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Overview of Station Coverage and Travel Time Estimates

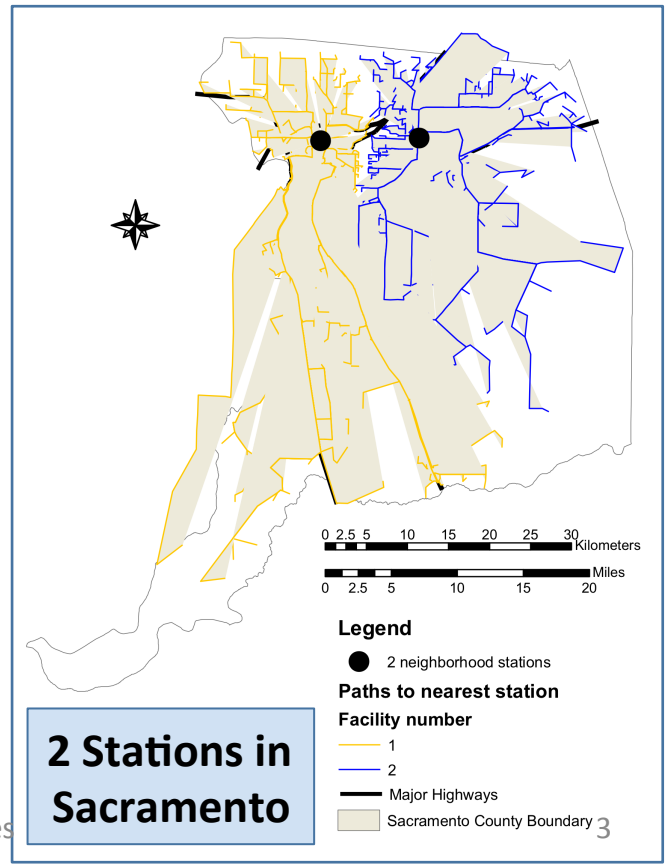
Marc Melaina, NREL
California Energy Commission
Sept 30, 2015 - Sacramento, CA

Presentation Overview

1) Estimates for average drive times to reach a limited number of stations (Nicholas et al.)
2) Translating drive times into cost penalties for consumers (Greene, Lin et al.)
3) What is the basis for the metric: "percent of gasoline stations"?
4) How might these rational actor estimates different from the perceived value of refueling availability by actual consumers?

Average Travel Time Metric

- For all residents in a given urban area, the distance from home to a nearby refueling station can be calculated using traffic models
- This home-to-station travel time an important measure of convenience for consumers considering a new alt fuel vehicle
- Nicholas (2004) determined optimal station locations to minimize average travel times
- **This algorithm estimates the number of stations needed to provide a sufficient level of coverage for early adopters of <u>dedicated</u> alt fuel vehicles – especially CNG and hydrogen vehicles**
- The UC Irvine STREET model estimates similar results using a different approach, and was used to guide the number of hydrogen stations in the CaFCP Roadmap



2 Stations in Sacramento

Nicholas et al (2004) Drive time estimates

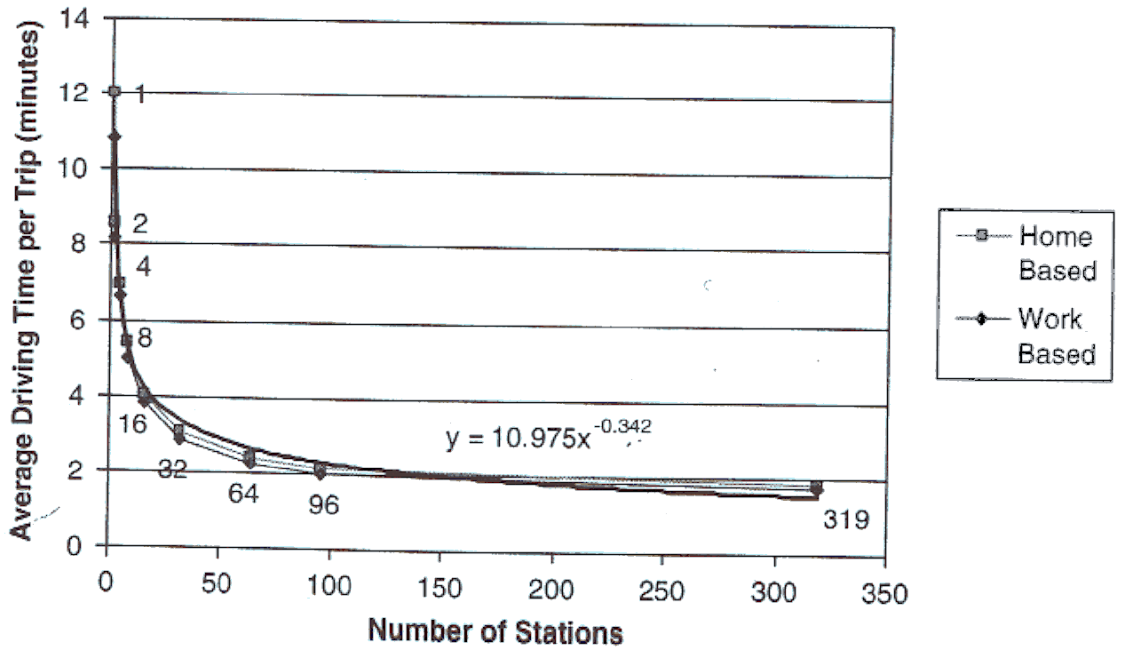
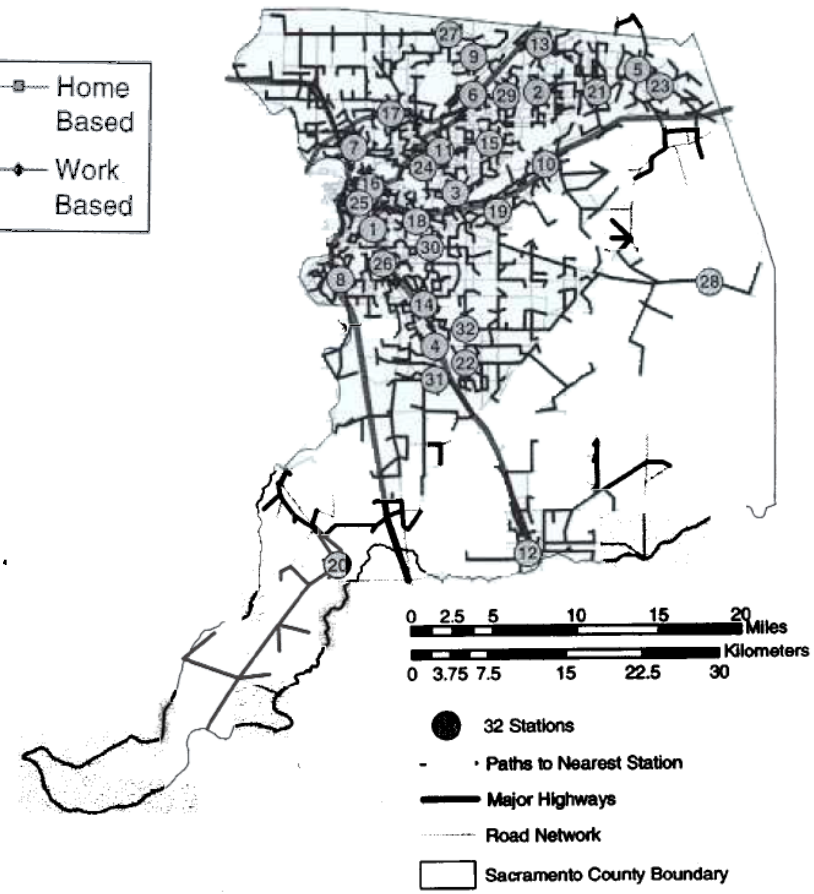


FIGURE 5 Relationship between station number and average driving time.



Transportation Research Record: Journal of the Transportation Research Board, No. 1880, TRB, National Research Council, Washington, D.C., 2004, pp. 126–134.

Average drive times can be translated to vehicle purchase price penalties

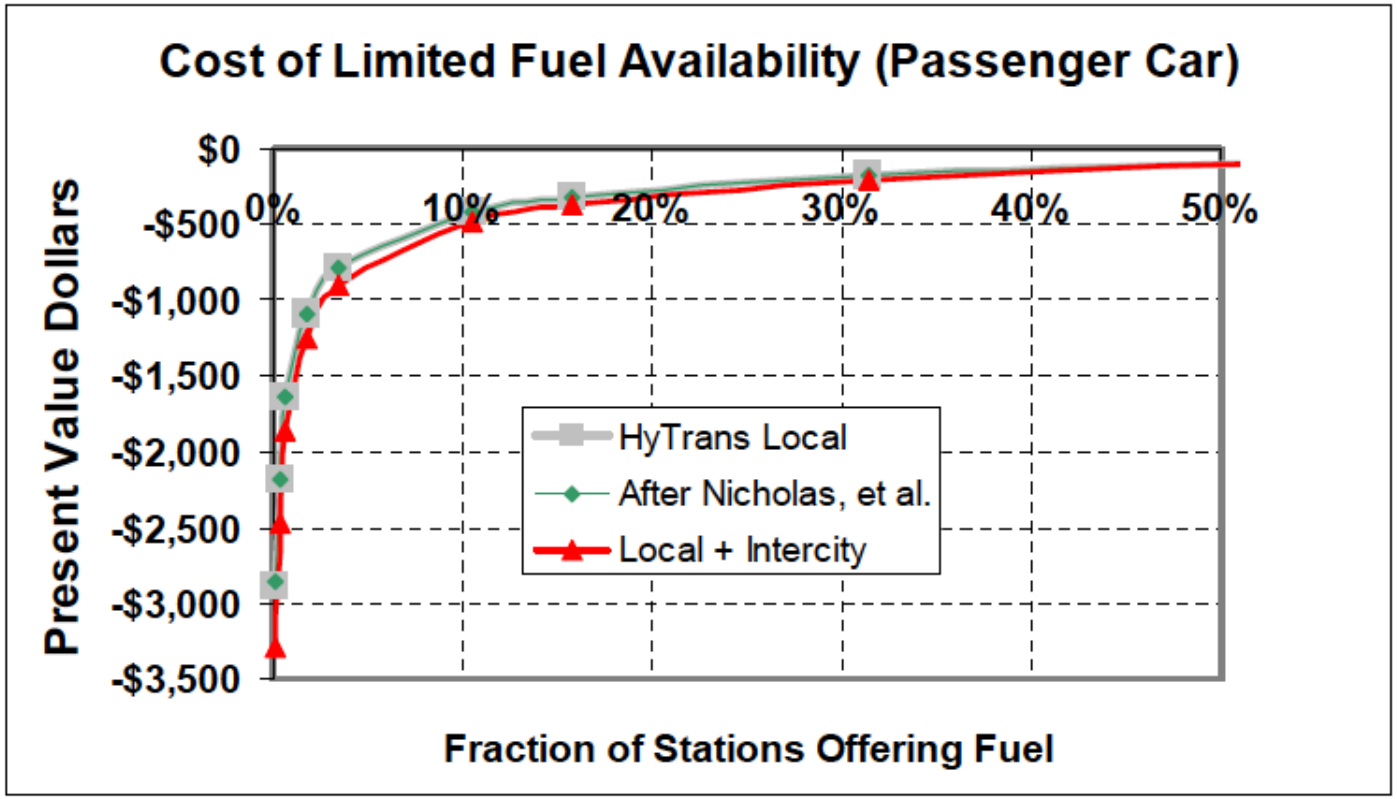
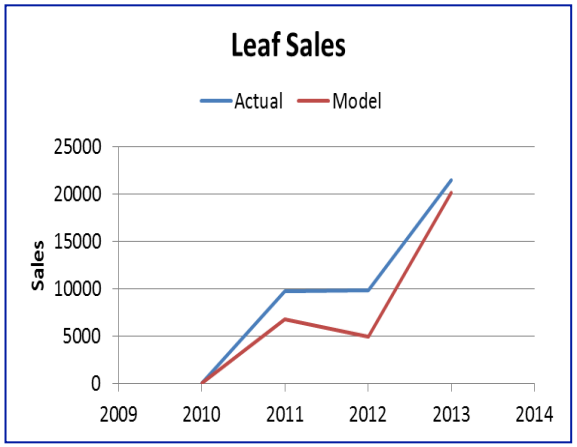


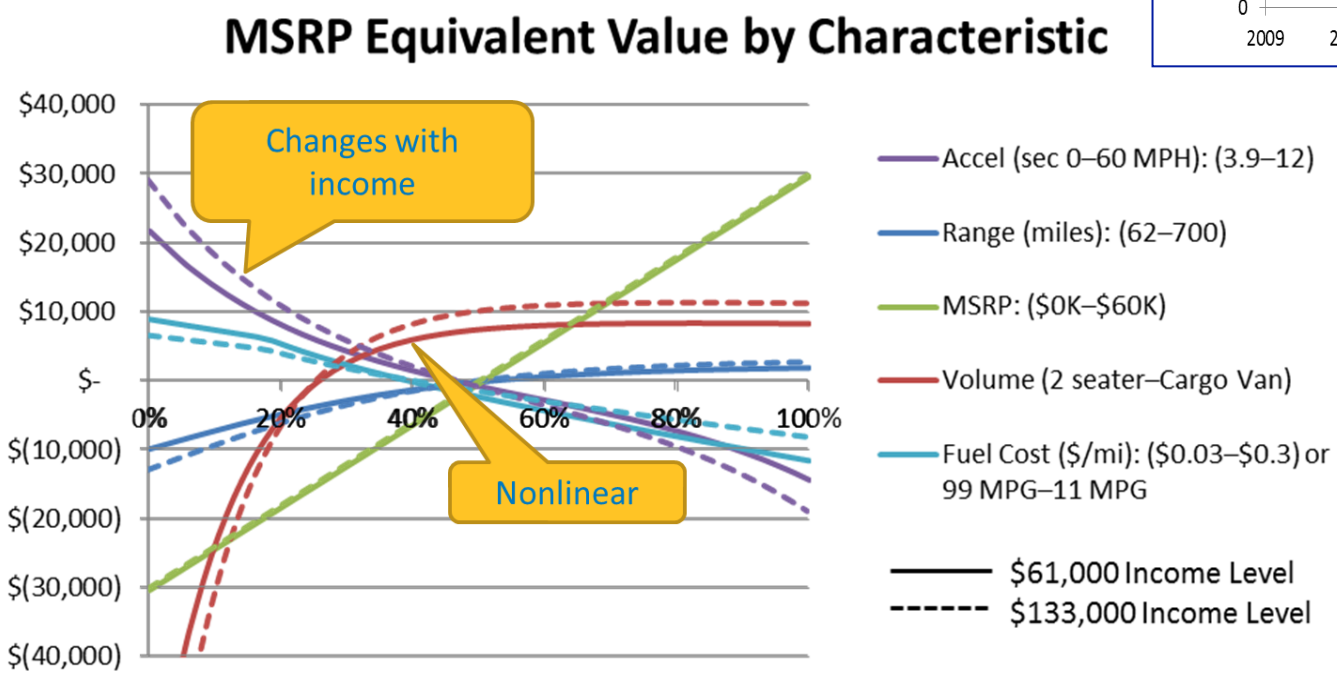
Figure 2.15. Cost of Fuel Availability

Reduces value of a vehicle to a consumer at point of purchase

Example: What is the penalty for limited range from a consumer perspective?

