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

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Department of Civil Engineering
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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
  ✔ TAP Meeting on May 8, 2013
  ✔ Focus on Task #3 Performance Measures
- Data Summary & Analysis Results
- Performance Measures (Mobility, Delay & Reliability)
- Truck Parking (Location & Duration)
- Ongoing Effort and Next Step
- Q & A
Project Progress

• Literature review (#1) – completed
• Obtain data from ATRI (#2) - completed
• Process data and generate performance measures (#3) - completed
• Process ATR/WIM/loop detector data (#4), due 9/30/13
• Identify freight node, freight significant corridor and congestion (#5), due 12/31/13
• Final report (#6), due 2/28/14
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

St. Cloud
Mankato
Rochester

University of Minnesota
Driven to Discover™
# Truck GPS Data

<table>
<thead>
<tr>
<th>Data Field</th>
<th>DS-A</th>
<th>DS-B</th>
<th>DS-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck ID</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Timestamp</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Spot Speed</td>
<td>√</td>
<td>NA</td>
<td>√</td>
</tr>
<tr>
<td>Heading</td>
<td>√</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Latitude</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Longitude</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>
# 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>Time Zone</td>
<td>GMT/UTC</td>
<td>GMT/UTC</td>
<td>GMT/UTC</td>
</tr>
<tr>
<td>Spot Speed?</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Static ID?</td>
<td>Yes</td>
<td>Rotate every 15 days</td>
<td>Rotate every 24 hours</td>
</tr>
<tr>
<td>Data Accuracy</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>Snap Tolerance Used</td>
<td>50 m</td>
<td>150 m</td>
<td>50 m</td>
</tr>
<tr>
<td>2012 Number of Truck Trips</td>
<td>29,555</td>
<td>69,063</td>
<td>66,632</td>
</tr>
<tr>
<td>2012 Raw Data Size</td>
<td>40,500,081</td>
<td>4,840,339</td>
<td>28,290,687</td>
</tr>
<tr>
<td>2012 Snapped</td>
<td>12,287,134</td>
<td>1,246,536</td>
<td>8,593,449</td>
</tr>
<tr>
<td>2012 Snapped Percentage</td>
<td>30.3%</td>
<td>25.8%</td>
<td>30.4%</td>
</tr>
<tr>
<td>Average (SD) Sampling Time</td>
<td>10 (15) min</td>
<td>22 (28) min</td>
<td>1 (5) min</td>
</tr>
<tr>
<td>WIM ID</td>
<td>36</td>
<td>37</td>
<td>40</td>
</tr>
<tr>
<td>-------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Route Name</td>
<td>MN 36</td>
<td>I-94</td>
<td>US 52</td>
</tr>
<tr>
<td>County Name</td>
<td>Washington</td>
<td>Wright</td>
<td>Dakota</td>
</tr>
<tr>
<td>Direction</td>
<td>EB</td>
<td>WB</td>
<td>NB</td>
</tr>
<tr>
<td>Mile Post</td>
<td>15</td>
<td>200</td>
<td>127</td>
</tr>
<tr>
<td>City Name</td>
<td>Lake Elmo</td>
<td>Otsego</td>
<td>West St. Paul</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>
</tr>
<tr>
<td>WIM Type</td>
<td>Volume / Speed / Class / Weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011 HCAADT</td>
<td>1,100</td>
<td>6,900</td>
<td>4,400</td>
</tr>
</tbody>
</table>
Truck Speed Analysis
Processed GPS vs. WIM Data

Weekdays Probe Vehicle Speed
Mn=63.2, Md=64.0, Sd= 6.5
N=113975

Weekdays WIM37 Speed
Mn=65.7, Md=65.0, Sd= 5.8
N=900114

GPS

WIM

I-94 WB Mile Post 200
GPS vs. WIM37 Vehicle Speed Comparison

I-94 WB @ Mile Post 200

Hour of Day

Speed (MPH)
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
Probe Vehicle Mean Speed by Month & Hour at I-94 WB Mile Post 200 (WIM37)
Heavy Vehicle Mean Speed by Month & Hour at WIM37 Station

![3D graph showing heavy vehicle mean speed by month and hour at WIM37 Station. The x-axis represents month, the y-axis represents speed (MPH), and the z-axis represents hour of day. The graph includes data points for each month and hour, showing variations in speed.]
Truck Volume Percentage
Weekday Volume % by Hour
I-94 WB Mile Post 200
(N_{WIM}=900,114, \ N_{Probe}=120,893)
ATR 382 vs. GPS

Comparison of Volume Percentage by Hour

ATR 382 - N of 180TH ST E, S of COATES ON US 52
## Correlation of GPS vs. ATR Hourly Volume %

