Volume & Turning Movements Project

Steering Committee Meeting #8

August 18, 2018

Conference call number: 1-719-867-1571 and enter 725437# at the prompt
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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
<table>
<thead>
<tr>
<th>Agencies and Organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado DOT</td>
</tr>
<tr>
<td>District DOT</td>
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<tr>
<td>Durham MPO (NC)</td>
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<tr>
<td>FHWA</td>
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<td>Florida DOT</td>
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<td>Georgia DOT</td>
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<td>HERE</td>
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<td>I-95 Corridor Coalition</td>
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<tr>
<td>INRIX</td>
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<td>Kentucky Transportation Center</td>
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<td>MWCOG</td>
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<td>New Hampshire DOT</td>
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<tr>
<td>North Carolina DOT</td>
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<td>North Jersey Transportation Planning Authority</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>StreetLight Data</td>
</tr>
<tr>
<td>Texas A&amp;M Transportation Institute</td>
</tr>
<tr>
<td>TomTom</td>
</tr>
<tr>
<td>UMD CATT</td>
</tr>
<tr>
<td>Virginia DOT</td>
</tr>
</tbody>
</table>
Speakers

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Please confirm that your line is muted *6

Thank you!
<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</td>
</tr>
<tr>
<td></td>
<td>Stan Young, NREL</td>
</tr>
<tr>
<td>2 Traffic Volume Estimation using GPS Traces:</td>
<td>Kaveh Sadabadi, UMD CATT</td>
</tr>
<tr>
<td>Florida and New Hampshire Update</td>
<td>Zach Vander Laan, UMD CATT</td>
</tr>
<tr>
<td>3 Insights from VTM Error Analysis</td>
<td>Stan Young, NREL</td>
</tr>
<tr>
<td>4 Future Work - Next Steps &amp; Wrap Up</td>
<td>Stan Young, NREL</td>
</tr>
<tr>
<td></td>
<td>Denise Markow, I-95 Corridor Coalition</td>
</tr>
</tbody>
</table>
Why Do We Need More and Better Volume Data?

• **Operations**
  - Detect real-time traffic volume in the network
  - Traffic volume during inclement weather and special events

• **Performance measures**
  - Assess user costs
  - Utilization of existing capacity

• **Economic and energy assessment**
  - Estimate economic impact of congestion
  - Quantify VMT and energy use
Ubiquitous Traffic Volumes

Ubiquitous network observability
- Ideal but expensive to achieve with sensors

Best alternative
- Utilize and fuse existing high-quality yet sparse data with probe data to predict traffic volumes on each and every link of the road network
Proposed Solution

Input
- Probe Traffic Data
- Road Characteristics
- Weather Info
- Temporal Info

Calibration Network

Estimator
Machine Learning Techniques

Output
- Traffic Volume Everywhere and All Times: Both real-time and historic
How Good is Good Enough?

- Mean Absolute Percentage Error (MAPE)
  - Volume dependent - estimate
  - 10-15% High Volume
  - 20-25% Mid Volume
  - 30-50% Low Volume
  (Mean Absolute Error may be appropriate)

- R^2 Coefficient of Determination
  - >70% good  >80% better  >90% best

- Error to Capacity (ETCR) or Max Flow (EMFR)
  - < 10% becomes useful  < 5% is target
  - {For highway operations, reflective of capacity constraint situations}
Traffic Volume Estimation Using GPS Traces: Florida and New Hampshire Update

Analysis Performed by:
Przemyslaw Sekula and Zachary Vander Laan

Presented by:
Kaveh Farokhi Sadabadi and Zachary Vander Laan

VTM Steering Committee Meeting
August 16, 2018
Presentation Outline

• Overview
  • Objectives
  • Volume estimation approach

• Florida case study
  • Dataset
  • Results
    • Statewide estimates
    • AADT/AAWDT
    • Truck Volumes
    • Flagging unusual behavior

• New Hampshire case study
  • Dataset
  • Results
    • Statewide estimates
    • AADT/AAWDT
    • Model transferability

• Summary / Next Steps
• Q & A
Objectives

• Given the following:
  – Probe volumes (processed from GPS traces of a subset of vehicles),
  – Other archived data (speeds, road geometry, weather, etc.)
  – Continuous count data from select locations

• Can we build a model to accurately estimate statewide volumes?
Volume Estimation: General Approach

Develop and Train Model
• Where? TMC segments associated with continuous count stations
• How? Construct machine learning model to learn relation between input variables and continuous count volumes

Apply model to state road network
• Where? All TMCs on road network
• How? Apply trained model to input variables from any TMC segment on the network
Data needed at all TMCs

- **GPS probe data** (INRIX)
  - 75M trips, 3.4B pts
  - Penetration rate: 2.1% median
  - Snapped to base map

- **Probe speeds** (HERE)

- **Road characteristics**
  - # lanes, speed limit, facility type, etc.

