide the greatest regional flexibility
- Destination stations allow a new “base” of activity and mobility.
Gasoline Refueling Takes Place Along a Route

- Many models (including some of my own) assume a closest station algorithm for convenience.

- Closest station does not hold for predicting gasoline sales.

- Closest station in the direction of travel such as to the highway predicts sales better.

- Initial stations should be sited near the highway or other high capacity road.

The Utility of a Station Can Independent of Usage

• Utility depends individual perception
  – Use (Home Stations - most used)
  – Usefulness (Home, connector-occasionally used)
  – Aspiration (Far Destinations-seldom used)

• Macro market utility
  – Vehicle Marketability (Home then connector, then destination)
12 Clusters Identified by Early California Fuel Cell Partnership Survey

- Two Ways to Measure Consumer Convenience
  - Home to the nearest station (Anchor)
  - “Diversion” time: time to nearest station while driving throughout LA Basin (Network)
8 Station Example (Only Local Refueling)

3.9 minutes home to sta.
5.6 minutes diversion time

Progress/Accomplishments

• Market areas are geographically separated
• Only local refueling
• Home to station time is low, diversion time is high
16 Station Example
Add 8 Connector Stations => Lower Diversion Time

3.8 minutes home to sta.
4.3 minutes diversion time

Progress/Accomplishments

- Geographically separated market traffic served by connector stations
- Lower diversion time
## Early Network Examples

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong># Stations</strong></td>
<td>8</td>
<td>20</td>
<td>42</td>
</tr>
<tr>
<td><strong># clusters</strong></td>
<td>4 (2 sta/cluster)</td>
<td>6 (3 sta/cluster)</td>
<td>12 (3 sta/cluster)</td>
</tr>
<tr>
<td><strong># connect.sta</strong></td>
<td>0</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td><strong>Station Mix</strong></td>
<td>4 Portable refuelers 4 SMRs (100 kg/d)</td>
<td>8 Portable Refuelers 12 SMRS (250 kg/d)</td>
<td>10 Portable refuelers 12 SMRs (250 kg/d) 20 SMRs (1000 kg/d)</td>
</tr>
<tr>
<td><strong>New Equip. Added</strong></td>
<td>4 Portable refuelers 4 SMRs (100 kg/d)</td>
<td>4 Portable Refuelers 12 SMRS (250 kg/d)</td>
<td>2 Portable refuelers 20 SMRs (1000 kg/d)</td>
</tr>
<tr>
<td><strong>Capital Cost</strong></td>
<td>$20 Million</td>
<td>$52 Million</td>
<td>$98 Million</td>
</tr>
<tr>
<td><strong>O&amp;M Cost</strong></td>
<td>3-5 $Million/y</td>
<td>11-14 $Million/y</td>
<td>30-40 $Million/y</td>
</tr>
<tr>
<td><strong>H2 cost $/kg</strong></td>
<td>77</td>
<td>37</td>
<td>13</td>
</tr>
<tr>
<td><strong>Ave travel time</strong></td>
<td>3.9 minutes</td>
<td>2.9 minutes</td>
<td>2.6 minutes</td>
</tr>
<tr>
<td><strong>Diversion time</strong></td>
<td>5.6 minutes</td>
<td>4.5 minutes</td>
<td>3.6 minutes</td>
</tr>
</tbody>
</table>
How Many Stations Are Needed?

- How many stations you need depends on your assumptions about the market. We generally know how people would like to refuel, but we don’t know the size of the market.
- Absolute minimums
- Anchor vs. Network
- Anchor station(s): how close do they have to be?
- Early market rollout study
Can you Have Just One Station for 34,000 Cars?

• Give away free fuel and free cars with unlimited warranty

• Therefore the number of station necessary is not absolute but depends on outside factors

\[ Utility = B_{veh} - P_{veh} - OC_{veh} - NI \]

- \( B_{veh} \) = Benefit of the Vehicle
- \( P_{veh} \) = Price of the Vehicle
- \( OC_{veh} \) = Operation Cost
- \( NI \) = Network Inconv.
Anchor(s) + Network (Illustrative)

- Initially, there will be more stations per vehicle.
- Other people’s anchor stations become network stations, till most demand is local.
- Stations become larger as well, reducing overall stations/vehicle.
Where People Refueled ≠ Willingness to Buy But…


### Equation can be adjusted. ½?

[Graph showing percent of fuel survey respondents vs distance with equation $y = -0.254\ln(x) + 0.9989$.]