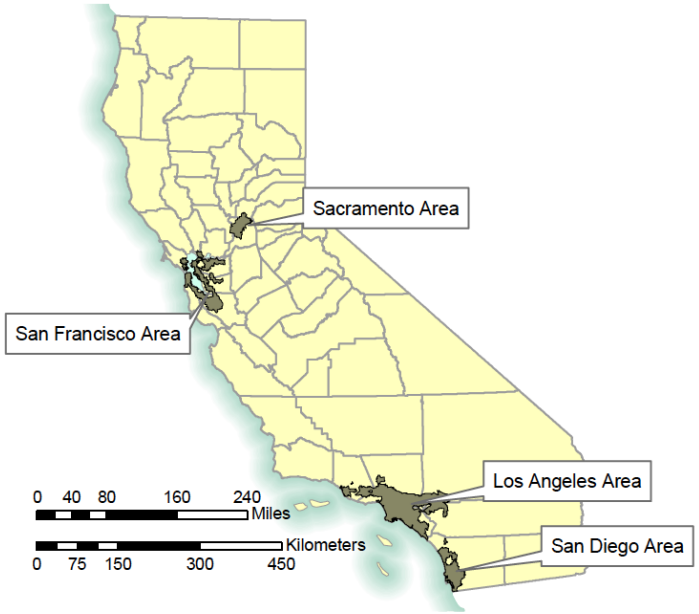
- NREL's ADOPT consumer preference model estimates market share using coefficients derived from empirical sales data
- Range penalty is based upon limited data, but aligns well with Leaf sales

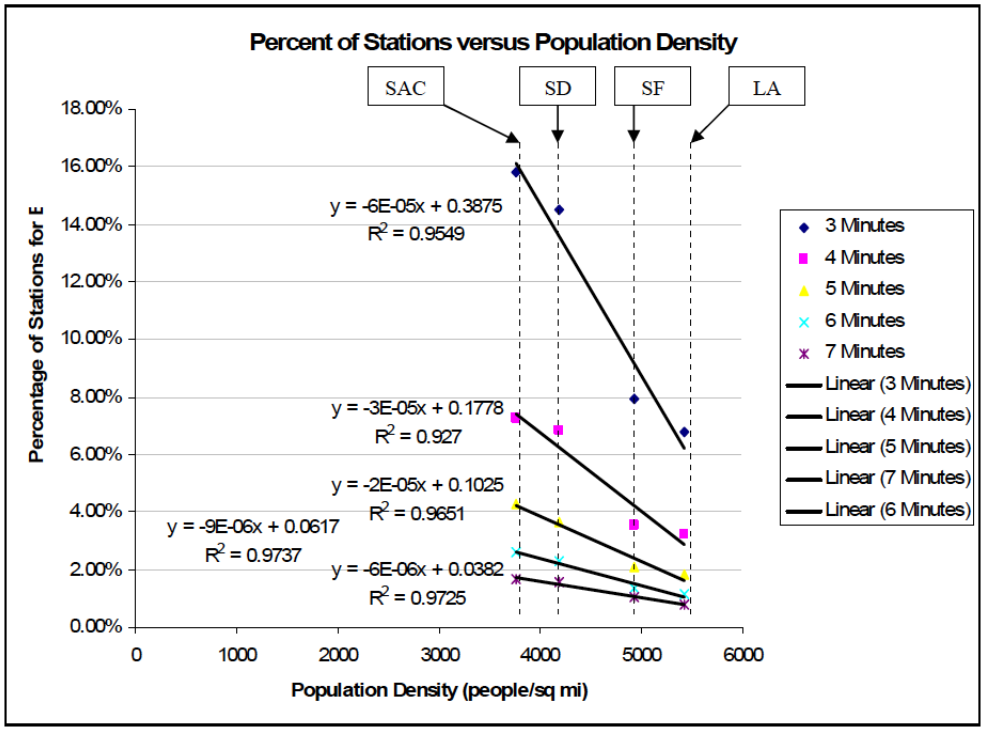




Source: Brooker, A. (2015) *ADOPT: A Historically Validated Light Duty Vehicle Consumer Choice Model*, SAE World Congress, 2015 (forthcoming)

Nicholas (2006) expanded to four metro areas





Characterized drive time results as a function of population density

	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

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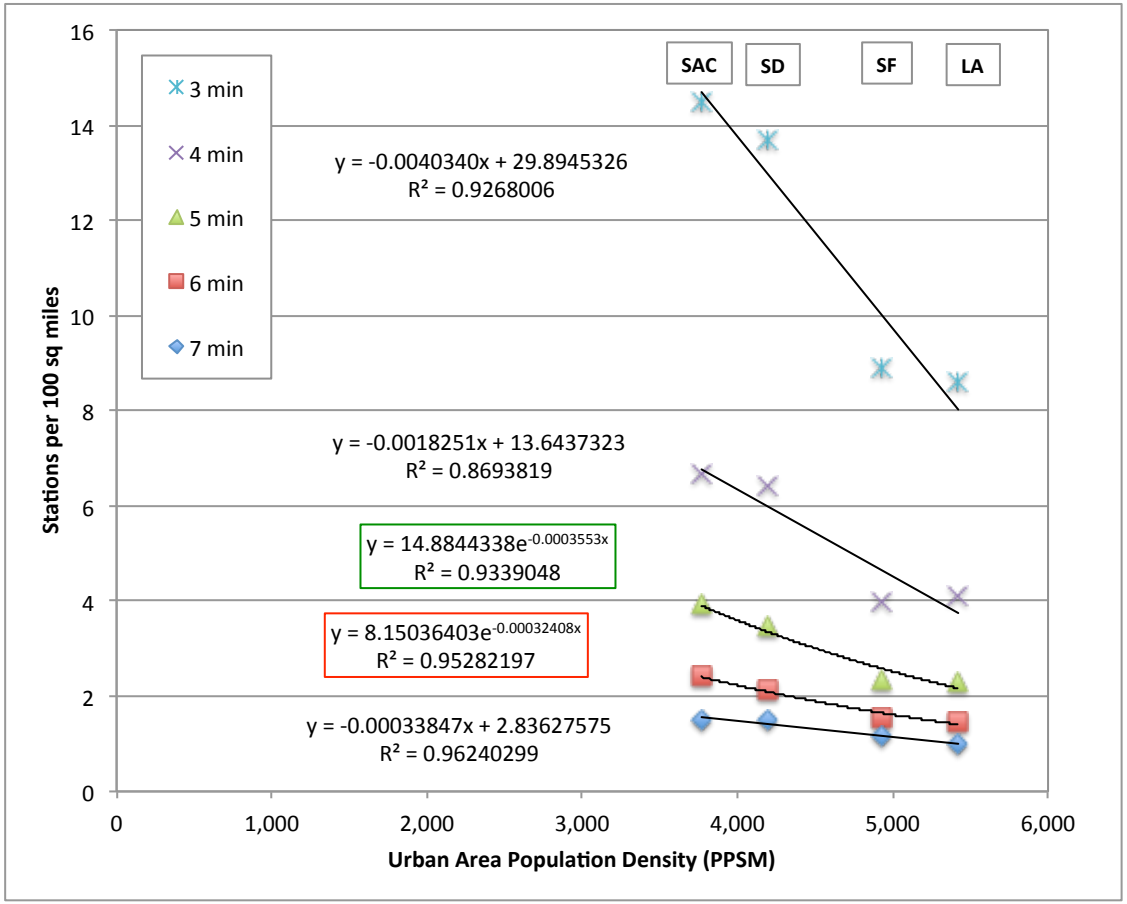
Submitted November 21, 2005

Detailed Analysis of Urban Station Siting for the California Hydrogen Highway Network

TRB 2006 Annual Meeting CD-ROM

6-minute Drive Time Coverage

- How many stations are needed to open up new early urban markets for dedicated AFVs?
- Use 6-min drive time based on UC Davis travel models for 4 cities in California (LA, SF, Sac, San Diego) (Nicholas et al 2004, TRB paper) to estimate "**Coverage stations**" needed per urban area



Trends can be extrapolated to any urban area

What is a baseline number of stations?

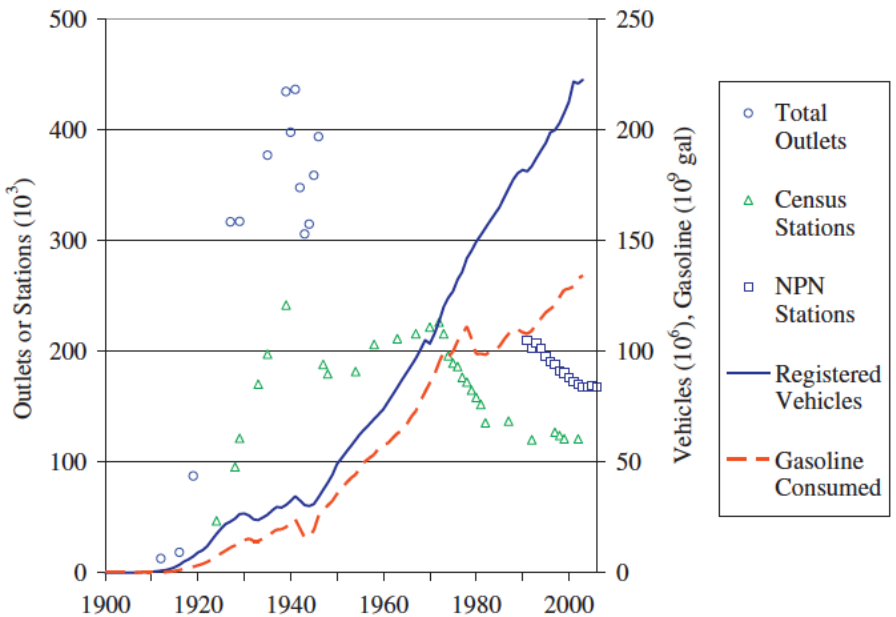


Fig. 1. Historical trends in gasoline outlets and stations, registered vehicles and gasoline consumption (NPN: National Petroleum News).

The number of stations in the U.S. has been going down while the number of vehicles has been increasing.

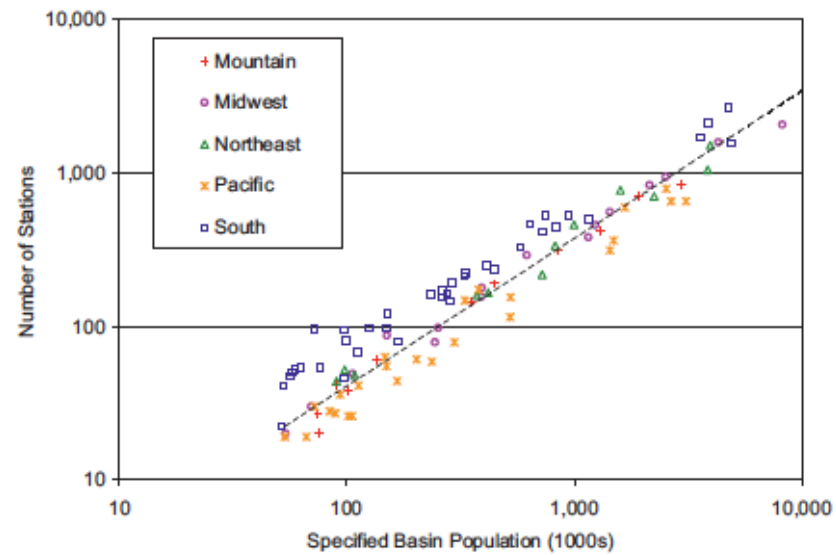


Fig. 3. Station numbers and populations for 103 specified basins.

The density of stations in urban areas varies in different parts of the U.S.

M. Melaina, J. Bremson / Energy Policy 36 (2008) 3233–3241

Estimating a sufficient coverage threshold: many urban markets maintain high densities of stations

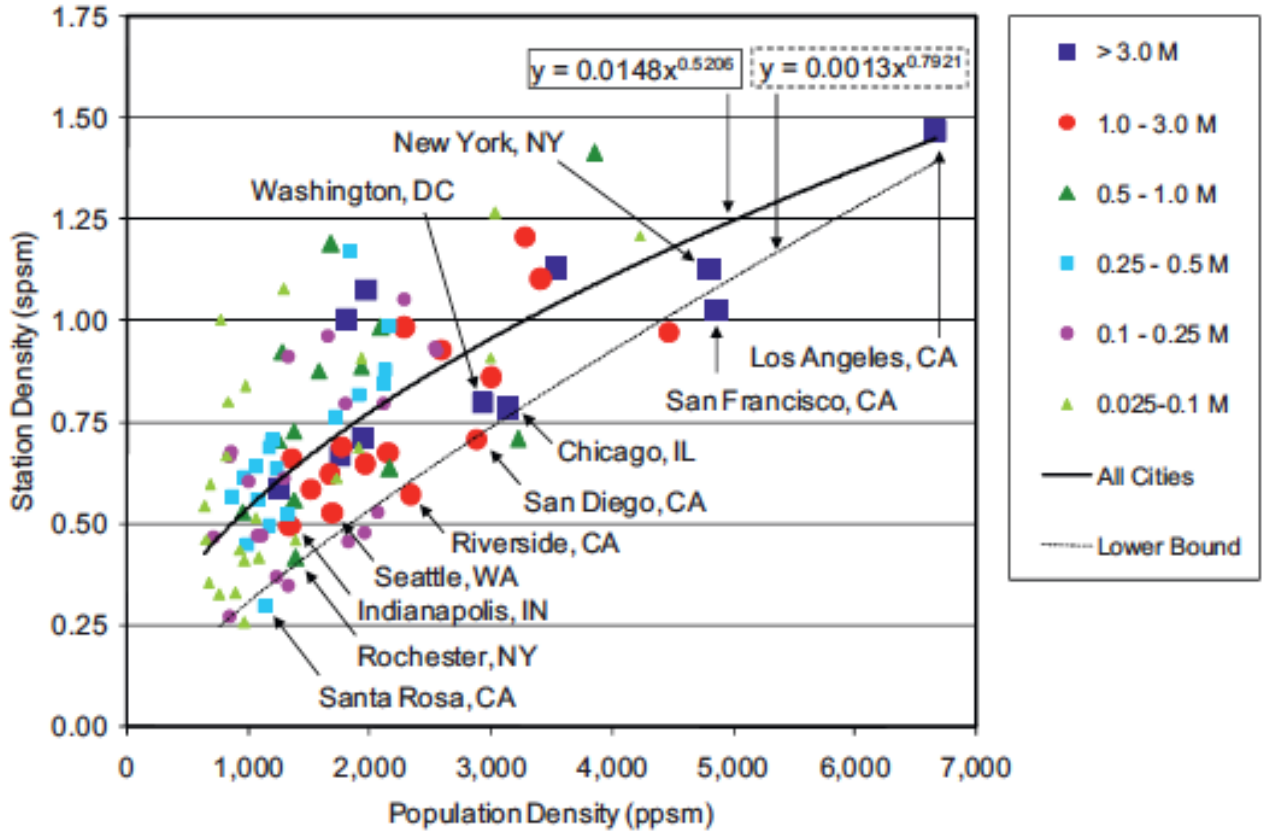


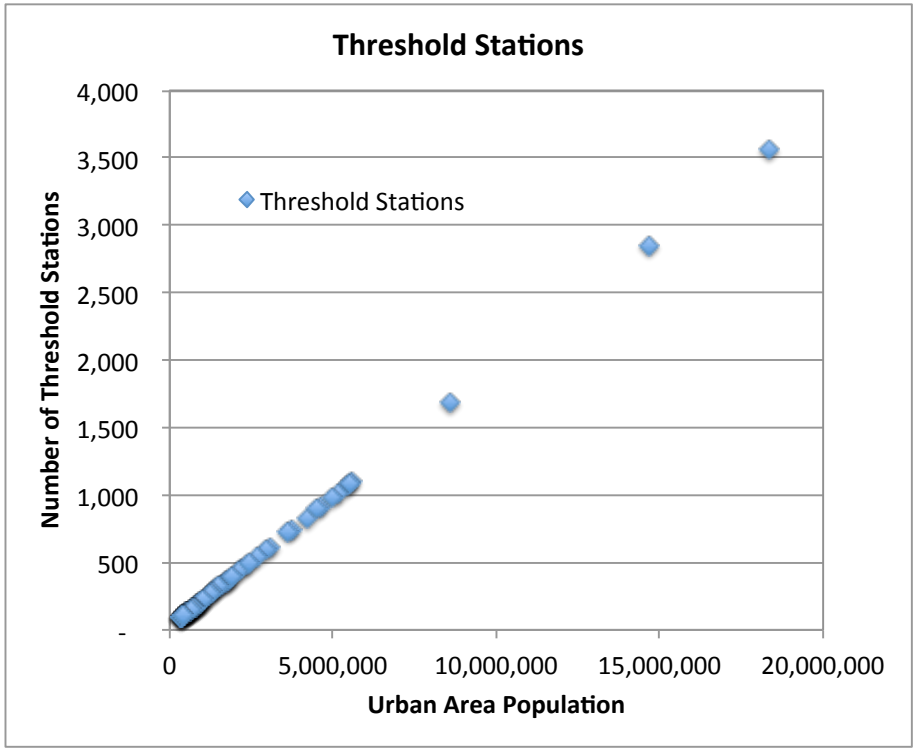
Fig. 5. Sufficient urban station coverage as a function of urban population density. Urban basin populations are indicated in millions of persons.

A baseline of stations must be established to make consistent coverage station and average drive time estimates

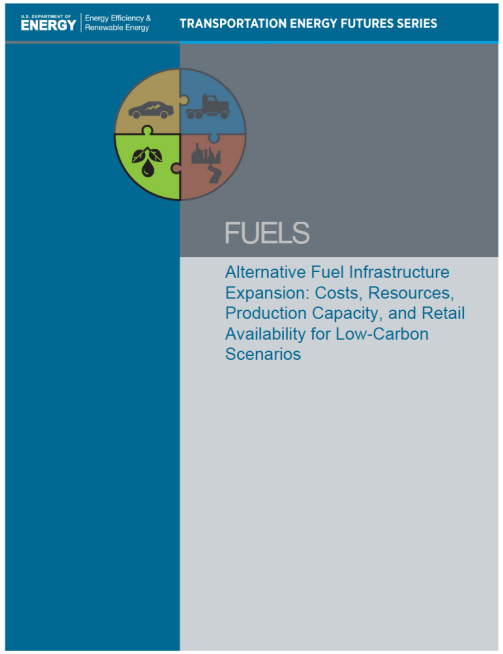
M. Melaina, J. Bremson / Energy Policy 36 (2008) 3233–3241

Estimating "threshold stations"

- Concept from TEF report; Function of Urban Area population



Stations as a Function of Population	
x = UA population (millions)	
Y = A*x+b	Threshold
A =	192.5
b =	27.5
SUM =	32,860



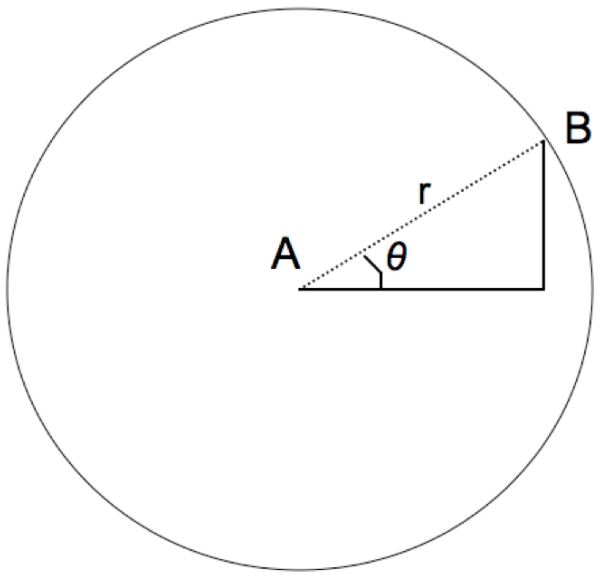
Clustering analysis to estimate the average additional distance traveled for a limited number of stations

Additional drive time values were estimated assuming some number of existing gasoline stations "disappeared", forcing drivers to drive to the next nearest station

