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INSTITUTE OF TRANSPORTATION STUDIES

# Deciding Where to Put Hydrogen Stations

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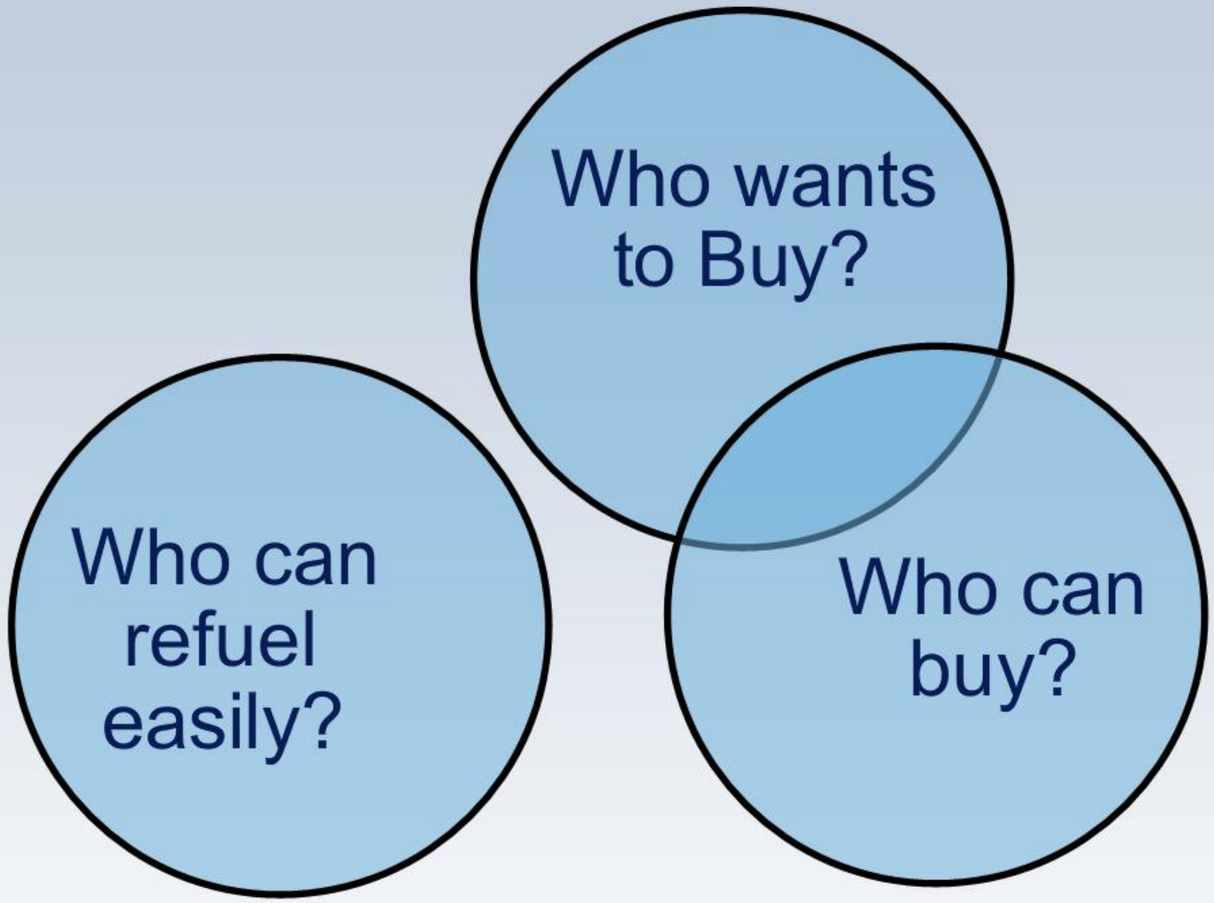
# Basic Questions – What are the Goals of Infrastructure Placement?

- **Increase purchases** of fuel cell vehicles
  - Near term
  - Long term
- **Increase the use** of already purchased vehicles

- What questions need to be asked?
  - Who buys cars in general?  Advanced technology veh?
  - What is the relationship between **purchasing** and H2 infrastructure availability?
  - What is the relationship between infr. and **use**?

# Demand for Hydrogen Vehicles




| | | | |
|---|---|---|---|
| **Who wants to Buy?** | People with higher education | Hybrid owners | Looking for a new vehicle |
| **Who can buy?** | Higher income | 2nd car in the HH | Travel patterns |
| **Who can refuel easily?** | Station close to home | Stations close to frequent routes | Stations close to desired destinations |

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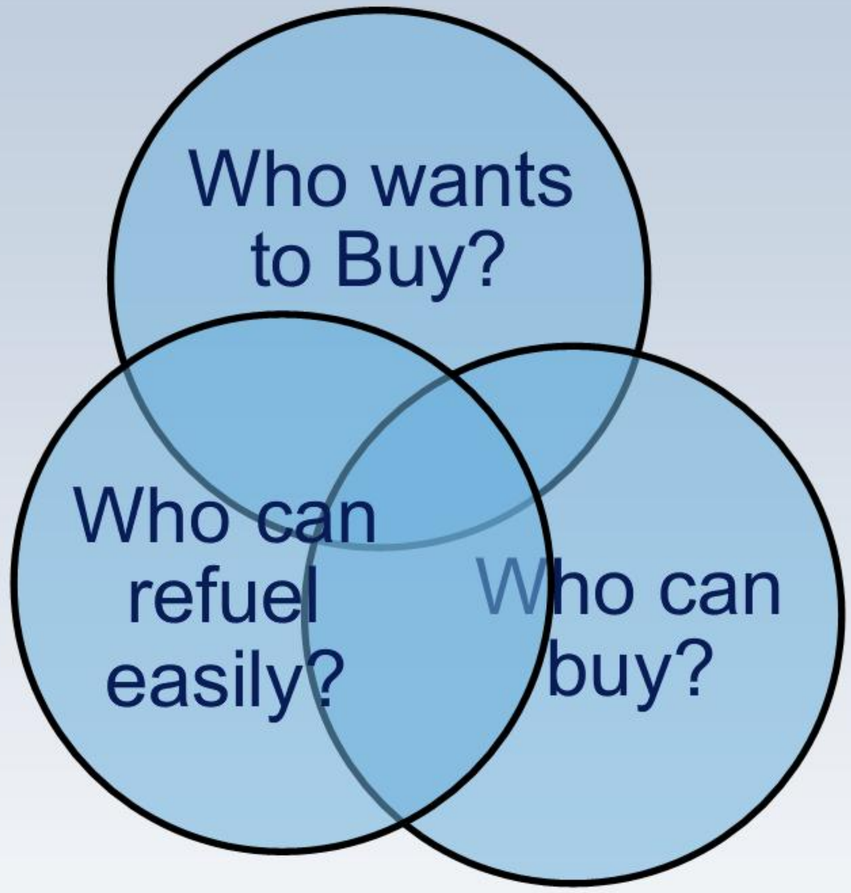


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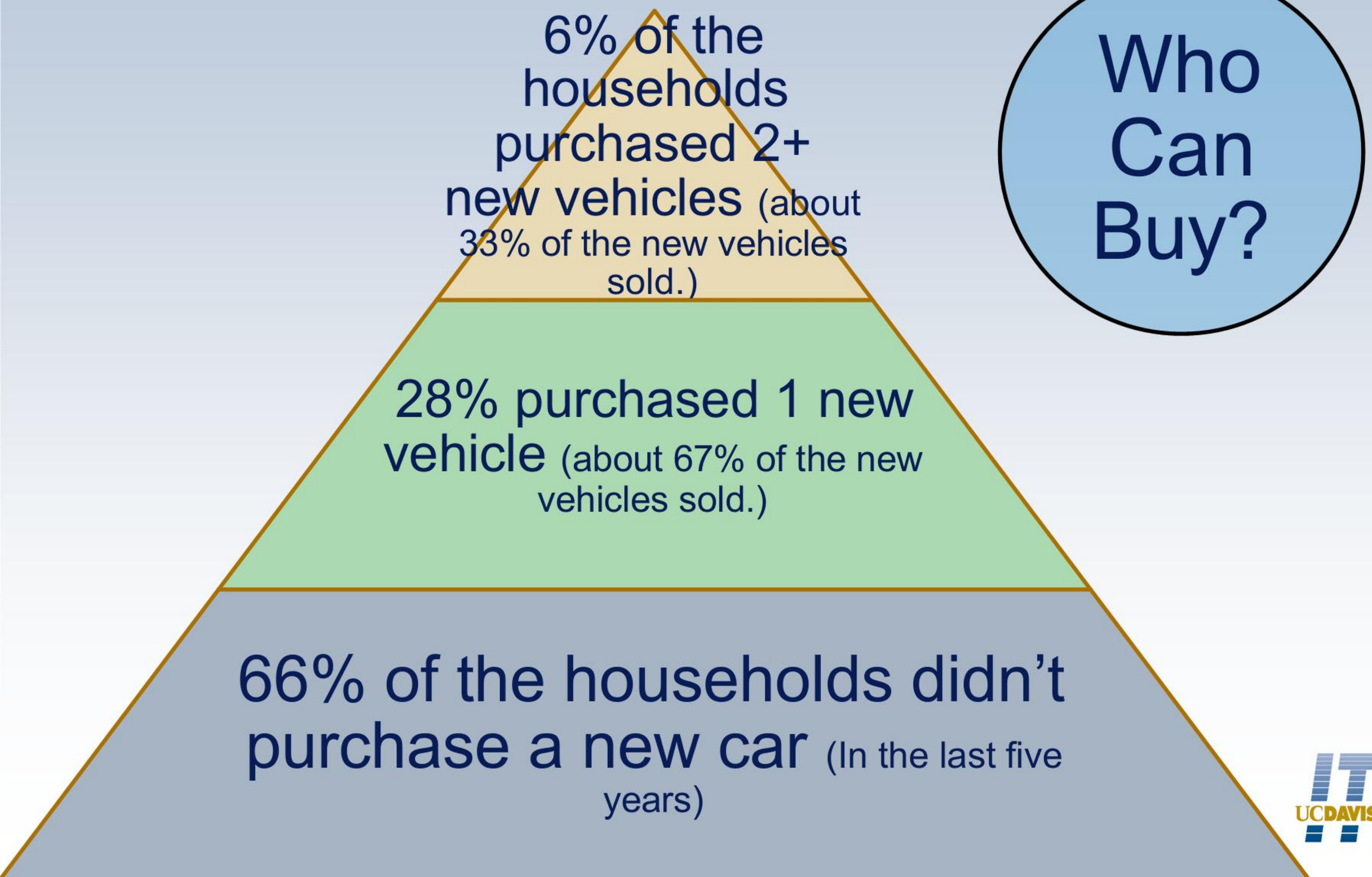
# Proposed Decision Framework

- A latent market exists for H2 vehicles without infrastructure or vehicles
- Ease of refueling increases the likelihood of a fuel cell vehicle purchase
  - Frequent or “Anchor” station is a prerequisite for vehicle purchase
    - Anchor station is more attractive the closer it is to home along a frequent travel path
  - Wider availability or “Network” stations (connector and destination stations) increase the attractiveness of  a fuel cell vehicle
    - Attractiveness is related to frequency of passing a station (regional)
    - Attractiveness is related to ability to expand what’s possible (aspirational)
- Other factors such as vehicle price, H2 price affect desirability

# New Car Buyers in California (last 5 years)

**(NHTS 2009)**




Who Can Buy?

