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INSTITUTE OF TRANSPORTATION STUDIES

Deciding Where to Put Hydrogen Stations

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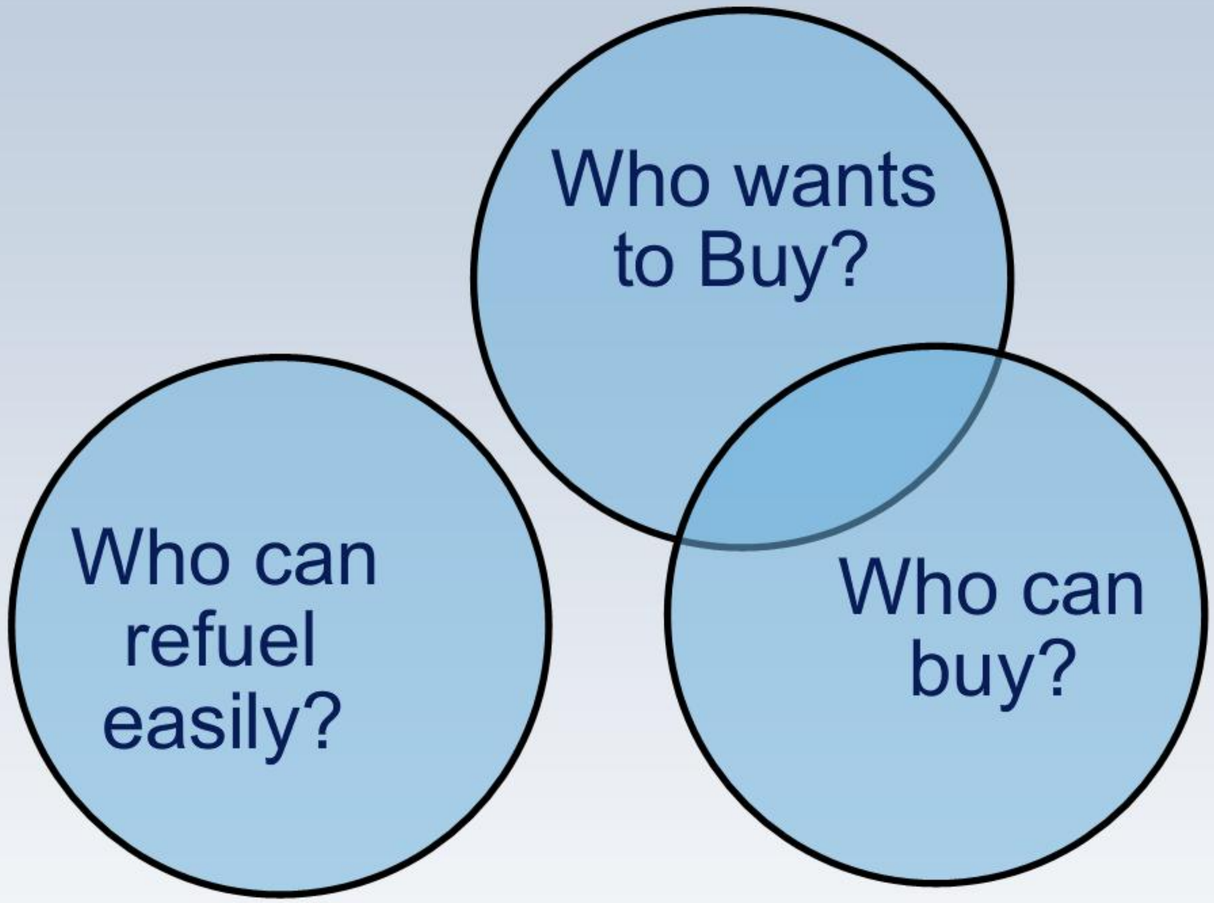
Basic Questions – What are the Goals of Infrastructure Placement?

- **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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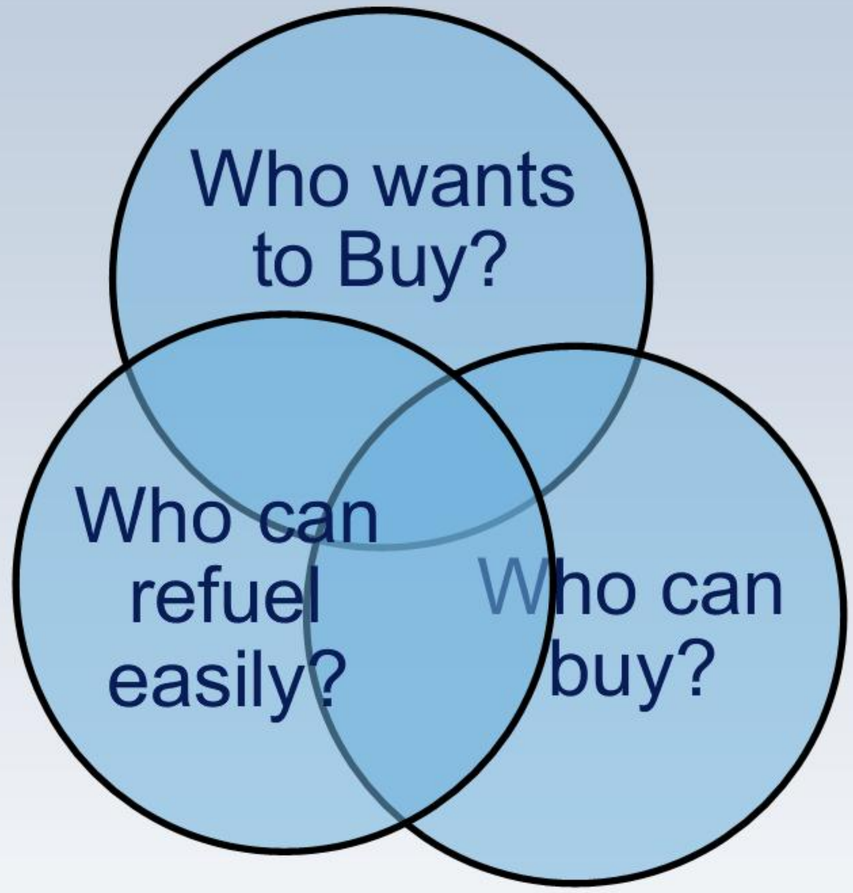

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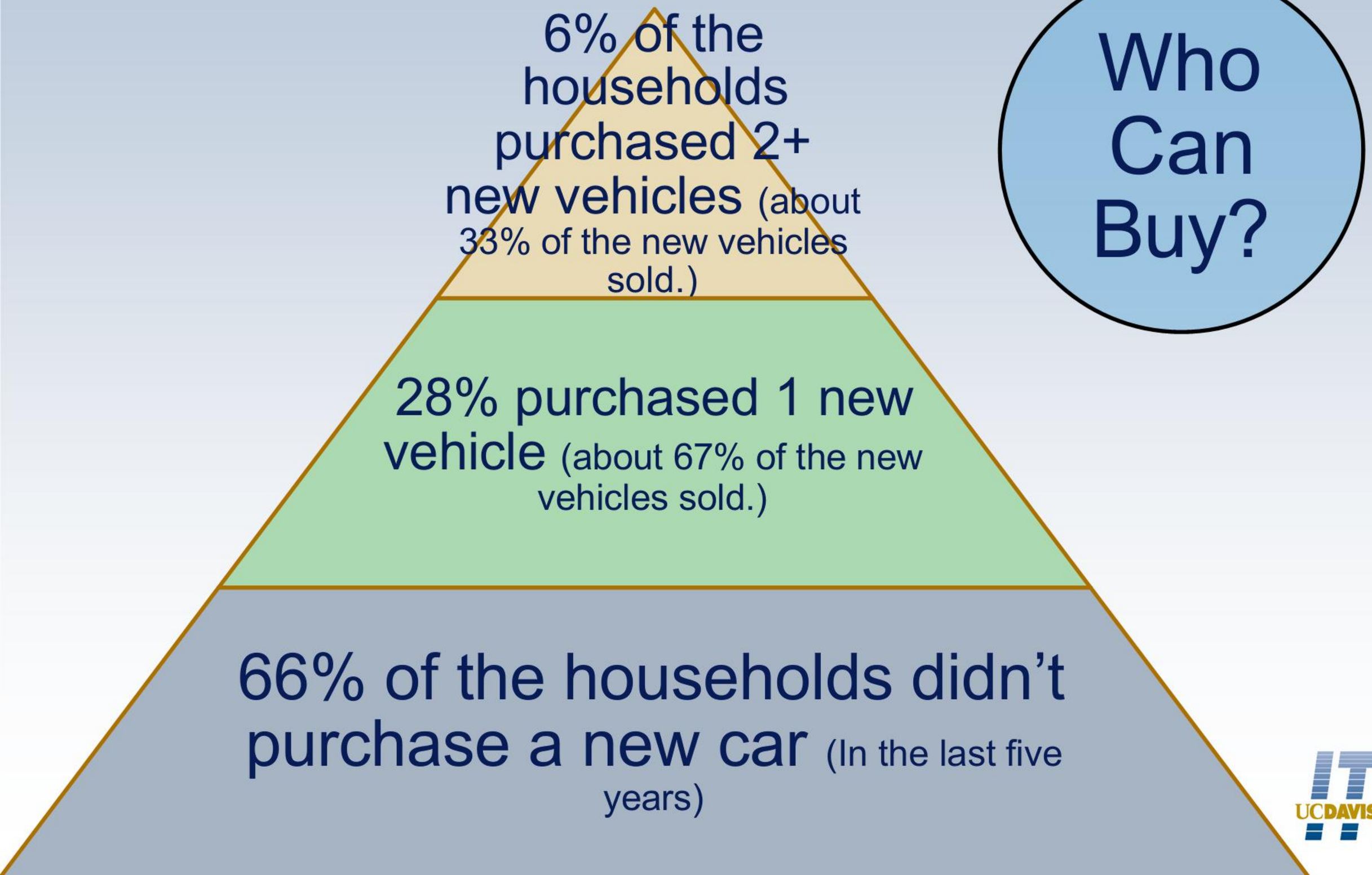
Proposed Decision Framework

- 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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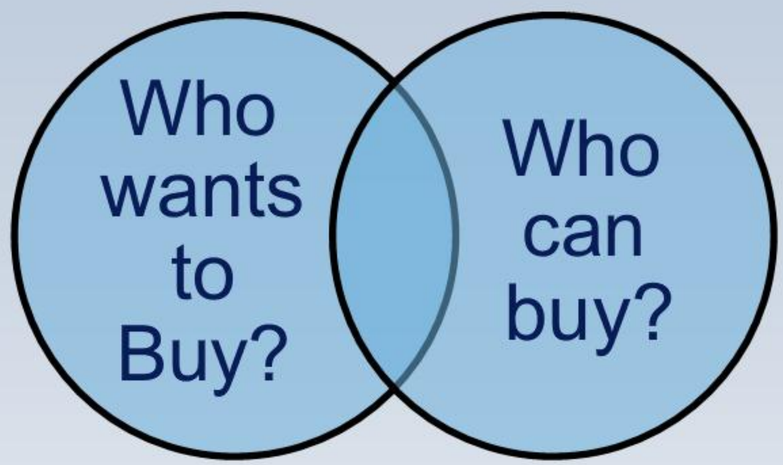
Who Will buy New Vehicle Types? LEAF Example