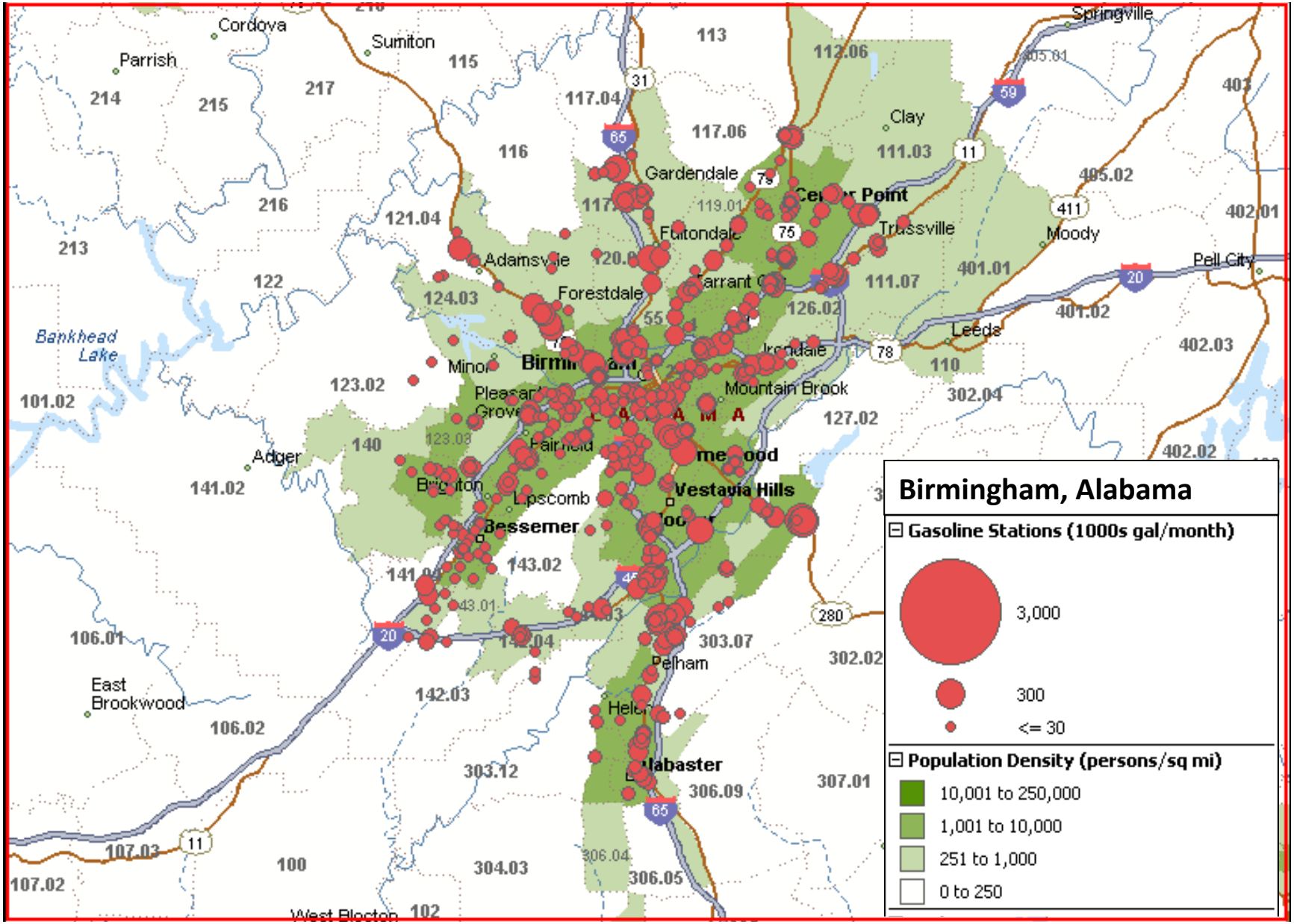
Approach relies upon access to data on station locations and output volumes

Analytic approach

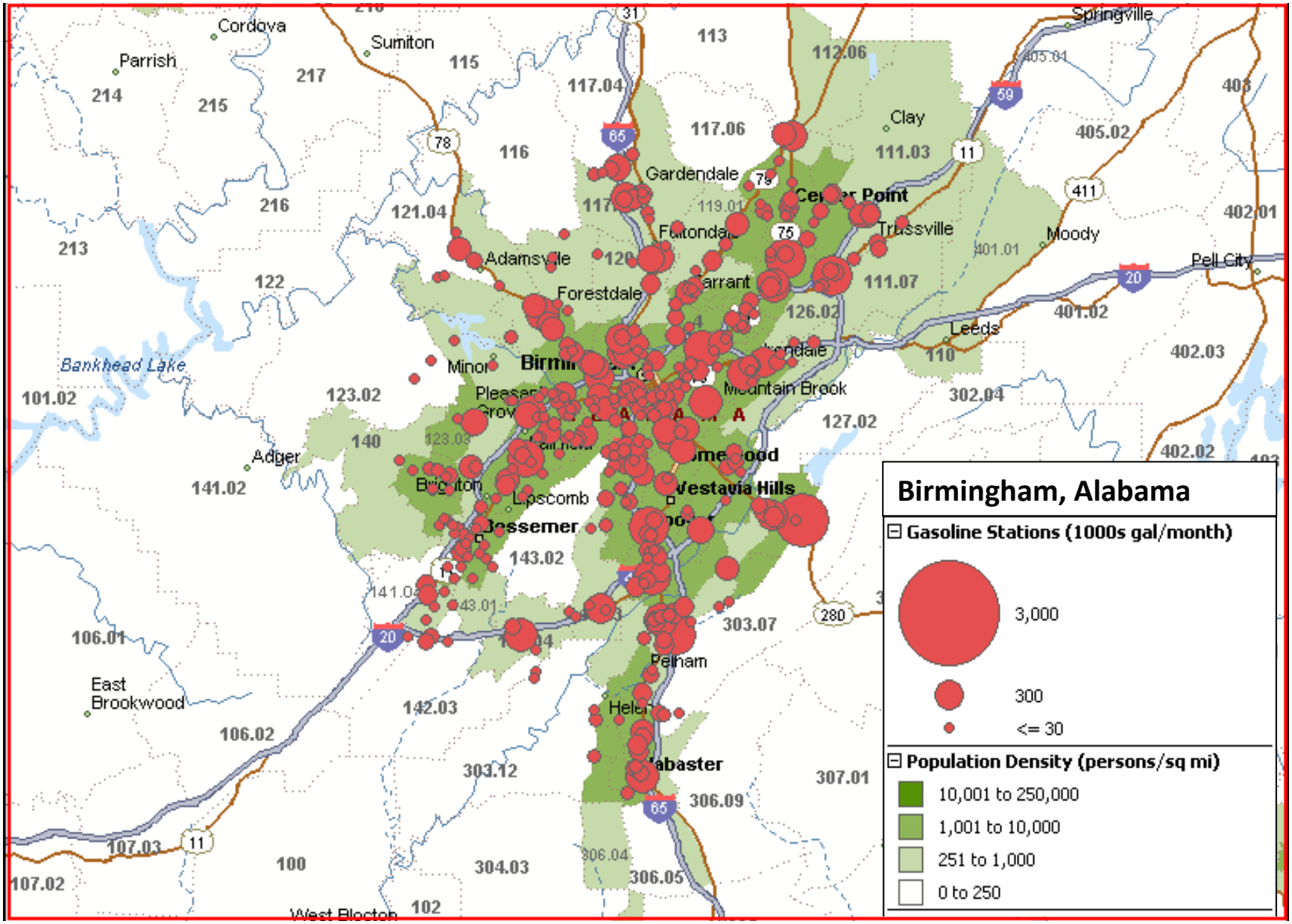
- If station A is eliminated from the network, we assume that drivers would begin their diversion from their normal driving routines from the same location, but would now drive to station B rather than station A.
- If actual diversion locations are randomly distributed within the circle (some closer 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*.



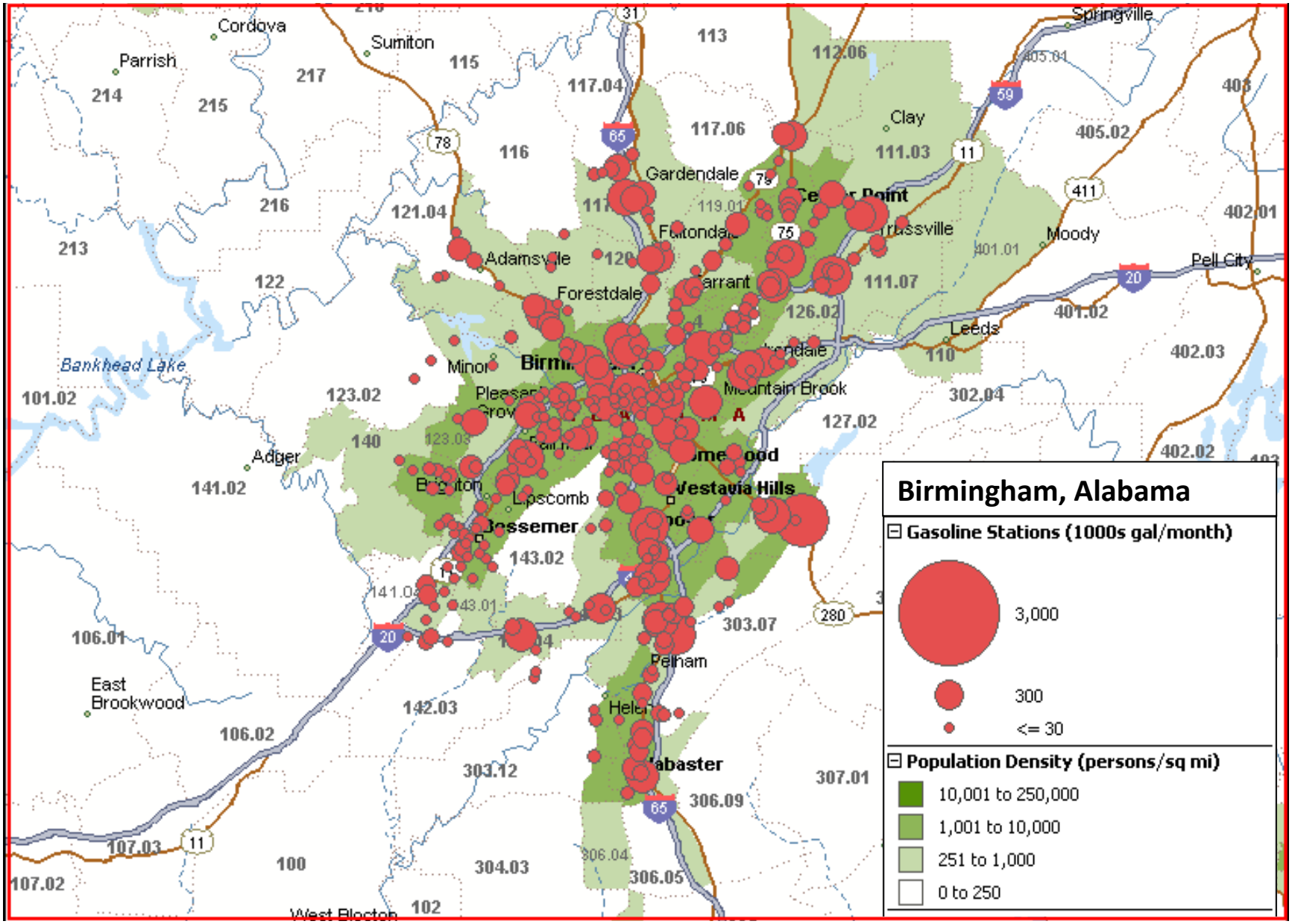
Station A Elimination Example



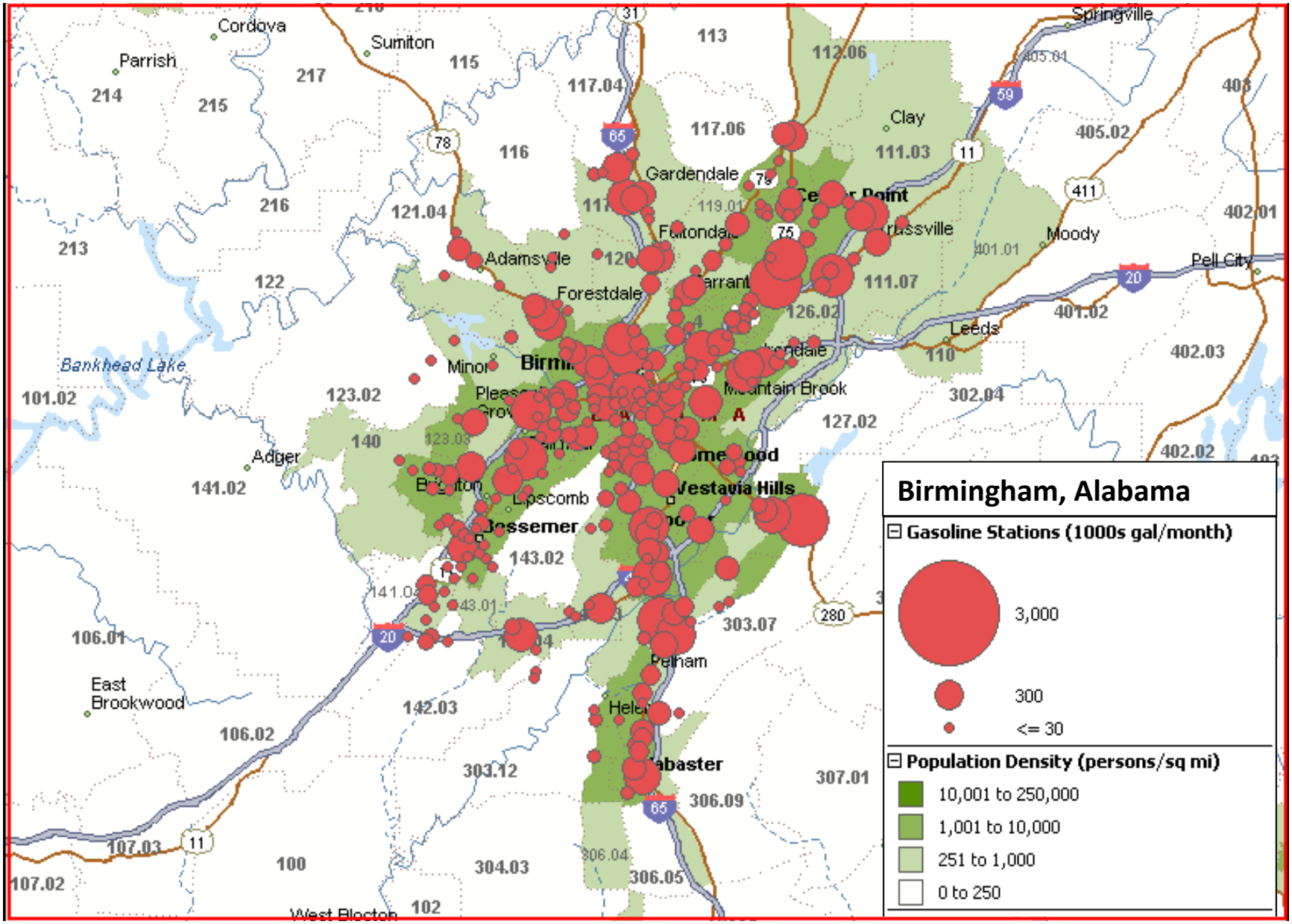
No Clustering



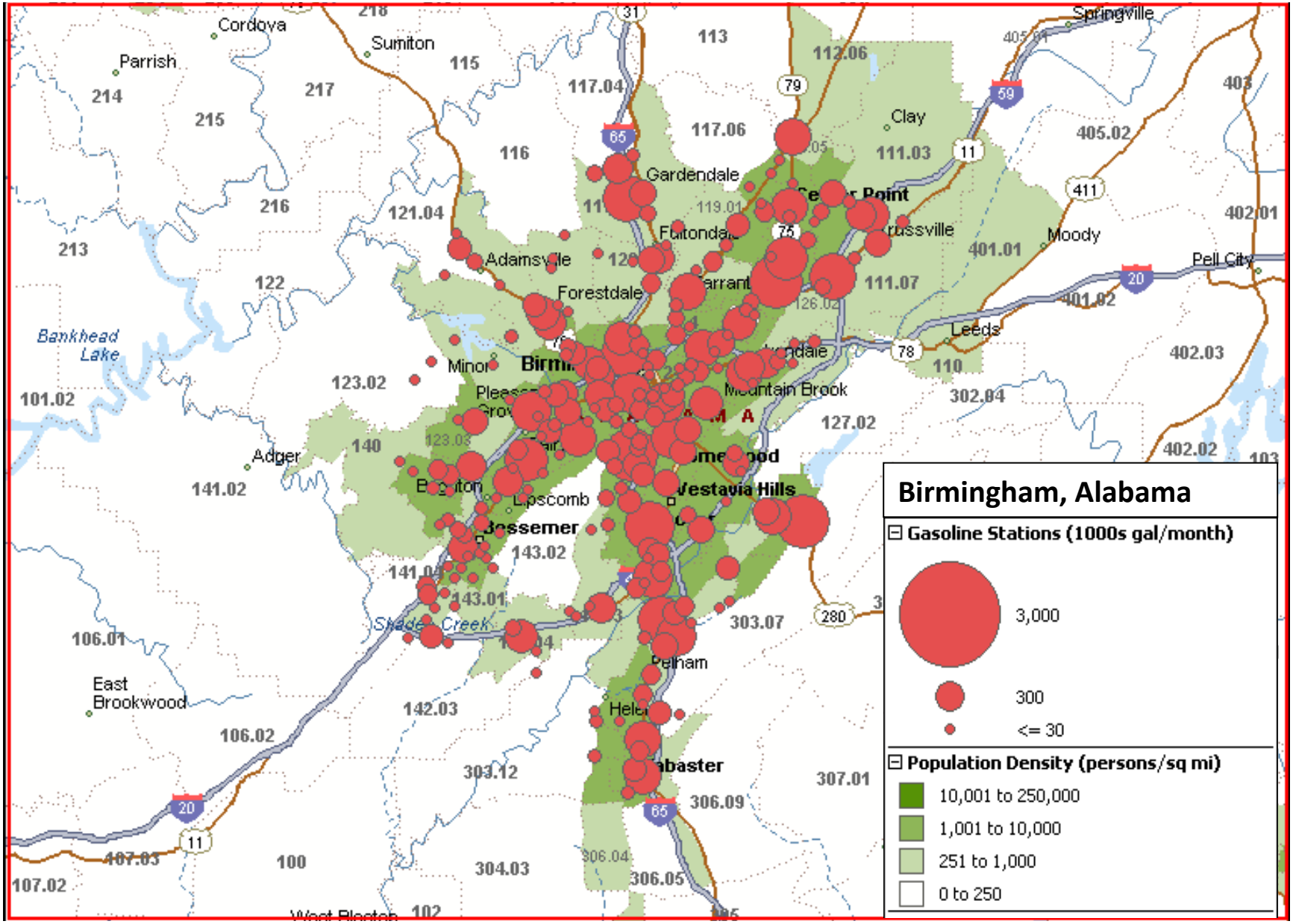
Cluster Distance = 0.1 miles (22% clustered)



