Using Truck GPS Data for Freight Performance Analysis in the Twin Cities Metro Area (TCMA)

Chen-Fu Liao
Minnesota Traffic Observatory (MTO)
Department of Civil Engineering
TAP Meeting, May 8, 2013
Acknowledgements

- MnDOT
- ATRI – Dan Murray & Jeff Short
- Tara Sasank Sunkara & Dayakar Reddy Singana – Graduate Research Students
- TAP members
- MTO, Civil Engineering, UMN
Outline

• Project progress overview
• Probe vehicle GPS data processing and preliminary analysis results
• Performance measures (mobility & reliability)
• Ongoing effort and next step
• Discussion and Q & A
Project Progress

- Literature review (#1) – completed
- Obtain data from ATRI (#2) - completed
- Process data and generate performance measures (#3) - ongoing
- Process ATR/WIM/loop detector data (#4)
- Identify freight node, freight significant corridor and congestion (#5)
- Final report (#6)
Key Freight Corridors in Twin Cities Metro Area

- ATR Volume
- ATR Volume/Speed
- ATR Volume/Speed/Class
- WIM

**HIGHWAY**
- County Road
- Interstate
- State Highway
- US Highway

**COUNTY**
- Anoka
- Carver
- Chisago
- Dakota
- Hennepin
- Ramsey
- Scott
- Washington
Probe Vehicle GPS Data

• ATRI Data – Largest database of large truck units in North America (400K-500K units)
• Officially used by the USDOT and over a dozen MPOs and 9 state DOTs for truck- and freight-related analyses
• “No other traffic provider in the U.S. has more than 10% of the large truck units that ATRI has.” – ATRI
Snapshot of Probe Vehicle GPS Point Cloud (Dec. 2012)
## GPS Data Summary

<table>
<thead>
<tr>
<th>Data Set</th>
<th>DS-A</th>
<th>DS-B</th>
<th>DS-C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time Zone</strong></td>
<td>GMT/UTC</td>
<td>GMT/UTC</td>
<td>GMT/UTC</td>
</tr>
<tr>
<td><strong>Spot Speed?</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Static ID?</strong></td>
<td>Yes</td>
<td>Rotate every 15 days</td>
<td>Rotate every 24 hours</td>
</tr>
<tr>
<td><strong>Data Accuracy</strong></td>
<td>Within 3 meters</td>
<td>Within 124-134 meters at 90% probability and 129-150 meters at 95% probability.</td>
<td>Within 13-56 meters at 90% probability and 15-58 meters at 95% probability.</td>
</tr>
<tr>
<td><strong>Snap Tolerance Used</strong></td>
<td>50 m</td>
<td>150 m</td>
<td>50 m</td>
</tr>
<tr>
<td><strong>2012 Number of Truck Trips</strong></td>
<td>29,555</td>
<td>69,063</td>
<td>66,632</td>
</tr>
<tr>
<td><strong>2012 Raw Data Size</strong></td>
<td>40,500,081</td>
<td>4,840,339</td>
<td>28,290,687</td>
</tr>
<tr>
<td><strong>2012 Snapped</strong></td>
<td>12,287,134</td>
<td>1,246,536</td>
<td>8,593,449</td>
</tr>
<tr>
<td><strong>2012 Snapped Percentage</strong></td>
<td>30.3%</td>
<td>25.8%</td>
<td>30.4%</td>
</tr>
<tr>
<td><strong>Average (SD) Sampling Time</strong></td>
<td>10 (15) min</td>
<td>22 (28) min</td>
<td>1 (5) min</td>
</tr>
</tbody>
</table>
### GPS Data Fields

<table>
<thead>
<tr>
<th>Data Field</th>
<th>DS-A</th>
<th>DS-B</th>
<th>DS-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>truckid</td>
<td>truckid</td>
<td>readdate</td>
</tr>
<tr>
<td>2</td>
<td>readdate</td>
<td>readdate</td>
<td>latitude</td>
</tr>
<tr>
<td>3</td>
<td>speed</td>
<td>latitude</td>
<td>longitude</td>
</tr>
<tr>
<td>4</td>
<td>heading</td>
<td>longitude</td>
<td>speed</td>
</tr>
<tr>
<td>5</td>
<td>latitude</td>
<td></td>
<td>truckid</td>
</tr>
<tr>
<td>6</td>
<td>longitude</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Data Processing

- Import raw GPS data
- Snapping & remove outliers
- Sort by vehicle ID and time
- Calculate average speed and remove speed outliers for each trip
- Perform segmentation
- Generate average speed per defined segment size
Data Processing Flow Chart

1. Raw Probe Vehicle GPS Data
2. Create Route Spatial Database
3. Locate Features
4. Merge AVL GPS Data on Route
5. Data Quality Filtering
6. Vehicle Stops and Stop Durations
7. Vehicle Spot Speed, if available
8. Generate Vehicle Speed Statistics
9. Vehicle Space Mean Speed by Segment
10. Calculate Segment Space Mean Speed
11. Sort by Vehicle Trips and Time
12. Segmentation Program

The flow chart illustrates the process of data processing, starting from raw probe vehicle GPS data, progressing through creating a route spatial database, locating features, merging AVL GPS data on route, applying data quality filtering, generating vehicle speed statistics, and calculating segment space mean speed.
Average Speed Calculation

1-mile Segmentation Example

- **Speed A** from 41.5 ~ 50.5 mile
- **Speed B** from 54.25 ~ 63.5 mile
- **Speed C** from 37.5 ~ 46.75 mile
- **Speed D** from 53.5 ~ 58.75 mile
- **Speed E** from 52.75 ~ 64.25 mile