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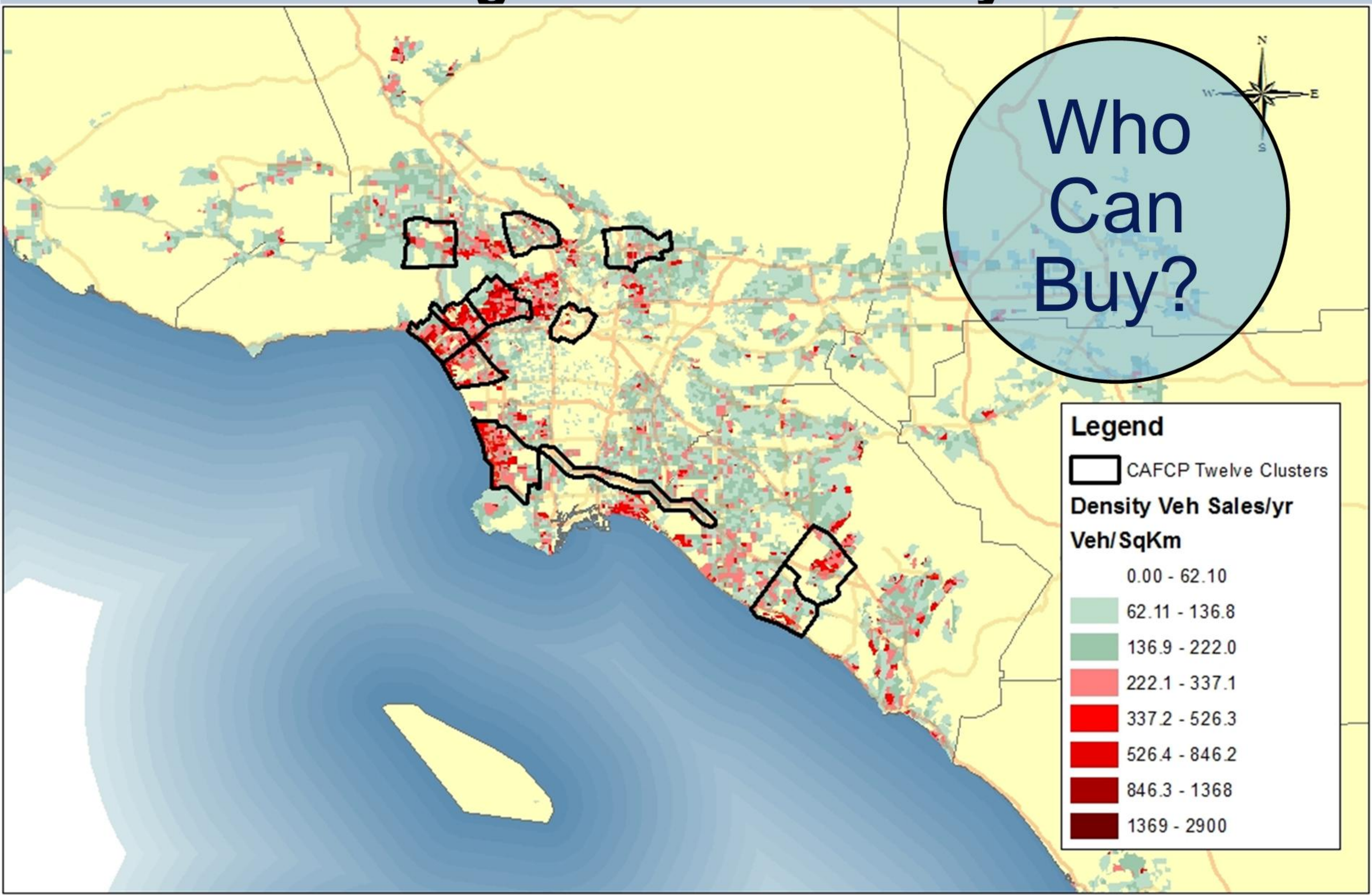
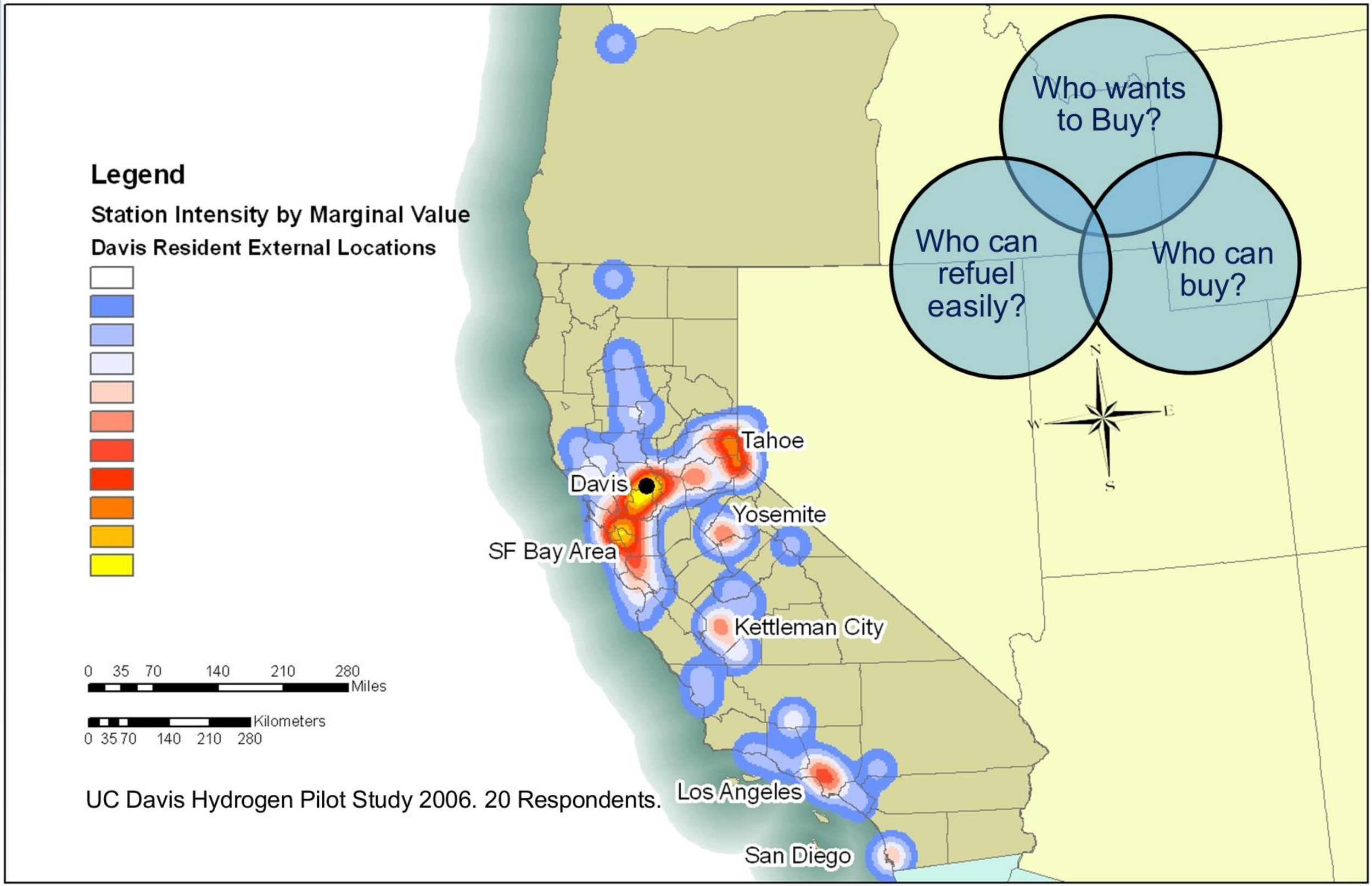
Where do Leaf Buyers Live ? (n=1151)

New Car Buyers? Same Places.

Los Angeles New Car Buyers

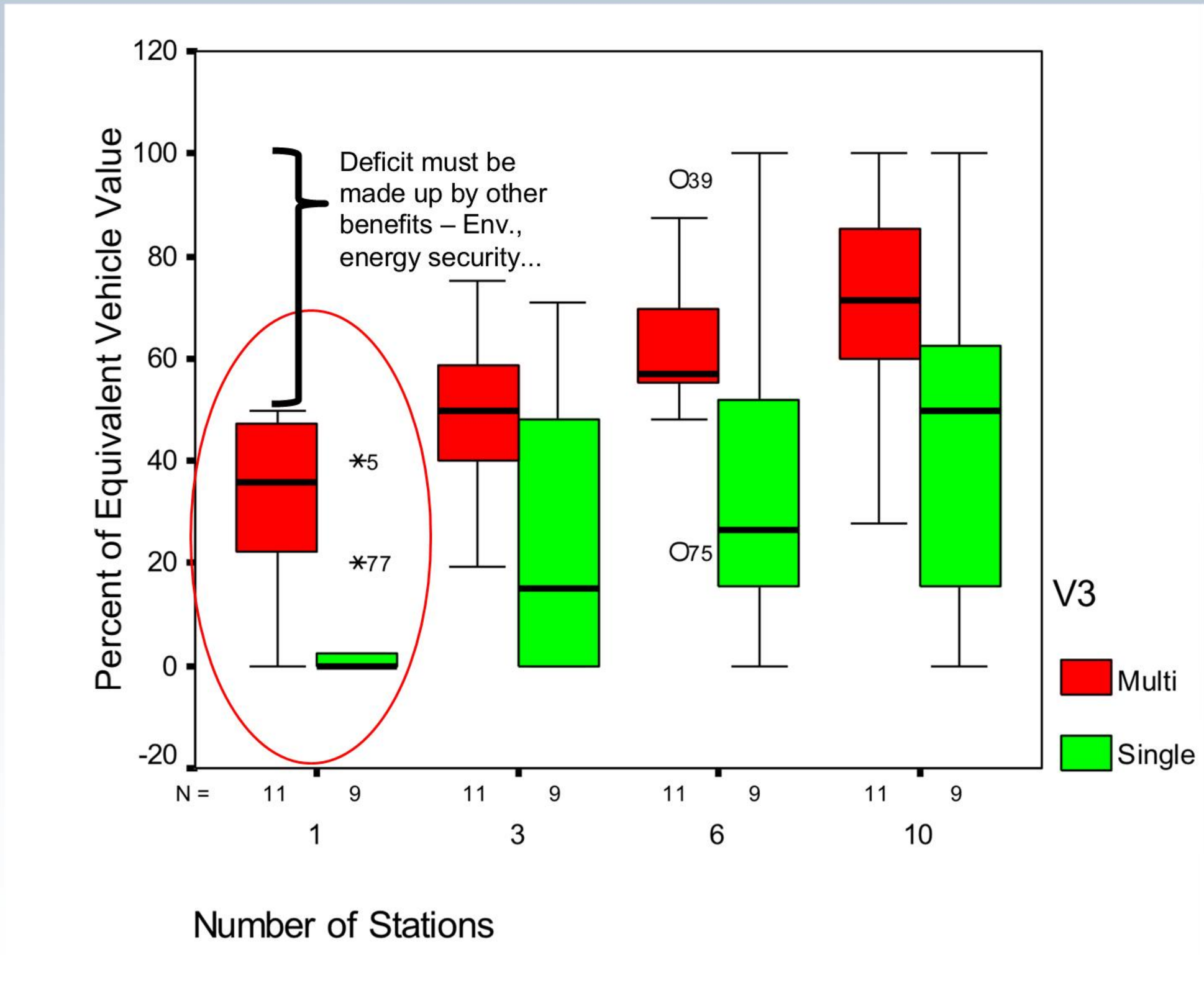


What do Willing Buyers Want for Infrastructure? (H2)
A: One "Anchor" and then Medium to Far.

