At least 3 decades’ research in travel behaviors

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Background
The larger context

- link to many grand problems of our society (e.g., energy consumption, air pollution, obesity, and quality of life…)

- matter directly individuals’ upward “mobility”

- addressing these issues must engage human factors
Supply based

Demand based
3 charges

• Provide guidance on the kinds and scale of policies needed

• Quantify the effect of policies

• Identify factors and mechanisms that fundamentally influence the course of a phenomenon
Major sub-fields

- movement patterns
- model development
- behavioral factors
macro-level demand models

O-D by mode and time of day

macro-level network assignment

micro-level vehicle interactions
Data
Household travel surveys

- data of active solicitation

- available at the national level and many metropolitan levels

- most often, cross-sectional survey (many subjects but one time point)

- contains three modules
  - household and person related (socio-demographics)
  - trip related (typically for 24 hours, or one day)
  - vehicle related
Household travel surveys

• Sampling
  • randomly selected from geographic subareas within the study region
  • oversampling typically done at subarea level or for specific populations
  • non-probability sampling as an option
• recruitment: first-class mail or telephone
• data retrieval: online instrument, paper-based, CATI
• GPS subsample sometimes available
### NATIONAL HOUSEHOLD TRAVEL SURVEY
#### TRAVEL DIARY

At the beginning of my travel day (4:00 a.m.) I was:  
☐ Home  ☐ Some other place

<table>
<thead>
<tr>
<th>WHERE did you go? (Name of place)</th>
<th>What <strong>TIME</strong> did you start and end each trip?</th>
<th>WHY did you go there?</th>
<th>HOW did you travel?</th>
<th>How <strong>FAR</strong> was it? (blocks or miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXAMPLE:</strong> West Park Theater</td>
<td>Started at: 2:00 p.m.  Arrived at: 2:55 p.m.</td>
<td>To see a movie</td>
<td>walk, bus, walk</td>
<td>6 miles</td>
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<td>1.</td>
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<td>3.</td>
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<td>4.</td>
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<td>5.</td>
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<td>6.</td>
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<td>7.</td>
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<tr>
<td>8.</td>
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</tr>
</tbody>
</table>
Wednesday, February 11, 2009

The map on the right displays one of your travel events corresponding to the details below. You need to:
- Click on each red question mark to update that detail.
- Click on each orange item to either confirm or update that detail.
You can also Insert missing stops and/or delete stops that are not correct.
After each red and orange item is updated, it will turn green.
After ALL the red and orange items become green, you will see a continue link at the bottom of the page.

4:45 PM → 4:47 PM  Stay on "D"
Activity that best describes what you were doing?  

4:47 PM → 5:02 PM  "D" → "E"
What means of travel did you use?  

Which of the following household members traveled with you to the next place?  

Is there a stop missing during this travel? If yes, please insert a stop by clicking Insert.

5:02 PM → 6:20 PM  Stay on "E"
If it was not a real stop, please delete this stop by clicking Delete.

6:20 PM → 6:33 PM  "E" → Other Place

You may return to this travel at any time by clicking on the green numbered circle above.
Sample records from a regional household travel survey.

<table>
<thead>
<tr>
<th>hhid</th>
<th>pid</th>
<th>actno</th>
<th>ptype</th>
<th>depart</th>
<th>arrive</th>
<th>tripdur</th>
<th>actdur</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>650</td>
<td>300</td>
<td>230</td>
<td></td>
<td>34°748.87°N</td>
<td>118°627.56°W</td>
</tr>
<tr>
<td>1200</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1437</td>
<td>740</td>
<td>50</td>
<td>417</td>
<td>34°843.56°N</td>
<td>118°858.78°W</td>
</tr>
<tr>
<td>1200</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>259</td>
<td>1530</td>
<td>53</td>
<td>629</td>
<td>34°748.87°N</td>
<td>118°627.56°W</td>
</tr>
</tbody>
</table>