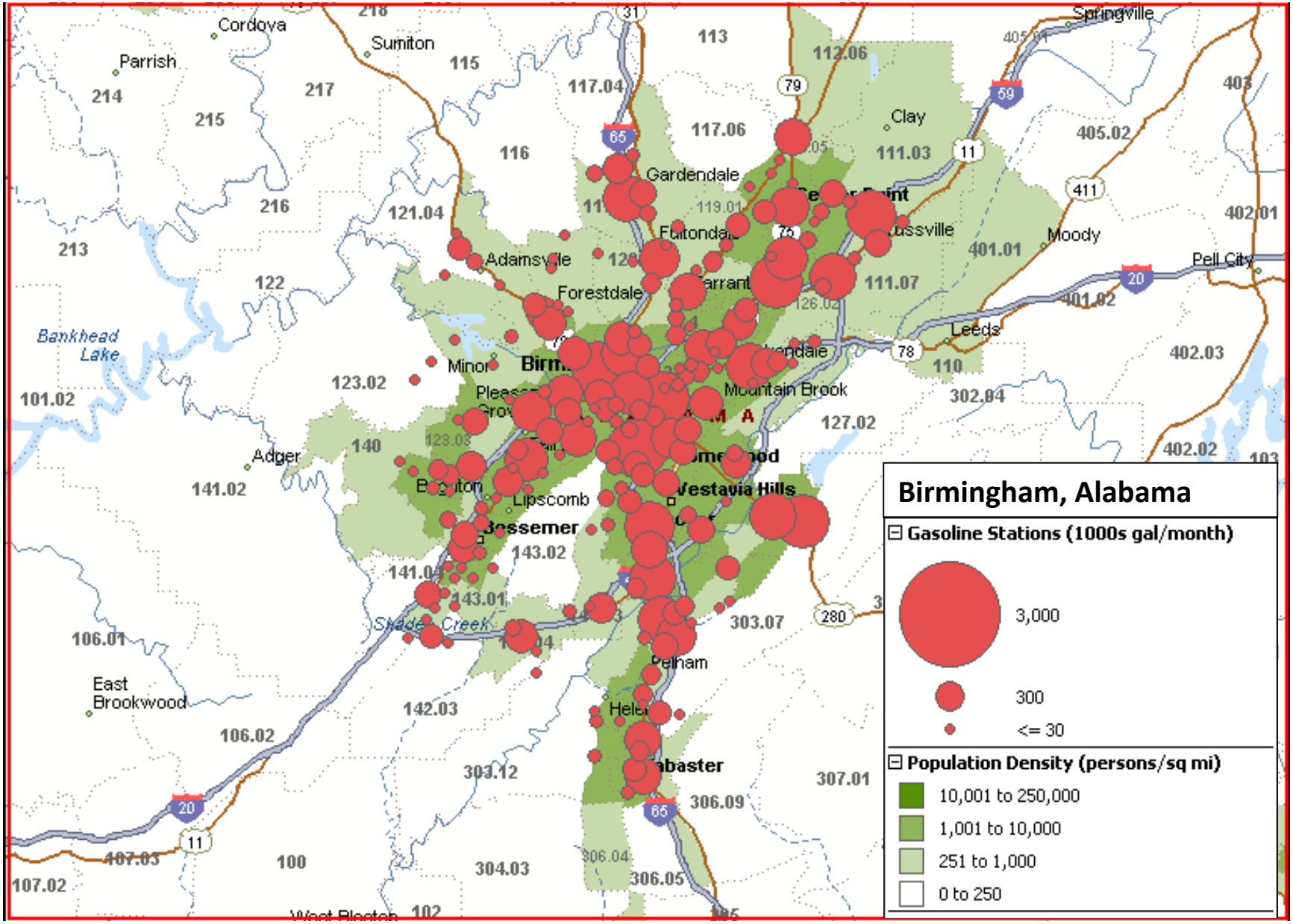
Cluster Distance = 0.2 miles (31% clustered)



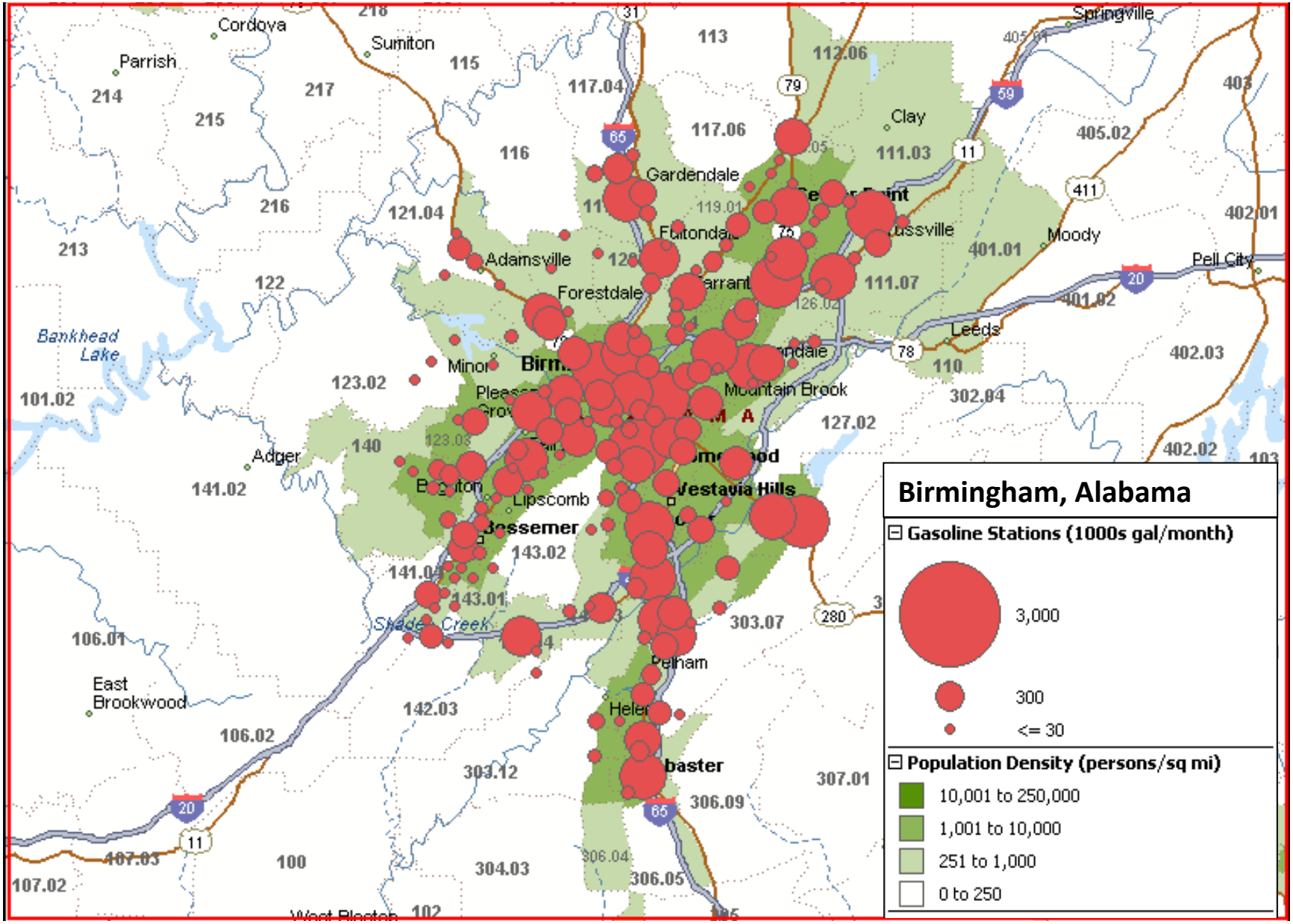
Cluster Distance = 0.3 miles (41% clustered)



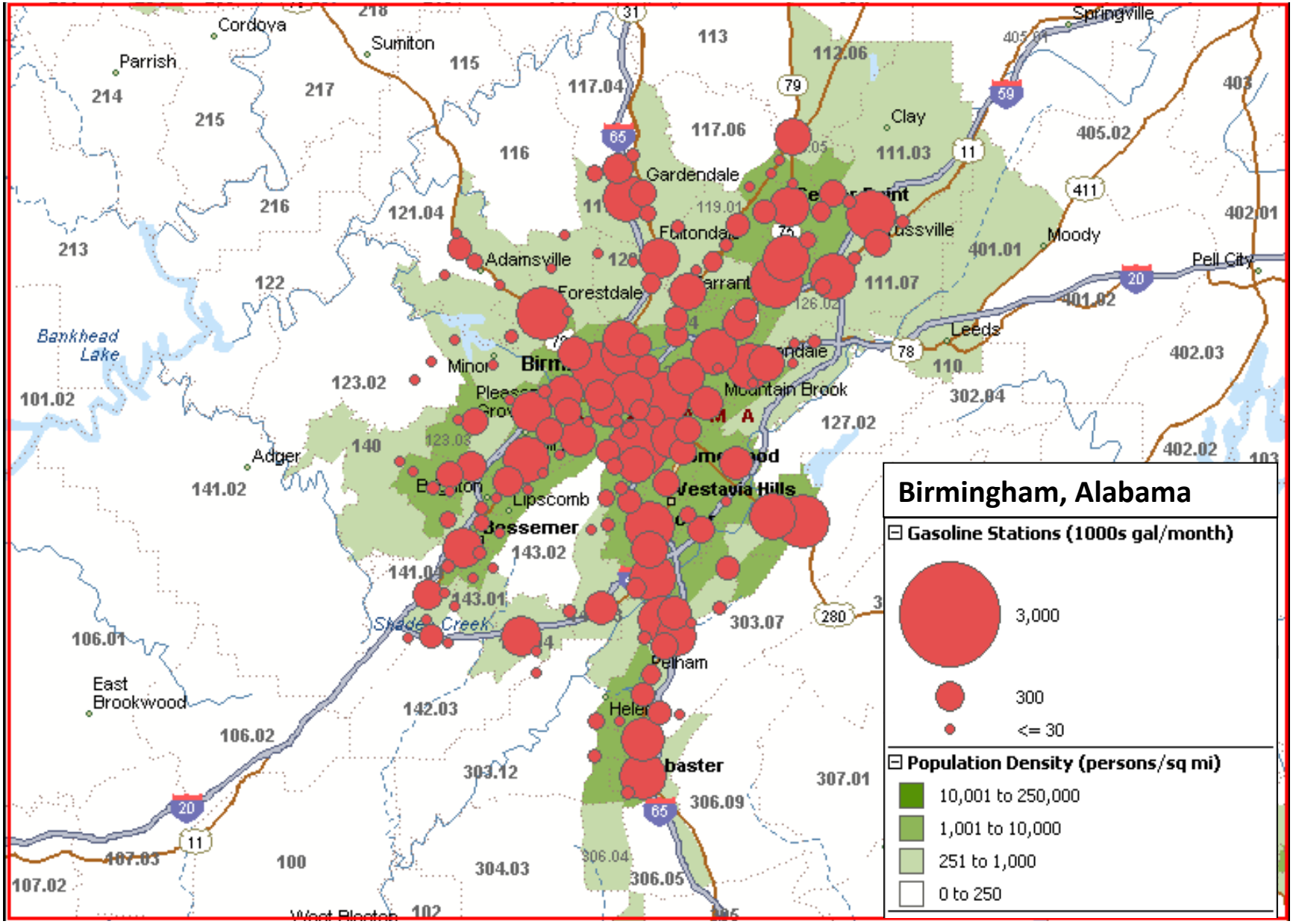
Cluster Distance = 0.4 miles (51% clustered)



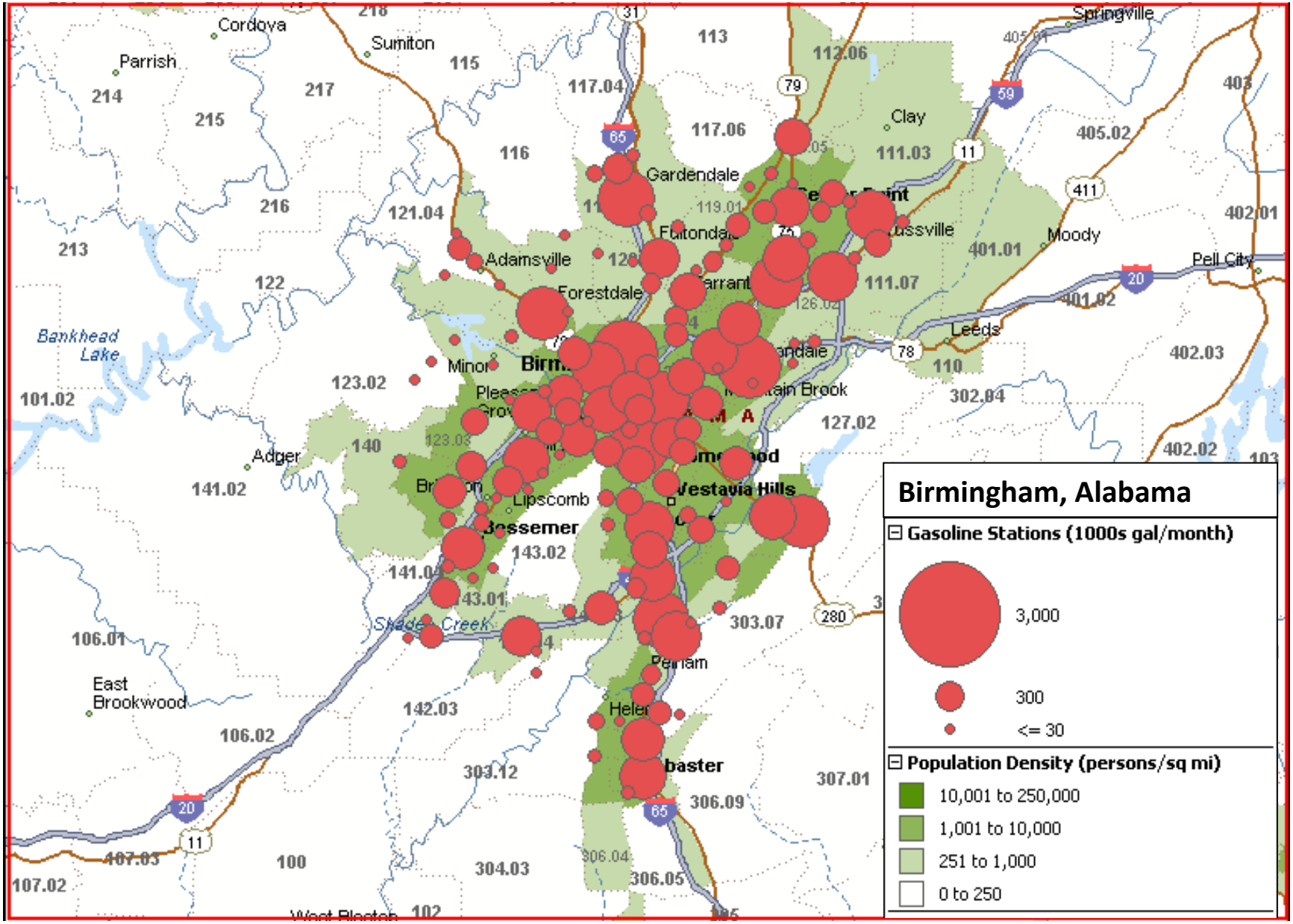
Cluster Distance = 0.5 miles (58% clustered)