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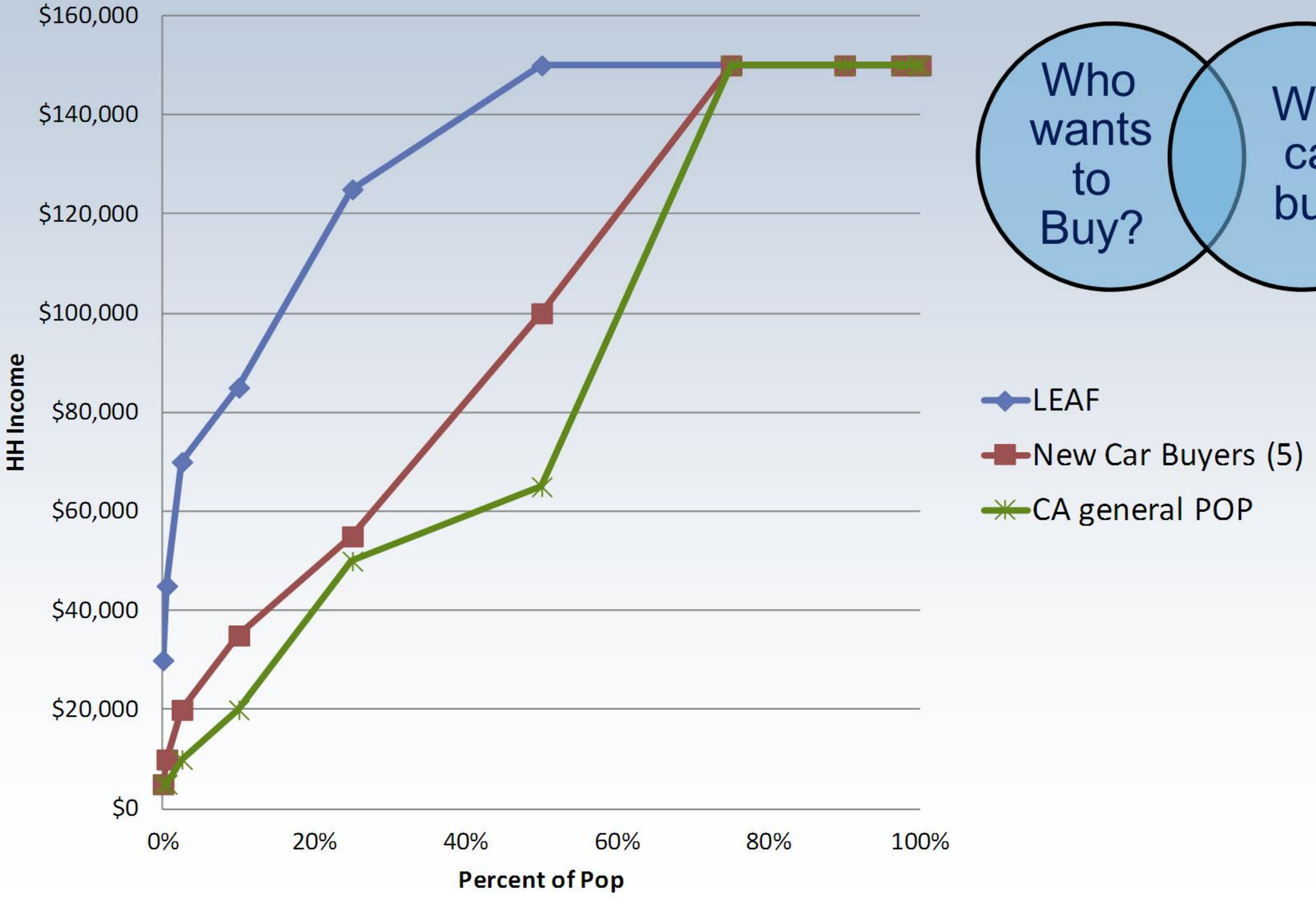
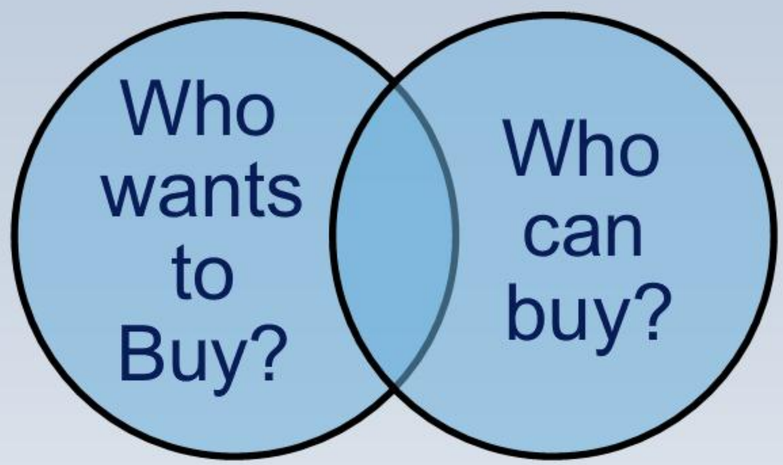
# Who Will buy New Vehicle Types? LEAF Example

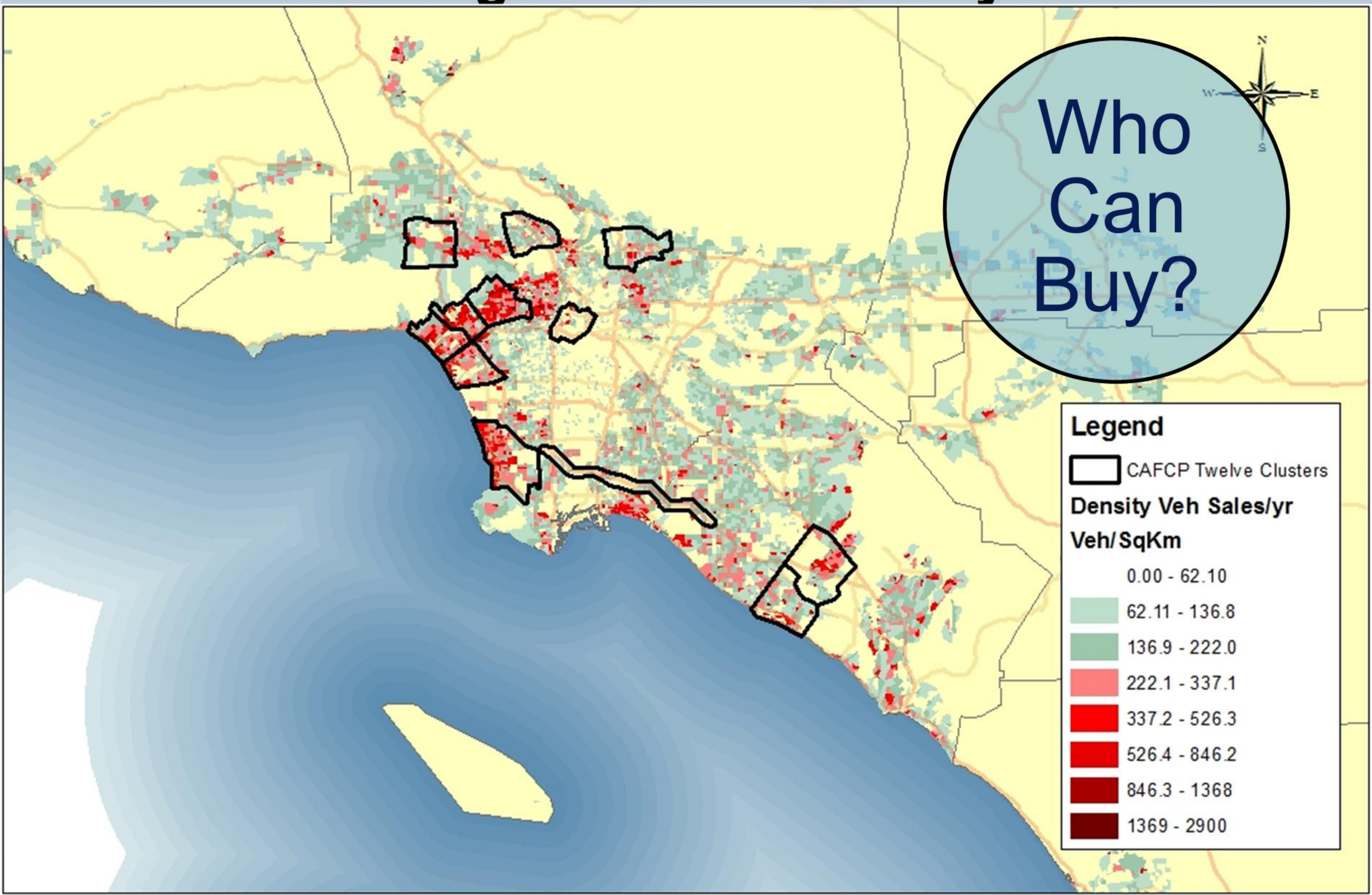


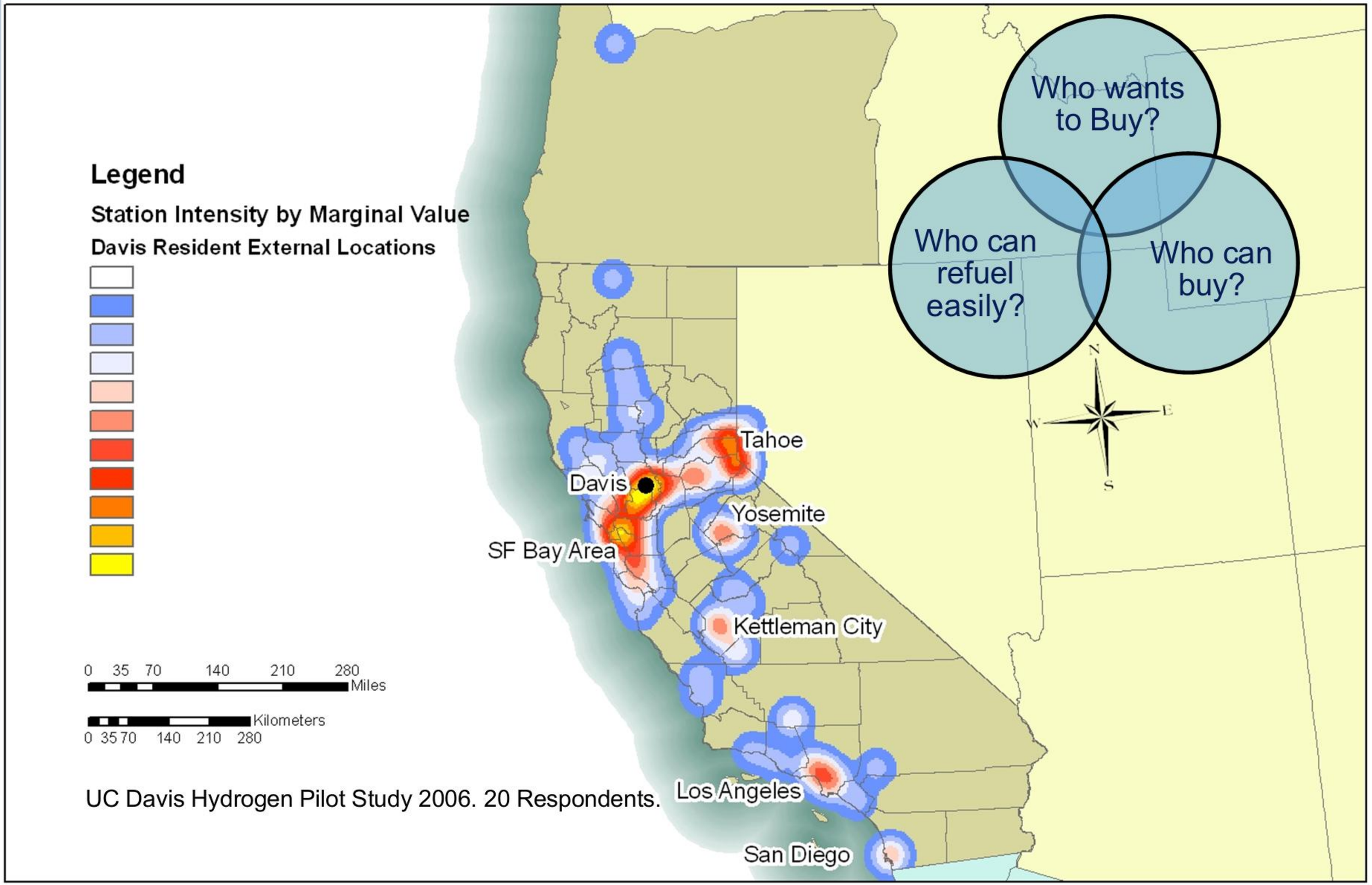
# Where do Leaf Buyers Live ? (n=1151)

