Travel Behavior Data Needs for New Mobility: Is GPS the Ultimate Solution?

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Outline

• GIS vs. GPS
• Travel Route Choice
• Transportation Modeling Paradigms
• GPS Data Collection Challenges
• Extensions from Travel Data Collection
• The Vermont UTC

GIS versus GPS

- Geographic Information Systems
- Global Positioning Systems
- Relational database management system with location
GIS as a Transportation Tool

- Database management
- Map making
- Spatial analysis

Bicycle Transportation

- Traffic Safety: Older & Younger Drivers

Route Choice

- Freight
  - Filling Data Gaps
  - Creative Data Collection
  - Spatial Analysis

Vehicle Emissions
GIS versus GPS

- Geographic Information Systems
- Valuable tool for transportation research

Global Positioning Systems

What about GPS Receivers?

- Vehicle + GPS + GIS
  - fleet location and management
  - in-vehicle navigation
  - infrastructure management
  - travel time probes
- And route data???
Fundamental Research Interest

- Route Choice Behavior
- NOT how people should route (generating optimal routing)
- What motivations (particularly beyond travel time) affect routing
  - scenery, traffic control, road type, congestion, turns
  - population segmentation – routing typology

Routing Behavior
Current Underlying Assumption

- All drivers seek to minimize their own travel time
- Stochastic algorithms account for variation
- Actual route data are needed for the highly developed assignment models
- The challenge is processing the data and modeling route choice behavior

Route Behavior Studies

- Stated Preference
- Map surveys
- Simulation
- GPS
Route Behavior Studies

- travel time is very important
- travel info matters
- demographic differences
- professional drivers
- scenery
- congestion and stopping
- habit
- time of day
- travel time certainty

Wide-spread route data are now within reach (10 yrs?)

- computer power and memory
- Geographic Information Systems (GIS)
- Global Positioning Systems (GPS)

What has taken so long?
Few comprehensive datasets exist
Transportation Planning / Modeling
Old Paradigm

- Land Use and Activities
  - Travel Demands
    - Infrastructure
      - No feedback loops
      - Limited design options - lack of diversity
      - Non-optimal and expensive

Transportation Planning / Modeling
New Paradigm

- Transportation Services ↔ Land Use & Activities
  - Mobility
    - feedback loops - interactions
    - multimodal
    - optimal solutions require more complex analysis … and better data
Data Needs

- More than routes
  - Activities by time and disaggregate location
  - Groupings of trips and travelers
  - Interaction of travel and non-travel
  - Modes and services
  - Social dynamics and decision making
- The US lags in typical travel data collection!!!
- Data (lack of) limit accomplishment of new mobility

Advantages of Passive Data Collection

- Methods
  - GPS
  - Accelerometers
  - Cell phones
- Advantages
  - Large datasets
  - Long time periods
  - Low participant burden and trip reporting fatigue
  - Lower equipment cost
  - Multi-modal potential
- Disadvantages
  - Lack of random large samples
GPS and Travel Route Data

GPS - Typical Errors

- satellite clock
- ephemeris
- receiver
- atmosphere
- S/A
- 2 feet
- 2 feet
- 4 feet
- 12 feet
- up to 25 feet

http://www.ca.uky.edu/agc/pubs/pa/pa5/pa5.htm
Urban Canyons / Moving Vehicle

- Vehicle Motion
- Satellite Lock
- Urban Canyons

Structure of Line Networks
Post Differential Correction?

- base station or unit
- moves points less than road width
- networks are more inaccurate than GPS!

