Volume & Turning Movements Project

Steering Committee Meeting #6

November 9, 2017

Conference call number: 1-719-867-1571 and enter 725437# at the prompt
Housekeeping Items

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  • Please do not place call “on hold” as your hold music will be heard by the group

• Speakers will answer questions at the end of their presentation

• The audio from this meeting is being recorded

• All materials & contact information will be available to participants after the webcast
Please confirm that your line is muted

*6

Thank you!
WELCOME!

Denise Markow, I-95 Corridor Coalition
### Attendees

<table>
<thead>
<tr>
<th>Agencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado DOT</td>
</tr>
<tr>
<td>District DOT</td>
</tr>
<tr>
<td>Durham MPO (NC)</td>
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<tr>
<td>FHWA</td>
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<tr>
<td>Georgia DOT</td>
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<tr>
<td>HERE</td>
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<tr>
<td>I-95 Corridor Coalition</td>
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<tr>
<td>INRIX</td>
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<tr>
<td>Maryland DOT/MdSHA</td>
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<tr>
<td>MWCOG</td>
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<tr>
<td>New Hampshire DOT</td>
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<tr>
<td>NJTPA</td>
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<tr>
<td>NREL</td>
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<tr>
<td>Pennsylvania DOT</td>
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<tr>
<td>Port Authority NY &amp; NJ</td>
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<tr>
<td>South Carolina DOT</td>
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<tr>
<td>Texas A&amp;M Transportation Institute</td>
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<tr>
<td>TomTom</td>
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<tr>
<td>UMD CATT</td>
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<tr>
<td>USDOT - BTS</td>
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<tr>
<td>Virginia DOT</td>
</tr>
</tbody>
</table>
## Agenda

<table>
<thead>
<tr>
<th>Topic</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Welcome &amp; Project Status Update</td>
<td>Denise Markow, I-95 Corridor Coalition&lt;br&gt;Stan Young, NREL</td>
</tr>
<tr>
<td>2. Spotlight Presentation: Traffic Volume Estimation using INRIX GPS traces: Updated Maryland Results and New Datasets</td>
<td>Zach Vander Laan, UMD CATT</td>
</tr>
<tr>
<td>3. TTI MnDOT Study Review</td>
<td>Shawn Turner, TTI</td>
</tr>
<tr>
<td>4. State DOT Feedback - shaping future direction</td>
<td>Steering Committee members</td>
</tr>
<tr>
<td>5. Next Steps &amp; Wrap Up</td>
<td>Stan Young, NREL&lt;br&gt;Denise Markow, I-95 Corridor Coalition</td>
</tr>
</tbody>
</table>
VTM Lexicon

• A glossary of terms relevant to the Volume and Turning Movement Project.

• Intended to complement other project deliverables by providing additional detail and background.
Project Goal

Accelerate the timeframe to a viable volume and turning movement data feed ---
• Anywhere/anytime on the network
• Archive and real-time
• Freeway and Non-Freeway

Insure that initial data products meet members’ information needs for operations, performance measurement, and planning.
Objectives - Original

• Define a practical and logistical framework for the delivery of probe-based volume and turning movement data

• Understand, document, and share data requirement needs for a variety of DOT applications requiring such data

• Create a calibration and validation testbed to assist vendors’ initial development efforts.

• Provide representative data products, and set appropriate expectations for data fidelity, form, granularity, and usability

• Anticipating the need for an ongoing calibration network, estimate resources needed to maintain/operate a national calibration/validation testbed
Status of Project

Calibration / Validation Testbed

INRIX / UMD

TomTom / NREL

HERE

Streetlight Data

UMD/NREL

Calibration Data (TMAS)

Validation Methods [Led by TTI]

- VTM products
- Validated
- Consistent formats
- Meets Coalition needs
Status of Project – Nov 2017

Data Experimentation
- INRIX / UMD
- TomTom / NREL

Collaborators
- HERE
- Streetlight Data

Calibration / Validation Testbed
- UMD/NREL
  - Calibration Data (TMAS / States)
  - Validation Methods [Led by TTI]