# New Car Buyers? Same Places.

# Los Angeles New Car Buyers

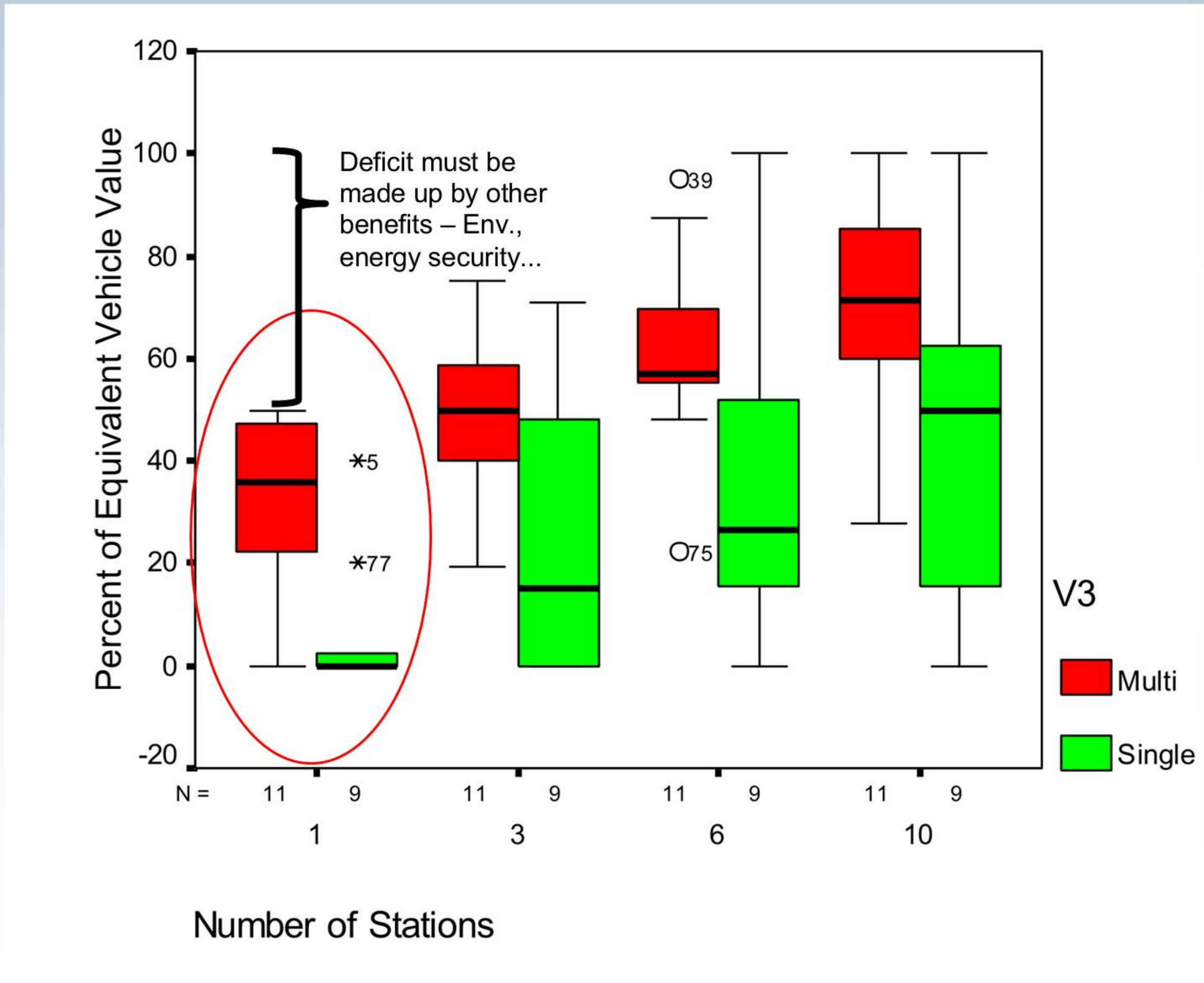


# What do Willing Buyers Want for Infrastructure? (H2)
# A: One “Anchor” and then Medium to Far.

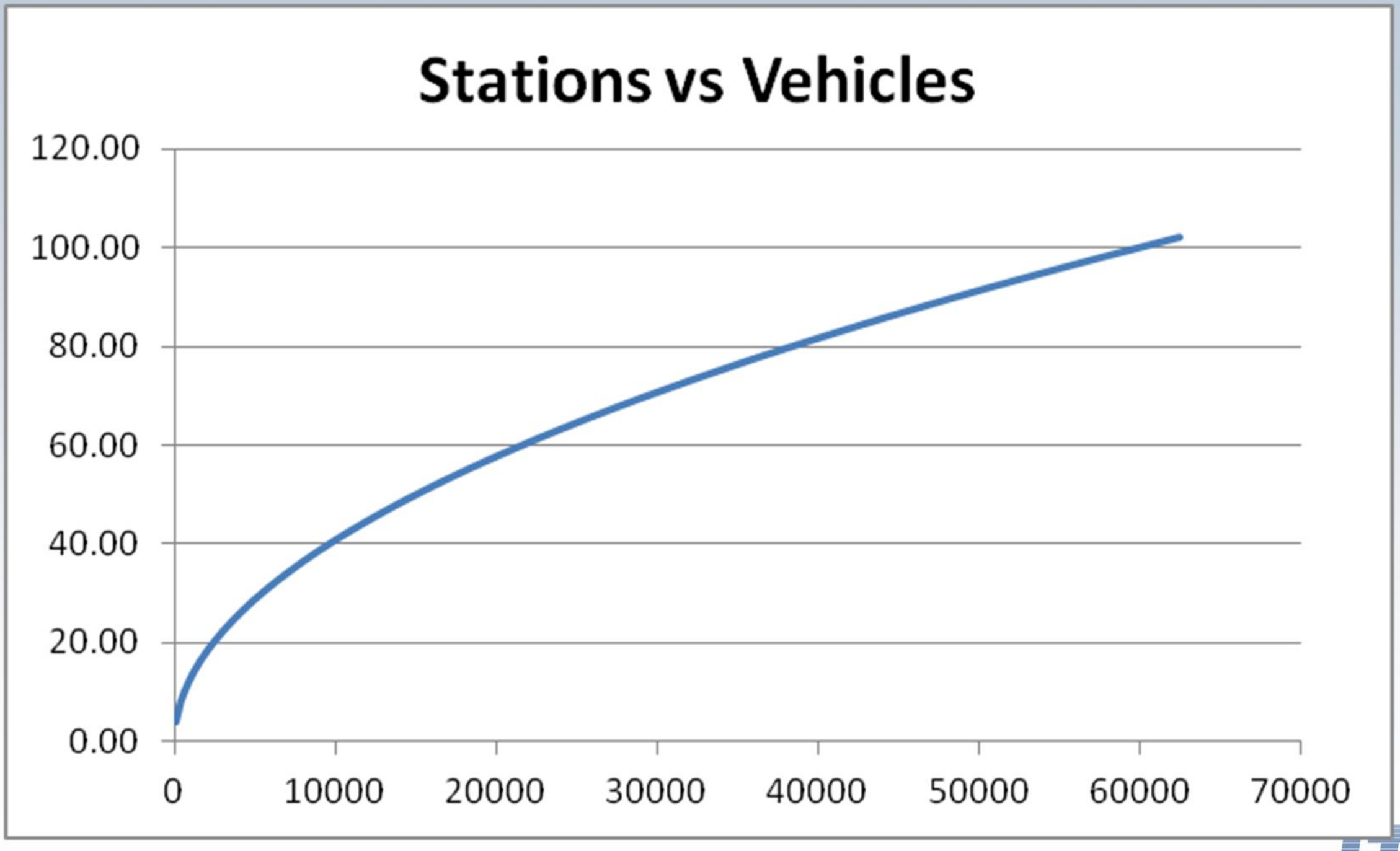



UC Davis Hydrogen Pilot Study 2006. 20 Respondents.

# What Does Just One Station Mean to the Consumer? How Important is the Network?

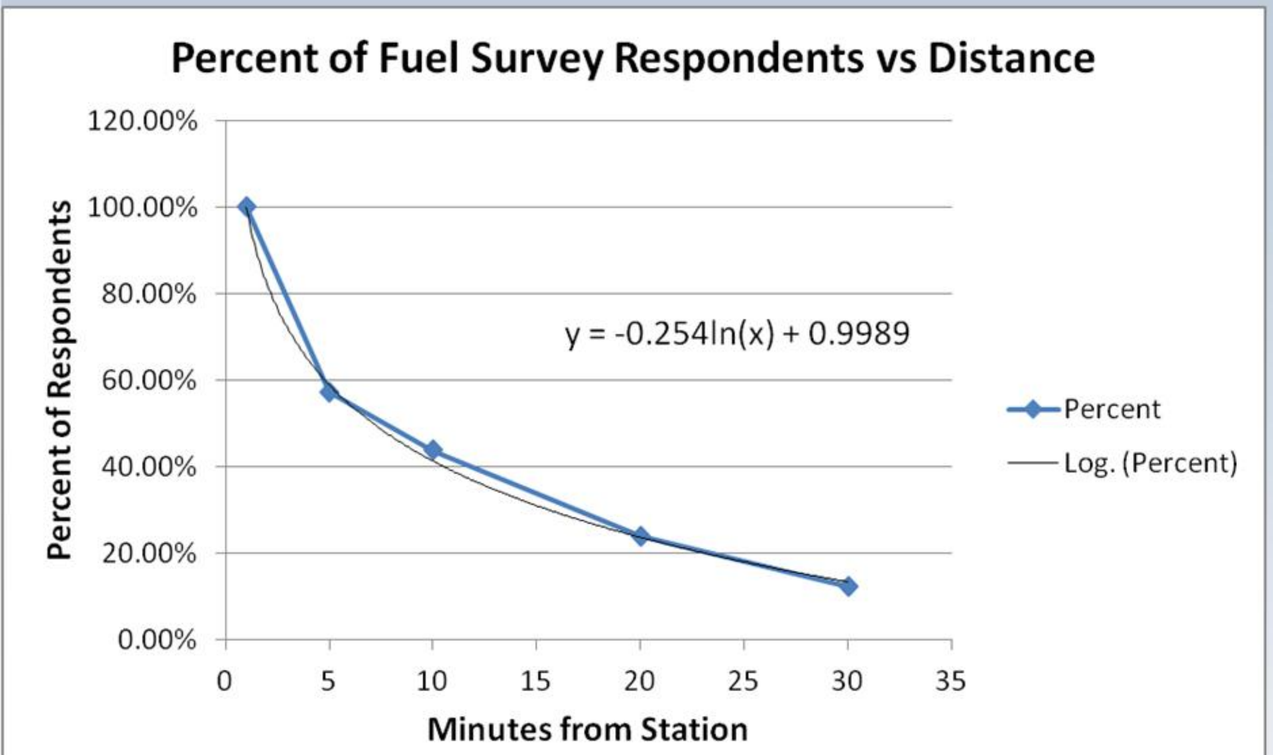


# Anchor(s) + Network (Illustrative)

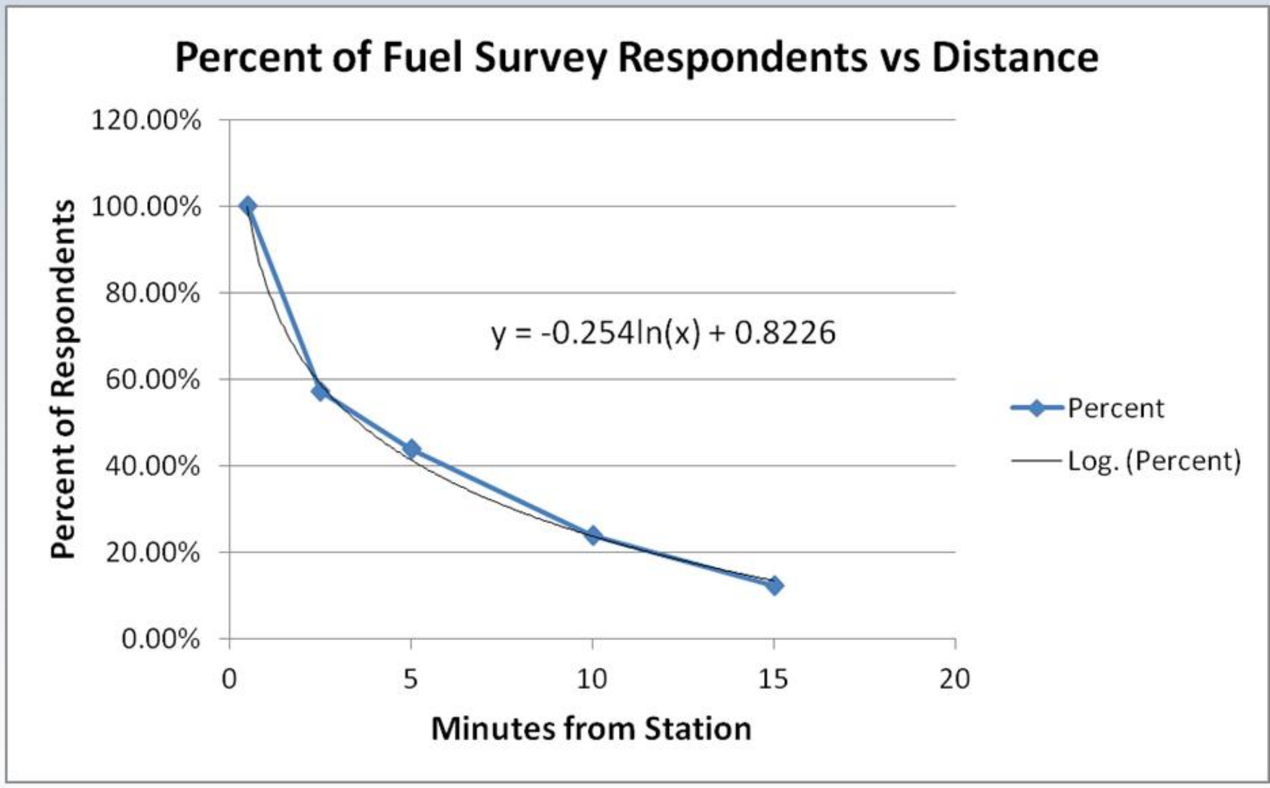


# Where People Refueled ≠ Willingness to Buy But…

Kitamura, Ryuchi. and Dan Sperling. 1987. Refueling Behavior of Automobile Drivers. *Transportation Research* 21A, no. No. 3: 235-245




