Social Networks and Travel Behavior

Investigations into the Role of Social Influence in the Transportation Mode Choices of Students

Sustainable Mobility Seminar
Precourt Energy Efficiency Center
Stanford University

Susan Pike PhD
April 29, 2016
Social networks provide pathways for many processes:

- Learning, cooperation, decision-making, influence, resource sharing, etc.

Networks help explain why and how decisions and other outcomes occur

- Policy outcomes, travel patterns, adoption (diffusion) of innovations and others

Bottom-up policies and strategies drawing on these processes may be effective tools.
Social Networks are Relevant

- Social networks and social influence are relevant to a number of behaviors and activities, such as:
  - voting (Klofstad 2007)
  - academic achievement (Carrel et al. 2001, Sacerdote 2001)
  - access to resources (Granovetter 1973)

- Growing knowledge of social influence and travel behavior:
  - transportation mode choice (Walker et al. 2011, Pike 2014)
  - decision to telecommute (Wilton et al. 2011, Scott et al. 2012)
  - transit ridership (Goetzke 2008)
  - bicycling (Goetzke and Rave 2010)
  - electric vehicle purchase (Axsen and Kurani 2011)
Types of Social Influence

Social influence Mechanisms:

• Information Sharing
• Persuasion or other means of pressure
• Establishment and reinforcement of social norms

Photo: Ansel Adams (1966);
Source: UC Davis Bicycle Plan (2011)

Source: Unitrans.ucdavis.edu
Strategies Using Social Influence

Draw on mechanisms of social influence to affect transportation mode choice

- Incentives for referring or sharing information with friends
- Discounts for carpooling, or other shared travel
- Team based cooperative and competitive strategies
- Receiving information about the actions of others
Challenge a Colleague

May is Bike Month

- Annual campaign to encourage biking
- Local events and activities, and
- Social network strategies

If you wish to block all future challenge emails from other friends, click here.
Make a Trip Together

Next Stop: Take 5
Bring up to 5 friends for $5 on weekends

Capitol Corridor

- Discount for Group Travel
- Normal fares range from $6 to $43
  - Discount on two tickets of $1 to $38 for travelling with a friend

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Refer a Friend to Win:
... help to spread the word ...
by encouraging friends
and coworkers to join the
program. If a new goClub member lists your name ...
you will be entered to **win**
a goClub prize basket...
89 out of 538; 17% of those who obtained any information about goClub joined goClub

From which sources have you received or obtained information about the UC Davis goClub? Please choose all that apply:

- TAPS website
- Talking to people I know
- Davis Wiki
- At a campus event
- Student or staff orientation
- Pamphlets or welcome materials
- Signs, placards, kiosks
- UC Davis website
- Google search

Notes: on average 1.9 sources of information
But, There are Remaining Questions

• How should we define social networks to explore social influence in travel behavior?

• Does social influence (and not other related factors) play a role in transportation mode choice?

• Is social influence the same for everyone, or for every mode of transportation?
Study Setting

University of California, Davis

• Flat topography, mild climate
• Extensive bicycle infrastructure
• High levels of biking

Source: taps.ucdavis.edu
Three survey iterations
• Academic years 2011-12 (fall), 2012-13 (spring) and 2013-14 (fall)
• In coordination with annual Campus Travel Survey
• Student participants invited to Social Networks and Travel Survey
Study Design and Survey

Campus Travel Survey
- Mode use, including limitations to certain modes
- Residential and university office location
- Attitudes, past behavior

Social Networks and Transportation Survey
- Mode use, including mode availability
- Importance of social and other factors in mode choice
- Information sources about campus programs
- Ego-network, and characteristics of contacts
In this question, think about all the people who have been in your social circle over the past six months; this includes people with whom you live, work or attend class, socialize or participate in activities etc. or people you speak with over the phone or internet. List the first names of:

- any five people who have been in your social circle over the past six months.
- the five contacts you have had the most frequent regular interaction with over the past six months.
- five people in your social circle, with whom you spoke about transportation in the past six months.
...what **means of transportation** does each of your contacts use most frequently for trips to work and/or school?