hhid, household id; pid, person id; actno, activity number; ptype, type of activity (1-home; 2-work); depart, departure time from the location of the corresponding activity (in military format: hhmm); arrive, arrival time at the location of the corresponding activity (in 24 h); tripdur, duration of the trip to arrive at the corresponding activity (in minutes); actdur, duration of the activity in minutes.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>AGENCY/PROJECT</th>
<th>STATE</th>
<th>SAMPLE SIZE</th>
<th>SAMPLING RATE</th>
<th>MODEL TYPE</th>
<th>METHODS</th>
<th>GPS SAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>North Front Range Metropolitan Planning Organization (NFRMPO)</td>
<td>CO</td>
<td>1,505</td>
<td>1.1%</td>
<td>Activity</td>
<td>Unknown</td>
<td>0%</td>
</tr>
<tr>
<td>2011</td>
<td>Community Planning Association of Southwest Idaho (COMPASS)</td>
<td>ID</td>
<td>2,000</td>
<td>0.9%</td>
<td>Trip</td>
<td>Phone, paper</td>
<td>0%</td>
</tr>
<tr>
<td>2011</td>
<td>Genesee Transportation Council (GTC)</td>
<td>NY</td>
<td>3,671</td>
<td>1.1%</td>
<td>Trip</td>
<td>Web, phone</td>
<td>0%</td>
</tr>
<tr>
<td>2011</td>
<td>Atlanta Regional Commission (ARC)</td>
<td>GA</td>
<td>10,278</td>
<td>0.6%</td>
<td>Trip/Activity</td>
<td>Web, phone, paper</td>
<td>10%</td>
</tr>
<tr>
<td>2011</td>
<td>Southeastern Wisconsin Regional Planning Commission (SEWRPC)</td>
<td>WI</td>
<td>16,500</td>
<td>2.1%</td>
<td>Trip</td>
<td>Unknown</td>
<td>0%</td>
</tr>
<tr>
<td>2011</td>
<td>New York Metropolitan Transportation Council (NYMTC)</td>
<td>NY</td>
<td>18,966</td>
<td>0.9%</td>
<td>Trip</td>
<td>Web, phone</td>
<td>10%</td>
</tr>
<tr>
<td>2011</td>
<td>Metropolitan Washington Council of Governments (MWCOG)</td>
<td>DC</td>
<td>4,800</td>
<td>0.8%</td>
<td>Activity</td>
<td>Phone, paper</td>
<td>0%</td>
</tr>
<tr>
<td>2012</td>
<td>Twin Cities Metropolitan Council</td>
<td>MN</td>
<td>10,362</td>
<td>0.9%</td>
<td>Trip</td>
<td>Web, phone, paper</td>
<td>0%</td>
</tr>
<tr>
<td>2012</td>
<td>Wasatch Front Regional Council (WFRC) and Utah DOT</td>
<td>UT</td>
<td>9,159</td>
<td>1.0%</td>
<td>Trip</td>
<td>Web, phone</td>
<td>0%</td>
</tr>
<tr>
<td>2012</td>
<td>Metroline Regional Household Travel Survey</td>
<td>NC</td>
<td>4,231</td>
<td>0.9%</td>
<td>Activity</td>
<td>Phone, paper</td>
<td>0%</td>
</tr>
<tr>
<td>2012</td>
<td>Nashville Area Metropolitan Planning Organization</td>
<td>TN</td>
<td>6,500</td>
<td>2.6%</td>
<td>Activity</td>
<td>Phone, web</td>
<td>10%</td>
</tr>
<tr>
<td>2013</td>
<td>California Department of Transportation (CA DOT)</td>
<td>CA</td>
<td>42,000</td>
<td>0.3%</td>
<td>Activity</td>
<td>Web, phone, paper</td>
<td>13%</td>
</tr>
<tr>
<td>Name of the survey*</td>
<td>Year</td>
<td>Original focus</td>
<td>Location(s)</td>
<td>Period</td>
<td>Resolution: geocoding</td>
<td>Resolution: purposes</td>
<td>Persons</td>
</tr>
<tr>
<td>---------------------</td>
<td>------</td>
<td>----------------</td>
<td>-------------</td>
<td>--------</td>
<td>-----------------------</td>
<td>---------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Uppsala Household Travel Survey</td>
<td>1971</td>
<td>Travel behaviour</td>
<td>Uppsala, Sweden</td>
<td>35 days</td>
<td>Building</td>
<td>All purposes</td>
<td>144</td>
</tr>
<tr>
<td>Mobidrive: Dynamics and routines of travel behaviour</td>
<td>1999</td>
<td>Stability of temporal patterns</td>
<td>Karlsruhe and Halle, Germany</td>
<td>42 days</td>
<td>Street block</td>
<td>All purposes</td>
<td>361</td>
</tr>
<tr>
<td>Borlänge GPS study (ISA Rätt Fart)</td>
<td>2000-2002</td>
<td>Speeding behaviour</td>
<td>Borlänge, Sweden</td>
<td>Up to 80 weeks</td>
<td>Trip ends: GPS; unique locations: pre-defined clusters of trip ends</td>
<td>Unknown, potentially all</td>
<td>189 veh **</td>
</tr>
<tr>
<td>Leisure study (SVI Gesetz-mässigkeiten des Wochenend-Freizeitverkehrs)</td>
<td>2002</td>
<td>Leisure travel behaviour and activities</td>
<td>Zürich, Switzerland</td>
<td>84 days</td>
<td>Post-code level</td>
<td>31 leisure purposes</td>
<td>75</td>
</tr>
<tr>
<td>Thurgau diary (SVI Study of the stability of transport behaviour)</td>
<td>2003</td>
<td>Stability of temporal patterns</td>
<td>Frauenfeld and villages in the Swiss canton of Thurgau</td>
<td>42 days</td>
<td>Building</td>
<td>All purposes</td>
<td>230</td>
</tr>
<tr>
<td>Copenhagen GPS study (AKTA Road Pricing Experiment in Copenhagen)</td>
<td>2001-2003</td>
<td>Route choice under road pricing</td>
<td>Copenhagen, Denmark</td>
<td>18-24 weeks</td>
<td>Trip ends: GPS; unique locations: pre-defined clusters of trip ends</td>
<td>Unknown, potentially all</td>
<td>500 veh.</td>
</tr>
<tr>
<td>Atlanta GPS study (Commute Atlanta Study)</td>
<td>2004-2006</td>
<td>Travel behaviour; test of policy measures such as pricing</td>
<td>Atlanta, USA</td>
<td>Up to two years</td>
<td>Trip ends: GPS; unique locations: pre-defined clusters of trip ends</td>
<td>Unknown, potentially all</td>
<td>Approx. 500 veh.</td>
</tr>
</tbody>
</table>
Emerging data sources