No more accurate system or equipment is coming

A Model to Map GPS Data to Networks
A Model to Map GPS Data to Networks

Algorithm Development

- GPS points
- bearing velocity
- traffic line network
- link route data
- route choice models
Data Processing is the Challenge

- several GPS travel datasets collected
- significant manual interpretation
- used primarily for estimation of trip rate underestimation

GPS Methodological Issues

1. Dividing the GPS data stream into trips
2. A) Finding start and end nodes
   B) Converting points to link-by-link routes

Route Behavior Results
Lexington, KY
Population 250,000
293 Square Miles
1350 miles road

Lexington Road Network
GPS Travel Dataset

- 10-days in each of 250 vehicles in Lexington KY

Data Collection

- Phone survey for demographic information
  - Gender; age; occupation, etc.
- In-vehicle passive GPS receiver for GPS data
- In-vehicle booklet
  - Time
  - Trip purpose
  - Driver
  - Passengers
Customized In-Vehicle Booklet

<table>
<thead>
<tr>
<th>Trip</th>
<th>Driver</th>
<th>Passengers</th>
<th>Day</th>
<th>Appro. Start Time</th>
<th>Type of Activity at the Destination of This Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bob</td>
<td>6 AM</td>
<td>Su</td>
<td>6:10 AM</td>
<td>Home, Personal Business, Recreational Activity, Social Activity, Other (Please specify)</td>
</tr>
<tr>
<td></td>
<td>Bill</td>
<td>6 AM</td>
<td>Su</td>
<td></td>
<td>Workplace, Work-related Business, School (Where I am a student), Shopping, Pick up/Drop off Passengers</td>
</tr>
<tr>
<td>2</td>
<td>Bob</td>
<td>6 AM</td>
<td>Su</td>
<td>6:55 AM</td>
<td>Home, Personal Business, Recreational Activity, Social Activity, Other (Please specify)</td>
</tr>
<tr>
<td></td>
<td>Bill</td>
<td>6 AM</td>
<td>Su</td>
<td></td>
<td>Workplace, Work-related Business, School (Where I am a student), Shopping, Pick up/Drop off Passengers</td>
</tr>
</tbody>
</table>

Module 1: Trip End Identification

- Continuous GPS data stream (average number of records 28,552 / household) over ten days

```
RECORD,FLAG,DATE_,TIME_,TOTSEC,DELTASEC,LAT,LONG_,SPEED,HEAD,ALTITUDE,HDOP,SATS,QUAL
9394,A,5/6/2003,11:29:03,329049,1.38.03,-84.48,4.69,25,1004,2.5,4,0
9455,A,5/6/2003,17:51:01,351967,1.38.03,-84.48,2.59,40,1000,3.9,7,0
9456,A,5/6/2003,17:51:02,351968,1.38.03,-84.48,2.79,41,1000,3.4,7,0
9457,A,5/6/2003,17:51:03,351969,1.38.03,-84.48,2.9,42,1000,3.4,7,0
9458,A,5/6/2003,17:51:04,351970,1.38.03,-84.48,3.09,42,1000,3.4,7,0
9459,A,5/6/2003,17:51:05,351971,1.38.03,-84.48,3.2,41,1004,3.9,7,0
9460,A,5/6/2003,17:51:06,351972,1.38.03,-84.48,3.2,41,1004,3.9,7,0
9461,A,5/6/2003,17:51:07,351973,1.38.03,-84.48,3.2,41,1004,3.9,7,0
9462,A,5/6/2003,17:51:08,351974,1.38.03,-84.48,3.2,41,1004,3.9,7,0
```
The First Challenge

- Goal \(\Rightarrow\) divide into individual trips
- Dwell time
  - \(\Delta t < T_1\) no trip end
  - \(\Delta t > T_2\) trip end
- Problem \(T_1 < \Delta t > T_2\)

The Drop Off

- heading change
- link used twice
- off network
- log as a back up
Challenges of Identifying Trip Ends

- Dwell time? Short-stay trips? Traffic jams / Long waiting time for a gap for turning left?
- Circuitous trips / Purposeless driving

Features of Possible Trip Ends

- Dwell time
- Heading changes
- Distances from the road network

A combination of multiple rules: Extensive programming in GIS environment

References: Doherty (2000); Pearson (2001); Wolf (2001); Stopher (2003); Schonfelder (2002; 2003);
The Heuristic Model Constructed in GIS to Identify Trip Ends