<table>
<thead>
<tr>
<th>ATR Data</th>
<th>Probe Vehicle Data</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>HCAADT</td>
<td>Route ID</td>
</tr>
<tr>
<td>188</td>
<td>2,600</td>
<td>29</td>
</tr>
<tr>
<td>191</td>
<td>2,150</td>
<td>33</td>
</tr>
<tr>
<td>200</td>
<td>7,900</td>
<td>24</td>
</tr>
<tr>
<td>335</td>
<td>3,450</td>
<td>34</td>
</tr>
<tr>
<td>341*</td>
<td>5,100</td>
<td>4</td>
</tr>
<tr>
<td>351</td>
<td>1,600</td>
<td>9</td>
</tr>
<tr>
<td>352</td>
<td>1,600</td>
<td>31</td>
</tr>
<tr>
<td>353</td>
<td>1,750</td>
<td>37</td>
</tr>
<tr>
<td>365**</td>
<td>1,700</td>
<td>26</td>
</tr>
<tr>
<td>381</td>
<td>1,350</td>
<td>14</td>
</tr>
<tr>
<td>382</td>
<td>2,700</td>
<td>29</td>
</tr>
<tr>
<td>388</td>
<td>830</td>
<td>25</td>
</tr>
<tr>
<td>400</td>
<td>1,600</td>
<td>9</td>
</tr>
<tr>
<td>422</td>
<td>NA</td>
<td>1</td>
</tr>
</tbody>
</table>

* ATR341 - S OF CSAH35 (50TH ST N) IN OAKDALE (I-694)
** ATR365 - S OF CSAH116 (BUNKER LAKE BLVD NE) IN HAM LAKE (State Highway 65)
Correlation of GPS vs. WIM Hourly Volume %

<table>
<thead>
<tr>
<th>WIM Data</th>
<th>Probe Vehicle Data</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
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<td>36</td>
<td>1,100</td>
<td>5</td>
</tr>
<tr>
<td>37</td>
<td>6,900</td>
<td>24</td>
</tr>
<tr>
<td>40</td>
<td>4,400</td>
<td>29</td>
</tr>
<tr>
<td>41</td>
<td>1,750</td>
<td>27</td>
</tr>
</tbody>
</table>
Performance Measures
Performance Measures

Truck Mobility

Percent of freight corridor miles in TCMA with average speed < 45 MPH in AM or PM Peak

Truck Daily Delay

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

Travel Time Reliability Index

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

Threshold Speed = 45 MPH, Max Throughput Speed
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, $RI_{80}$
Average Speed AM Peak (5-10 AM)
Segments with Average Speed Below Threshold Speed in AM Peak

Average AM Speed < 45 MPH in TCMA
Average Speed
PM Peak (2-7 PM)
Segments with Average Speed Below Threshold Speed in PM Peak

Average PM Speed < 45 MPH in TCMA
# Truck Mobility Measure

<table>
<thead>
<tr>
<th>Time Period (2012 Weekdays TCMA)</th>
<th>AM Peak 5-10 AM</th>
<th>PM Peak 2-7 PM</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Miles with Average Speed &lt; 45 MPH</td>
<td>96</td>
<td>147</td>
</tr>
<tr>
<td>Total Miles of RTMC Stations in TCMA</td>
<td>774</td>
<td>774</td>
</tr>
<tr>
<td>Percentage of Miles &lt; 45 MPH</td>
<td><strong>12.4%</strong></td>
<td><strong>19.0%</strong></td>
</tr>
</tbody>
</table>
Truck Delay

\[ \sum \sum \left( \frac{\text{Segment Length}}{\text{Travel Speed}} - \frac{\text{Segment Length}}{\text{Threshold Speed}} \right) \times HCAADT_{\text{Segment}} \]

Threshold Speed = 45 MPH, Max Throughput Speed
Average Daily Delay and Speed

I-694

HCAADT 6,300~15,100

HCAADT 5,900~7,400

Threshold Speed 45 MPH

Total Truck Delay = 22 (+1) + 44 (-1) = 66 Hours / Day
Average Daily Delay and Speed

- Delay Dir (+1)
- Delay Dir (-1)
- Speed Dir (+1)
- Speed Dir (-1)

I-494

HCAADT 5,900~8,900
HCAADT 5,500~8,400
HCAADT 4,150~7,400

Total Truck Delay = 37 (+1) + 95 (-1) = 132 Hours / Day

Threshold Speed 45 MPH
Travel Time Reliability

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

Threshold Speed = 45 MPH, Max Throughput Speed
Reliability Index
AM Peak (5-10 AM)
Reliability Index
PM Peak (2-7 PM)
Truck Stop and Parking
Truck Stops / Parking

Near Roadway
- Spot/Space Speed < 5 MPH
- Stop Duration > 0.5 hour
- Travel Distance < 0.1 mile

Near Rest Area
- Spot Speed = 0 MPH
- Stop Duration > 0.5 hour
Truck Parking at I-94 Rest Area in Maple Grove
Histogram of Parking Duration at the Rest Area on I-94 in Maple Grove
Truck Parking at I-94 Rest Area in West Lakeland
Histogram of Parking Duration at the Rest Area on I-94 in West Lakeland
Ongoing Effort & Next Step

• Truck parking or rest facilities in TCMA
• Loop detector data (#1222, 1171, 1172, 1157, 1158, 1598)
• ATR Volume/Class/Speed data on stations: 188, 191, 200, 335, 341, 351, 352, 353, 365, 381, 382, 388, 400 & 422
• Identify freight node & bottleneck
• Final report
Thank You!

Questions?