Equation can be adjusted. ½

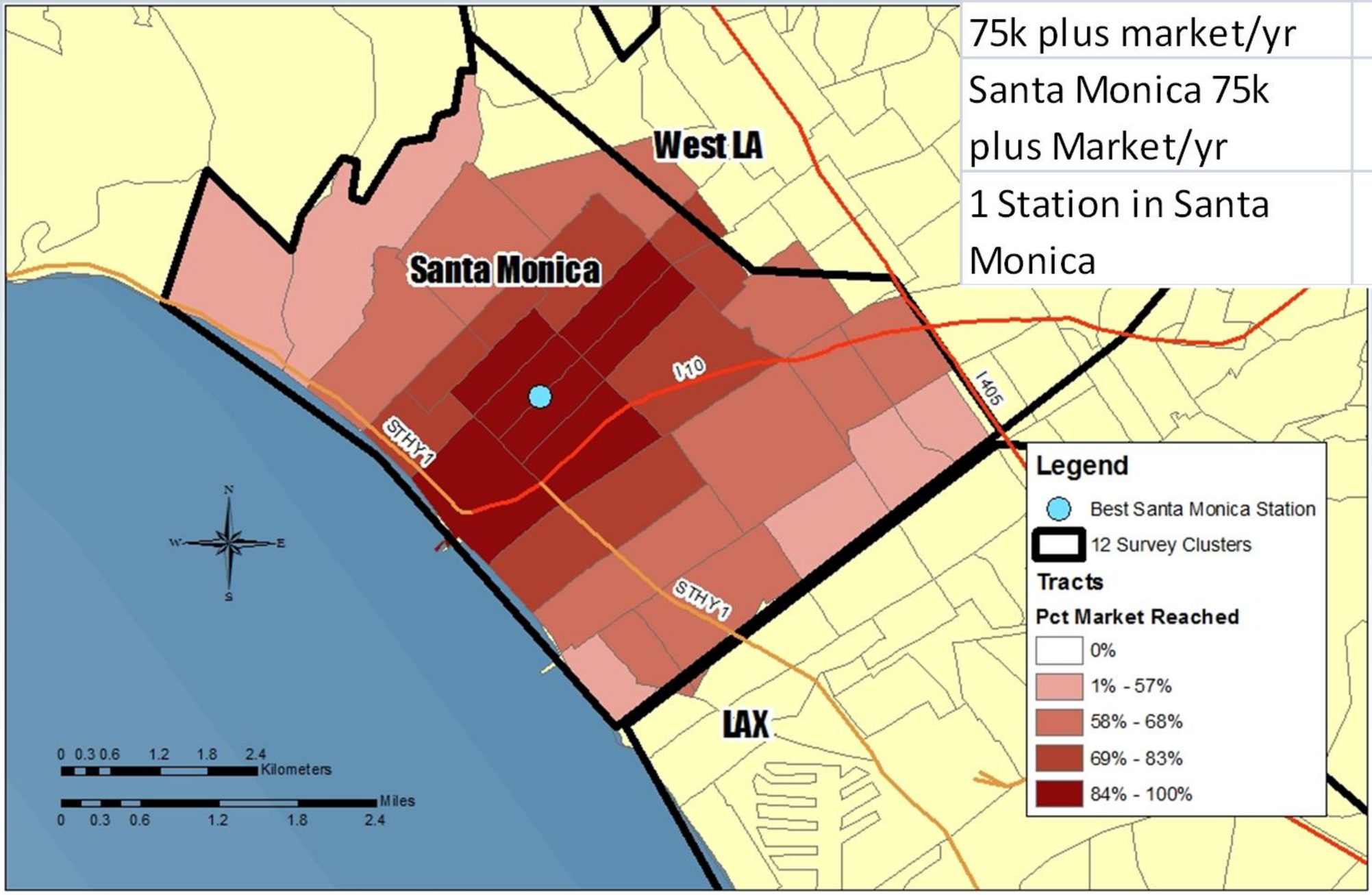



| Trip time from work | Trip time from home (min) 0-5 | 6-10 | 11-20 | 21-30 | >30 | Total |
|---|---|---|---|---|---|---|
| 0-5 | 238 (18.7) | 53 (4.2) | 92 (7.2) | 52 (4.1) | 33 (2.6) | 468 (36.8) |
| 6-10 | 95 (7.5) | 51 (4.0) | 37 (2.9) | 11 (.9) | 10 (.9) | 204 (16.0) |
| 11-20 | 103 (8.1) | 33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