- 18 sets of parameter values (dwell times, distances and heading change checks) tested
- Calibrated with known trip ends (from 12 best recorded in-vehicle booklets)
  - Best set of parameters 94% effective (comparing to effectiveness of 88% if using dwell time of 140 seconds only) *
- Applying the best parameter combination to the whole GPS datasets: 14,943 trips identified

* Jianhe Du and Lisa Aultman-Hall "Increasing the Accuracy of Trip Rate Information from Passive Multi-Day GPS Travel Datasets: Automatic Trip End Identification Issues", Forthcoming Transportation Research Part A

Module 2: Point-to-Link Conversion

- Not always the case that the closest link is the right link
Convert Points to Links

Software environment: ArcInfo WorkStation in ArcGIS

- **Step A: Node Prediction Model**
  - Identify start and end nodes (topological intersecting point of two links) for each trip

- **Step B: Route Prediction Model**
  - Buffer GPS points (45 meters/150 feet)
  - Assign impedance values to road links
  - Use Minimum Path Algorithm to trace minimum impedance route

References: Lee-Gosselin (2000); Doherty (2000)

Calibration Dataset

- **Different Data**
- **Data collection well designed and controlled**
  - In Lexington, Kentucky (December 2000 to July 2001)
  - 18 deliberately designed routes (Shortest route 2.8 miles; longest route 19.7 miles; average 11.9 miles) repeatedly traveled
  - Total 674 routes (8020 miles) collected
Sample Routes

Links Completely Within Buffer
Optimizing Buffer Distance

- Step 2: Route Prediction Model
  - Buffer GPS points (45 meters/150 feet)
  - Link points with lines, buffer the lines AND points and merge all buffered polygons
  - Assign impedance values to road links
  - Use Minimum Path Algorithm to trace minimum impedance route

Dealing with GPS Gaps
Point-to-Link Model Performance

- Different buffer distances tested
- High accuracy: 95% routes are predicted 100% accurate*
- Uniqueness: Calibration is based on known routes


GPS Methodological Issues

1. Dividing the GPS data stream into trips
2. A) Finding start and end nodes
   B) Converting points to link-by-link routes
3. Network Travel Times from GPS Probes

Route Behavior Results
Module 3: Link Travel Time Estimation over the Network

- GPS data provide real-world speed on some of the links (6,366 of 11,447 links have probe data)
- Necessary to know travel times on all links
- Geostatistical model - Kriging – to spatially interpolate unknown link travel time from road links with GPS data

Classification and Regression Trees

- Continuous dependent variable ⇒ TT ratio
- Categorical predictor variables
  - road class
  - distance from downtown
  - radial (yes/no)
  - time of day, day of week
- Minimize variance within category
- Maximize variance between categories
• Few trips have diversion of > 30%
• >65% of trips have < 5% diversion

N = 13,387

Who Diverts

Percentage of People Diverted

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>age 21-30</td>
<td>24%</td>
<td>11%</td>
</tr>
<tr>
<td>age 31-50</td>
<td>23%</td>
<td>13%</td>
</tr>
<tr>
<td>age 51-65</td>
<td>21%</td>
<td>21%</td>
</tr>
<tr>
<td>age &gt;65</td>
<td>21%</td>
<td>19%</td>
</tr>
</tbody>
</table>
GPS Travel Data Collection
Where are we going?

- Methodological issues remain
- Awareness limited
- Broad comprehensive discussion is needed
- Wearable devices / GPS cell phones / accelerometers
- New standard method for household travel data collection
Vehicle Emission Models

- Traffic Simulation
  - Function of
    - average link speed
    - time resolved and vehicle-based speed

Current On-road Emissions Models

- Mobile
  Regional models based on vehicle class, average speeds and road class

- EMFAC

- Measure

- CMEM
  Emissions models developed based on operating mode but are still under development
The Minivan Experiment

The Minivan Experiment
ScanTool

- OBD II
- Velocity
- 4 Records per Second

Accelerometers

- Mounted on Roof
- 1 Axis and 3 Axis
- Acceleration
- 10 Records per Second
GPS Receivers