- data of passively generated
  - mobile phone data
    - CDR
    - sightings
  - social media data
  - transit smart-card data
  - taxi data
## Call Detail Record

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>ID</th>
<th>TIME</th>
<th>DURATION (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>195925</td>
<td>32464</td>
<td>J000001</td>
<td>82141</td>
<td>81</td>
</tr>
<tr>
<td>195925</td>
<td>32464</td>
<td>J000001</td>
<td>82456</td>
<td>75</td>
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<tr>
<td>195018</td>
<td>31555</td>
<td>J000002</td>
<td>82100</td>
<td>140</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number_1</th>
<th>Number_2</th>
<th>Call type</th>
<th>Date</th>
<th>Time</th>
<th>Duration (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>J188760</td>
<td></td>
<td>02</td>
<td>07-21-07</td>
<td>00:20:12</td>
<td>2</td>
</tr>
<tr>
<td>J077553</td>
<td>J125738</td>
<td>02</td>
<td>07-21-07</td>
<td>00:00:38</td>
<td>238</td>
</tr>
<tr>
<td>J394476</td>
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<td>01</td>
<td>07-21-07</td>
<td>00:13:06</td>
<td>22</td>
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</tbody>
</table>
Sightings data

<table>
<thead>
<tr>
<th>ID</th>
<th>TIME</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>3X35E90</td>
<td>1319242582</td>
<td>34.044162</td>
</tr>
<tr>
<td>3X35E90</td>
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<tr>
<td>3X35E90</td>
<td>1319301785</td>
<td>34.044392</td>
</tr>
</tbody>
</table>
Some differences

- temporal resolution
- spatial resolution
- user interactions
Concepts and measurements
Household travel surveys
Travel as a derived demand
What is a trip?