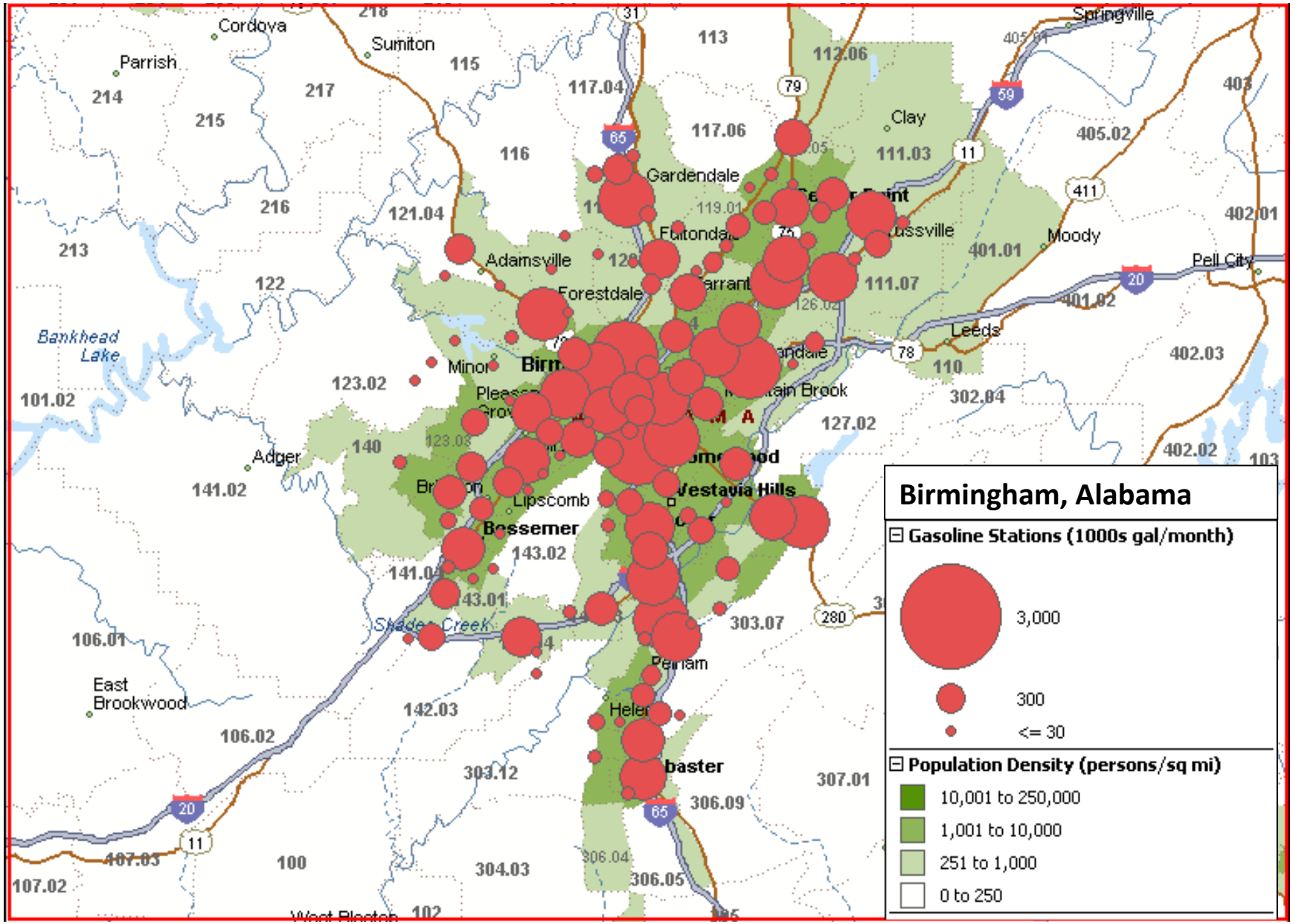
Cluster Distance = 0.6 miles (62% clustered)



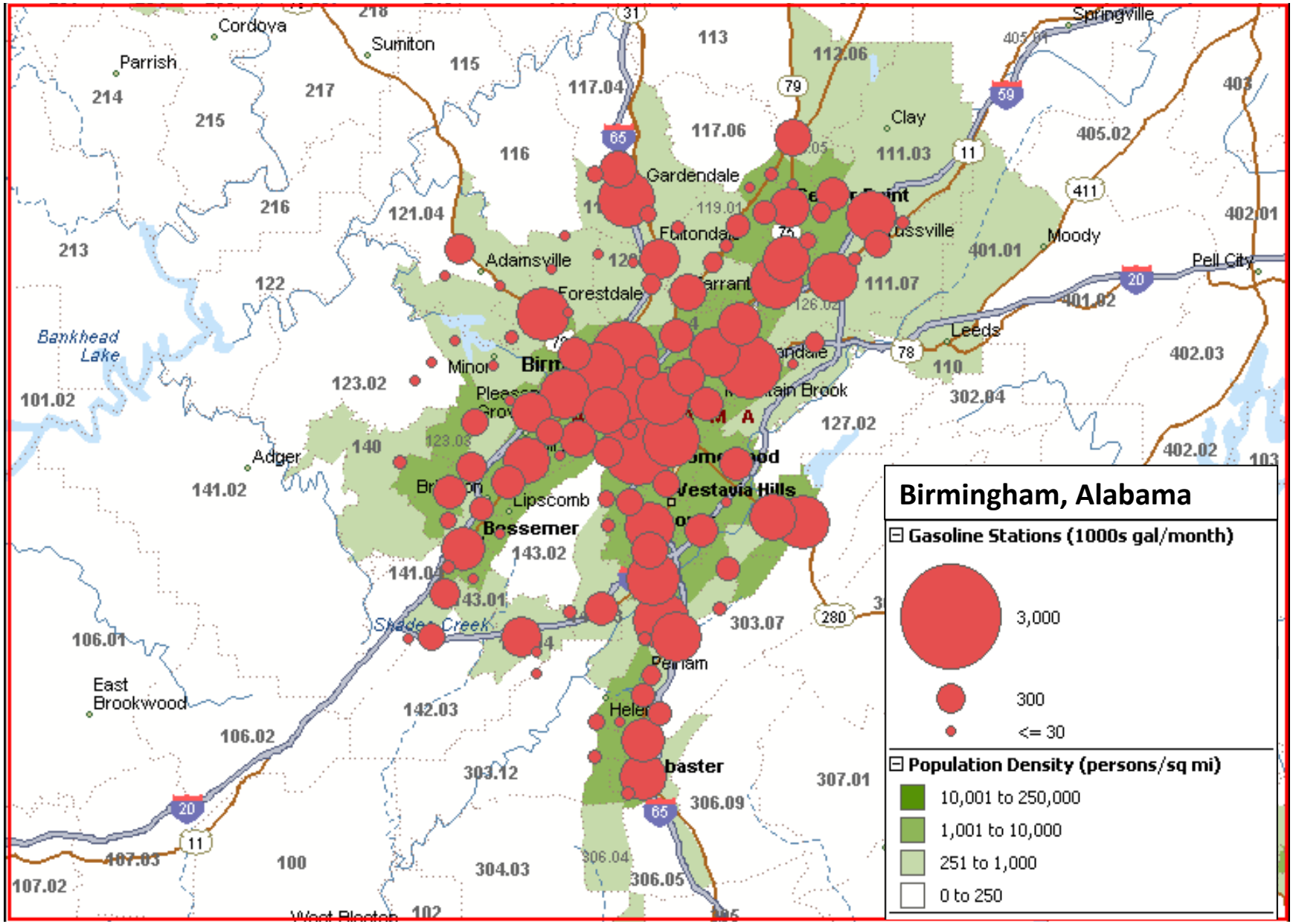
Cluster Distance = 0.7 miles (66% clustered)



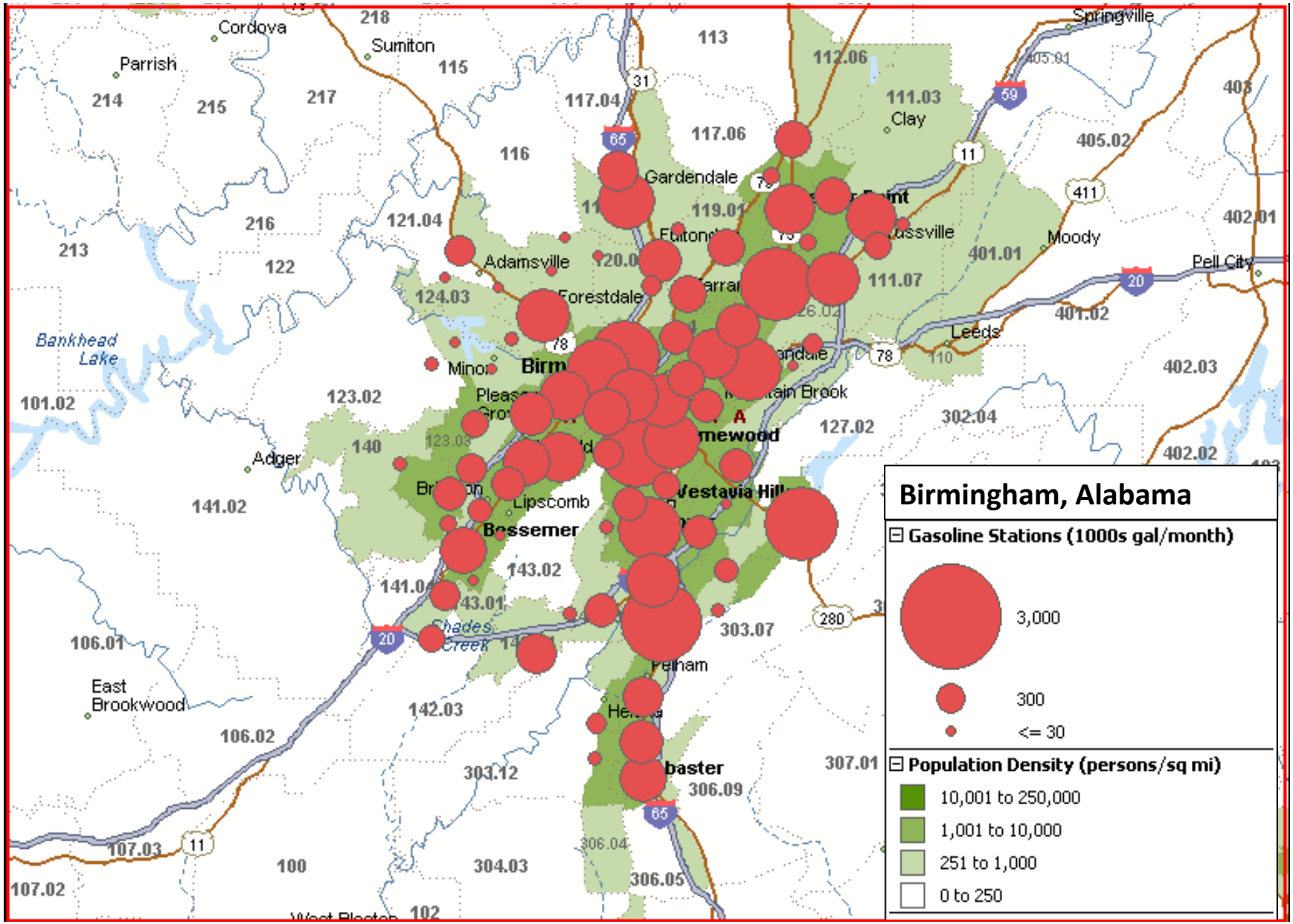
Cluster Distance = 0.8 miles (70.5% clustered)



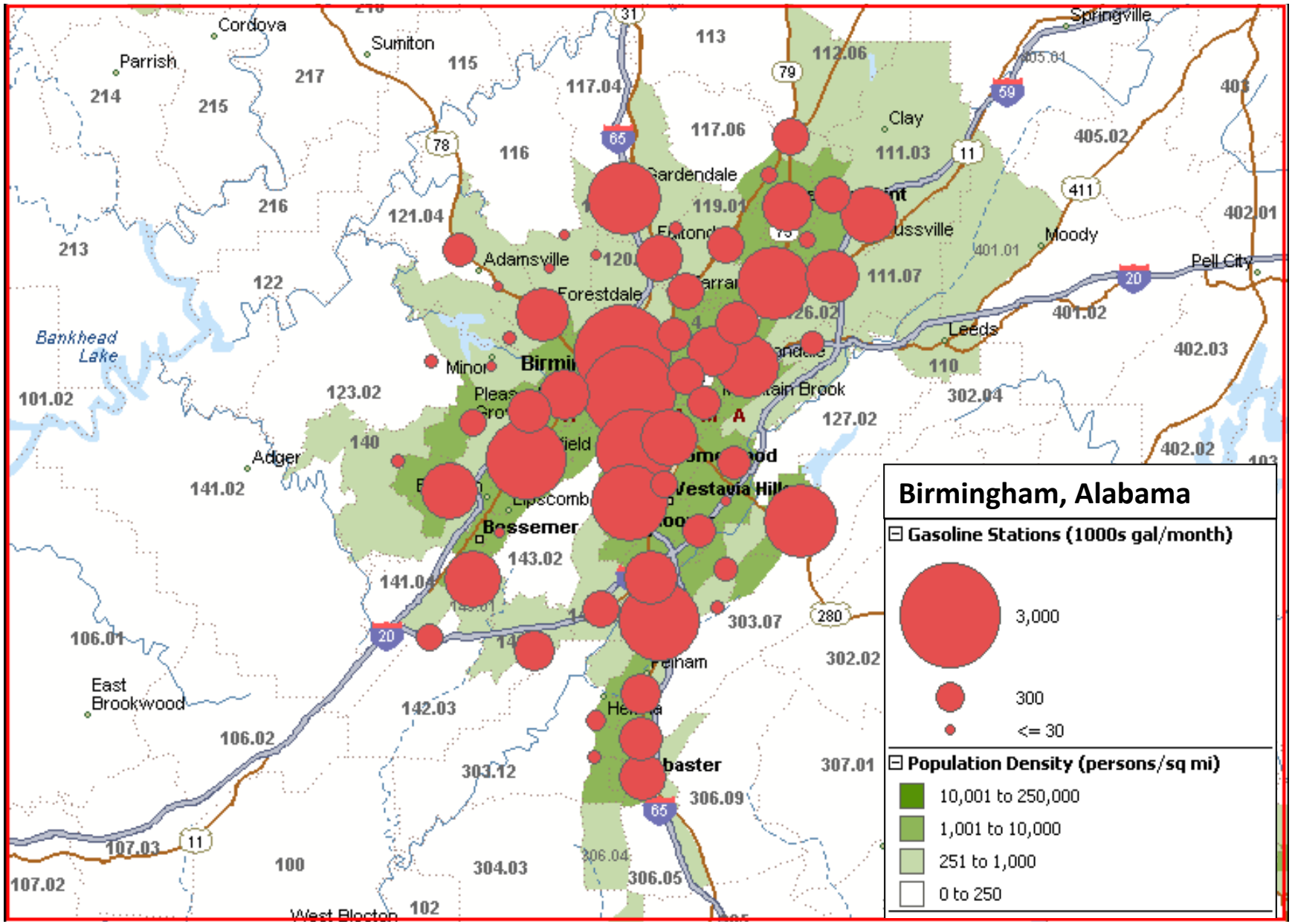
Cluster Distance = 0.9 miles (74% clustered)



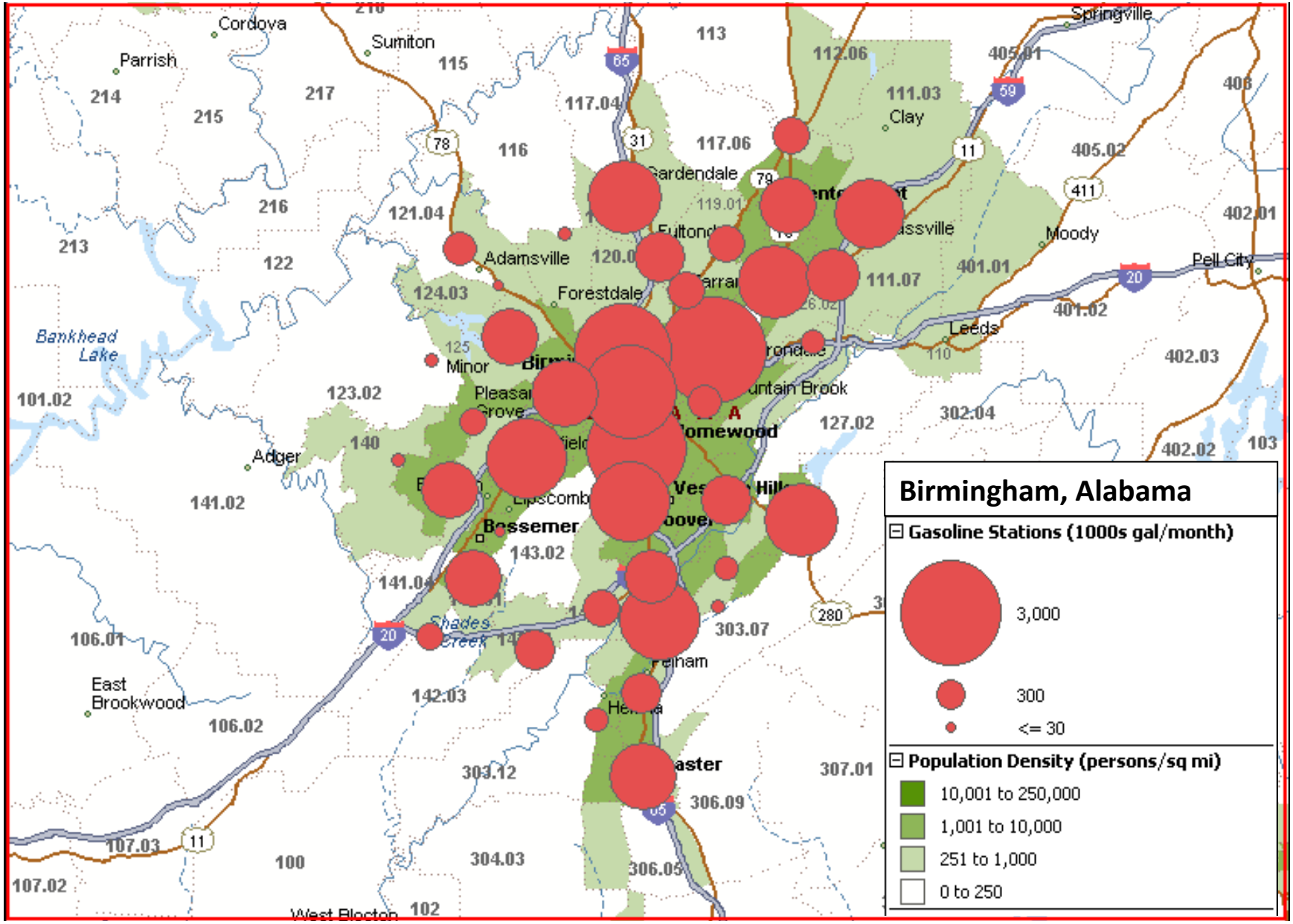
Cluster Distance = 1.0 miles (76% clustered)