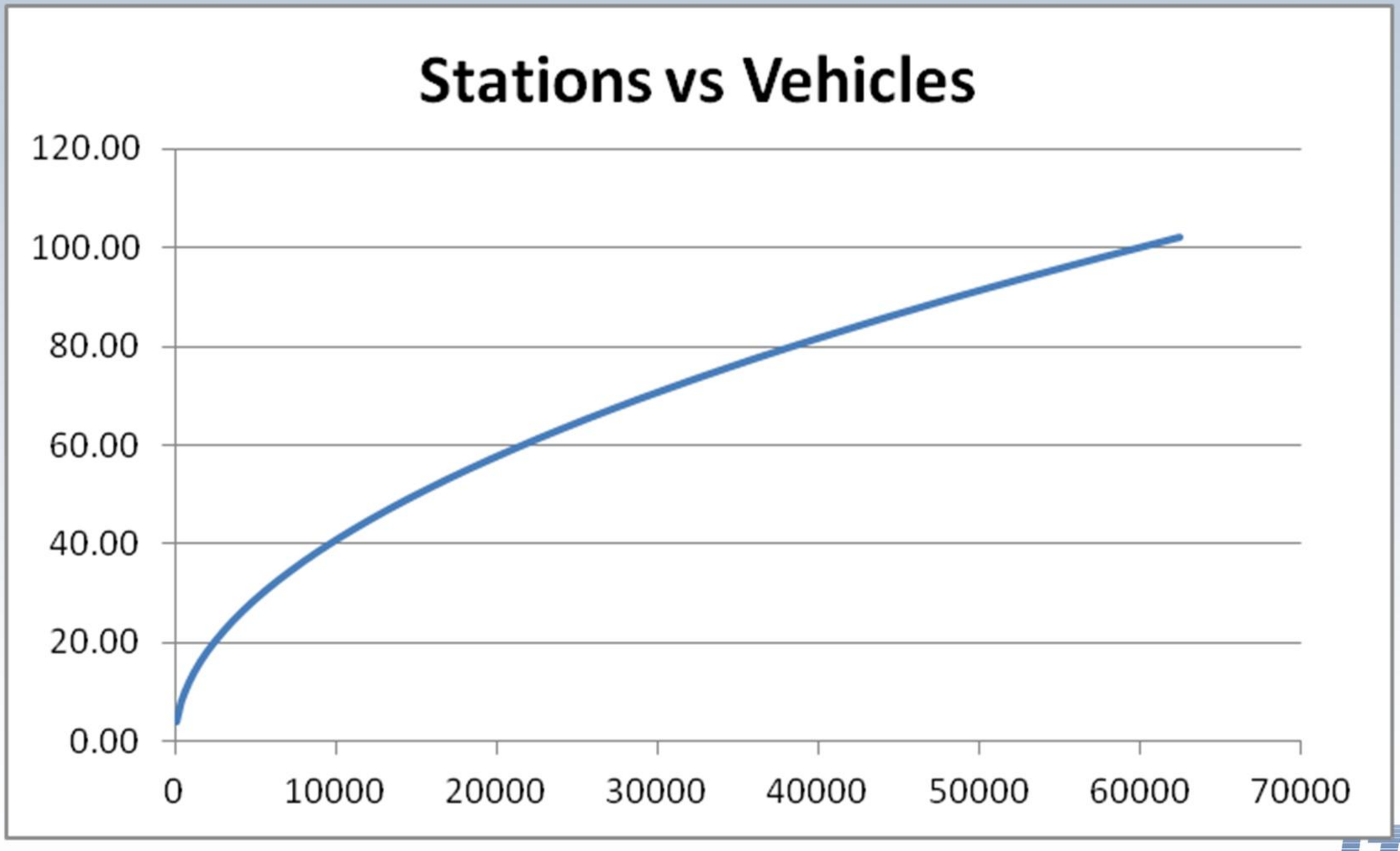


UC Davis Hydrogen Pilot Study 2006. 20 Respondents.

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

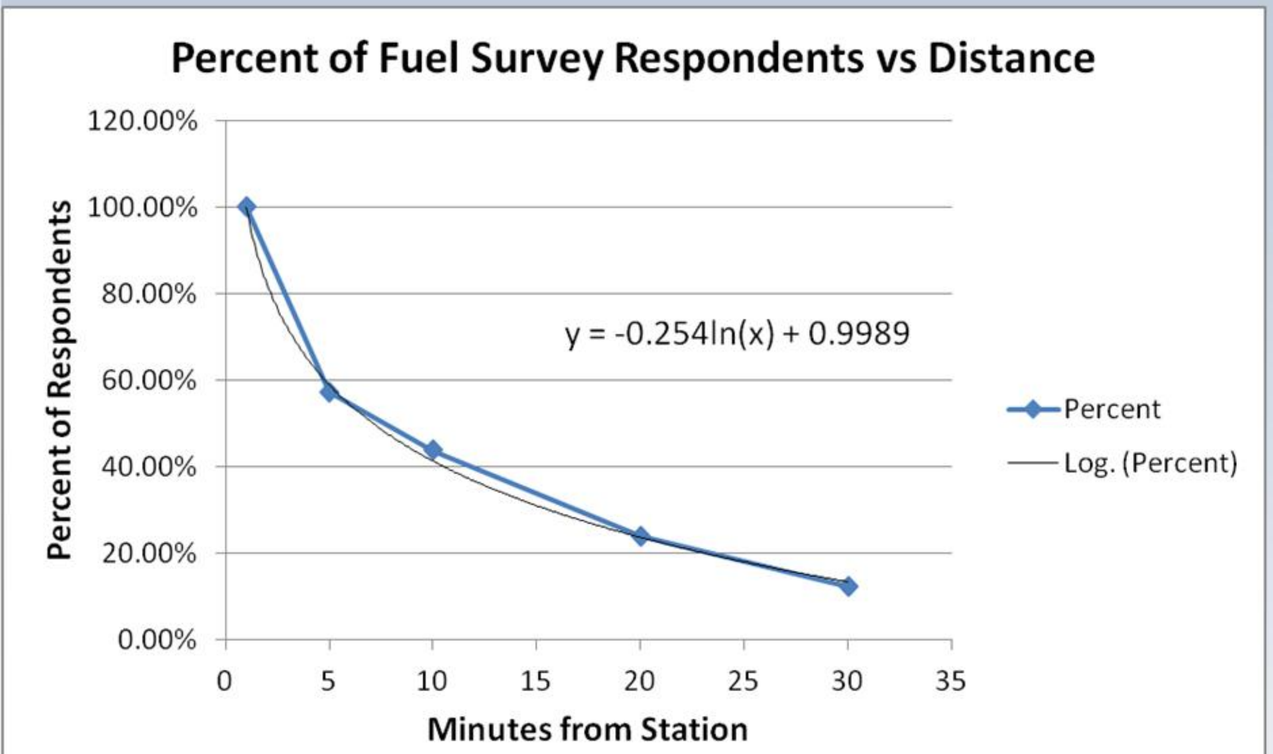


Anchor(s) + Network (Illustrative)