Proportion of alters that ____

\[
\frac{\text{count of alters that ____}}{\text{total alters (up to 5)}}
\]
Social Influence

Do egos in networks with high levels of ego-network biking make the choice to bike more than egos with lower levels of ego-network biking?
Egos Behave Like Their Alters

Proportions of Alters Using Each Mode (Mean)

- Bike (N = 362): 50%
- Drive (N = 39): 31%
- Bus (N = 143): 27%
- Total (N = 544): 43%

Ego Modes

- Mean proportion of alters biking (p < 0.001)

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... and Like Their Neighbors

Ego residential location, with 0.3 mile radius neighborhood

Neighborhood bike density = percentage of neighbors that bike (as reported in Campus Travel Survey, Social Networks Survey or reported for alters by egos)
Is it the Neighborhood or Network?

How should we define social networks to explore social influence in travel behavior?

Ego-Networks?

Neighborhoods?
## Results; Multinomial Logit

### Variables in Model Estimation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1 Drive</th>
<th>Model 1 Bus</th>
<th>Model 2 Drive</th>
<th>Model 2 Bus</th>
<th>Model 3 Drive</th>
<th>Model 3 Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-5.66**</td>
<td>-2.89**</td>
<td>-5.94***</td>
<td>-1.86*</td>
<td>-3.71</td>
<td>-0.16</td>
</tr>
<tr>
<td>Male</td>
<td>-1.28*</td>
<td>-0.78**</td>
<td>-1.19*</td>
<td>-0.94***</td>
<td>-1.15*</td>
<td>-0.94***</td>
</tr>
<tr>
<td>Distance to Campus</td>
<td>0.67**</td>
<td>0.29*</td>
<td>0.72**</td>
<td>0.36**</td>
<td>0.70**</td>
<td>0.38**</td>
</tr>
<tr>
<td>Importance of “Cost of owning a car or other vehicle”</td>
<td>-0.52***</td>
<td>0.01</td>
<td>-0.58***</td>
<td>0.02</td>
<td>-0.56***</td>
<td>0.07</td>
</tr>
<tr>
<td>Importance of “Going other places before, during or after work”</td>
<td>0.85***</td>
<td>-0.10</td>
<td>0.86***</td>
<td>-0.22**</td>
<td>0.80***</td>
<td>-0.23**</td>
</tr>
<tr>
<td>Importance of “Using the same means of transportation every day”</td>
<td>0.13</td>
<td>0.30***</td>
<td>0.24</td>
<td>0.40***</td>
<td>0.22</td>
<td>0.43***</td>
</tr>
<tr>
<td>Agreement with “Feel safe biking” (reverse scale)</td>
<td>0.47**</td>
<td>0.53***</td>
<td>0.61***</td>
<td>0.54***</td>
<td>0.63***</td>
<td>0.54***</td>
</tr>
<tr>
<td>Number of sources of information about parking</td>
<td>-0.02</td>
<td>0.24**</td>
<td>-0.01</td>
<td>0.21**</td>
<td>0.00</td>
<td>0.23**</td>
</tr>
<tr>
<td>Familiarity with campus tire air repair stations (reverse scale)</td>
<td>-0.78*</td>
<td>-0.75***</td>
<td>-0.49</td>
<td>-0.48**</td>
<td>-0.45</td>
<td>-0.51**</td>
</tr>
<tr>
<td>Familiarity with in vehicle parking meter (reverse scale)</td>
<td>0.46</td>
<td>0.79***</td>
<td>0.42</td>
<td>0.73***</td>
<td>0.40</td>
<td>0.69***</td>
</tr>
<tr>
<td>Familiarity with UC Davis GoClub (reverse scale)</td>
<td>-0.20</td>
<td>-0.39*</td>
<td>0.17</td>
<td>-0.42**</td>
<td>0.21</td>
<td>-0.41**</td>
</tr>
</tbody>
</table>