- VTM products
- Validated
- Consistent formats
- Meets Coalition needs

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Visualizing the Solution

• A volume estimator
• ATRs uses as ‘base stations’
  • Calibrating estimator
  • Assessing accuracy
• Uses a variety of data
  • Probe data is key
• Complements existing sensors
Today’s Agenda

• UMD results – Maryland
  • Augmenting with TTI methodology
  • Zack Vander Laan, UMD CATT Works

• MNDOT Study Review
  • Shawn Turner, TTI

• State DOT Feedback - shaping future direction
  • Stan Young, NREL
Traffic Volume Estimation using INRIX GPS Traces: Updated Maryland Results and New Datasets

Przemyslaw Sekula, Nikola Markovic, Zachary Vander Laan, and Kaveh Farokhi Sadabadi

Presented by:
Zachary Vander Laan

VTM Steering Committee Meeting
November 9, 2017
Today’s Presentation

• Objectives and updates
• Maryland analysis
  – GPS dataset
  – Regression Models
  – Results
  – Comparison with previous results & conclusion
• New datasets
  – Florida
  – Rhode Island
Objectives

• Given the following:
  – Probe volumes (processed from GPS traces of a subset of vehicles),
  – Other archived data (speeds, road geometry, weather, etc.)
  – ATR counts
  – TTI volume estimates

• Can we build a model to accurately estimate statewide volumes?
Updates

Main changes:
• Feature engineering
  – TTI volume estimates as a model input
• Model selection
  – using a recurrent neural network to take advantage of temporal patterns in data
• 10 additional ATR stations (mostly low-volume)

Goals
• Quantify current model performance
• Compare current and previous results
Maryland GPS Data

- 4 months of INRIX data during 2015 (February, June, July, October)
  - 20 million trips, 1.4 billion waypoints
  - Waypoints are typically 1 sec apart
Waypoint Snapping and Map Matching

• Waypoints only identified by lat/lon, but need to be associated with road network
  – No longer the case with most recent INRIX data (i.e., Florida, Rhode Island)

• Two step process
  – Snapping
  – Map matching

• OpenStreetMap tools used

• Requires significant amount of fine-tuning
GPS Penetration Rates

- Hourly penetration rates of GPS traces are computed at 45 ATR locations over the 4 month period.

- Average hourly penetration rates vary from 0.83% to 5.56%, with a median of 1.88%.

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Other Data & Correlations

- Speed data from RITIS
- Road characteristics
  - Type of the road (IS, US, MD)
  - Number of lanes
  - Speed limit
  - Directions separated
- Weather data
  - Temperature, humidity, pressure, visibility, wind speed, precipitation
- Temporal characteristics
  - Hour of day, weekday/Sat/Sun, federal holiday
- **TTI volume estimates** (by time of day / day of week)
Machine Learning Regression Models

• Previous Model
  • Dense (fully-connected) artificial neural network (ANN)
  • Does not use TTI volumes as an input

• Current Model
  • Long Short-Term Memory Network (LSTM)
    - A type of recurrent neural network (i.e., has “memory”)
    - Leverages temporal patterns (without requiring an excessive number of features)
  • Uses TTI volumes as an input

• Implementation
  • TensorFlow™
  • Train models on dedicated computer with GPU

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Model Evaluation

• In each iteration
  - Use 44 ATR stations for training
  - Use 1 ATR station for testing

• Repeat 45 times and report test results for each location

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Results: R2 and MAPE

- R-squared varies from 0.16 to 0.98, with a median of 0.86
- MAPE varies from 7% to 231% with a median of 23%
Results: ETCR and EMFR