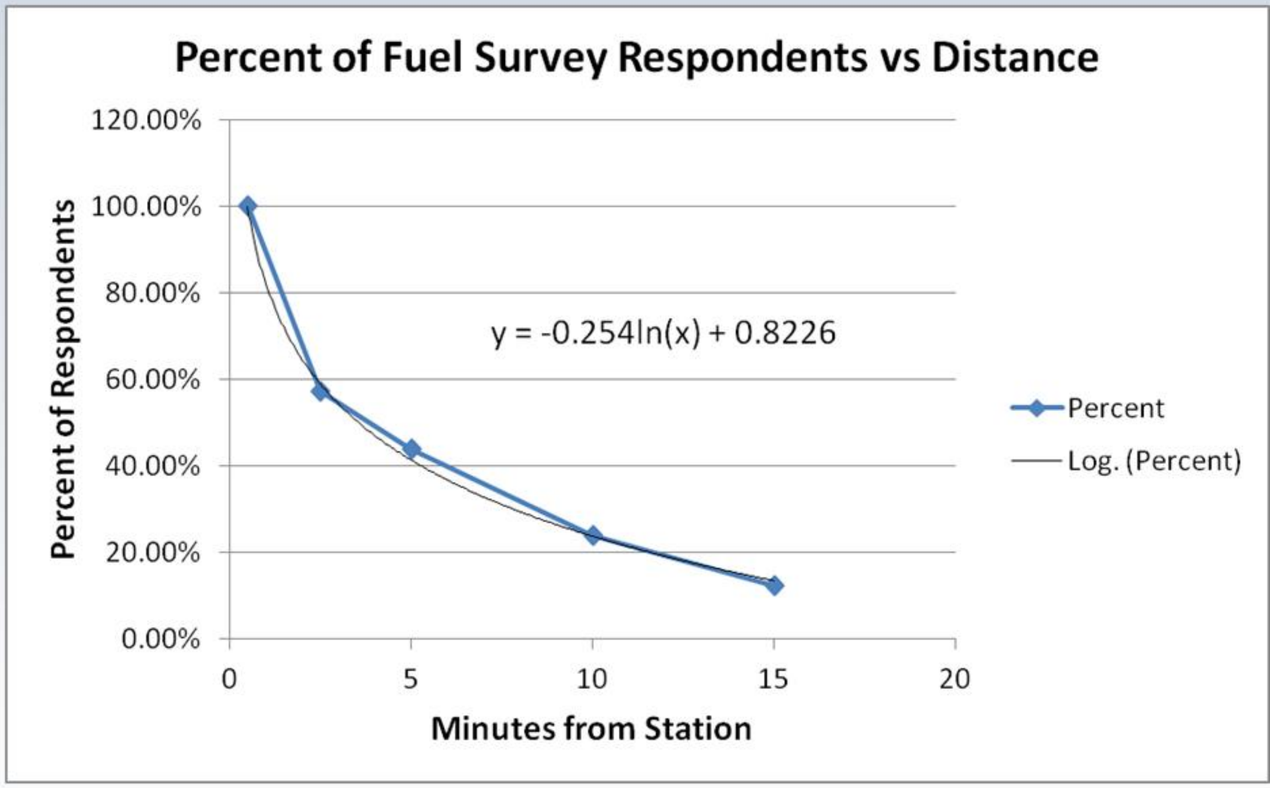


Where People Refueled ≠ Willingness to Buy But…

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



Equation can be adjusted. ½

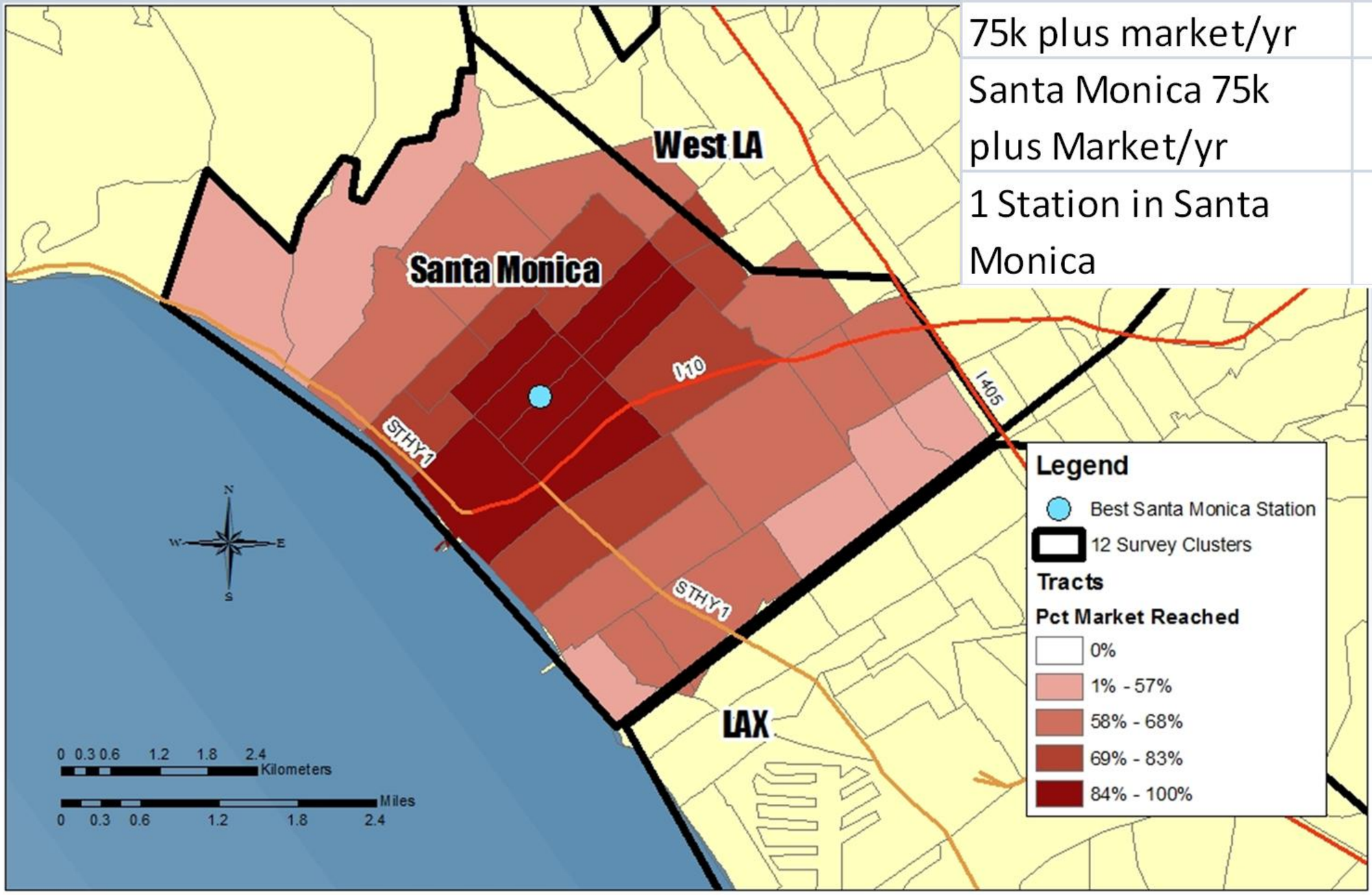


Trip time from work	Trip time from home (min) 0-5	6-10	11-20	21-30	>30	Total
0-5	238 (18.7)	53 (4.2)	92 (7.2)	52 (4.1)	33 (2.6)	468 (36.8)
6-10	95 (7.5)	51 (4.0)	37 (2.9)	11 (.9)	10 (.9)	204 (16.0)
11-20	103 (8.1)	33 (2.6)	72 (5.7)	25 (2.0)	14 (1.1)	247 (19.4)
21-30	55 (4.3)	17 (1.3)	24 (1.9)	50 (3.9)	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)

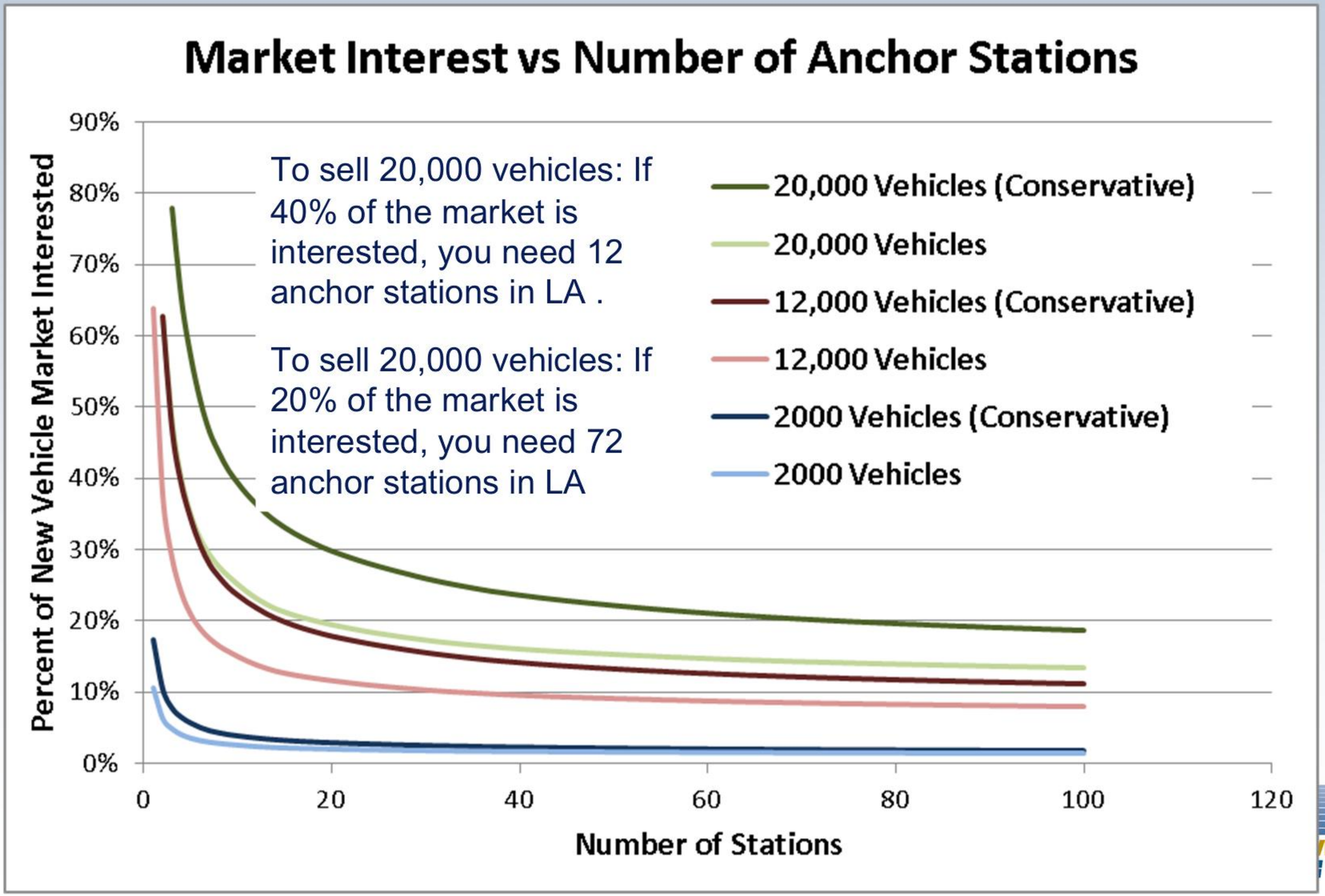
( ) = Percent of grand total

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”