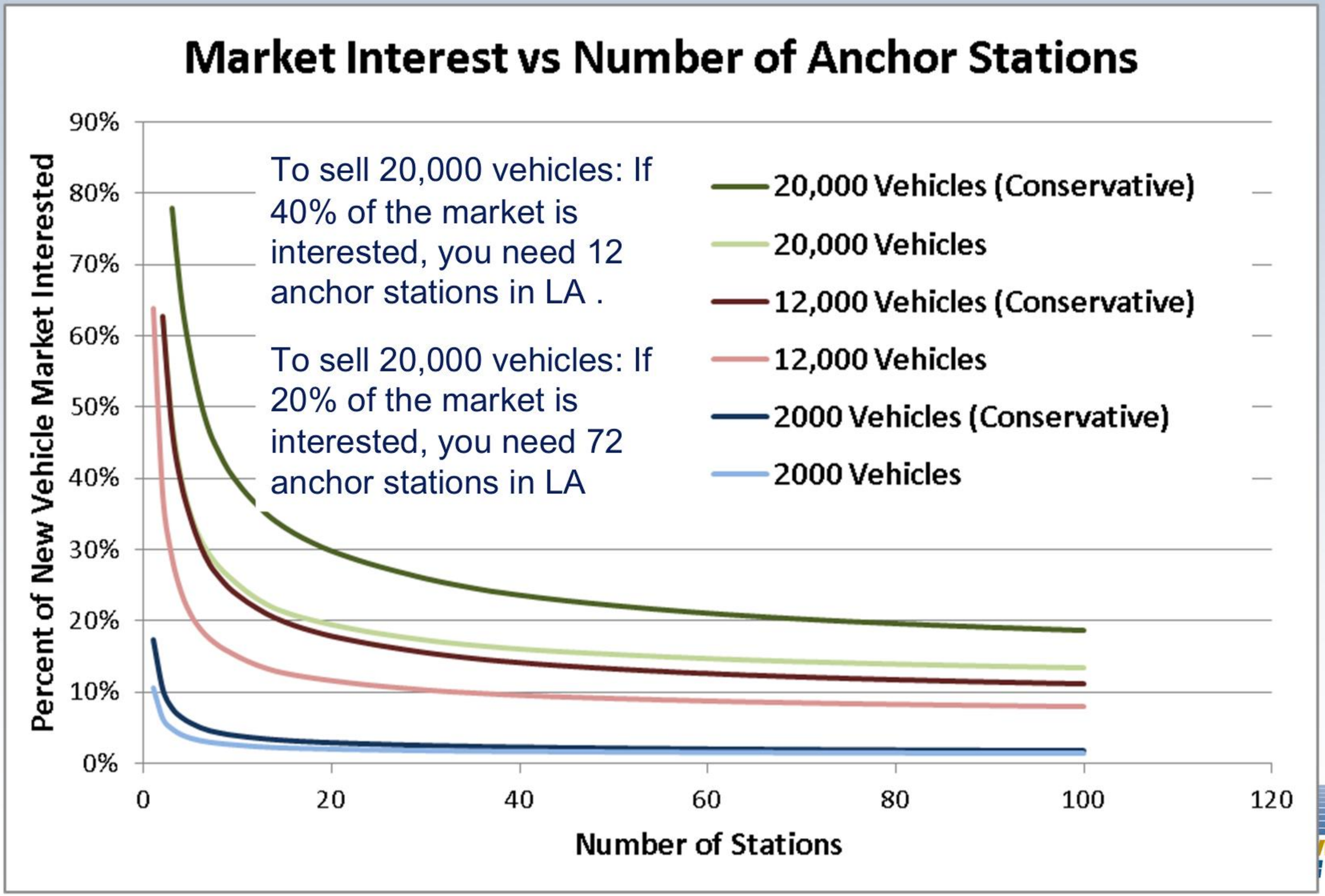
( ) = Percent of grand total

# 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% |



# How Many Stations Are Nessecary Depends on How Many People are “Just Waiting For Infrastructure”

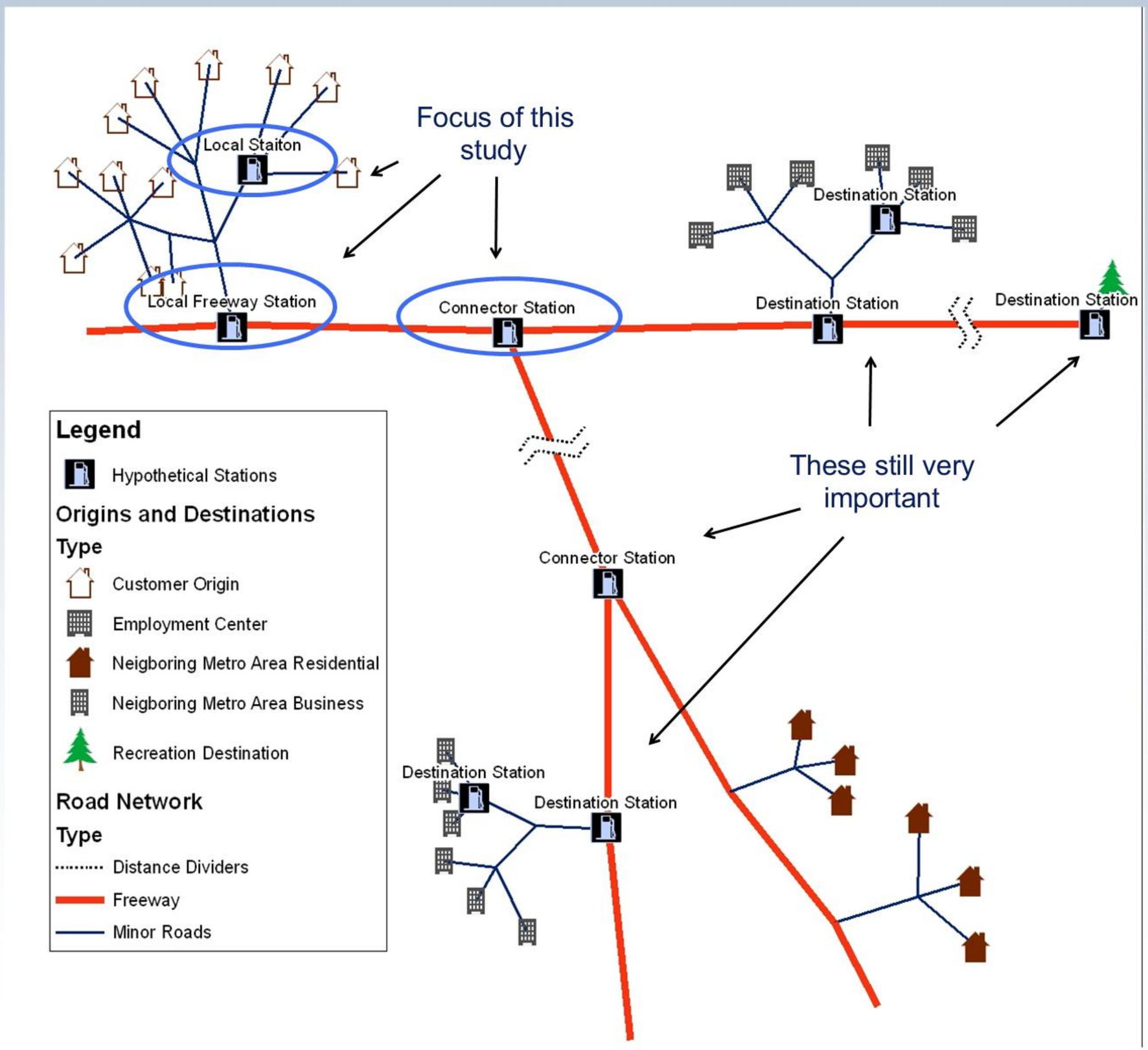


# 12 Clusters Identified by Old CAFCP Survey

# Two Ways to Measure Consumer Convenience

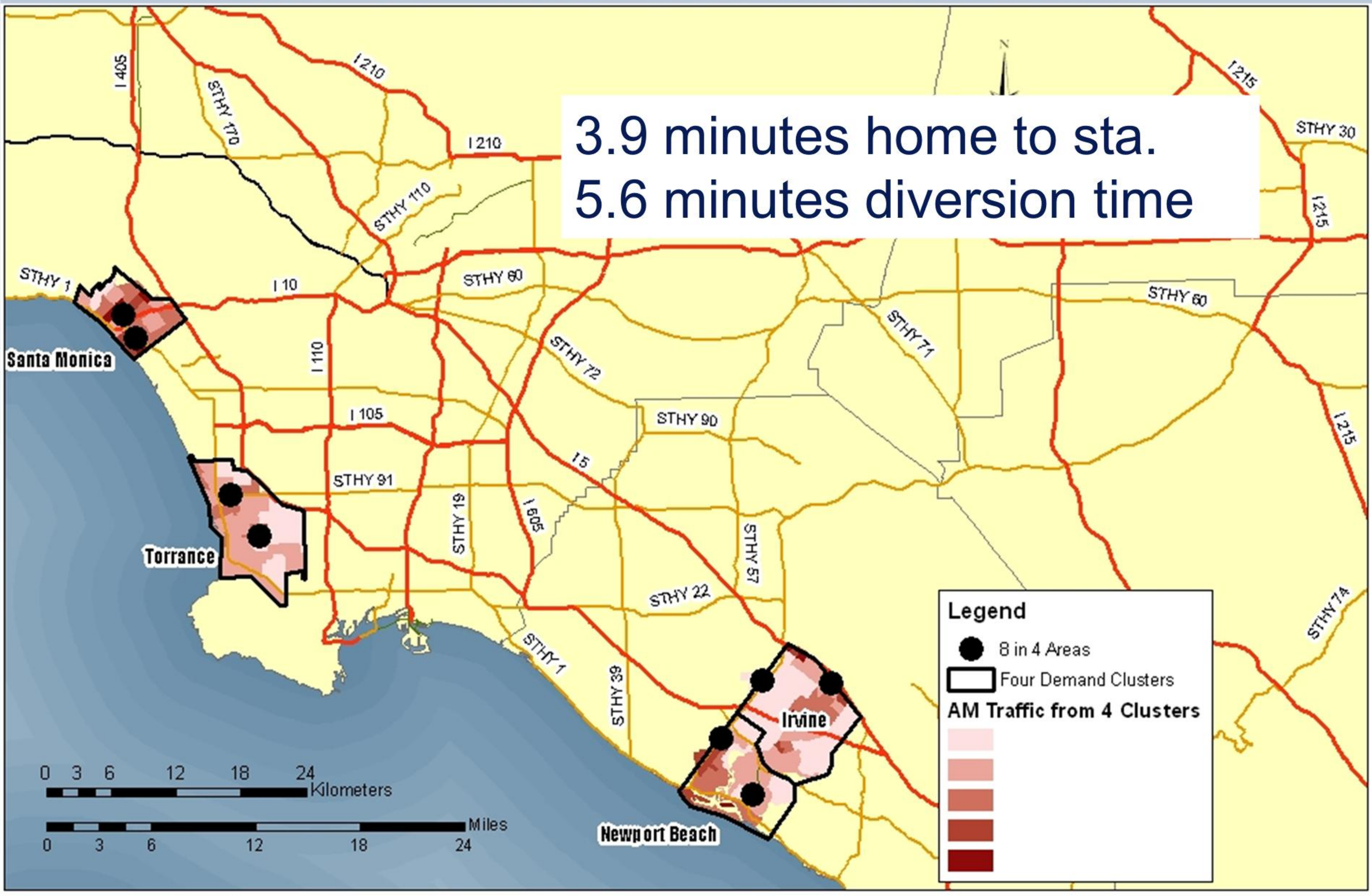
- Home to the nearest station (Anchor)
- “Diversion” time: time to nearest station while driving throughout LA Basin (Network)
- Independent of sales targets, what are the needs for numbers of stations?