- ETCR varies from 1.8% to 8.4%, with a median of 4.3%
- EMFR varies from 1.6% to 13.8% with a median of 6.5%
<table>
<thead>
<tr>
<th>Description</th>
<th>R2</th>
<th>MAPE (%)</th>
<th>ETCR (%)</th>
<th>EMFR (%)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day (6am-8pm)</td>
<td>0.58</td>
<td>17.9</td>
<td>5.7</td>
<td>8.5</td>
<td>93,282</td>
</tr>
<tr>
<td>Night (8pm-6am)</td>
<td>0.82</td>
<td>26.4</td>
<td>2.0</td>
<td>3.4</td>
<td>64,758</td>
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<td>Peak (7am-9am &amp; 4pm-6pm)</td>
<td>0.62</td>
<td>20.0</td>
<td>6.4</td>
<td>9.4</td>
<td>26,858</td>
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<tr>
<td>Off-peak</td>
<td>0.86</td>
<td>23.0</td>
<td>3.6</td>
<td>5.6</td>
<td>131,182</td>
</tr>
<tr>
<td>Hourly volume (0-1000)</td>
<td>0.76</td>
<td>28.9</td>
<td>3.0</td>
<td>7.2</td>
<td>68,460</td>
</tr>
<tr>
<td>Hourly volume (1000-2000)</td>
<td>0.84</td>
<td>25.1</td>
<td>5.5</td>
<td>6.7</td>
<td>31,492</td>
</tr>
<tr>
<td>Hourly volume (2000-3000)</td>
<td>0.91</td>
<td>15.1</td>
<td>4.6</td>
<td>5.8</td>
<td>20,444</td>
</tr>
<tr>
<td>Hourly volume (3000+)</td>
<td>0.94</td>
<td>12.5</td>
<td>4.5</td>
<td>5.2</td>
<td>37,644</td>
</tr>
<tr>
<td>IS</td>
<td>0.91</td>
<td>15.3</td>
<td>4.3</td>
<td>5.8</td>
<td>86,264</td>
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<tr>
<td>US</td>
<td>0.77</td>
<td>30.3</td>
<td>3.2</td>
<td>7.1</td>
<td>44,136</td>
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<tr>
<td>MD</td>
<td>0.78</td>
<td>30.0</td>
<td>5.9</td>
<td>8.2</td>
<td>27,640</td>
</tr>
<tr>
<td>Overall (1000+)</td>
<td>0.9</td>
<td>16.2</td>
<td>4.7</td>
<td>5.9</td>
<td>89,580</td>
</tr>
<tr>
<td>Overall</td>
<td>0.86</td>
<td>22.8</td>
<td>4.3</td>
<td>6.5</td>
<td>158,040</td>
</tr>
</tbody>
</table>

* Median values
Q: How is model performance impacted by number of GPS probe vehicles?

• Divide testing locations into 3 groups (low / med / high number of probe counts)
  – 45 ATR stations → 90 TMCs (2 directions measured at each ATR station)
  – 30 TMCs per group

• Quantify model performance for each group using violin plots

• Violin plot interpretation:
  – Enhanced box plot
  – Ideal model
    • good median value
    • short & wide
Current Model Accuracy vs. GPS Volumes

- Higher average hourly GPS volumes = higher accuracy, fewer outliers
Current vs Previous Model (1/4)

- 45-degree line represents ideal case (estimate = actual volume)
- Previous model and current model both more concentrated about 45-degree line than TTI
- Is there a difference between the previous and current models?
Current vs Previous Model (2/4)

- Focus on lower-volume region (0 - 2000 vph)
- Previous model has a number of outliers at low volumes (circled)
- Current model much better in the circled region, and more concentrated about 45-degree line
All models have outliers for low GPS counts
Current model most accurate, has fewest outliers at all 3 GPS probe intensity levels
Current vs Previous Model (4/4)

- Improvement in median of all 4 error metrics (statistically significant)

<table>
<thead>
<tr>
<th>Model</th>
<th>R2</th>
<th>MAPE (%)</th>
<th>ETCR (%)</th>
<th>EMFR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTI</td>
<td>0.70</td>
<td>33.7</td>
<td>5.8</td>
<td>9.1</td>
</tr>
<tr>
<td>Previous</td>
<td>0.76</td>
<td>28.2</td>
<td>5.3</td>
<td>7.8</td>
</tr>
<tr>
<td>Current</td>
<td>0.86</td>
<td>22.8</td>
<td>4.3</td>
<td>6.5</td>
</tr>
</tbody>
</table>