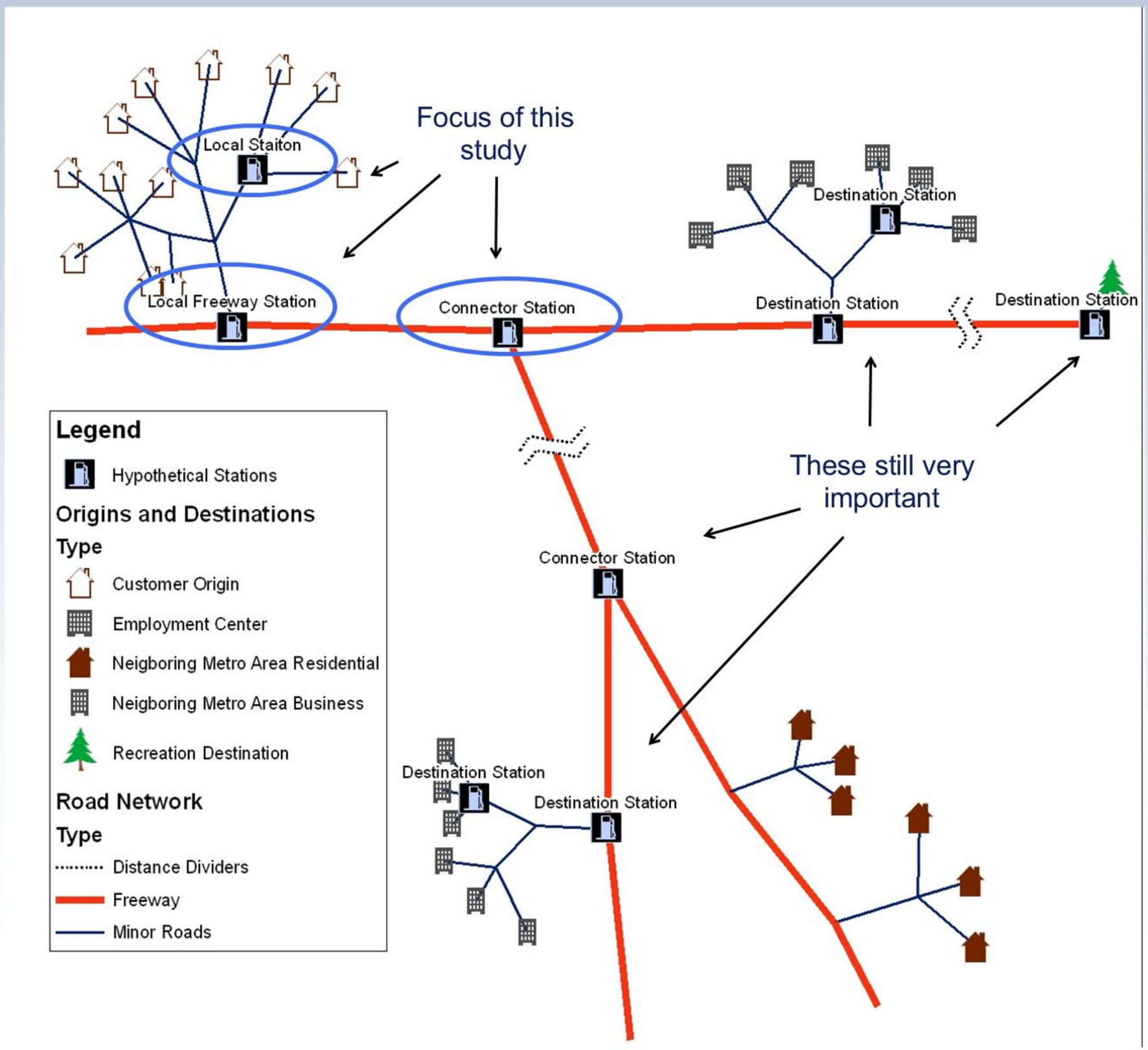


12 Clusters Identified by Old CAFCP Survey

Two Ways to Measure Consumer Convenience

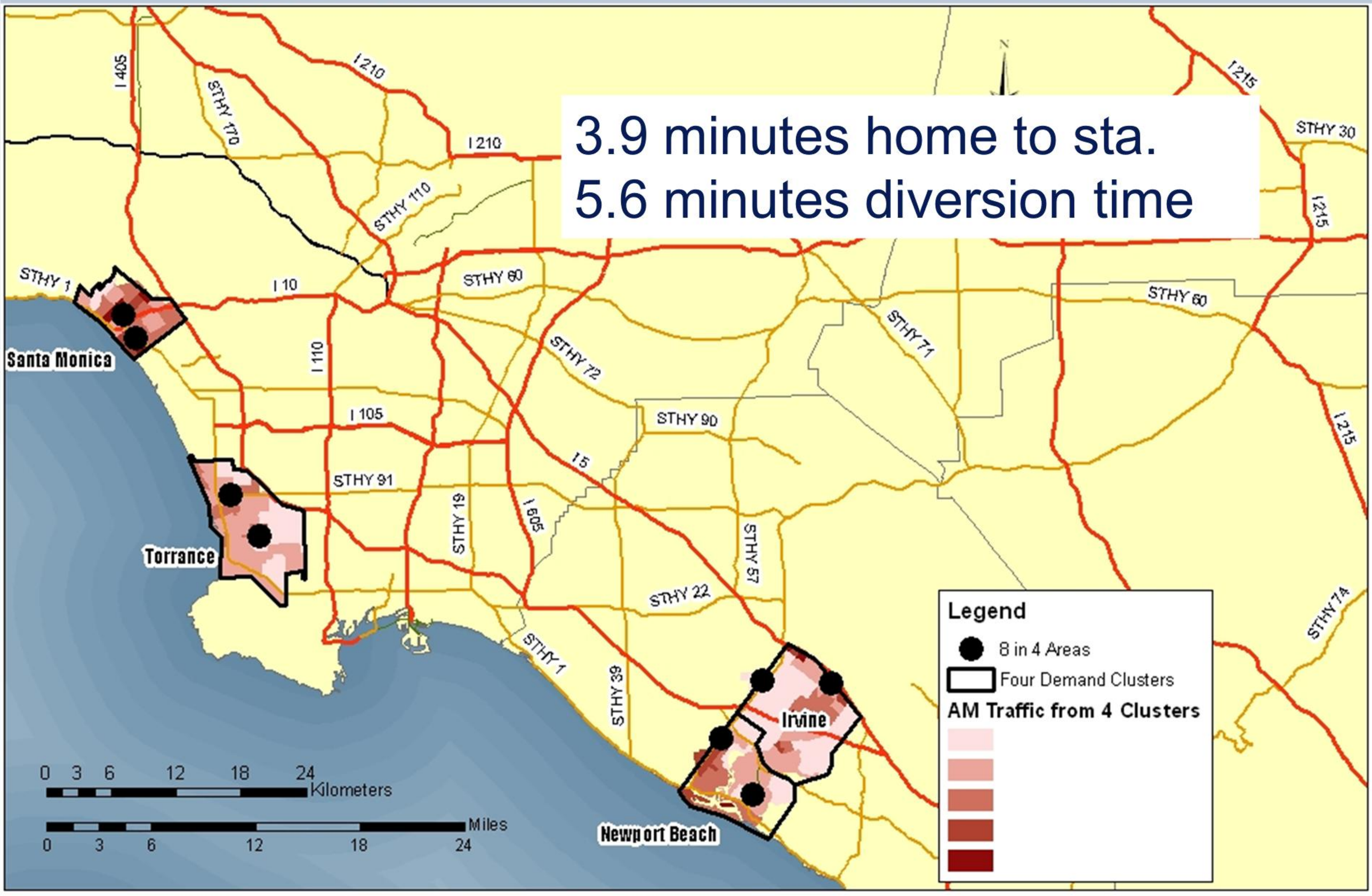
- Home to the nearest station (Anchor)
- “Diversion” time: time to nearest station while driving throughout LA Basin (Network)
- Independent of sales targets, what are the needs for numbers of stations?