# Idealized Network with Station Types

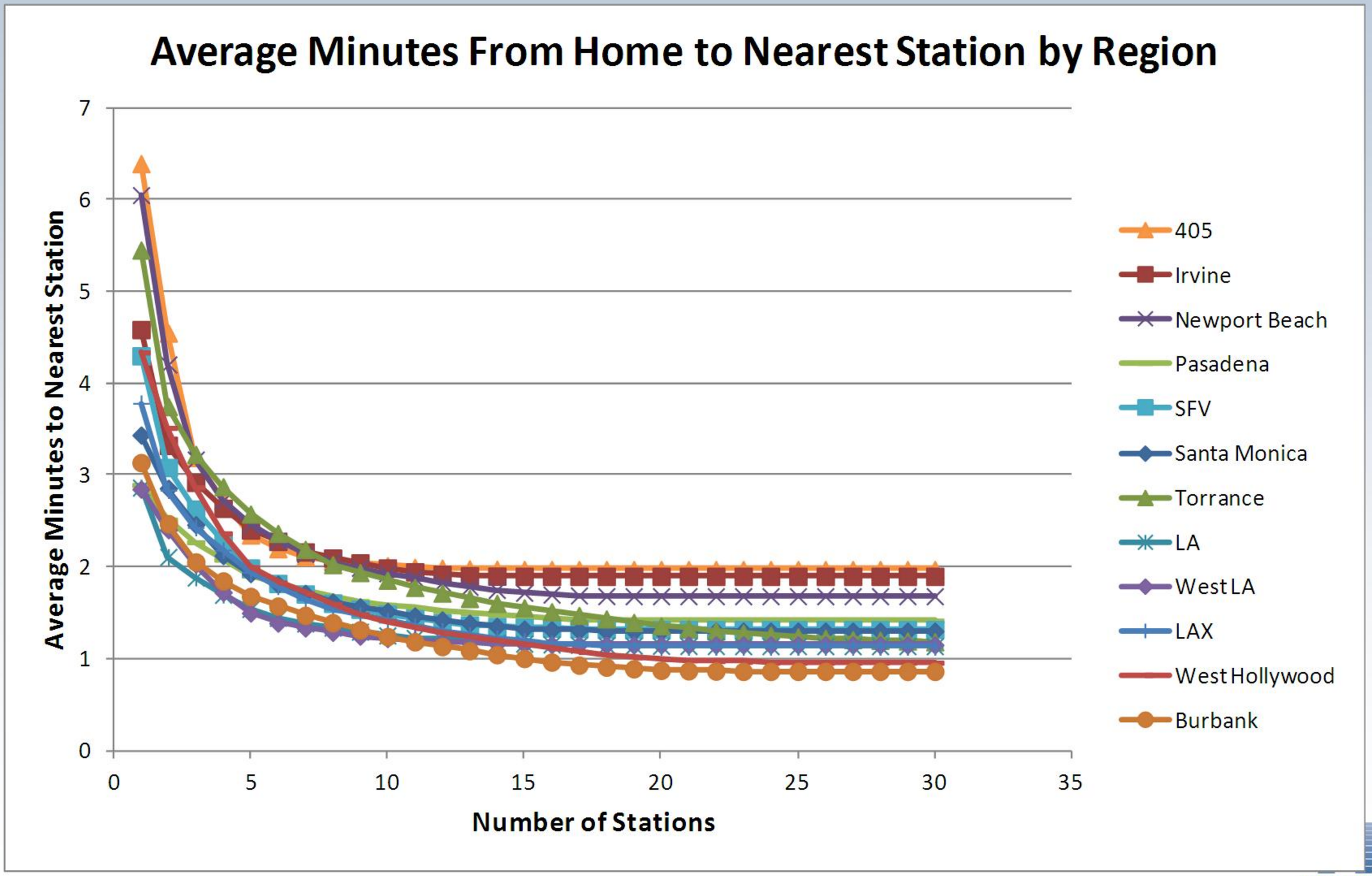


# 8 Station Example

## 4 Clusters – 2 Local Stations Per Cluster

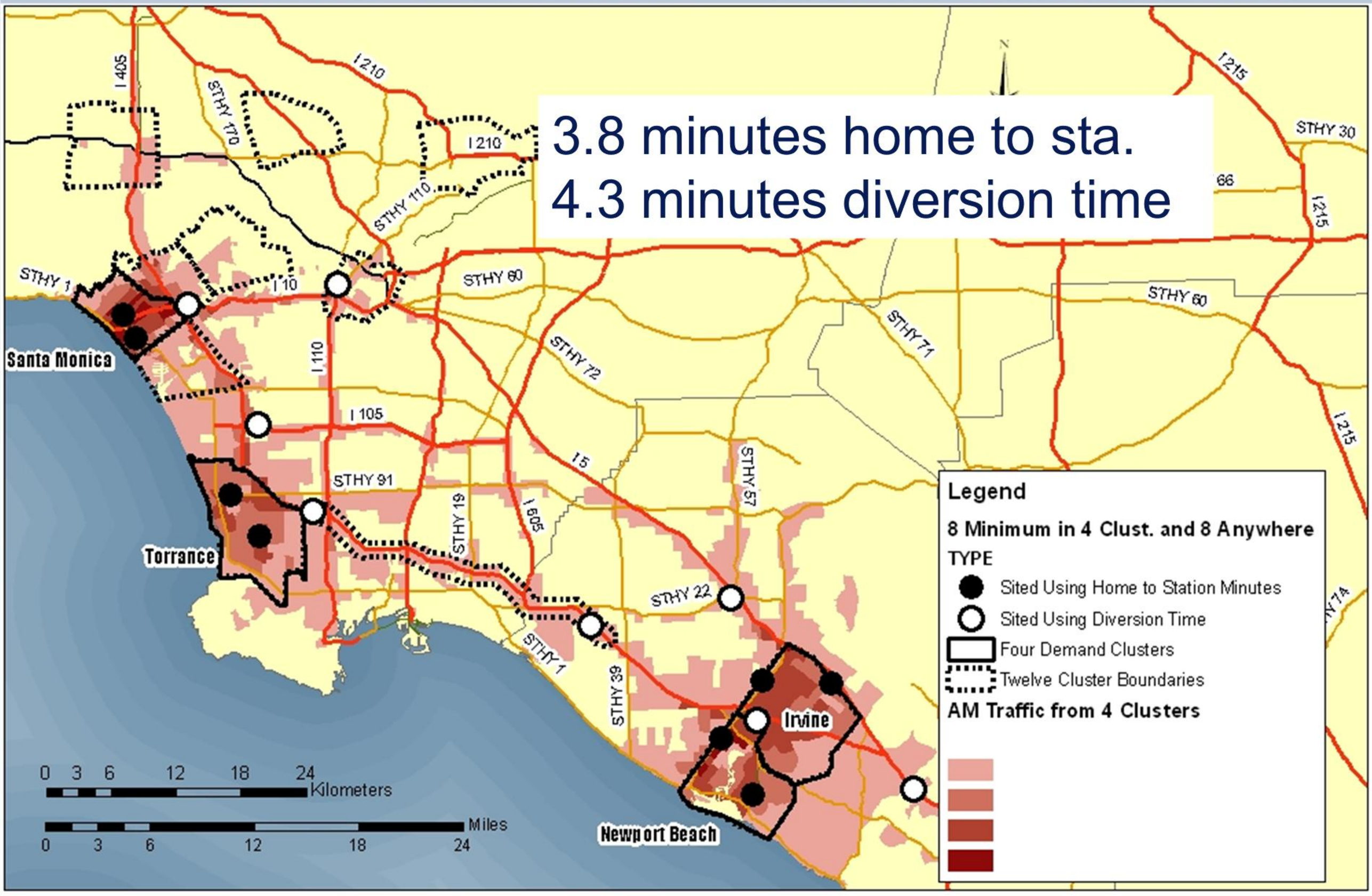


# Home to Nearest Station for Each Cluster



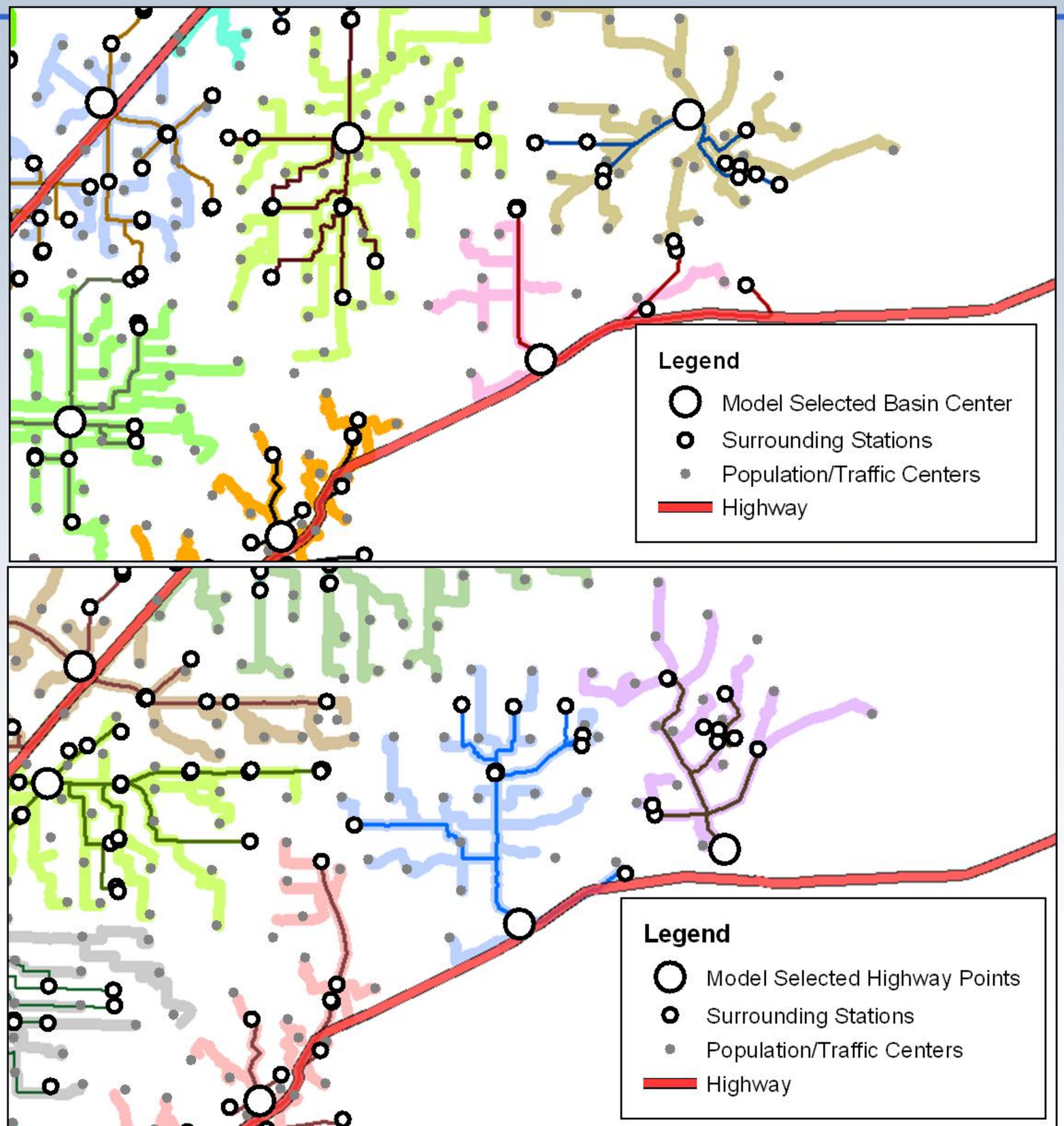
# 16 Station Example

## Add 8 Connector Stations => Lower Diversion Time



# How do people actually refuel?

## (Nicholas 2010, Journal of Transport Geography)

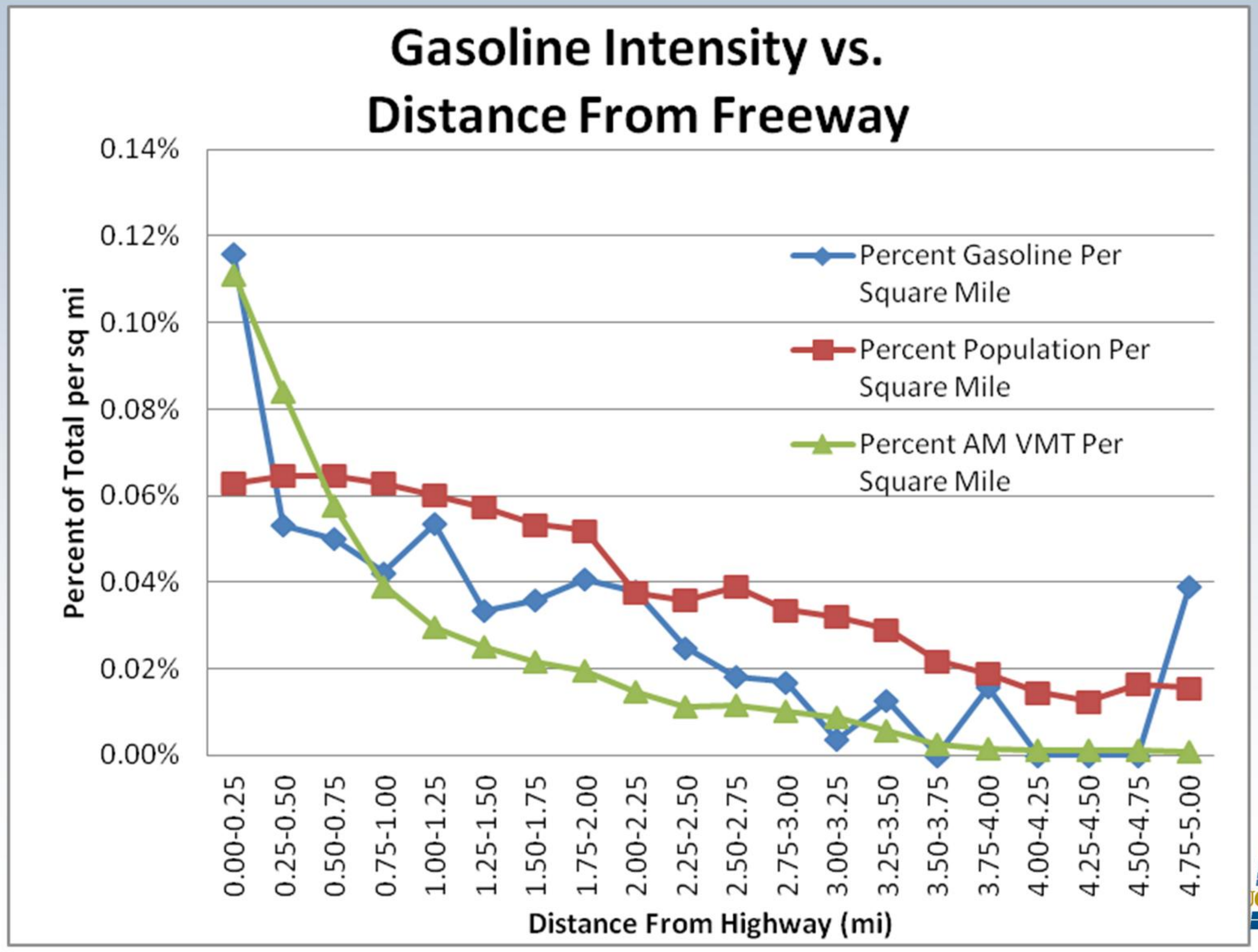



Nearest Station?

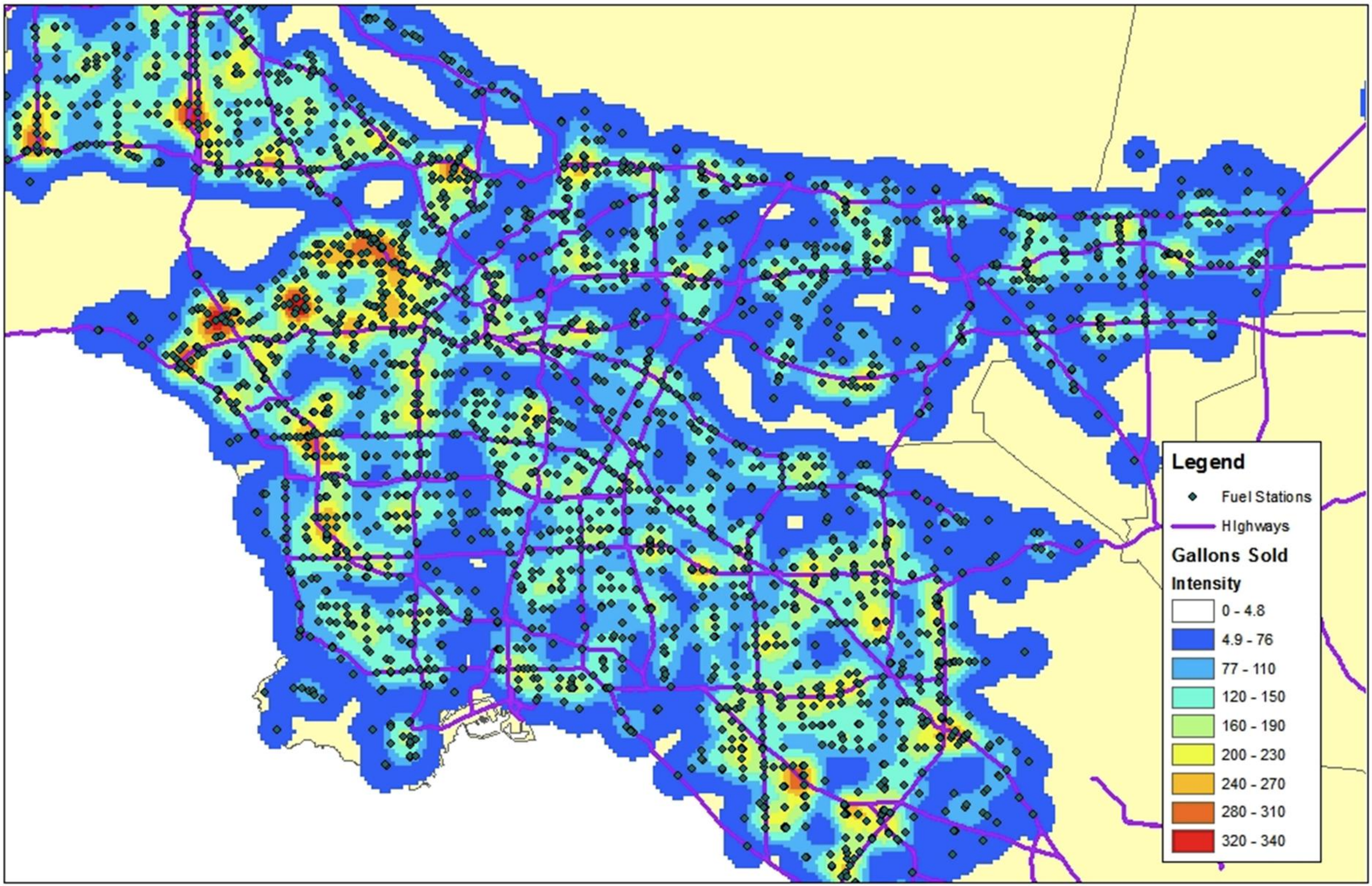
Direction of Travel?

Anywhere along path to freeway is acceptable in most cases

# Influence of the Freeway



# Fuel Distribution in Los Angeles



# Optimal Approach to Siting Stations

1. Find predisposed customers

   Hybrid sales, EV sales, OEM marketing input

2. Site stations as close as possible to their commute and shopping paths (nearest freeway/large road entrance)

3. Fill in regional holes in the network (local connector)

   Run model to identify travel paths that potential customers use

4. Connect regions together with interregional connector and destination stations

   Survey for “aspirational” stations

# Station Siting Conclusions

- An “anchor” (or set of anchor stations) station is a prerequisite for many potential buyers
- Anchor stations should be sited to attract potential buyers (new car, early adopter buyers)
- If anchor stations are like gasoline stations:
  - They could be sited on the path from home to the freeway or other frequent path
  - Closer to home is better
- Potential buyers near a station are limited
- Point of diminishing returns may be reached rather quickly in an area

# Station Siting Conclusions (Cont.)

- Market will develop over several years as people replace vehicles. ie stations under capacity
- The number of stations necessary is not absolute because it depends on  a market and price that is unknown
- Aspirational stations add value for the customer
  - Las Vegas, I-5, Tahoe, Yosemite, Palm Springs, Santa Barbara, Big Sur, Napa
- Redundancy is important.  “One station means 2”
  - Perhaps within 5 minutes of each other

# Questions

- What is the optimal approach to select site locations for hydrogen fueling stations in the future? (e.g., how to decide between two locations in one town).
- What defines the optimal station location?
- How would you advise the Energy Commission to choose the optimal/best locations for hydrogen fueling stations in the future?
- Approaches for selecting the locations of hydrogen fueling stations for California's hydrogen infrastructure network strategy
- Existing research about how to optimize the selection of potential hydrogen fueling station locations
- Definition of clusters, connector stations and destination stations. Identification and definition of other regional prioritization concepts
- Role of automakers' fuel cell vehicle sales projections in hydrogen infrastructure siting and award selection
- Other ideas and recommendations on hydrogen infrastructure siting
- Other issues related to hydrogen fueling infrastructure location or the design of a solicitation