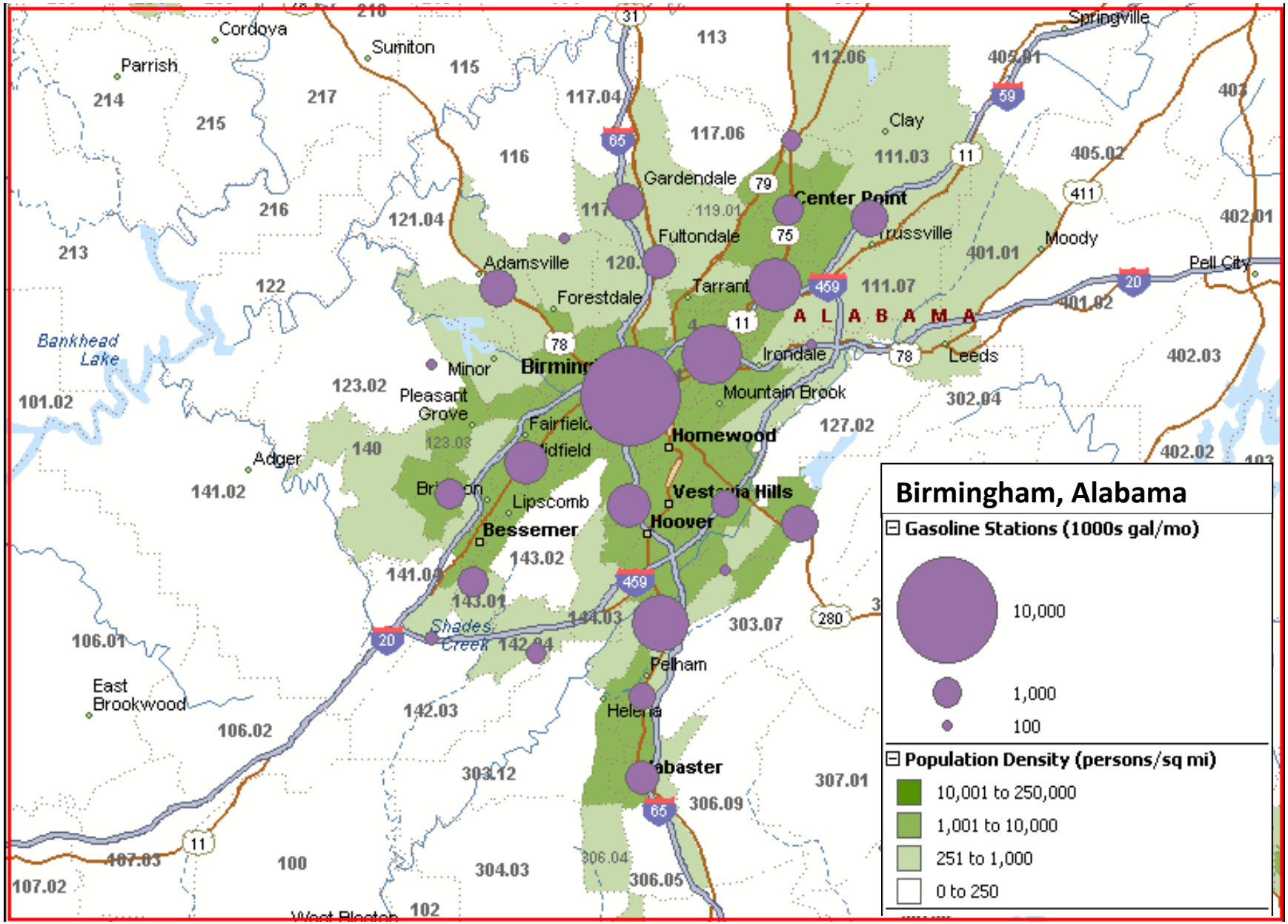
Cluster Distance = 1.3 miles (83% clustered)



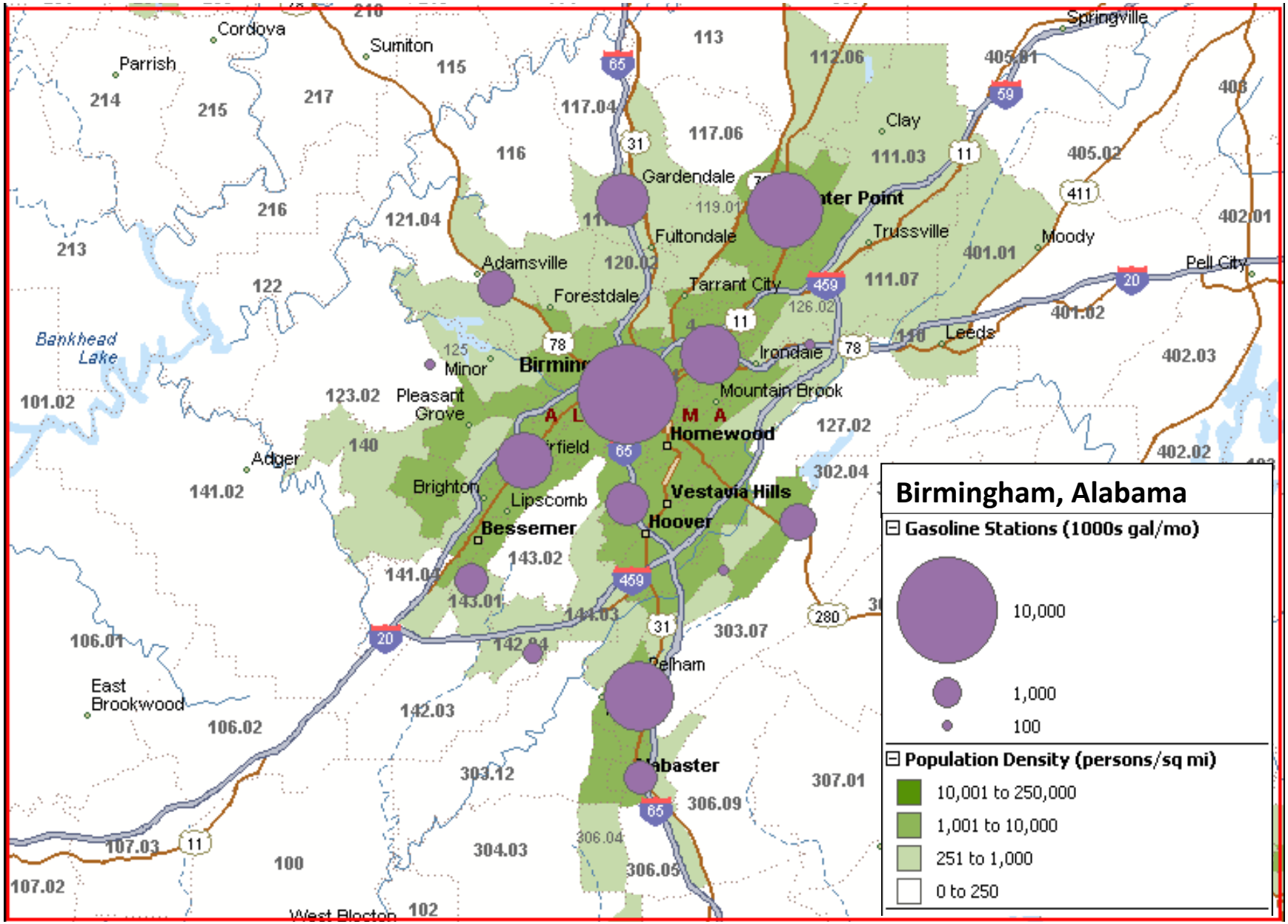
Cluster Distance = 1.6 miles (87% clustered)



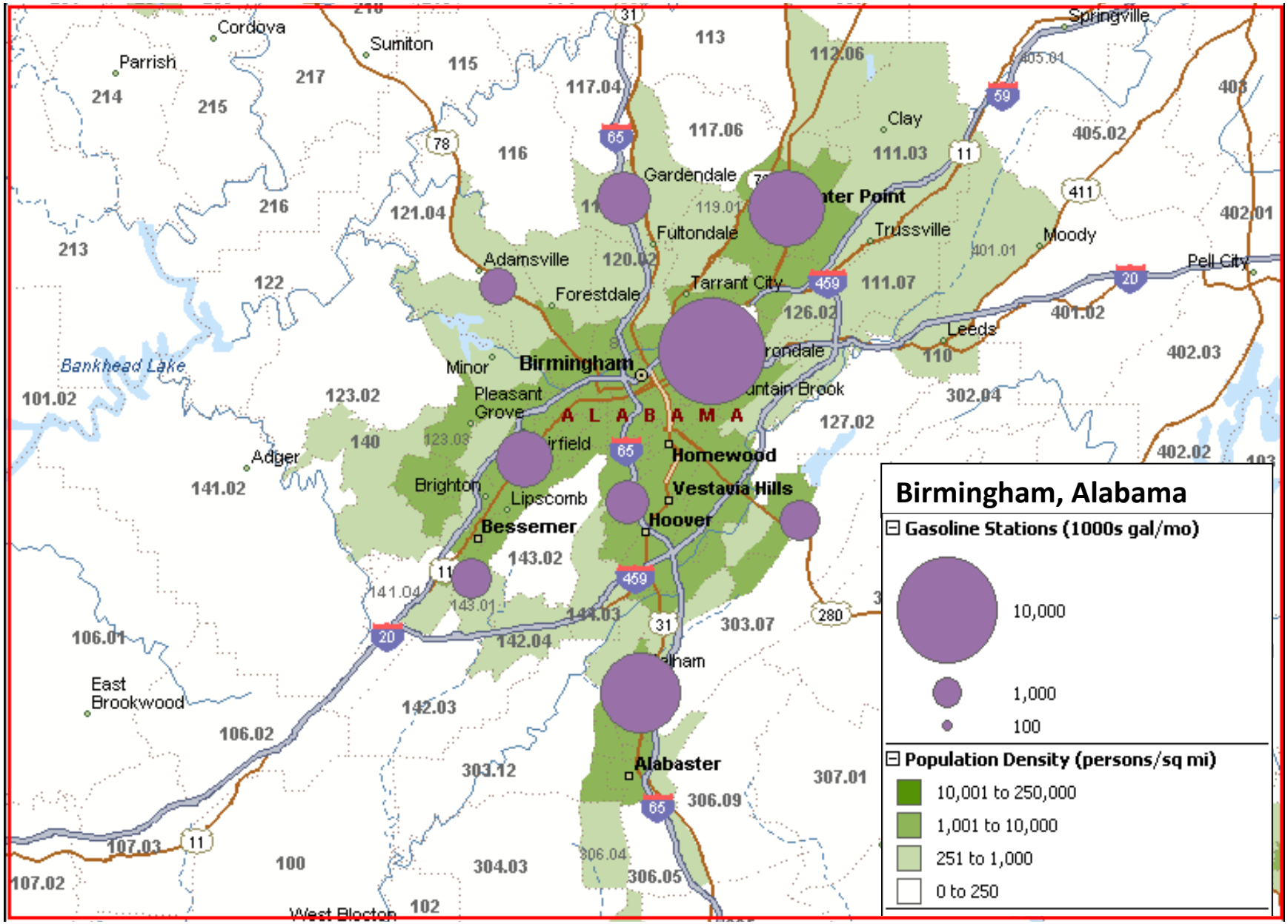
Cluster Distance = 2.0 miles (91.5% clustered)



Cluster Distance = 3.0 miles (95% clustered)

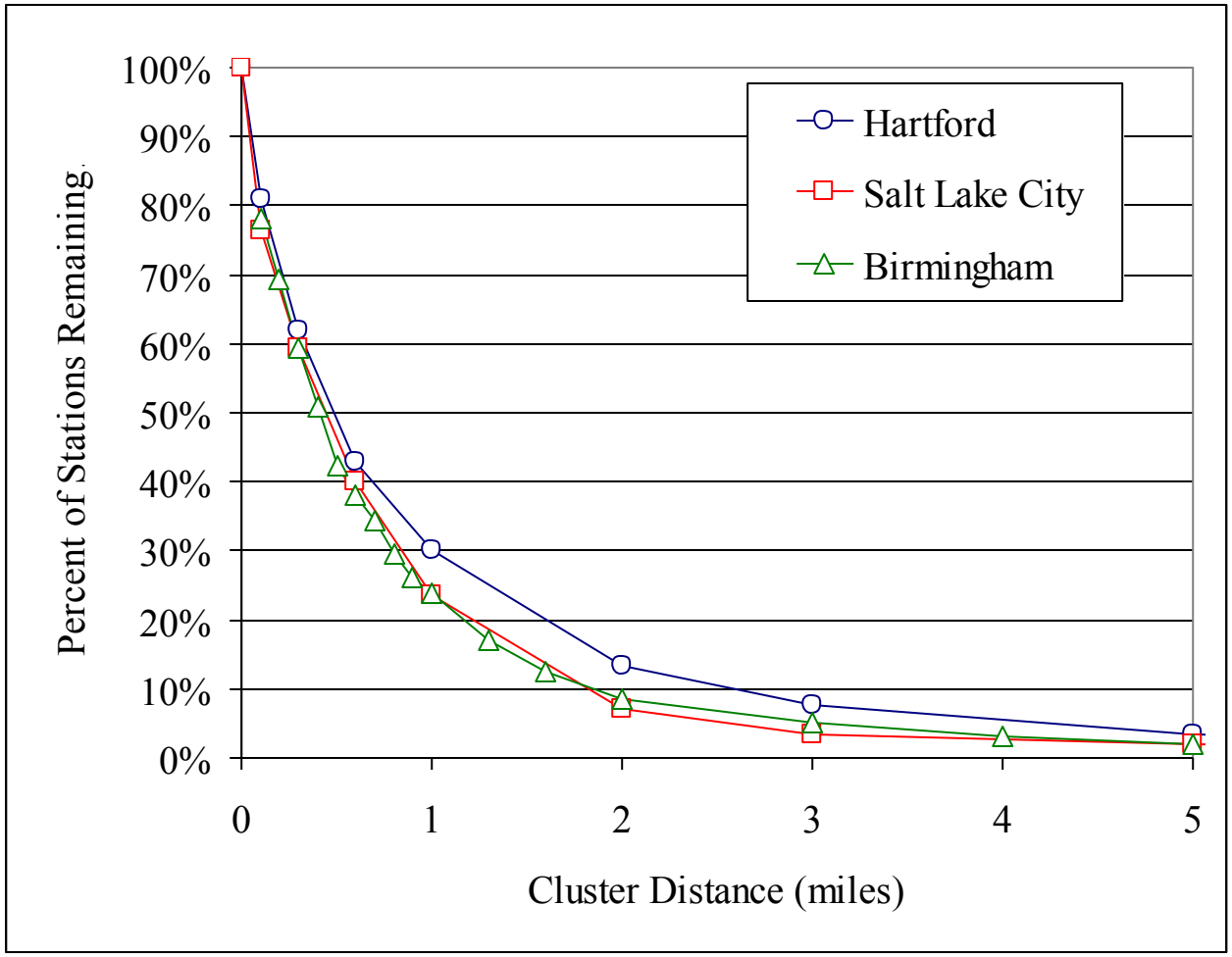


Cluster Distance = 4.0 miles (97% clustered)



Cluster Distance = 5.0 miles (98% clustered)

Clustering Results Compared to Hartford and Salt Lake City



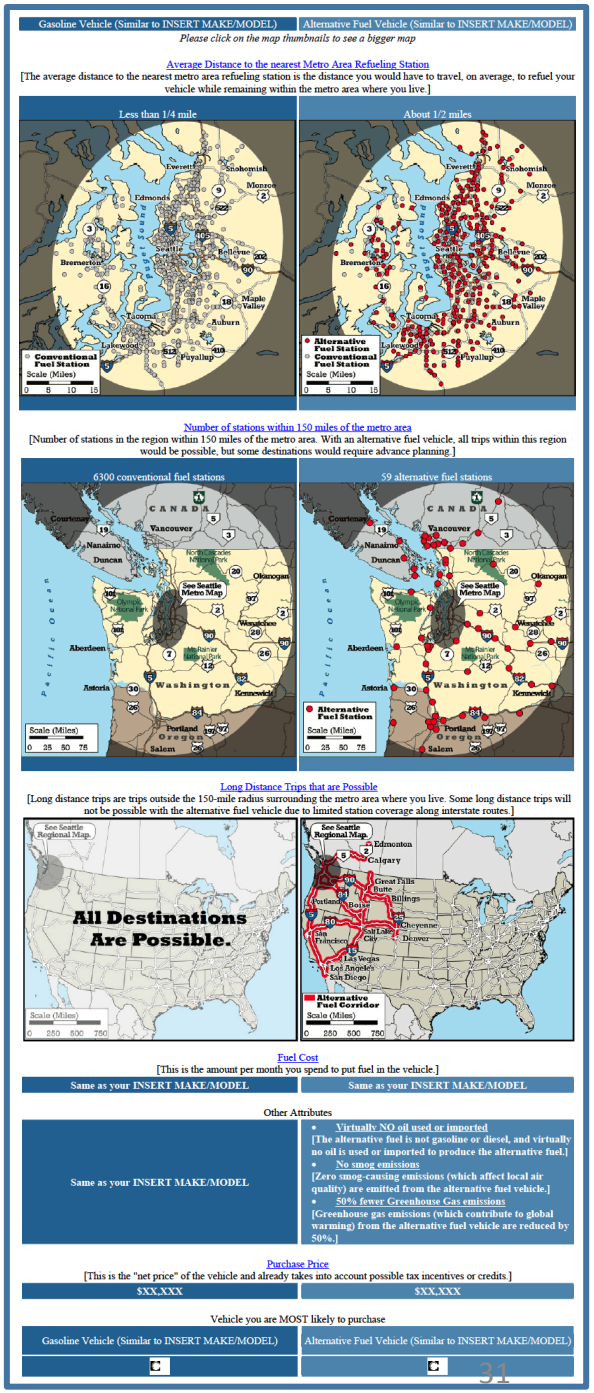
Stated Preference Survey

NREL and *PA Consulting* study

- Developed and fielded 3 discrete choice surveys, each improving on the previous design
- Final survey gave best results
- Relied upon in-house computer survey panels