Idealized Network with Station Types

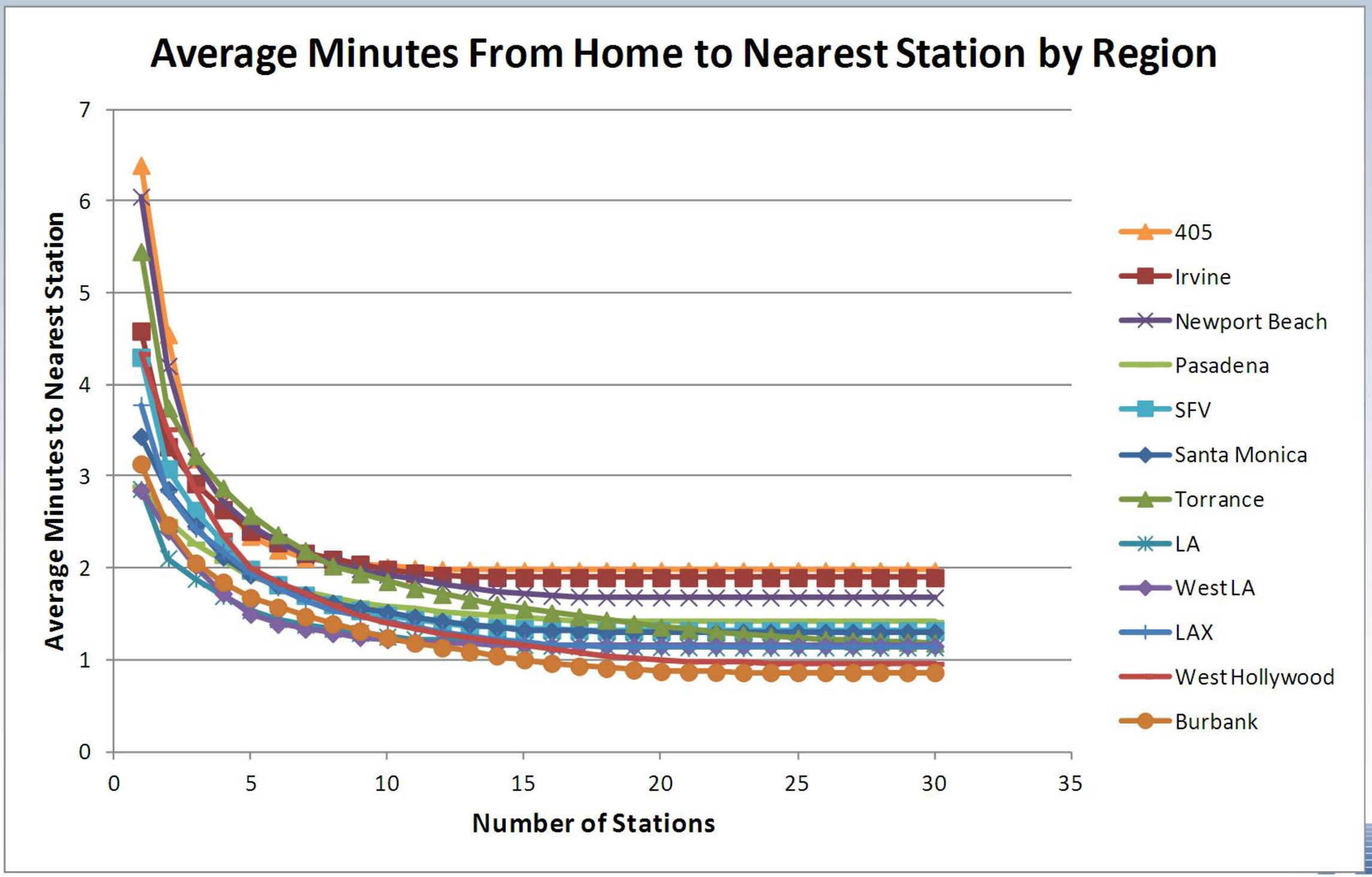


8 Station Example

4 Clusters – 2 Local Stations Per Cluster

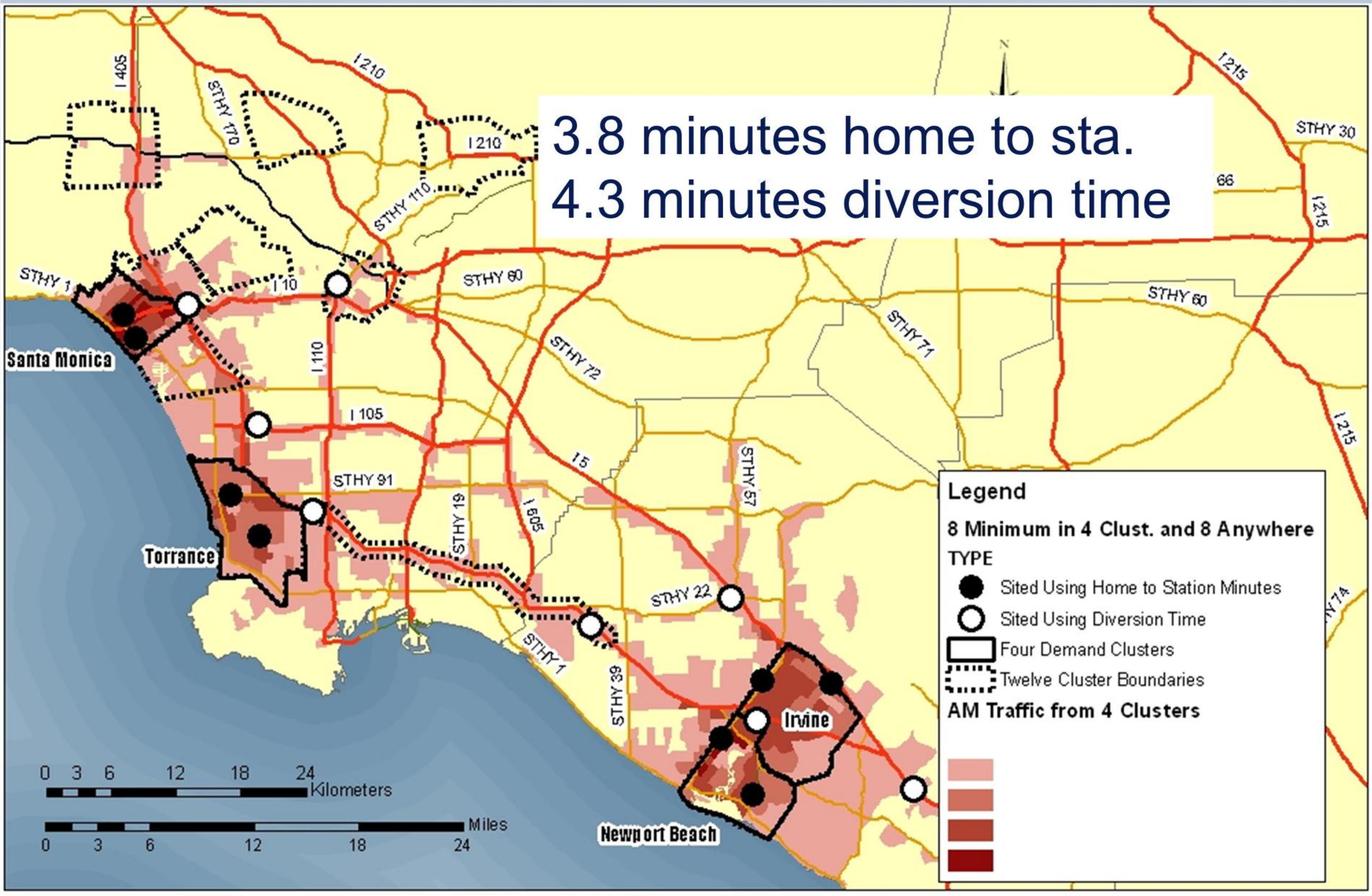


Home to Nearest Station for Each Cluster



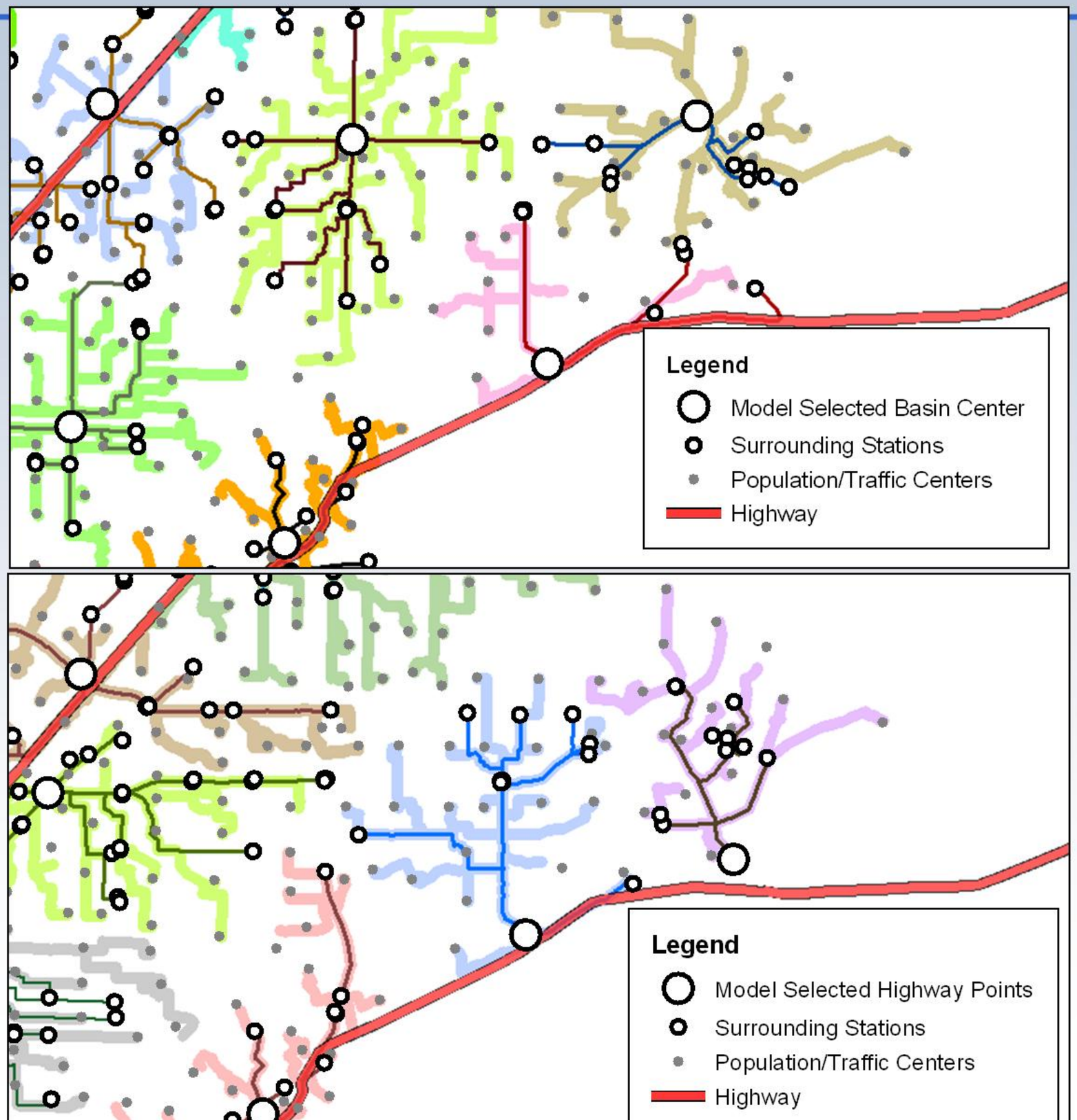
16 Station Example

Add 8 Connector Stations => Lower Diversion Time



How do people actually refuel?

(Nicholas 2010, Journal of Transport Geography)

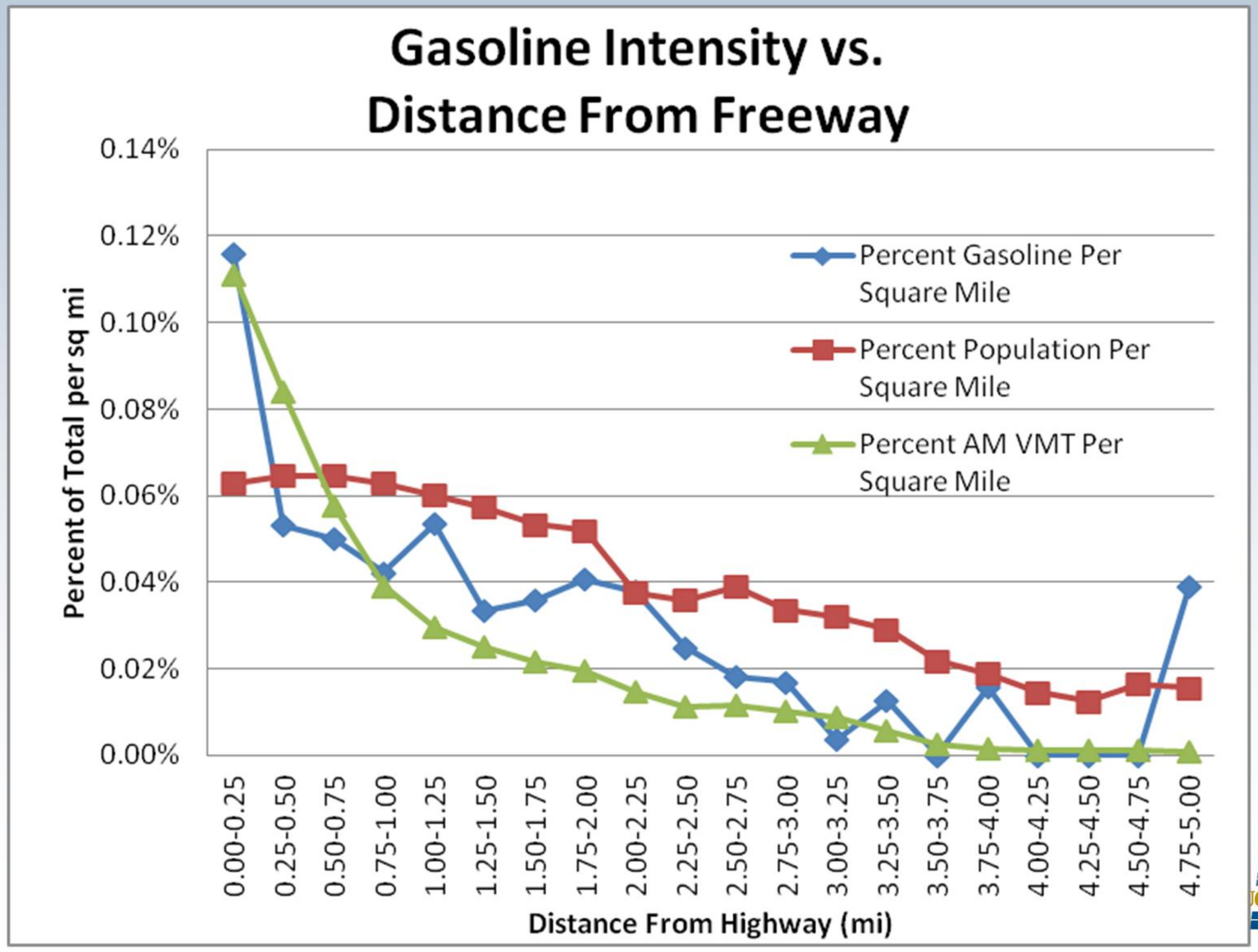


Nearest Station?

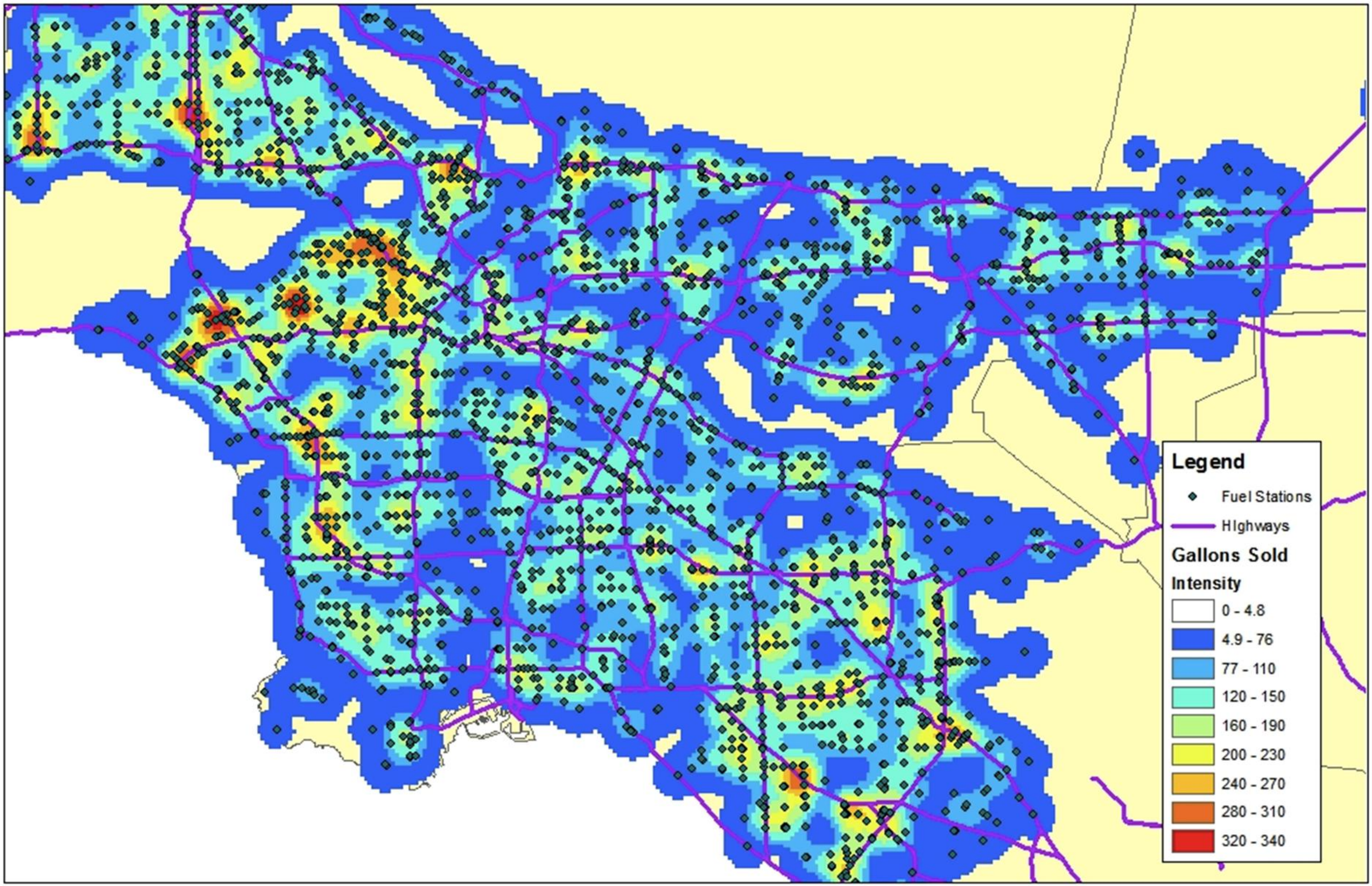
Direction of Travel?