- 27% average improvement relative to TTI, 17% relative to previous model

<table>
<thead>
<tr>
<th>Baseline Model</th>
<th>R2</th>
<th>MAPE (%)</th>
<th>ETCR (%)</th>
<th>EMFR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTI</td>
<td>22.9</td>
<td>32.3</td>
<td>25.9</td>
<td>28.6</td>
</tr>
<tr>
<td>Previous</td>
<td>13.2</td>
<td>19.1</td>
<td>18.9</td>
<td>16.7</td>
</tr>
</tbody>
</table>

November 9, 2017
• General interpretation for error-to-capacity ratio (i.e., ETCR):
  – 10%: begins to provide value
  – 5%: acceptable / useful
  – 3%: very good

• At current GPS penetration rate of 1.8%, we can estimate volumes with about 23% MAPE, 0.86 R2, 4.3% ETCR, and 6.5% EMFR
  – We are beginning to achieve useful results

• Estimation accuracy is highly dependent on the number of GPS probe vehicles
  – Penetration rates will likely increase over time
New Datasets: Florida and Rhode Island

- INRIX Q4 2016 data obtained for Florida and Rhode Island
- Waypoints snapped to XD segments $\rightarrow$ statewide estimation capability

- Florida
  - Much larger dataset than Maryland
  - Have ATR data
  - Higher probe penetration rate

- Rhode Island
  - Smaller dataset than Maryland
  - Waiting on ATR data
  - Penetration rate may be higher than MD or FL based on trips / population
Questions

Contact Information

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November 9, 2017
Using Mobile Device Samples to Estimate Annual Average Traffic Volumes in MN

Shawn Turner, P.E.
Texas A&M Transportation Institute

I-95 Corridor Coalition Webinar ~ November 9, 2017
Evaluation Synopsis

• Multiple companies interested, only StreetLight Data (STL) provided volume estimates
• TTI used MnDOT counts as benchmark
• STL used MnDOT ATRs to calibrate
• Planning-level focus & multiple comparisons:
  – AADT at 7,800+ short duration count locations
  – Avg. annual hourly counts at 69 perm count locations
  – Avg. annual day-of-week hourly counts at 12 non-public perm count locations
AADT at 7,837 short-duration locations

<table>
<thead>
<tr>
<th>Traffic Volume Level Category</th>
<th>Number of MnDOT Sites</th>
<th>Mean Absolute Percent Error</th>
<th>Mean Absolute Difference</th>
<th>Mean Signed Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 to 5,000 AADT</td>
<td>5,090</td>
<td>68%</td>
<td>1,155</td>
<td>+701</td>
</tr>
<tr>
<td>5,000 to 10,000 AADT</td>
<td>1,119</td>
<td>58%</td>
<td>4,023</td>
<td>-2,963</td>
</tr>
<tr>
<td>10,000 to 20,000 AADT</td>
<td>759</td>
<td>44%</td>
<td>5,885</td>
<td>+5,043</td>
</tr>
<tr>
<td>20,000 to 50,000 AADT</td>
<td>346</td>
<td>29%</td>
<td>8,578</td>
<td>+6,544</td>
</tr>
<tr>
<td>&gt; 50,000 AADT</td>
<td>323</td>
<td>34%</td>
<td>34,112</td>
<td>+32,142</td>
</tr>
<tr>
<td>All Traffic Levels Combined</td>
<td>7,837</td>
<td>61%</td>
<td>3,782</td>
<td>+3,056</td>
</tr>
</tbody>
</table>
Avg. annual hourly estimates at 69 perm count locations