### Percent alters

| Percent alters biking          | -2.40**       | -0.94       | ---           | ---          | ---           | ---          |
| Percent alters taking the bus  | 0.38          | 3.66***     | ---           | ---          | ---           | ---          |
| Percent alters driving         | 1.70          | 1.12        | ---           | ---          | ---           | ---          |

### Percent neighborhood

| Percent neighborhood biking   | ---           | ---         | -2.14**       | -1.99***     | -4.80*        | -4.29***     |
| Percent neighborhood taking the bus | ---     | ---         | -0.79         | 2.08***      | -2.31         | 0.65         |
| Percent neighborhood driving  | ---           | ---         | -0.56         | -0.55        | -2.25         | -2.03        |

### Model Diagnostics

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log-likelihood of full model estimation</td>
<td>-237.98</td>
<td>-266.12</td>
<td>-268.12</td>
</tr>
<tr>
<td>Adjusted rho-squared (pseudo r-squared)</td>
<td>0.499</td>
<td>0.446</td>
<td>0.442</td>
</tr>
</tbody>
</table>
Both spatial reference group and social reference group are related to mode choice

- Are these effects connected?
- Do social and spatial reference groups overlap?
- Does *shared environment* account for the social reference group effect?
Is it *Shared Environment*?

- Does social influence (and not other related factors) play a role in transportation mode choice?
Egos Behave Like Their Alters

Shared or similar environment

Alters influence egos

Egos influence alters

Self-selection into relationships

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<table>
<thead>
<tr>
<th>Ego Mode Choice</th>
<th>Bike</th>
<th>Bus</th>
<th>Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
<td>388</td>
<td>162</td>
<td>96</td>
</tr>
<tr>
<td>Average proportion of alters that bike; p &lt; 0.000</td>
<td>49%</td>
<td>26%</td>
<td>27%</td>
</tr>
<tr>
<td>Average proportion of alters that bus; p &lt; 0.000</td>
<td>13%</td>
<td>41%</td>
<td>10%</td>
</tr>
<tr>
<td>Average proportion of alters that drive; p &lt; 0.041</td>
<td>20%</td>
<td>20%</td>
<td>45%</td>
</tr>
</tbody>
</table>

1 Percentages do not add up to 100% because alters can use other modes, and because these are averages across mode choice
2 p-values for analysis of variance of mean percentage across mode choices (across each row)
Biking Density Varies Geographically

Distance to Campus (miles)

Campus Reference Point

neighborhood biking density (0.3 mile radius)
- no biking
- 91-100%
- 81-90%
- 71-80%
- 61-70%
- 51-60%
- 41-50%
- 31-40%
- 21-30%
- no biking
Downtown Facilitates Walking

Campus Reference Point

Distance to Campus (miles)

Downtown Walk 20.8%

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Freeway is a Barrier for South Davis

Distance to Campus (miles)
Campus Reference Point
1/2 1 1-1/2 2 2-1/2 3

Downtown
Walk 20.8%

South Davis
Bus 32.5%

neighborhood biking density (0.3 mile radius)
- no biking
- 41-50%
- 71-80%
- 21-30%
- 51-60%
- 81-90%
- 31-40%
- 61-70%
- 91-100%

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Highest Bus Ridership in North Davis

North Davis
Bus 37.4%

Downtown
Walk 20.8%

South Davis
Bus 32.5%

Distance to Campus (miles)

Campus Reference Point

1/2 1 1-1/2 2 2-1/2 3

neighborhood biking density (0.3 mile radius)

- no biking
- 41-50%
- 51-60%
- 61-70%
- 71-80%
- 81-90%
- 91-100%

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Neighborhood Biking Density

- Geographic Patterns of Mode Use
  - Bicycle Infrastructure
  - Public Transportation; Access to Bus Lines
  - Barriers to Bicycling – Freeway for South Davis
  - Neighborhood Social Influence?
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In order to better understand the transportation options available to each of your contacts, we would like a general idea of where they live now.