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

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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

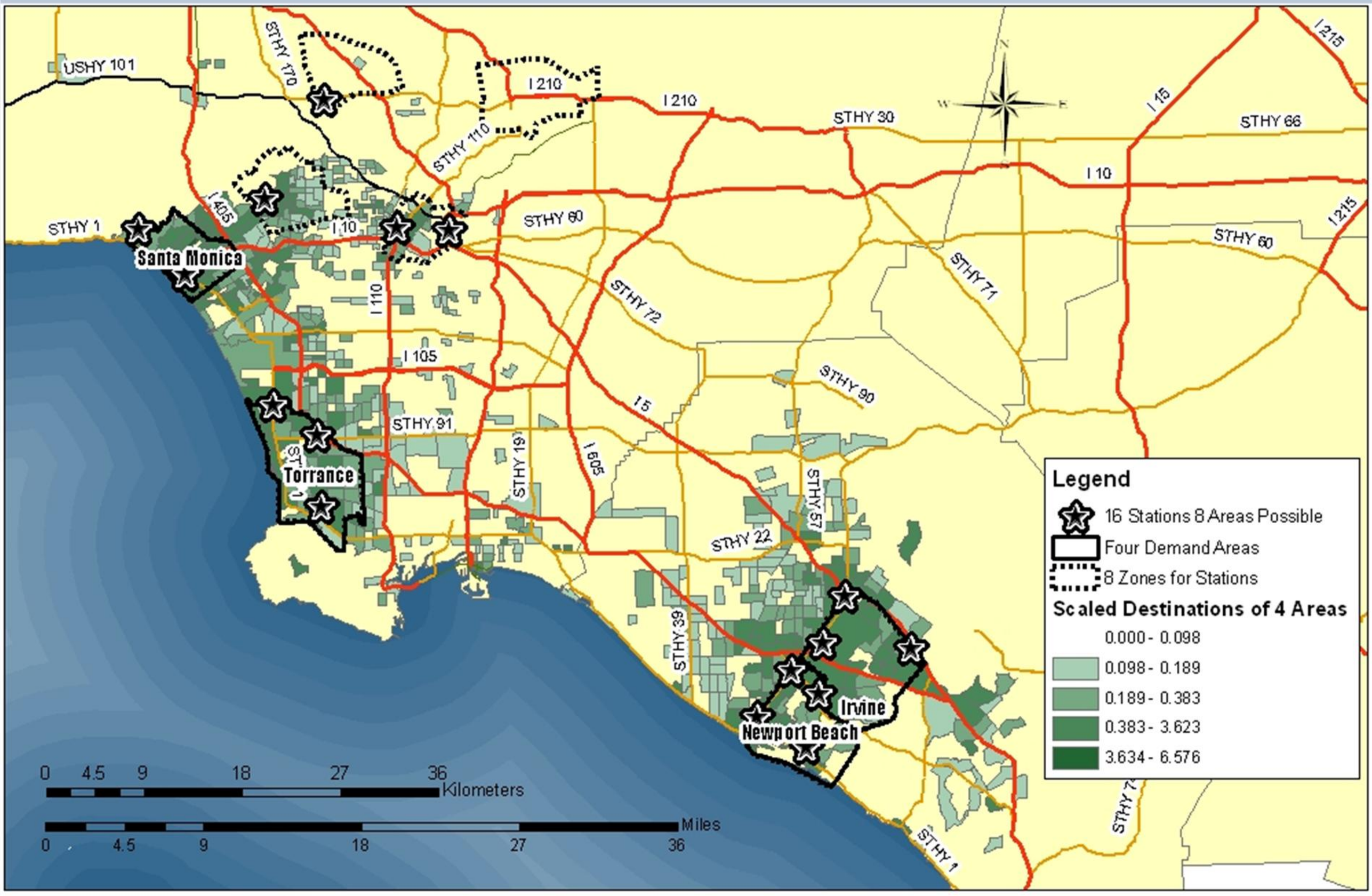
Can you Have Just One Station for 34,000 Cars?

- Give away free fuel and free cars with unlimited warranty

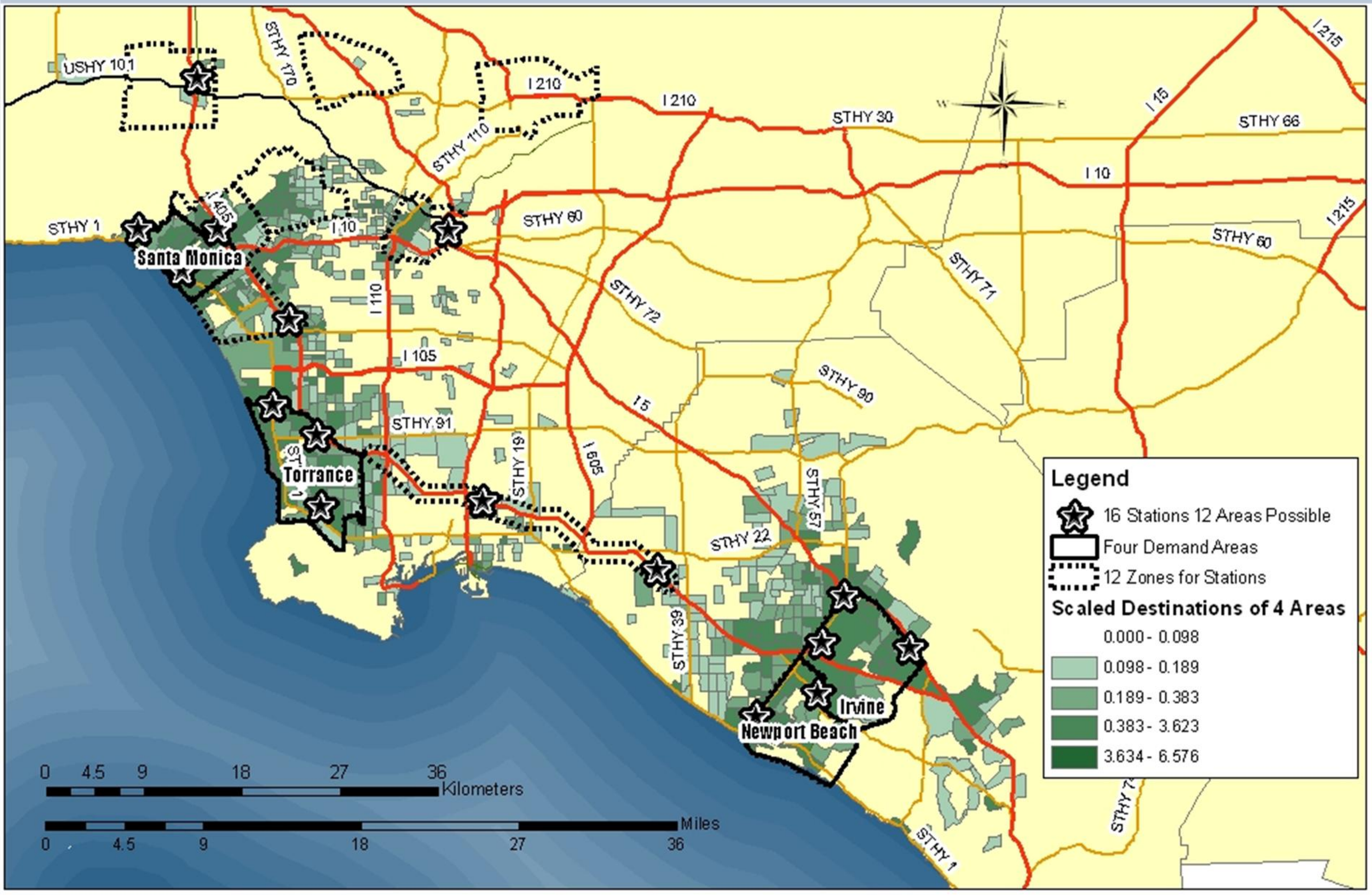
$$Utility = B_{veh} - P_{veh} - OC_{veh} - NI$$

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

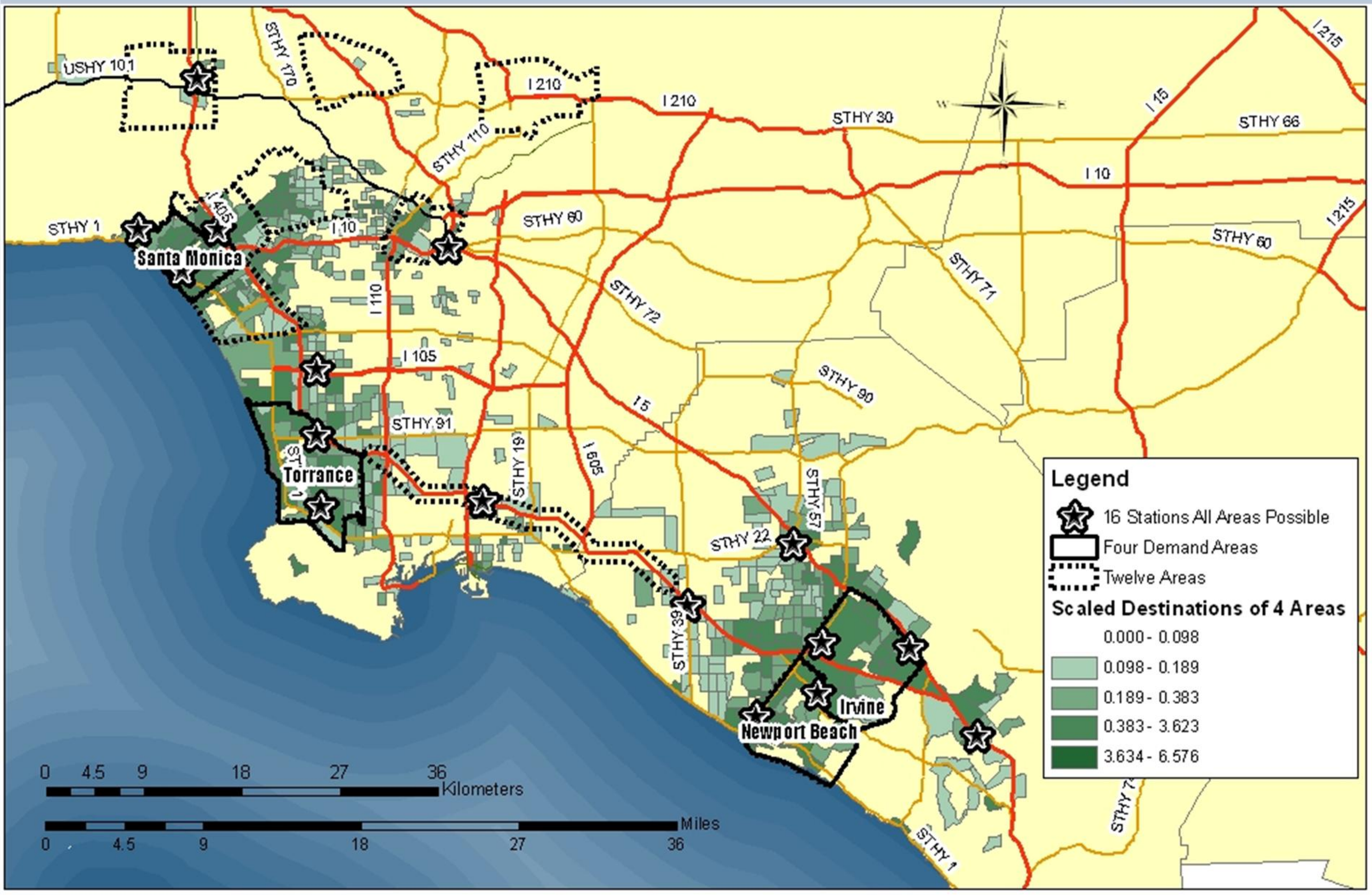
Destinations of 4 Clusters: 16 Stations in 8 Areas