<table>
<thead>
<tr>
<th>Traffic Volume Level Category</th>
<th>Number of Hourly Values</th>
<th>Mean Absolute Percent Error</th>
<th>Mean Absolute Difference</th>
<th>Mean Signed Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1,000 vehicles per hour (vph)</td>
<td>2,129</td>
<td>49%</td>
<td>82</td>
<td>-14</td>
</tr>
<tr>
<td>1,000 to 5,000 vph</td>
<td>868</td>
<td>21%</td>
<td>424</td>
<td>-202</td>
</tr>
<tr>
<td>5,000 to 10,000 vph</td>
<td>195</td>
<td>16%</td>
<td>1091</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 10,000 vph</td>
<td>23</td>
<td>28%</td>
<td>3041</td>
<td>1981</td>
</tr>
<tr>
<td>All Traffic Levels Combined</td>
<td>3,215</td>
<td>39%</td>
<td>257</td>
<td>-49</td>
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</tbody>
</table>
Avg. annual day-of-week hourly estimates at 12 non-public perm count locations

<table>
<thead>
<tr>
<th>Traffic Volume Level Category</th>
<th>Number of Hourly Values</th>
<th>Mean Absolute Percent Error</th>
<th>Mean Absolute Difference</th>
<th>Mean Signed Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1,000 vehicles per hour (vph)</td>
<td>1,247</td>
<td>53%</td>
<td>165</td>
<td>-63</td>
</tr>
<tr>
<td>1,000 to 5,000 vph</td>
<td>334</td>
<td>34%</td>
<td>535</td>
<td>-433</td>
</tr>
<tr>
<td>5,000 to 10,000 vph</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&gt; 10,000 vph</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>All Traffic Levels Combined</td>
<td>1,581</td>
<td>49%</td>
<td>243</td>
<td>-141</td>
</tr>
</tbody>
</table>
Conclusions

• Has potential, but not there yet

• STL has plans for more granular estimates, refinements to analytics

• Some locations within 10-20% range, but others significantly higher

• Did not use error with respect to capacity; instead used volume ranges to separate higher expected error % at low volumes

• Planning focus – MnDOT wants accurate volumes even when much less than capacity
Poll

What is the most important priority for remaining research?

- Results for non-freeway, low-volume roads
- Better characterization of when/where the process works well and where it does not
- Development of a confidence metric
- Estimate AADT, and other tradition aggregate measures
- Other – please volunteer in discussion or email to Denise Markow
State DOT Feedback

DOT Audiences

• Colorado DOT
  • Planning and Operations (TMC) Departments

• Kansas DOT
  • Planning Department

• Virginia DOT
  • Planning, Operations, Traffic (Much thanks to Mena & Mike)
Top Issues – 1 & 2

• Off-Freeway Performance
  • Signal controlled arterials
  • Rural highways

• Additional performance characterization
  • Volume, time-of-day, roadway class, congestion level, anything else
  • More than just R^2, MAPE, ETCR
  • Confidence measure
Top Issues – 3 & 4

• **Opportunities to Operationalize**
  • Current research sun-downs mid 2018
  • Identifying project level opportunities to move forward

• **Other**
  • Major event impact, example: Eclipse of 2017
  • Spatial and time transferability (Denver to KC)
  • Min/Max calibration sights (point of diminishing returns)
  • Heavy truck volume estimation
  • AADT
Future Work

• UMD to extend work with Florida
  ➢ Data in house, significantly larger

• UMD to extend work with Rhode Island
  ➢ Recent truck toll charges

• NREL – continued work in Colorado
  ➢ Non-freeway, error characterization, confidence measure
  ➢ AADT and other aggregate measures

• Establish validation framework with TTI, test
Poll

What is the next step to operationalize the results?

- A collective effort at the Coalition level
- Direct state effort (early adopter)
- Project level initiative
Wrap Up

• Next Meeting/Webinar
  • Thursday, March 8, 2018
  • 10:30a.m. - 12:00p.m. (EST)
Final Questions
Thank You!

For Questions, please contact:

• PI – Kaveh Sadabadi (UMD-CATT) 301-405-1352 or kfarokhi@umd.edu

• Co-PI – Denise Markow (I-95 Corridor Coalition) 301-789-9088 or dmarkow@i95coalition.org

• Co-PI – Stanley Young (NREL) 301-792-8180 or Stanley.Young@nrel.gov

• Logistics – Joanna Reagle (KMJ Consulting, Inc.) 610.228.0760 or jreagle@kmjinc.com