- A movement between two activity locations

- Definition of a trip depends on the definition of “*what is an activity*”
  - kinds of activity and purposes
  - duration
  - effort required to undertake the activity (e.g., physical or monetary)
  - group size and composition
  - urgency of activity
  - etc.
Passively generated mobile phone data
Oscillation
From traces to locations

Methods

• frequency-based
• clustering
  • distance based
  • time based
• density based
• model-based
Inferring types of locations

Methods

• frequency-based
• behavior-based
• model-based
Inferring mode and route choices

Route choice

• use intermediate points between O-D

• not use intermediate points (apply assignment techniques)

Mode choice

• speed-based
Validation: nearly NONEXISTENT

A FEW EXAMPLES

• comparing two different populations

• comparing between different scales (individuals vs regional levels)

• comparing the same sample, the same level (individual levels), using a simulation dataset
Movement patterns
Results from TB literature

• habitual or routine behavior
• rhythmic patterns
• variability
• equilibrium of behavior
• dynamics
• variety seeking
(Ir)regularity in travel behaviors

What has been measured?

- *daily trip rates*
- *daily trip distances*
- *action space*
- *activity time use*
- unique trip sequences
- similarity indexes

significant repetition and variation
Two-person household.
Top: male, 37, homemaker; bottom: female: 35, works full time:
Susan Hanson et al (1980s)

- habitual and routine behavior dominates
- developed similarity indexes that reveal little similarity in the behavior of a single traveler on different days
Total behavioral variability

Interpersonal variability

explainable variability
random variability

Intrapersonal variability

explainable variability
random variability
Mahmassani et al (1990s)

- day-to-day dynamics on departure time choice, trip training and route choice
- stronger propensities for changing route choices than departure time choices
Axhausen et al (2000s)

periodicity

probability of occurrence

duration
<table>
<thead>
<tr>
<th>Covariate</th>
<th>Daily shopping</th>
<th>Long-term shopping</th>
<th>Private business</th>
<th>Meet family/friends</th>
<th>Club meeting</th>
<th>Active sports</th>
<th>Excursion into nature</th>
<th>Going for a stroll</th>
<th>Going out (bar, restaurant, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal information</td>
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<tr>
<td>Male</td>
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<td>+</td>
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<td>Age</td>
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<tr>
<td>Age$^2$</td>
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<td>+</td>
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<tr>
<td>Married / cohabiting</td>
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<td>Parent</td>
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<td>-</td>
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<tr>
<td>Club member</td>
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<td>Works full time</td>
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<tr>
<td>N household members</td>
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<td>+</td>
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<td>+</td>
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<td>High income</td>
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<td>Car availability</td>
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<tr>
<td>Main car user</td>
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<tr>
<td>Type of area</td>
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<td>Karlsruhe</td>
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<td>+</td>
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<tr>
<td>McFadden’s rho$^1$</td>
<td>0.01</td>
<td>0.00</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.08</td>
<td>0.12</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Axhausen et al, 2010
Spatial behaviors

• destination choices, and

• the broader spatial opportunities
space-time path

Hagerstrand, 1982
Hagerstrand’s 3 constraints

• capacity
• coupling
• authority
long-term
- residential location
- job location
- transit pass purchase
- vehicle transactions

short-term
- activity type
- mode choice
- destination choice
- activity duration
- departure time
- route choice
- scheduling and rescheduling
Measurement of human activity space

• enumeration of trips and/or unique locations

• continuous representation of use of spaces
Mean shares of trips to 10 most frequently visited locations
Dispersion of locations visited

Schonfelder and Axhausen, 2010
Kernel densities by day of the week

* Cells of positive kernel density

Schonfelder and Axhausen, 2010
Area covered*

Day of the week

Volume

Day of the week

* Cells of positive kernel density