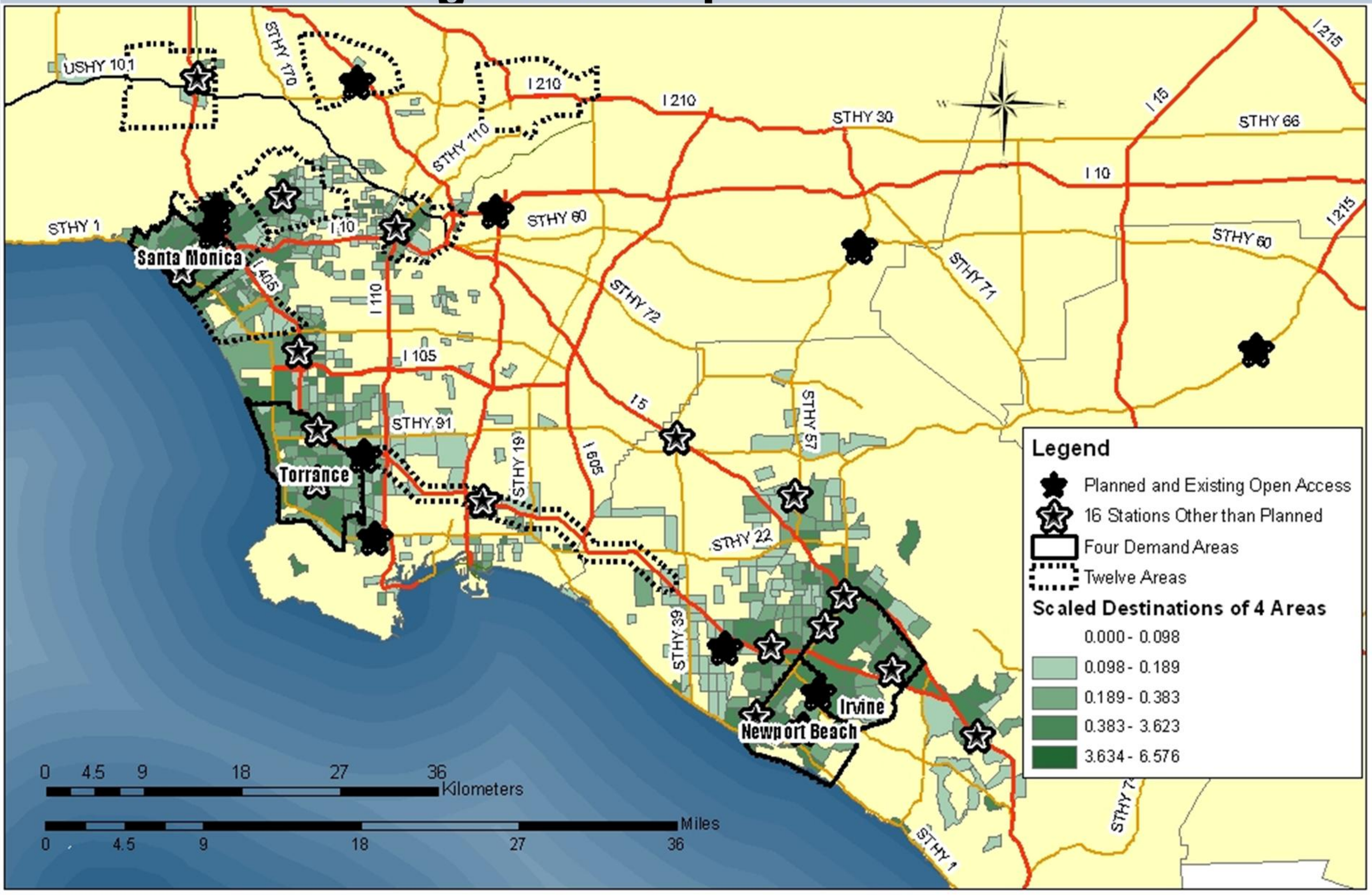
Destinations of 4 Clusters: 16 Stations in 12 Areas



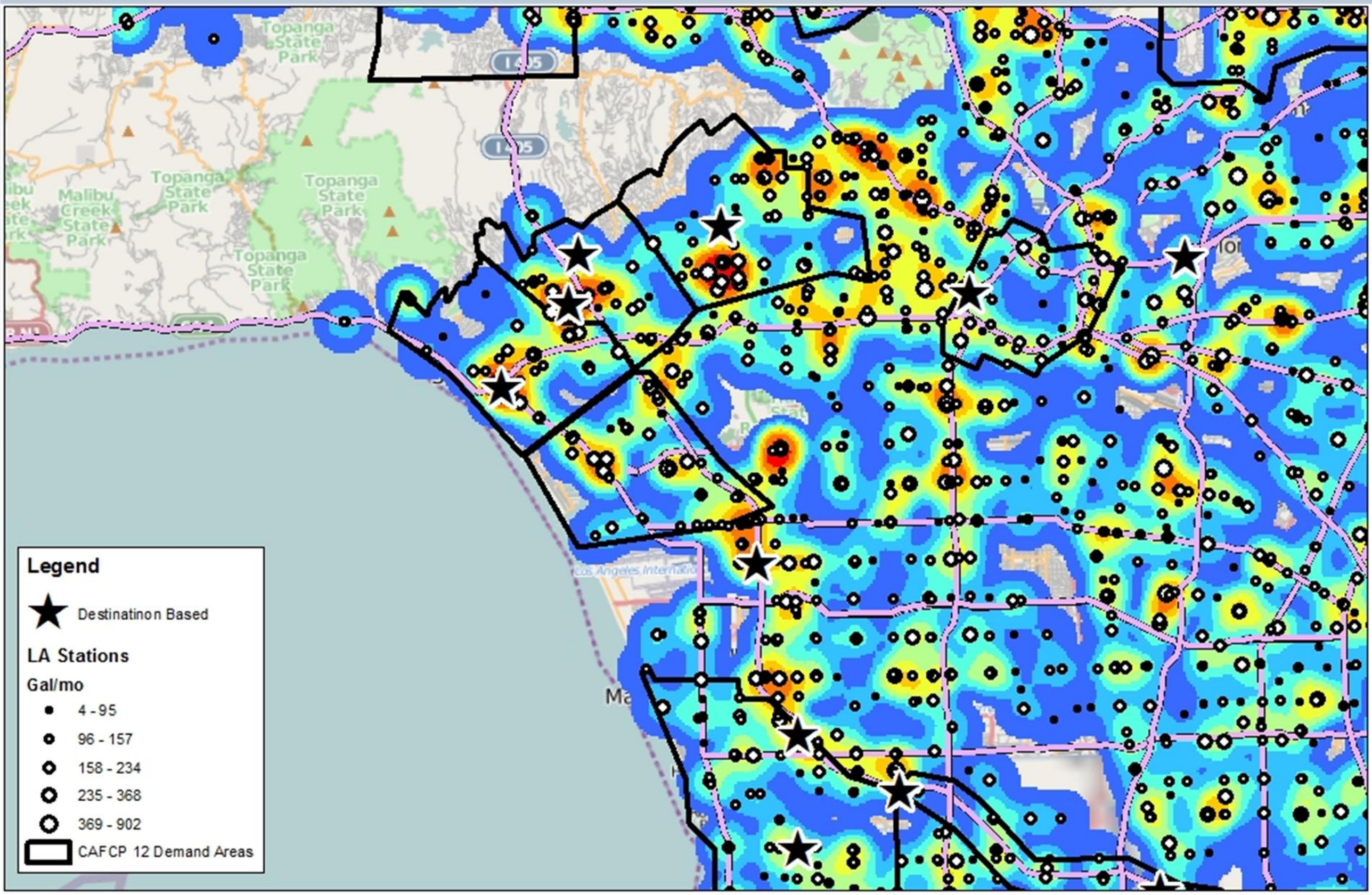
Destinations of 4 Clusters: 16 Stations Regionwide



Destinations of 4 Clusters:
Existing stations plus 16 Stations



Planned, Existing, and Model Stations



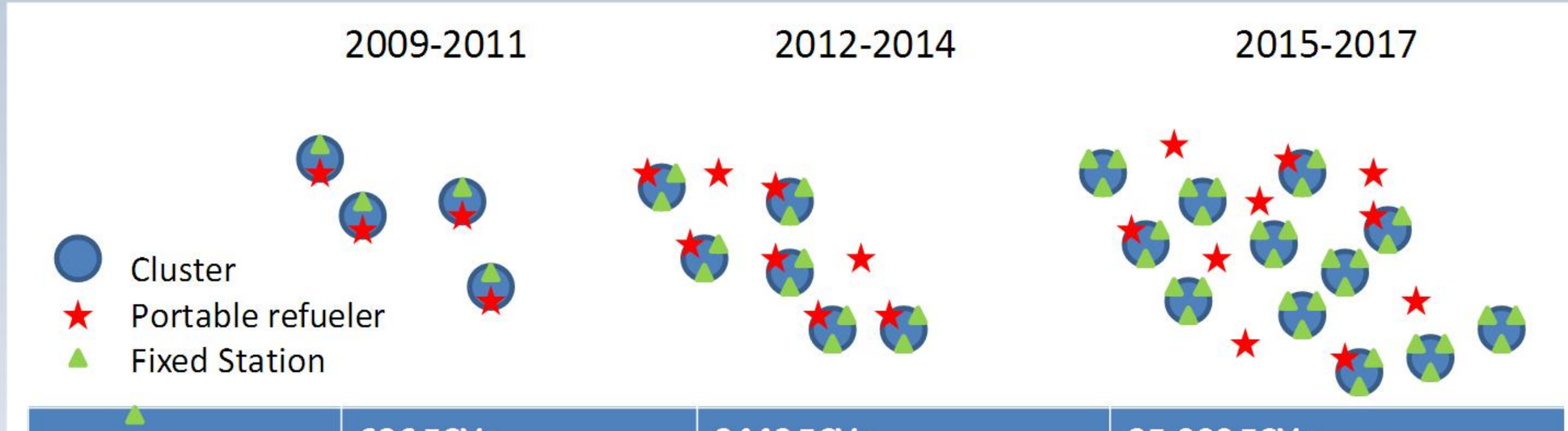
Characterizing the Demand by Region (TRB 2005)

	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 4 SMRs (100 kg/d)	8 Portable Refuelers 12 SMRS (250 kg/d)	10 Portable refuelers 12 SMRs (250 kg/d) 20 SMRs (1000 kg/d)
New Equip. Added	4 Portable refuelers 4 SMRs (100 kg/d)	4 Portable Refuelers 12 SMRS (250 kg/d)	2 Portable refuelers 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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