# Extras

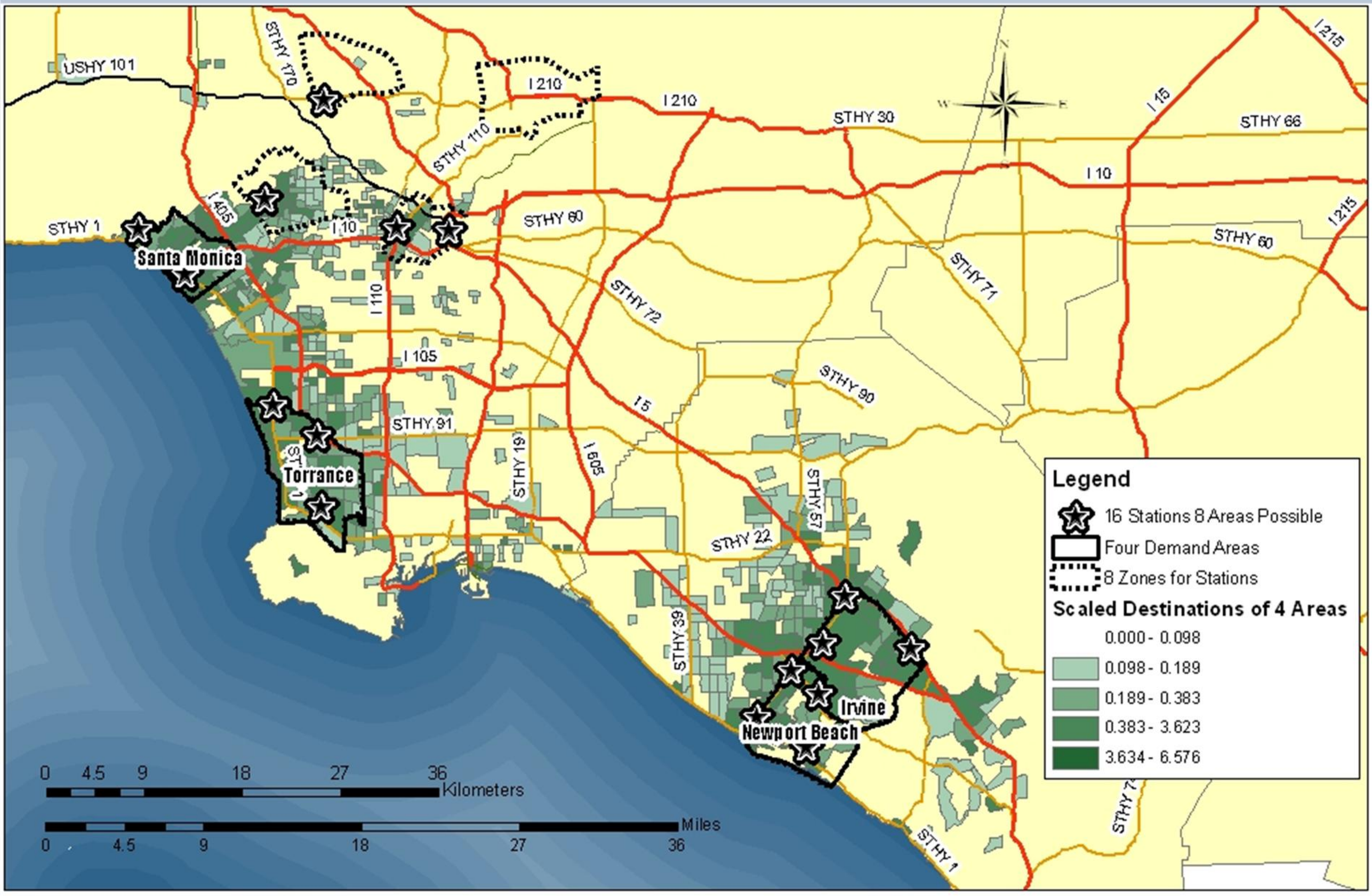
# Can you Have Just One Station for 34,000 Cars?

- Give away free fuel and free cars with unlimited warranty

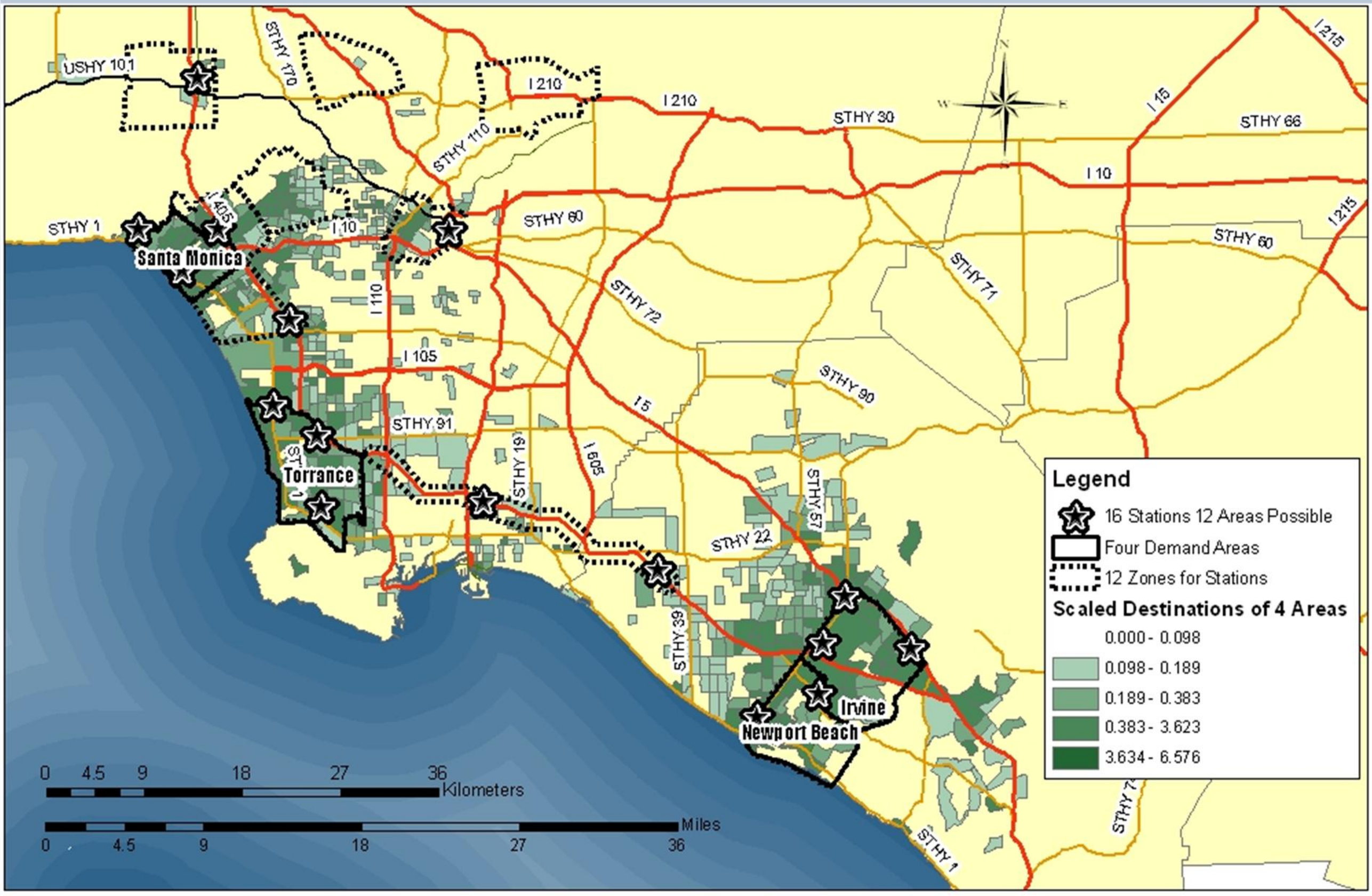
$$Utility = B_{veh} - P_{veh} - OC_{veh} - NI$$

$B_{veh}$ = Benefit of the Vehicle
$P_{veh}$ = Price of the Vehicle
$OC_{veh}$ = Operation Cost
$NI$ = Network Inconv.

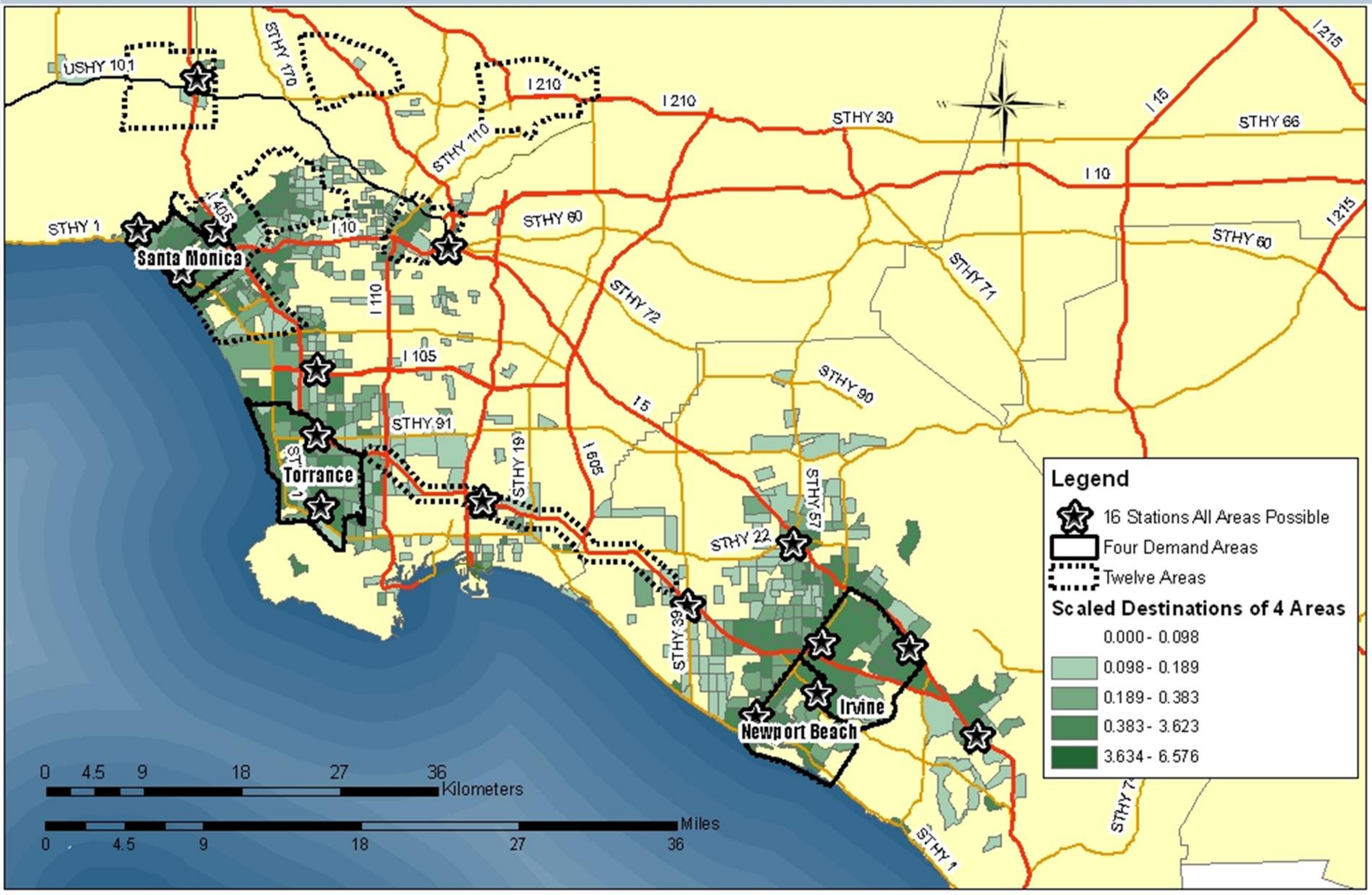
# Destinations of 4 Clusters: 16 Stations in 8 Areas



