An Investigation of the Distribution of Driving Speeds Using In-vehicle GPS Data

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Problem Statement

- Traditional speed collection methods cannot record driver’s individual information.
- Does speed vary by age or sex?
- Do certain roads consistently have larger average speed to speed limit ratio?
Our Research Goals

- Collect GPS data that can be linked to drivers’ demographic information
- Compare the speed profile of men versus women and among different age groups
- Compare the ratio of average speed to speed limits on different road types
Outline

- In-vehicle GPS data collection
- Data processing
- Analysis of speed distributions
- Conclusions
GPS Device Used in the Study

- Carry Bag
- Power Cord
- GPS Data Logger
- GPS Receiver
Attributes of the Garmin Instrument

- **GPS receiver performance**
  - Tracks up to 12 satellites
  - Update rate: 1 second
  - Position Accuracy: Non-differential GPS: 15 meters RMS
  - Velocity Accuracy: 0.2 m/s RMS steady state

- **Logging options**
  - Record position only, position and speed only, or position, speed, and altitude
  - Record at either 1-second or 5-second intervals

- **Download software**
  - Windows-based software downloads data to a PC in ASCII format
Lexington Travel Habits Study

- **Select study area**
  - A Self-Contained Medium-Sized City: Lexington, Kentucky

- **Recruit volunteers by emails**
  - Staff, professors and their families at the University of Kentucky and other residents of the city

- **Procedure**
  - 12 vehicles every 2 weeks

- **Date**
Number of Households Participated

- Total number of households surveyed = 276
- Total number of valid GPS datasets = 256
  - total number of one-driver datasets = 124
Lexington, Kentucky

Lexington
Population = 250,000
Area = 293 Square Miles
Survey Methodology

Step 1: Volunteers are called to collect demographic information such as number of people in the household, sex and age of each family member, etc.

Step 2: GPS Data-Logger is installed in the volunteer’s vehicle on Thursday or Friday together with an in-vehicle booklet.

Step 3: GPS DataLogger stays in vehicle for approximately 10 days, which includes 5 weekdays and 2 weekends.

Step 4: GPS DataLogger is picked up on Monday or Tuesday.
Data Obtained

- Demographic data for each household
- 10-day GPS travel data for each household
- GIS road network database of Lexington, Kentucky
GPS Data Structure

- The information recorded by the GPS instrument includes date, time, latitude, longitude, speed, altitude, etc.
- Each dataset (household) contains up to 250,000 records.
- Each record represents one GPS point.
A well-coded GIS network consisting of about 13,000 separate street segments (or links)

Well-coded roads, intersection connections, turns, one-way, speed limit, name, type, and length
GPS Data Sample in ArcView
Data Processing

- Overlay GPS points with underlying road network
- Spatially join GPS points and road links to assign GPS points to the road links they traveled on
- Calculate the time difference $t$ and distance $l$ between the first and the last GPS point assigned to a link
- Calculate average speed $\bar{V} = \frac{l}{t}$
Data Processing (Cont’d)

- Keep links with more than 3 GPS points in sequence assigned to it as valid data

Wrongly Assigned Points
Data Processing (Cont’d)

Product: Average travel speed by link by person

Note:
- If a link is traveled more than once, there is more than 1 observation.
- Average speed including acceleration and deceleration

<table>
<thead>
<tr>
<th>Link ID</th>
<th>Average Speed</th>
<th>Speed Limit</th>
<th>Sex</th>
<th>Age</th>
<th>Time</th>
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</thead>
</table>

Speed Ratio

Example to calculate speed ratio:

On a road link with 50 mph as the speed limit and length of 1 mile, it took a driver 1.5 minutes to drive through. The average speed is 40 mph and the speed ratio is -20%. 

\[
Speed \text{ Ratio} = \left( \frac{\bar{V} - \text{speed limit}}{\text{speed limit}} \right) \times 100\%
\]
Data Summary

- Non-Peak Hour Data: 8 AM – 4 PM; 6 PM – 6 AM
- Total number of observations = 98,899
  - Maximum speed ratio = 1.68
  - Minimum speed ratio = -0.85
  - Average speed ratio = -0.25
  - Standard Deviation speed ratio = 0.22
- Number of different links = 5421
  - Average observations per link = 19
Significant Factors Affecting Speed Ratio

- Speed limit – 25, 35, 45 and 65mph
- Sex of the driver
- Age of the driver
  - Age group 1: 21-30
  - Age group 2: 31-50
  - Age group 3: 51-65
  - Age group 4: > 65
## Number of Observations

<table>
<thead>
<tr>
<th>Age</th>
<th>21 - 30</th>
<th>31 - 50</th>
<th>51 - 65</th>
<th>&gt; 65</th>
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</thead>
<tbody>
<tr>
<td>Sex</td>
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<td>M</td>
<td>F</td>
<td>M</td>
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<td></td>
<td>22</td>
<td>27</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>
Distribution of Speed Ratios

$\frac{1}{4}$ Positive and $\frac{3}{4}$ Negative
Median of the Speed Ratio of Different Age Groups

- Medium-ages faster
- Older females slower

Average over speed limit

Median of the Speed Ratio

SEX  female  male

AGE  21-30  31-50  51-65  >65
Median of the Speed Ratio on Different Types of Road Links

Expressways higher
Females slower
Median of the Speed Ratio on Roads with Speed Limit of 25 and 35 MPH

- Medium-ages faster
- Older females slower
- Younger females faster

No obvious difference
Median of the Speed Ratio on Roads with Speed Limit of 45 and 65 MPH

No obvious difference

- Younger slower
- Older women slower
Median of the Speed Ratio of Age Group 21-30 and 31-50

- Females faster on local
- No obvious difference other cases
- Arterials slower
- Expressways and locals faster
Median of the Speed Ratio of Age Group 51-65 and > 65

- Arterials slower
- Expressways and locals faster
- Females slower on expressways
- Females slower on locals and expressways
- Expressways higher
Speed Ratio on Local Streets
Speed Ratio on Arterials and Expressways

Speed Ratios on Arterials and Expressways

Arterials and Expressways

Streetfolder\Freeway\05.shp
Significantly Below
Slightly Below
Slightly Above
Significantly Above
Spatial Distribution of the Speed Ratios

- Low speed in downtown area
- Relatively high speed on circle roads and expressways outside of the town center
- Low speed on ramps and interchanges
Conclusions

- GPS is very effective in collecting speed data of individual driver.
- Women are driving slower than men in most cases. This trend is more obvious in some age groups than others.
Conclusions (Cont’d)

- Young drivers, at least young drivers in Lexington, are not necessarily more aggressive than older people. An alternative reason for this is that young drivers are more cautious about driving with GPS devices on board. The relatively small sample size of young drivers is another explanation.
Next Steps

- Peak travel
- Cruise speeds
- Acceleration/Deceleration pattern for emission study
Thank you!