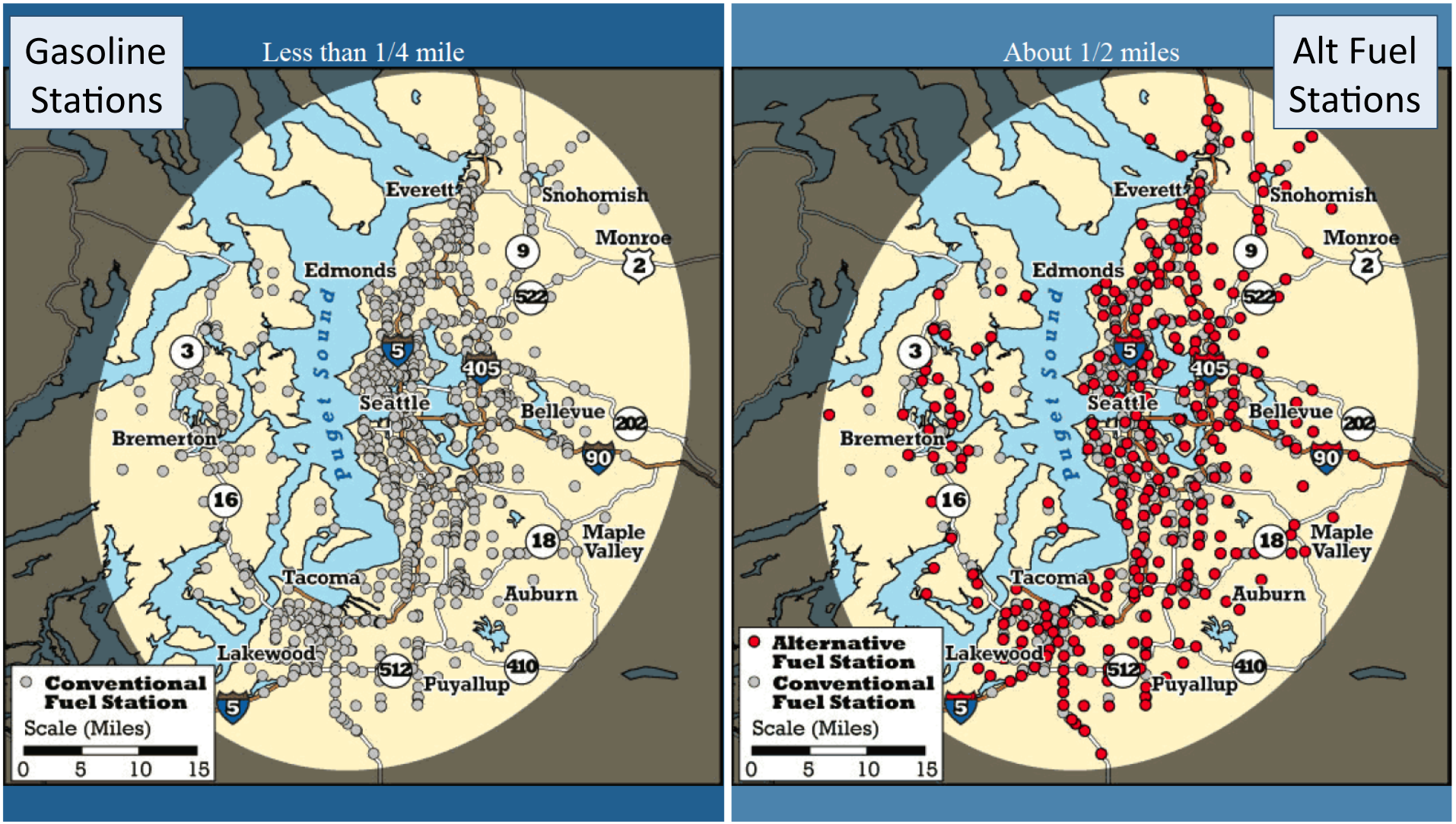
Survey Design

- Sequence of 10 vehicle purchase decisions, with attributes shown side-by-side: Vehicle purchase price, fuel cost, and *station coverage at three geographic scales: local, regional, national*
- Algorithm varies attribute levels based upon previous responses
- Dedicated vehicle for generic alternative fuel
- ~500 surveys completed in each major city: Los Angeles, Atlanta, Minneapolis and Seattle



Source: Melaina, M., J. Bremson, K. Solo (2012). Consumer Convenience and the Availability of Retail Stations as a Market Barrier for Alternative Fuel Vehicles, Presented at the 31st USAEE/IAEE North American Conference, Austin, Texas, November 4-7, 2012.
Available online: http://www.nrel.gov/publications/

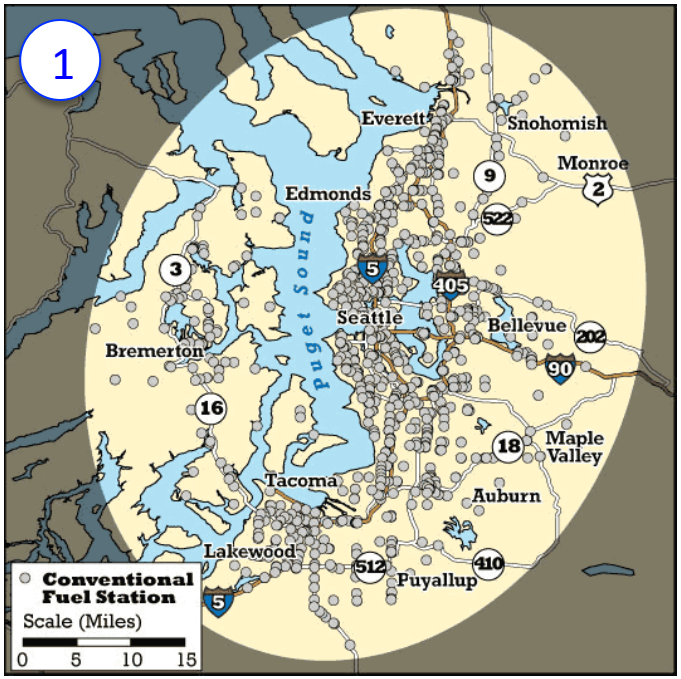
Example of Local Coverage Maps: Seattle

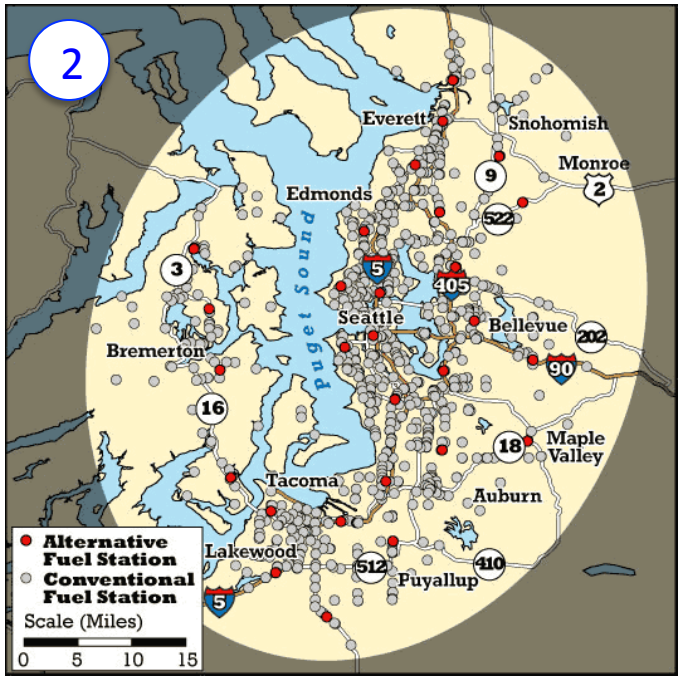


Four Levels: (1) No Alt Fuel Stations, (2) sparse, (3) many, (4) same as gasoline

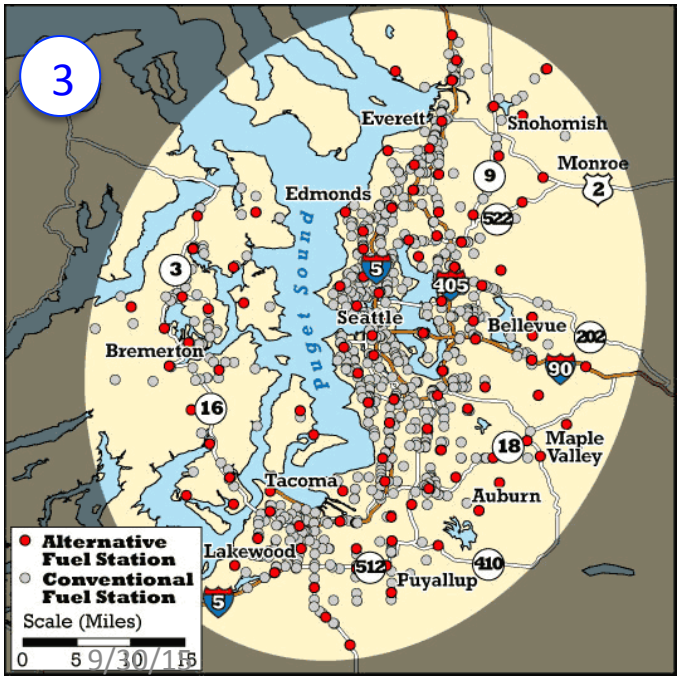
Source: Melaina, Bremson and Solo (2012).

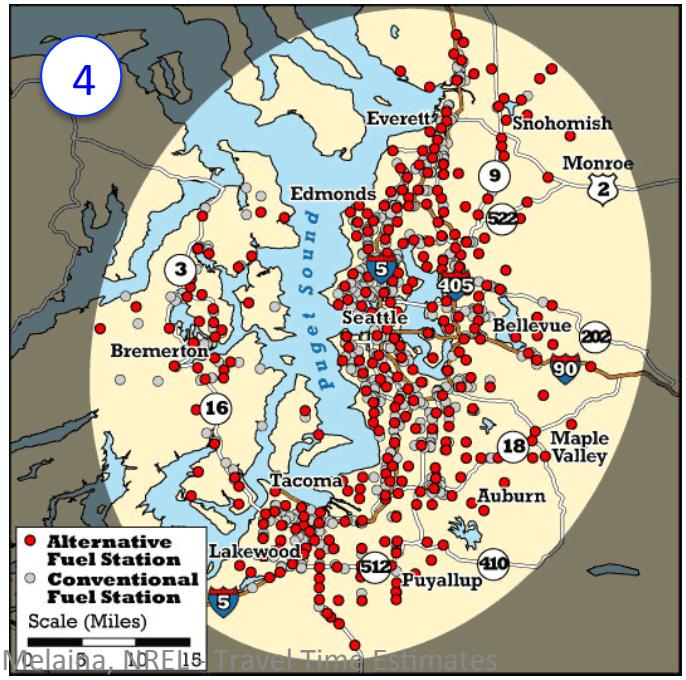
Metro Coverage for Seattle

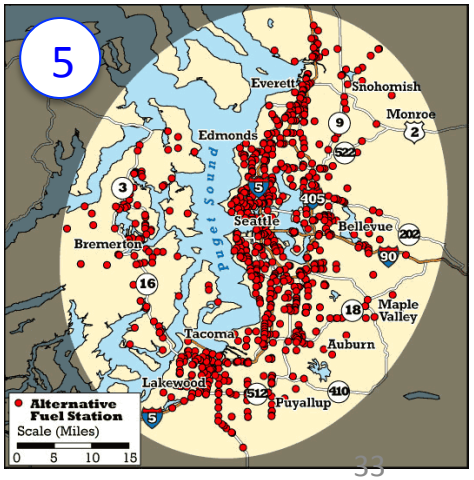




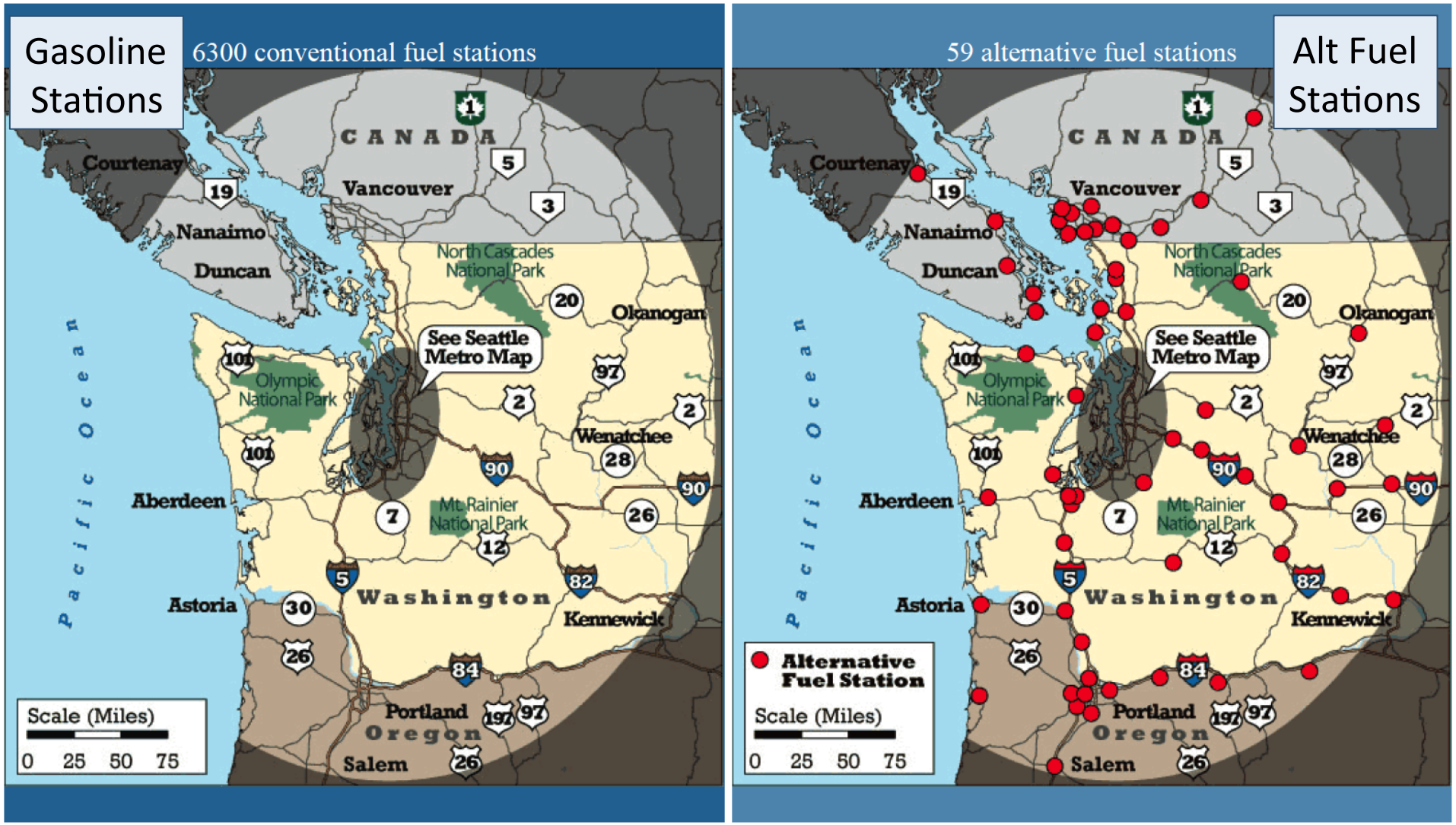
In earlier versions respondents had difficulty distinguishing between 2 & 3.







Example of Regional Coverage Maps: Seattle



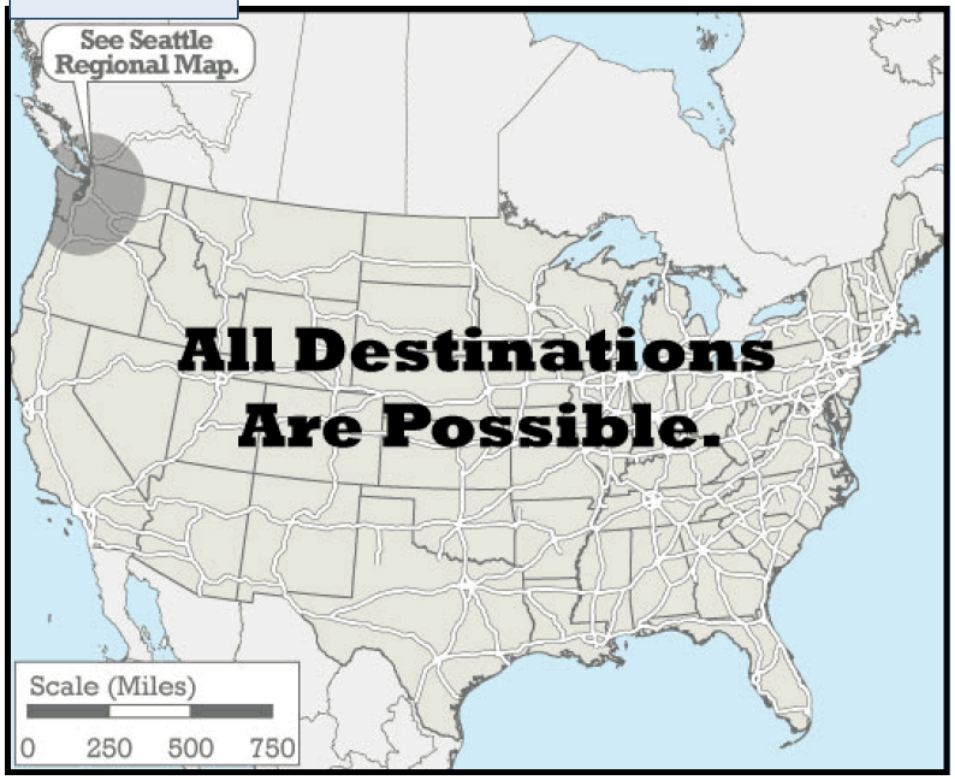
Four Levels: (1) No Alt Fuel Stations, (2) sparse, (3) many, (4) same as gasoline

Regional Coverage for LA.