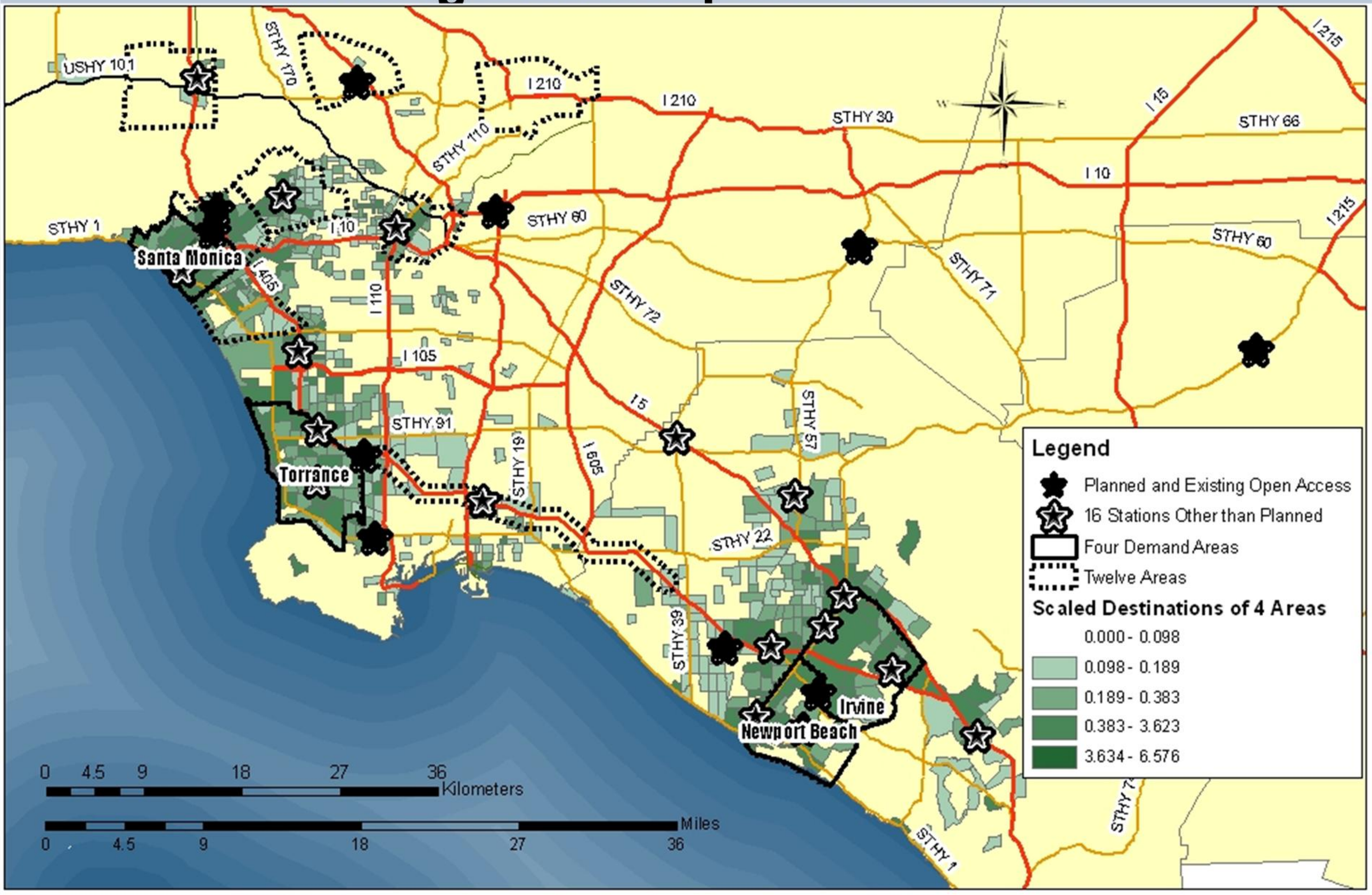
# Destinations of 4 Clusters: 16 Stations in 12 Areas



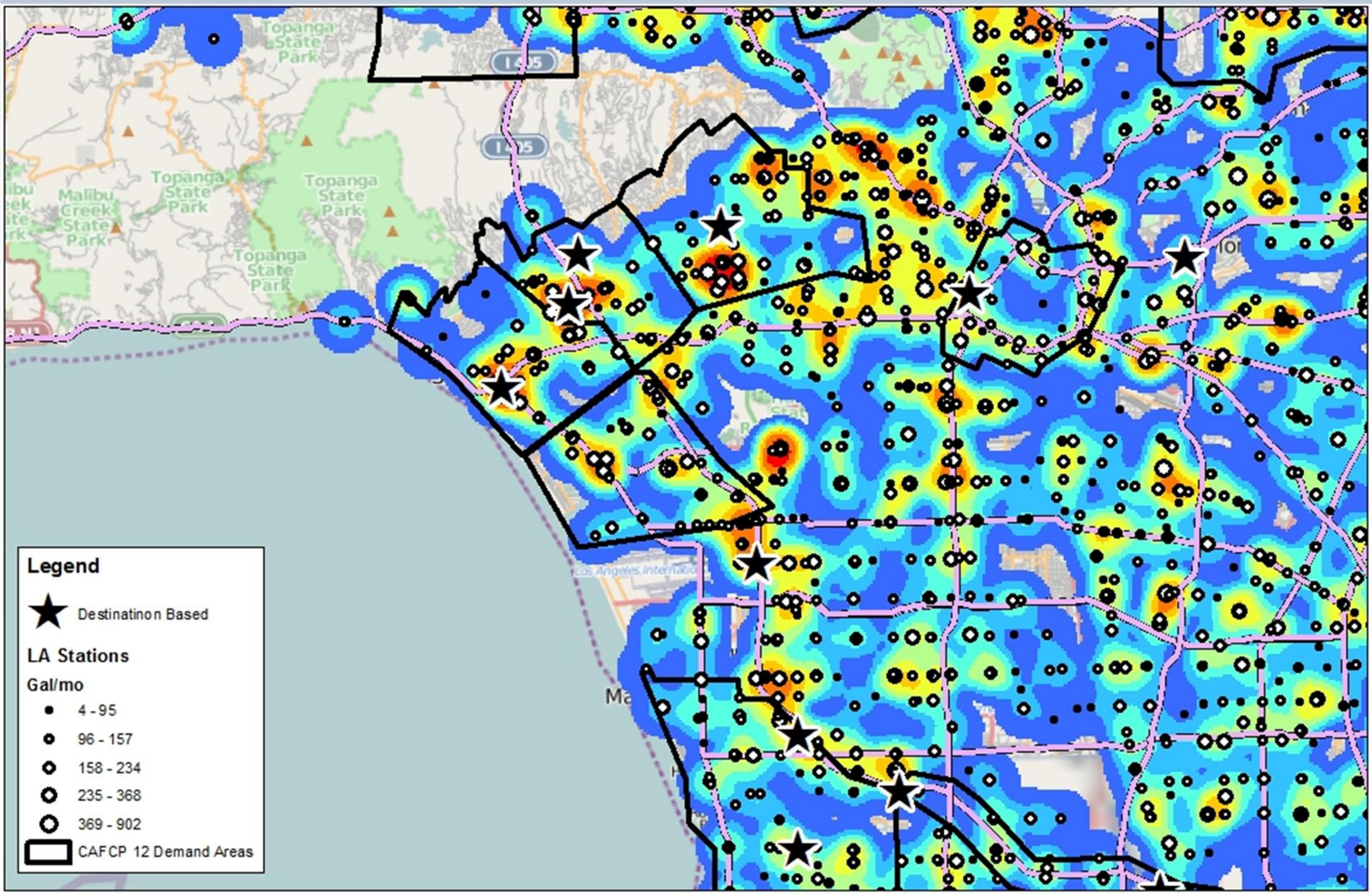
# Destinations of 4 Clusters: 16 Stations Regionwide



# Destinations of 4 Clusters:
# Existing stations plus 16 Stations



# Planned, Existing, and Model Stations



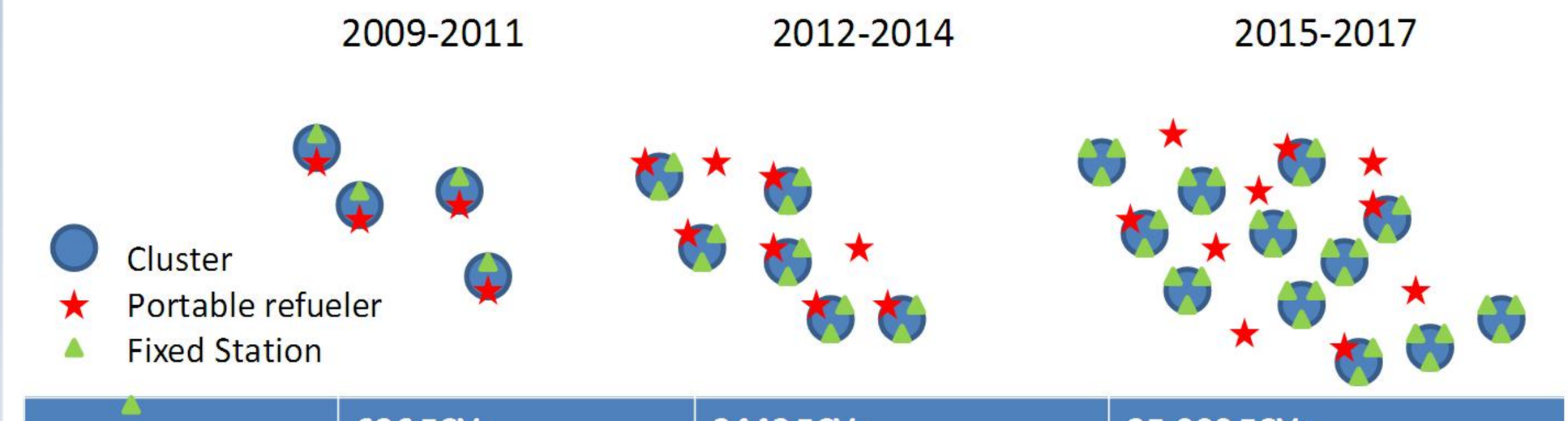
# Characterizing the Demand by Region (TRB 2005)

| | Population in Urban Center | Urban Area (sq mi) | Urban Density (people / sq. mi) | Urban Density (people / sq. km) | Avg. Tract Size (mi) | Avg. Tract Size (km) | Number of Urban Stations | Number of People Per Station | Avg. Minutes to Closest Station |
|---|---|---|---|---|---|---|---|---|---|
| L.A. | 14,340,402 | 2,645 | 5,421 | 2,093 | 0.9 | 2.33 | 3,355 | 4,274 | 1.60 |
| S.F. | 5,474,575 | 1,111 | 4,927 | 1,903 | 0.96 | 2.48 | 1,246 | 4,394 | 1.72 |
| SD | 2,538,862 | 606 | 4,189 | 1,618 | 1.1 | 2.84 | 572 | 4,439 | 2.20 |
| Sac | 1,247,224 | 331 | 3,768 | 1,454 | 1.21 | 3.12 | 304 | 4,103 | 2.24 |

| | LA | SF | SD | SAC |
|---|---|---|---|---|
| 3 Minutes | 6.8% | 7.9% | 14.5% | 15.8% |
| 4 Minutes | 3.2% | 3.5% | 6.8% | 7.2% |
| 5 Minutes | 1.8% | 2.1% | 3.7% | 4.3% |
| 6 Minutes | 1.2% | 1.4% | 2.3% | 2.6% |
| 7 Minutes | 0.8% | 1.0% | 1.6% | 1.6% |

| | LA | SF | SD | SAC | Total |
|---|---|---|---|---|---|
| 3 Minutes | 228 | 99 | 83 | 48 | 327 |
| 4 Minutes | 109 | 44 | 39 | 22 | 153 |
| 5 Minutes | 61 | 26 | 21 | 13 | 87 |
| 6 Minutes | 39 | 17 | 13 | 8 | 56 |
| 7 Minutes | 26 | 13 | 9 | 5 | 39 |

# Anchor + Network Examples




| | 636 FCVs | 3442 FCVs | 25,000 FCVs |
|---|---|---|---|
| # Stations | 8 | 20 | 42 |
| # clusters | 4 (2 sta/cluster) | 6 (3 sta/cluster) | 12 (3 sta/cluster) |
| # connect.sta | 0 | 2 | 6 |
| Station Mix | 4 Portable refuelers<br>4 SMRs (100 kg/d) | 8 Portable Refuelers<br>12 SMRS (250 kg/d) | 10 Portable refuelers<br>12 SMRs (250 kg/d)<br>20 SMRs (1000 kg/d) |
| New Equip. Added | 4 Portable refuelers<br>4 SMRs (100 kg/d) | 4 Portable Refuelers<br>12 SMRS (250 kg/d) | 2 Portable refuelers<br>20 SMRs (1000 kg/d) |
| Capital Cost | $20Million | $52 Million | $98 Million |
| O&M Cost | 3-5$Million/y | 11-14 $Million/y | 30-40 $Million/y |
| H2 cost $/kg | 77 | 37 | 13 |
| Ave travel time | 3.9 minutes | 2.9 minutes | 2.6 minutes |
| Diversion time | 5.6 minutes | 4.5 minutes | 3.6 minutes |

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