For each of your contacts, provide as much information as you can about where they live now. If you do not know, leave blank.

<table>
<thead>
<tr>
<th>Street they live on</th>
<th>Nearby cross street</th>
<th>Area of town or neighborhood name</th>
<th>City or Town, State</th>
</tr>
</thead>
<tbody>
<tr>
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Alter Choice Environment

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In order to better understand the transportation options available to each of your contacts, we would like a general idea of where they live now.

For each of your contacts, provide as much information as you can about where they live now. If you do not know, leave blank.

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</tbody>
</table>

• Instrumental variable based on alter choice environment:
  • Correlated with endogenous variable – proportion of alters that bike
  • Uncorrelated with dependent variable – ego’s choice to bike
Two Stage Residual Inclusion

• Instrumental variable or control function approach
  • Stage 1; endogenous variables are modeled as a linear function of instruments and the residuals are saved
  • Stage 2; residuals and endogenous variables are included as predictors in binary probit model
    • Rivers and Vuong (1988)
    • Terza et al. (2008)
  • Stage 2 estimates are consistent, but scaled by the parameter: \((1 – \rho^2)^{-1/2}\)
### Social Influence is Relevant

<table>
<thead>
<tr>
<th>Variables in Model (Coefficients reflect effect on likelihood of biking)</th>
<th>Excluding Household Members</th>
<th>Including Household Members</th>
<th>Including Household – Reduced Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>N = 249; 156 Bike (63%)</td>
<td>N = 388; 241 Bike (62%)</td>
<td>N = 249; 156 Bike (63%)</td>
<td></td>
</tr>
<tr>
<td><strong>Estimate</strong></td>
<td><strong>(Std. Error)</strong></td>
<td><strong>Estimate</strong></td>
<td><strong>(Std. Error)</strong></td>
</tr>
<tr>
<td><strong>Intercept</strong></td>
<td>-3.326***</td>
<td>(0.972)</td>
<td>-1.794*</td>
</tr>
<tr>
<td>Proportion of Alters Biking</td>
<td>1.313*</td>
<td>(0.65)</td>
<td>2.148***</td>
</tr>
<tr>
<td>Stage 1 Residual</td>
<td>-0.857</td>
<td>(0.685)</td>
<td>-1.328*</td>
</tr>
<tr>
<td>Ego’s Age (years)</td>
<td>0.085**</td>
<td>(0.029)</td>
<td>0.042.</td>
</tr>
<tr>
<td>Ego is female</td>
<td>-0.39.</td>
<td>(0.209)</td>
<td>-0.501**</td>
</tr>
<tr>
<td>Ego’s Distance to Campus</td>
<td>-0.197**</td>
<td>(0.071)</td>
<td>-0.156**</td>
</tr>
<tr>
<td>Ego Member of GoClub</td>
<td>0.244</td>
<td>(0.254)</td>
<td>0.431*</td>
</tr>
<tr>
<td>Ego has Annual Parking Permit</td>
<td>-1.983**</td>
<td>(0.667)</td>
<td>-1.266**</td>
</tr>
<tr>
<td>Ego’s Commute Days Per Week</td>
<td>0.356**</td>
<td>(0.113)</td>
<td>0.156.</td>
</tr>
</tbody>
</table>

**Model Diagnostics**

- **First Stage R-squared**: R² = .145
- **First Stage F Statistic (Instrument)**: F = 37.65
- **Log Likelihood**: -124.879
- **Rho-Squared – Market Share Base**: 0.24
- **Likelihood Ratio Test (Stage1 Residual)**: 1.53; Pr(>Chisq): 0.216

- **Including Household Members**
  - R² = .177
  - F = 68.45
  - -197.29
  - 0.24
  - 30.53; Pr(>Chisq): < .001

- **Including Household – Reduced Sample**
  - R² = .169
  - F = 50.65
  - -118.61
  - 0.28
  - 20.68; Pr(>Chisq): < .001
Does Social Influence Vary?