Spot Speed
## WIM Station Summary

<table>
<thead>
<tr>
<th>WIM ID</th>
<th>36</th>
<th>37</th>
<th>40</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route Name</td>
<td>MN 36</td>
<td>I-94</td>
<td>US 52</td>
<td>US 61</td>
</tr>
<tr>
<td>County Name</td>
<td>Washington</td>
<td>Wright</td>
<td>Dakota</td>
<td>Washington</td>
</tr>
<tr>
<td>Direction</td>
<td>EB</td>
<td>WB</td>
<td>NB</td>
<td>SB</td>
</tr>
<tr>
<td>Mile Post</td>
<td>15</td>
<td>200</td>
<td>127</td>
<td>119</td>
</tr>
<tr>
<td>City Name</td>
<td>Lake Elmo</td>
<td>Otsego</td>
<td>West St. Paul</td>
<td>Cottage Grove</td>
</tr>
<tr>
<td>WIM Location Description</td>
<td>0.7 mi W of CSAH17 Lake Elmo Ave N) in Lake Elmo</td>
<td>1.2 mi NW of CSAH19 (La Beaux Ave) in Otsego</td>
<td>0.5 mi N of CSAH14 in West St. Paul</td>
<td>0.4 mi S of TH95 (Manning Ave S), S of Cottage Grove</td>
</tr>
<tr>
<td>WIM Type</td>
<td>Volume / Speed / Class / Weight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011 HCAADT</td>
<td>1,100</td>
<td>6,900</td>
<td>4,400</td>
<td>1,750</td>
</tr>
</tbody>
</table>
I-94 WB Mile Post 200
Probe vs. WIM37 Vehicle Speed Comparison

I-94 WB @ Mile Post 200
Weekday Volume % by Hour
I-94 WB Mile Post 200
\((N_{\text{WIM}}=900,114, N_{\text{Probe}}=120,893)\)
Heavy Vehicle Mean Speed by Month & Hour at WIM37 Station
Probe Vehicle Mean Speed by Month & Hour at I-94 WB Mile Post 200 (WIM37)
Probe Vehicle Median Speed by Month & Hour at I-94 WB Mile Post 200 (WIM37)
Probe Vehicle Count (7~8AM in 2012)
Weekday Mean Speed Dir = -1 (7AM 2012)

Mean Speed (MPH)
- 0 - 5
- 6 - 15
- 16 - 35
- 36 - 45
- 46 - 55
- 56 - 75

COUNTY
- Anoka
- Carver
- Chisago
- Dakota
- Hennepin
- Ramsey
- Scott
- Washington

St. Cloud
Mankato
Rochester
Weekday Mean Speed Dir = 1 (7AM 2012)

Mean Speed (MPH)
- 0 - 5
- 6 - 15
- 16 - 35
- 36 - 45
- 46 - 55
- 56 - 75

COUNTY
- Anoka
- Carver
- Chisago
- Dakota
- Hennepin
- Ramsey
- Scott
- Washington

St. Cloud
Mankato
Rochester
Performance Measures

Truck Daily Delay

\[
\sum_{\text{Segment}} \sum_{\text{Hour}} \left( \frac{\text{Segment Length}}{\text{Travel Speed}} - \frac{\text{Segment Length}}{\text{Threshold Speed}} \right) \times \text{HCAADT}_{\text{Segment}}
\]

Travel Time Reliability Index

\[
\text{RI}_{80} = \frac{80^{\text{th}} \text{ percentile Travel Time}}{\text{Travel Time at MnDOT Specified Threshold Speed}}
\]

Threshold Speed = 50 MPH, Max Throughput Speed
Average Daily Delay and Speed

- Daily Delay (Weeday)
- Average Speed (Weekday)

HCAADT 6,700~12,300
HCAADT 4,850~6,600

Total Truck Delay = 128 Hours / Day
I-494

Average Daily Delay and Speed

- **Average Daily Delay (Weekday)**
- **Average Speed (Weekday)**

**Total Truck Delay = 168 Hours / Day**

- **HCAADT 5,300~7,300**
- **HCAADT 5,600~9,100**
- **HCAADT 4,450~6,700**

**Mile**

**Speed (MPH)**

- State Highway 55
- I-35W
- US Highway 212
- TH-100
- I-394
- I-35E
- State Highway 77

**Hours**
Performance Measures

- Annual hours of truck delay in the TCMA
- Truck delay by route & direction
- Average delay in peak & off-peak hours
- Average delay per mile
- Cost of truck delay
  - TTI UMR (2011) $88.0 per hour
  - ATRI (2011) $68.21 per hour
- Truck reliability index, $RI_{80}$
Ongoing Effort & Next Step

- Data processing and analysis
- Obtain 2012 HCAADT Data from MnDOT
- Truck parking or rest facilities shapefile?
- Compute performance measures
- ATR, Wavetronix, or loop detector data consideration?
ATR/Wavetronix/Loop Data

• Vehicle classification availability
• ATR – Binned vehicle counts by hour, class, and speed
• Wavetronix data - Store only binned data on the unit. A live connection to the unit can be configured to log individual vehicle data from a PC.
• Loop detector data – No vehicle class info, require calibration vehicle length to derive speed
Discussion and Questions?

- Select threshold speed for performance index calculation
  - Free-flow speed – 65 MPH
  - Posted speed – 55 MPH
  - Max throughput speed – 50 MPH
  - Severe congested speed – 35 MPH

- Use WIM data for probe vehicle data verification and comparison?