### Percent of Fuel Survey Respondents vs Distance

<table>
<thead>
<tr>
<th>Trip time from station (min)</th>
<th>0-5</th>
<th>6-10</th>
<th>11-20</th>
<th>21-30</th>
<th>&gt;30</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>238</td>
<td>53</td>
<td>92</td>
<td>52</td>
<td>33</td>
<td>468</td>
</tr>
<tr>
<td>(18.7)</td>
<td>(4.2)</td>
<td>(7.2)</td>
<td>(4.1)</td>
<td>(2.6)</td>
<td>(36.8)</td>
<td></td>
</tr>
<tr>
<td>6-10</td>
<td>95</td>
<td>51</td>
<td>37</td>
<td>11</td>
<td>10</td>
<td>204</td>
</tr>
<tr>
<td>(7.5)</td>
<td>(4.0)</td>
<td>(2.9)</td>
<td>(.9)</td>
<td>(.9)</td>
<td>(16.0)</td>
<td></td>
</tr>
<tr>
<td>11-20</td>
<td>103</td>
<td>33</td>
<td>72</td>
<td>25</td>
<td>14</td>
<td>247</td>
</tr>
<tr>
<td>(8.1)</td>
<td>(2.6)</td>
<td>(5.7)</td>
<td>(2.0)</td>
<td>(1.1)</td>
<td>(19.4)</td>
<td></td>
</tr>
<tr>
<td>21-30</td>
<td>55</td>
<td>17</td>
<td>24</td>
<td>50</td>
<td>8</td>
<td>154</td>
</tr>
<tr>
<td>(4.3)</td>
<td>(1.3)</td>
<td>(1.9)</td>
<td>(3.9)</td>
<td>(.6)</td>
<td>(12.1)</td>
<td></td>
</tr>
<tr>
<td>&gt;30</td>
<td>54</td>
<td>16</td>
<td>28</td>
<td>9</td>
<td>93</td>
<td>200</td>
</tr>
<tr>
<td>(4.2)</td>
<td>(1.3)</td>
<td>(2.2)</td>
<td>(.7)</td>
<td>(7.3)</td>
<td>(15.7)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>545</strong></td>
<td><strong>170</strong></td>
<td><strong>253</strong></td>
<td><strong>147</strong></td>
<td><strong>158</strong></td>
<td><strong>1273</strong></td>
</tr>
<tr>
<td>(42.8)</td>
<td>(13.4)</td>
<td>(19.9)</td>
<td>(11.5)</td>
<td>(12.4)</td>
<td>(100.0)</td>
<td></td>
</tr>
</tbody>
</table>

( ) = Percent of grand total

• If willingness to by is related to distance to anchor station, and refueling frequency, 58% of people within 2.5 minutes to a station would find no infrastructure barrier to purchase.
How Many Stations?
Depends on How Many People are Interested

To sell 20,000 vehicles/yr:
If 20% of the market is interested, you need 72 anchor stations in LA.

To sell 20,000 vehicles/yr:
If 40% of the market is interested, you need 12 anchor stations in LA.

Future Work
How Much Might One Station Do? Caveat: Estimates Illustrative Only

- CA Households: 12,384,351.00
- CA New Cars/yr: 1,081,526.97
- 75k plus market/yr: 613,215.90
- Santa Monica 75k plus Market/yr: 4,235.79
- 1 Station in Santa Monica: 70%

Future Work
Summary Results

• Project Goals
  – Examine existing refueling patterns
  – Apply lessons learned to the hydrogen context
  – Determine the number and spatial layout for a hydrogen refueling network that provides adequate coverage

• Key Results:
  – An “anchor” (or set of anchor stations) station is a prerequisite for many potential buyers
  – A wider network increases the marketability of the vehicle and hence increases the value of anchor stations
  – We think we know the general form of the network (anchor and network stations)
  – The number of stations necessary is not absolute because it depends on a market that is unknown
  – Going forward we need a strategy that can adapt with the market
Collaborations/Interactions

- California Fuel Cell Partnership: *provided survey data for future FCV projections; infrastructure working group discussions*
- NREL (Marc Melaina, Brian Bush): *Near term station siting*
- California Air Resources Board (Joshua Cunningham) *discussions on ZEV projections, rollout strategies*
- California Energy Commission (Jim McKinney, Tim Olson) *discussions of strategies for introducing hydrogen and other fuels*
- Members of UC Davis H2 Rollout Study (Shell, Chevron, Toyota, Honda, Daimler, GM, CARB) *scenario development*
- University of California, Irvine (Tim Brown, Shane Stevens-Romero); University of California, Berkeley (Tim Lipman) *discussions on rollout strategies*
- 23 Sponsors of NextSTEPS Research Program (see supplemental slides) *for partial support*
Project Summary

• **Relevance:** *Determine the minimum number of stations necessary for the maximum number of customers to reduce investment necessary*

• **Approach:** *Examine existing refueling patterns and apply lessons learned to the hydrogen context*

• **Technical Accomplishments and Progress:** *developed models, surveys, publications (journal papers, reports, presentations, spreadsheet model).*

• **Collaboration:** *Input/discussion w/ stakeholders (auto, energy, industrial gas, state agencies, national labs)*

• **Proposed Future Research:** *Determine the exact relationship between station placement and the purchase decision*
Technical Back-Up Slides
Given the Choice, do People Want Near or Far Stations? A: One “Anchor” and then Medium to Far.
What Does Just One Station Mean to the Consumer? How Important is the Network?

Deficit must be made up by other benefits – Env., energy security...

Number of Stations
Fuel Distribution in Los Angeles

Future Work