• Is social influence the same for everyone, or for every mode of transportation?
Are Some Egos Less Influenced?

Do external conditions impact the effect of social influence?

Diagram:
- Ego
- Bike
- Drive
- Bus
Are Some Egos Less Influenced?

Do external conditions impact the effect of social influence?
Are Some Egos Less Influenced?

Do external conditions impact the effect of social influence?
Are Some Egos Less Influenced?

Do external conditions impact the effect of social influence?
Are Some Egos Less Influenced?

Do external conditions impact the effect of social influence?
Conceptual Model

Does commute distance impact the effect of social influence?

- Short commute distance
- Long commute distance
- Full sample

Probability ego chooses bike

Social influence on choice to bike
Does commute distance impact the effect of social influence?
Distance and Ego-Alter Bike Use

- **Ego bike share**
  
  \[0.83 - 0.12 \times \text{distance} (\text{adj. } R^2 = .41)\]

- **Proportion of alters biking**

  \[0.51 - 0.04 \times \text{distance} (\text{adj. } R^2 = .19)\]
Distance and Ego-Alter Bike Use

**Ego Bus Share**
0.06 + 0.16 × distance (adj. $R^2 = .37$)

**Proportion of Alters Taking Bus**
0.11 + 0.05 × distance (adj. $R^2 = .17$)
Predicted Probabilities

<table>
<thead>
<tr>
<th>Sample Segment</th>
<th>Intercept</th>
<th>Proportion of alters biking</th>
<th>Stage 1 residual</th>
<th>F statistic: instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1½ miles (N = 144) 109 Bike; 76%</td>
<td>-0.53</td>
<td><strong>2.00</strong>*</td>
<td>-1.21</td>
<td>22.34</td>
</tr>
<tr>
<td>1½ to 3 miles (N = 205) 126 Bike; 61%</td>
<td>-0.90</td>
<td><strong>2.69</strong></td>
<td>-1.48</td>
<td>12.64</td>
</tr>
<tr>
<td>3 to 5 miles (N = 47) 22 Bike; 35%</td>
<td>-0.91</td>
<td>1.85</td>
<td>-1.76</td>
<td>8.88</td>
</tr>
<tr>
<td>Full sample (N = 397) 258 Bike; 61%</td>
<td>-0.88**</td>
<td><strong>2.50</strong>*</td>
<td>-1.51**</td>
<td>50.08</td>
</tr>
</tbody>
</table>
Influence Changes with Distance

- Binary Model of Biking and Taking the Bus

- Proportion of alters biking: -4.76***
- Ego’s distance to campus: 0.53*
- Interaction: alters biking × distance: 1.07*
- Ego is undergrad (1 = undergraduate student): 2.64***
- Importance of “Safety”: 0.12
- Importance of “Transit costs”: 0.43***
- Agreement with “Need a car to do most things…”: 0.20
- Agreement with “Like transit”: 0.77***
- Agreement with “Like biking”: -1.14***
- Intercept: -3.63**
Conclusions and Comments

• Social networks are relevant to transportation mode choice decisions
  • Neighborhood and social influence predict mode choice
  • Instrumental variables models indicate social effects beyond those expected because of shared environment

• Not all individuals respond to social influence to the same extent
  • Commute distance may affect individual responses to social influence
Future Directions

• Do other factors affect the importance of social influence?
  • Attitudes, importance of social acceptance/capital
  • Constraints on mode choice; i.e. household activities

• Are relationship types important?
  • How does closeness of relationships affect conformity within networks – to a particular mode?
  • Do different types of relationships have more influential effects?
Thank You

- Professor Mark Lubell, UC Davis
- Professor Susan Handy, UC Davis
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- Research Funding from the University of California Transportation Center, and
- National Science Foundation Graduate Research Fellowship

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