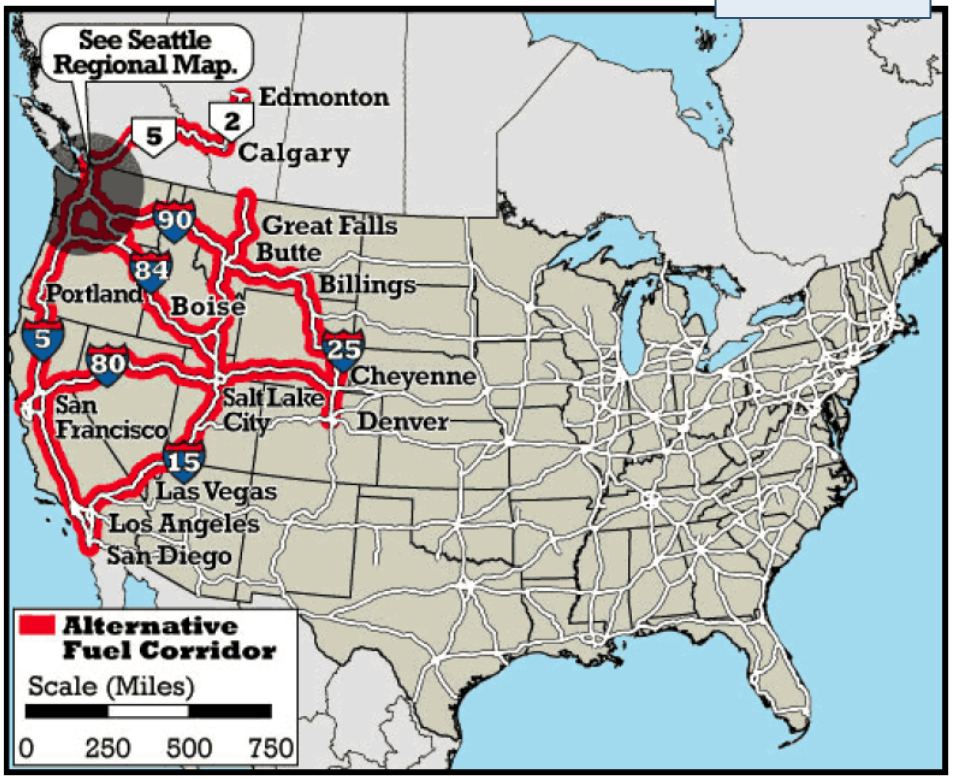
Regional baseline is based upon Melaina & Bremson 2008

Example of Interstate Coverage Maps: Seattle

Gasoline Stations

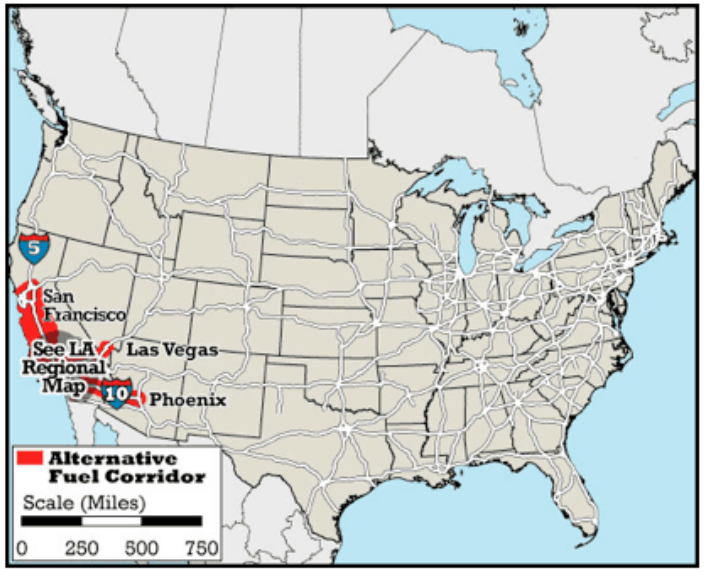


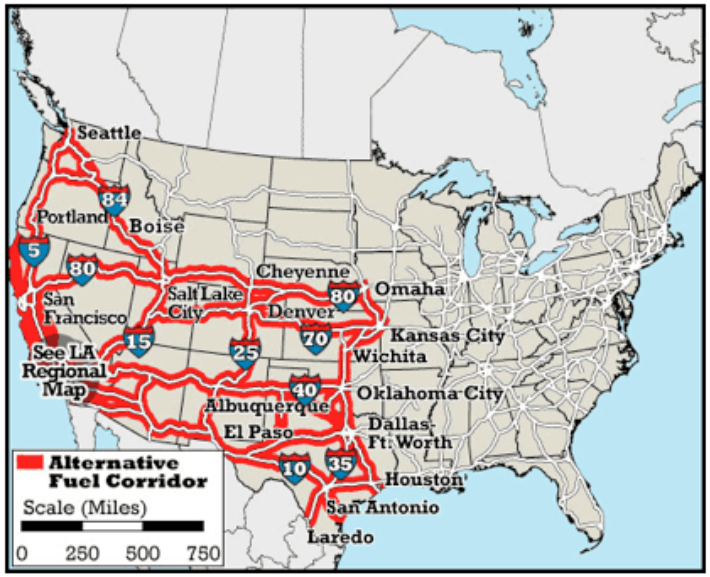
Alt Fuel Stations



Four Levels: (1) No Alt Fuel Stations, (2) nearby interstates, (3) many interstates, (4) all interstates.

Long-distance (interstate) coverage for L.A.





Study Results: Quantified Stated Preferences for Station Availability and Compared to Rational Behavior Model Results

<u>Stated Preference Estimates</u>

Survey results suggest that household consumers may perceive the following (cumulative) purchase price penalties:

- Local: $750 to $4,000 for retail station coverage at 1 to 10 percent of existing gasoline stations within metropolitan (urban) areas.
- Regional: $1,500 to $3,000 for limited medium-distance coverage, defined as 5 to 100 stations within 150 miles of the metro area
- Interstate: $2,000 to $9,000 for a lack of long-distance coverage along interstates connecting urban areas

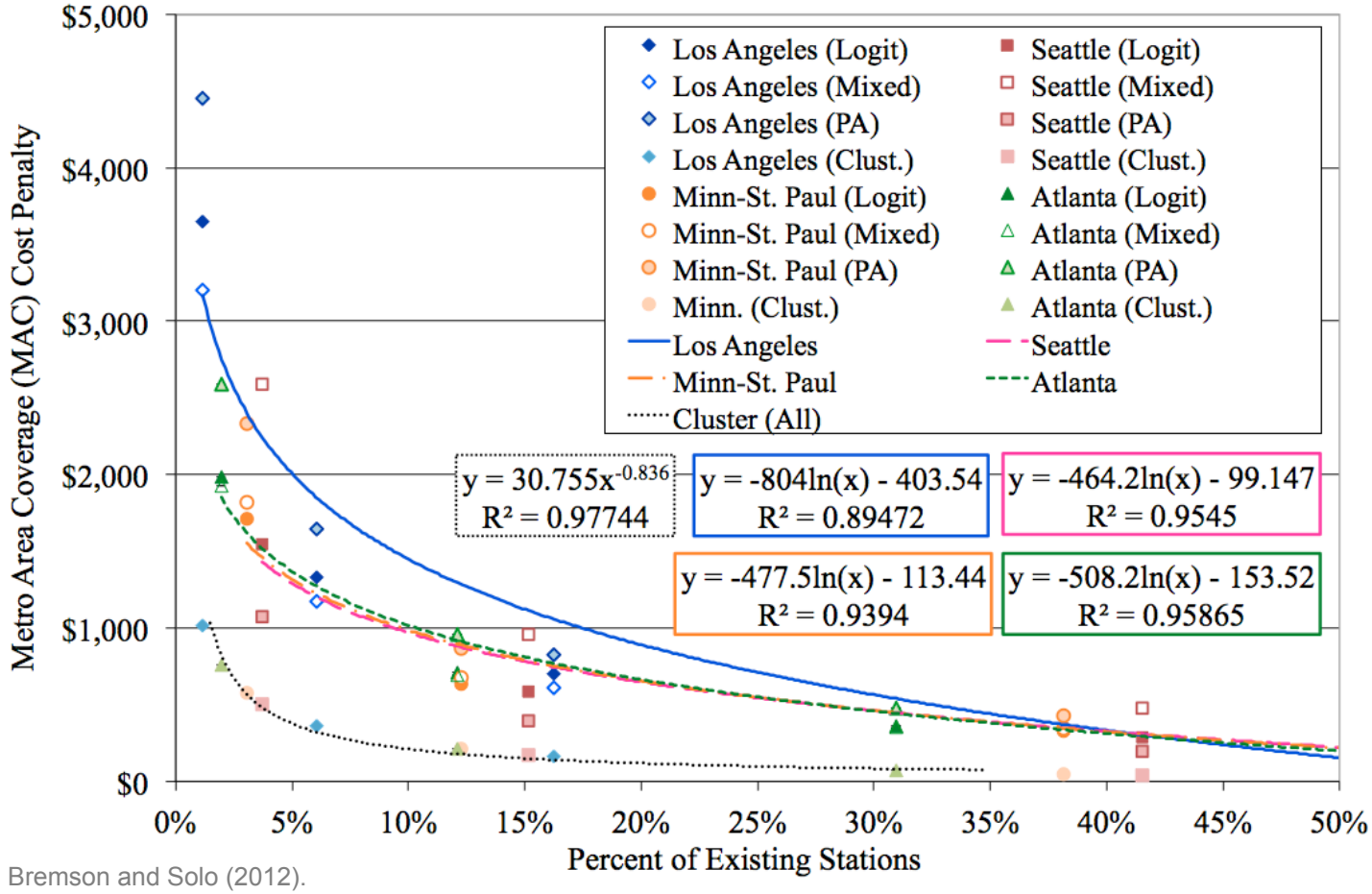
<u>Rational Actor Estimates</u>

A parallel analysis of urban travel time penalties for a "rational" decision maker (additional time needed to drive to stations in a sparse network):

- The "Rational model" based upon a clustering algorithm and travel times suggests $250 to $1,500 for coverage at 1% to 10% of existing stations.
- This is roughly 3-4 times less than the stated preference penalty for local availability within urban areas.

Local Station Availability Penalties

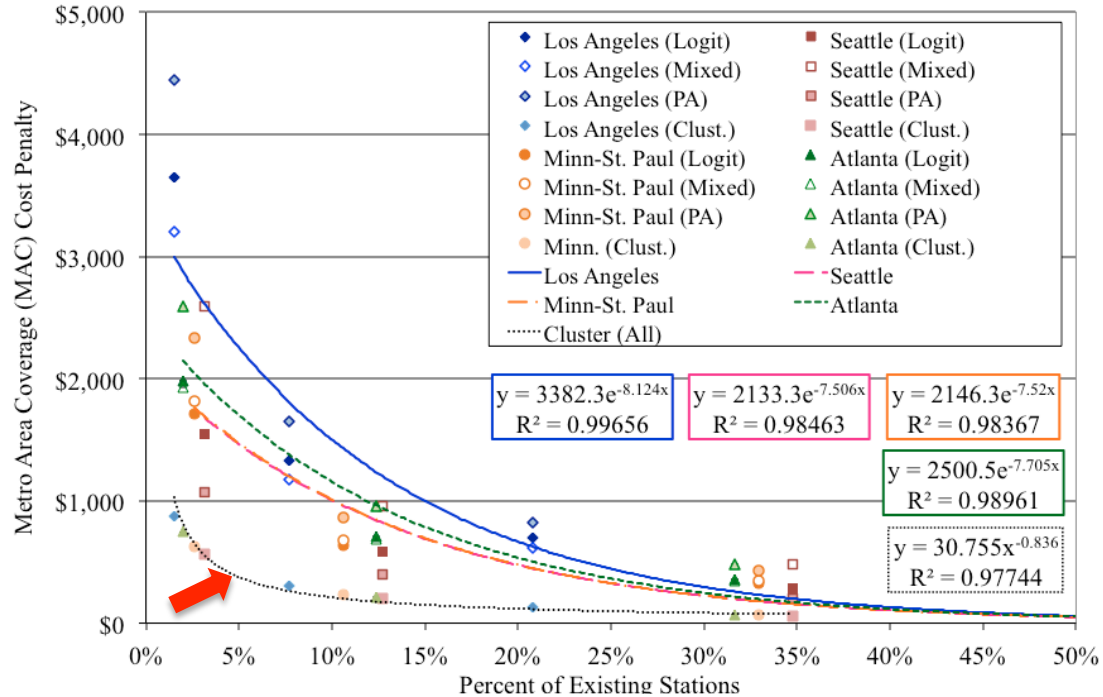
- Cost Penalty Estimates Against the Purchase Price of a New Dedicated AFV for Limited Urban Area Station Availability.
- Graph shows both Survey Results and Cluster Simulations

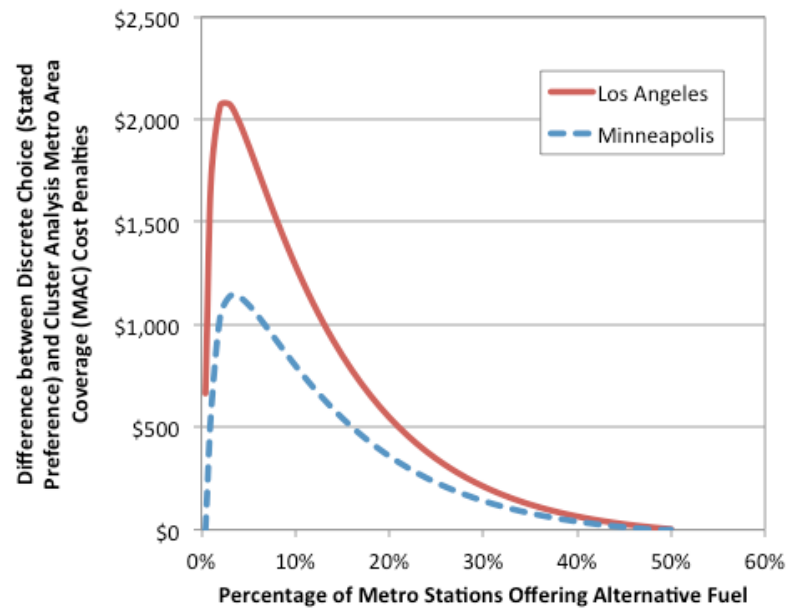


Source: Melaina, Bremson and Solo (2012).

Comparing results at the metro level

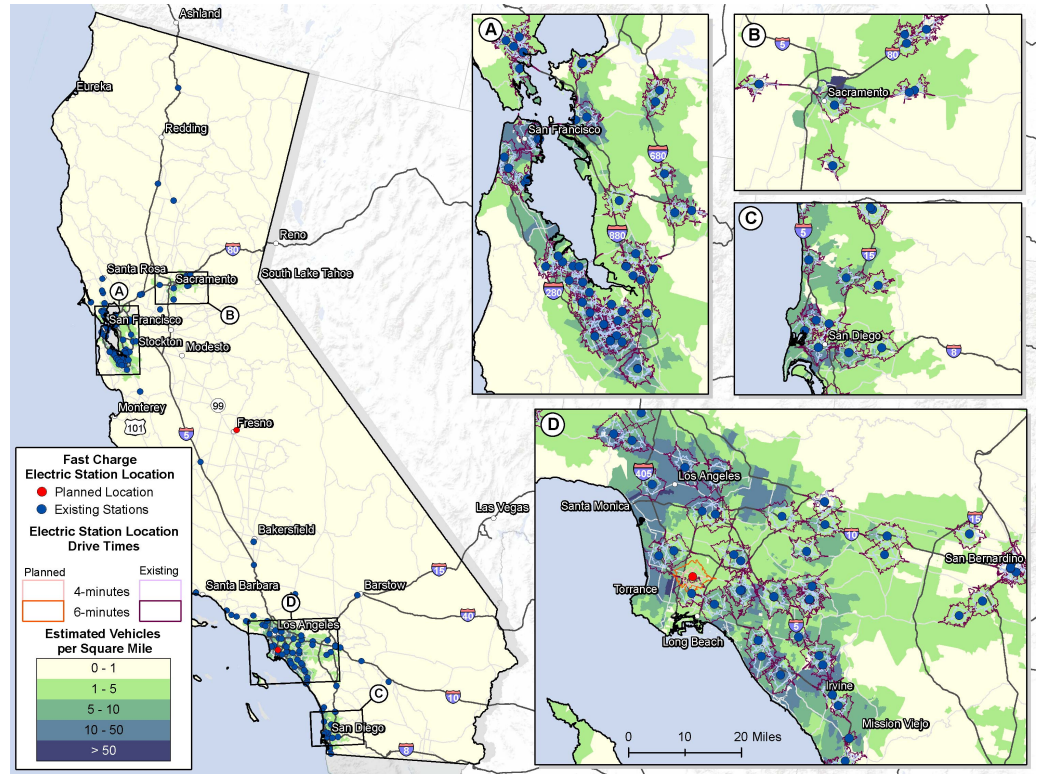
- Cluster results are significantly lower than discrete choice results
- Extremes between L.A. and Minneapolis suggest a difference on the order of $1000-$2000 (bottom right)
- This difference may be interpreted as the perceived penalty incurred on top of an estimate of a "rational" penalty





Summary and Conclusions

- Estimate average drive time distances can be estimated from traffic models
- Drive time results can be translated into consumer purchase penalties
- The basis for "percent of gasoline stations" must be handled carefully
- Penalties based upon travel times are probably a "floor" for a rational consumer
- "Perceived" penalties may be much higher
- State preference survey results suggest they may be 3-4 X greater, and are very high for long-distance trips
- These analyses can only partially inform our understanding of the role of DCFC locations to support PEV market growth



Source: NREL Infrastructure Market Assessment Report for CEC. Forthcoming