- Mounted on Roof
- Position and Velocity
- 1 Record per Second

Mode Accuracy

<table>
<thead>
<tr>
<th>Mode</th>
<th>Garmin GPS</th>
<th>Geologger GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle</td>
<td>99</td>
<td>97</td>
</tr>
<tr>
<td>Acceleration</td>
<td>90</td>
<td>87</td>
</tr>
<tr>
<td>Cruise</td>
<td>96</td>
<td>94</td>
</tr>
<tr>
<td>Deceleration</td>
<td>91</td>
<td>88</td>
</tr>
<tr>
<td>Overall</td>
<td>96</td>
<td>93</td>
</tr>
</tbody>
</table>

***Weak for acceleration
CT Emissions Test Route

- 17 miles
- Multiple Road Types
  - 13 miles (rural arterial)
  - 1 mile (divided highway)
  - 3 miles (local roads)
- Speed limits
  - 25-65 mph

Data Collection

- October 11th - 31st, 2006
- 22 Drivers Recruited
  - Each drove two circuits
- 986 miles of data
- 105,735 seconds of data
GPS enables Spatial Analysis

Normalized PN Emissions
Factor above Mean
Emissions Factor vs Speed

PN Emission Factor vs Acceleration
**PN Emissions Factor vs Grade**

![Graph showing PN Emissions Factor vs Grade](image)

**Vermont - UTC**

- **Theme** - Sustainable Systems & Advanced Technologies for Northern Communities
- **Cross-campus** (in Provost’s office)
- **Signature Research Projects** (3 years, up to $2M)

Photo from French Hill by Michael Sipe featured on new UTC brochures and posters
Signature Research Project #1

Integrated Transportation and Land Use Models: Complex Systems Approaches and Advanced Policy Applications

Drs. Adel Sadek and Austin Troy (and 10 others PIs)

What will the transportation system look like in 20 years?
What is the impact of transportation on climate change?
TRANSIM and URBANSIM
New output metrics: storm water, air quality, robustness, ground water impact

Signature Research Project #2

Emissions and Performance of Alternative Vehicles in Northern Climates

Drs. Britt Holmén, Lynn Gregory, Tom Streeter, Dryver Huston, Jeff Frolik

How do hybrid versus non-hybrid vehicles perform in the winter and in hilly terrain?
What are the emissions from biodiesel vehicles?
What does the public know about emissions and how does this impact consumer behavior
Unique UVM focus: on-road, particles, low-cost sensors
Signature Research Project #3

Sustainable Transportation for Tourism

Drs. Manning, Liang, Chase and Sadek

Development of DOT traffic measures for tourism areas.
Does e-tourism increase economic and community benefits?
Project involves LOS, simulation and biofuel coaches for tourist routes and ski area villages.

Photo by Local Motion, Burlington, VT

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Signature Research Project #4

Mobility and Livability - Seasonal and Built Environment Impacts

Drs. Jane Kolodinsky and Brian Flynn

How does the built environment including mobility impact quality of life?
Can latent demand measure quality of life or mobility?
How does climate impact walking and biking for both utilitarian and recreational trips?
Multi-state effort with NETI.

Photo by Local Motion, Burlington, VT
GPS Data Collection in Transportation
Problem?

“GIS and GPS do not need research, they are fully developed and in the realm of the private sector”

GPS and Travel Data

Where are we?
- The methodological / research challenges are significant
- But the potential for new contributions to new mobility systems is also significant
- Academia not significantly involved in technical issues
- Travel / mobility data are not the primary driver of GPS system developments
GPS for Travel Data

- Where do I hope we are going?
  - Dispel the myth that these tools are fully developed as research instruments
  - Address the complex data issues in open academic discourse

- GPS as the base backbone for new mobility data
- Incorporation with cell phones and accelerometers
- American travel data sets become larger and more comprehensive

Travel Behavior Data

Needs for New Mobility: Is GPS the Ultimate Solution?

Answer: One part of the ultimate solution, but much more research work is needed

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