- **Weather**

- **TTI hourly volume estimates**

Data needed only at continuous count stations

- **Ground truth count data** (FDOT)
  - Used for model training / evaluation
  - Used to estimate probe penetration rate
Florida Model Evaluation

- **Model**: “Dense” Artificial Neural Network (ANN)
- **Cross validation** (repeat 173 times)
  - Train model using data from 172 of 173 continuous count stations
  - Generate model predictions using data from remaining station
- **Evaluation**: Compare estimates with actual volumes & generate metrics

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Florida Results: Summary

→ Overall median error metrics:
  • R2 = 0.83
  • MAPE = 25%
  • EMFR = 7%

Summary
Promising model performance, even over a variety of scenarios

Observations
  • ↑ Road class = ↑ Accuracy
  • ↑ Avg. hourly volume = ↑ Accuracy
  • ↑ Avg. hourly GPS counts = ↑ Accuracy

### Median Error Metrics by Scenario

<table>
<thead>
<tr>
<th>Road Classification</th>
<th>R2</th>
<th>MAPE (%)</th>
<th>EMFR (%)</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRC 1 (Interstates)</td>
<td>0.86</td>
<td>21</td>
<td>6</td>
<td>195704</td>
</tr>
<tr>
<td>Maryland (mostly FRC 1)</td>
<td>0.86</td>
<td>23</td>
<td>7</td>
<td>158040</td>
</tr>
<tr>
<td>FRC 2 (Other Freeways &amp; Expressways)</td>
<td>0.82</td>
<td>26</td>
<td>7</td>
<td>370567</td>
</tr>
<tr>
<td>FRC 3 &amp; 4 (Other principal &amp; minor arterials)</td>
<td>0.83</td>
<td>33</td>
<td>7</td>
<td>128419</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hourly Volume (vph)</th>
<th>R2</th>
<th>MAPE (%)</th>
<th>EMFR (%)</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1k</td>
<td>0.81</td>
<td>29</td>
<td>7</td>
<td>465591</td>
</tr>
<tr>
<td>1k-2k</td>
<td>0.86</td>
<td>22</td>
<td>6</td>
<td>164465</td>
</tr>
<tr>
<td>2k-3k</td>
<td>0.88</td>
<td>18</td>
<td>6</td>
<td>49221</td>
</tr>
<tr>
<td>3k+</td>
<td>0.87</td>
<td>19</td>
<td>6</td>
<td>15413</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Avg probe counts / hr</th>
<th>R2</th>
<th>MAPE (%)</th>
<th>EMFR (%)</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Low” [0-6]</td>
<td>0.78</td>
<td>38</td>
<td>8</td>
<td>214557</td>
</tr>
<tr>
<td>“Medium” [6-17]</td>
<td>0.84</td>
<td>24</td>
<td>7</td>
<td>249730</td>
</tr>
<tr>
<td>“High” [17-145]</td>
<td>0.85</td>
<td>22</td>
<td>6</td>
<td>230403</td>
</tr>
</tbody>
</table>

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Florida Statewide Model

- Apply trained model to entire road network
  - Requires 3 months of hourly input data at ~20k TMCs
  - Generate hourly volume estimates at each input time/location

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Florida Statewide Model: Tampa Bay Area

Continuous count station selected that exhibits typical (median) model performance.
Florida: AADT & AAWDT Estimation

<table>
<thead>
<tr>
<th>Measure (VPD)</th>
<th>R²</th>
<th>MAPE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td>0.86</td>
<td>15</td>
</tr>
<tr>
<td>AAWDT</td>
<td>0.87</td>
<td>15</td>
</tr>
</tbody>
</table>
Florida: Freight Volume Estimation

→ Apply model to estimate hourly freight volumes
   • Leverage highly-granular FDOT continuous count data

→ Initial freight volume results look promising, particularly on higher functional road classes

<table>
<thead>
<tr>
<th>All Trucks</th>
<th>FHWA Class 5-13</th>
<th>R²</th>
<th>MAPE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.77</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>FRC 1</td>
<td>0.83</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>FRC 2</td>
<td>0.76</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>FRC 3 &amp; 4</td>
<td>0.65</td>
<td>49</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heavy Trucks</th>
<th>FHWA Class 7-13</th>
<th>R²</th>
<th>MAPE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.66</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>FRC 1</td>
<td>0.80</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>FRC 2</td>
<td>0.62</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>FRC 3 &amp; 4</td>
<td>0.38</td>
<td>54</td>
<td></td>
</tr>
</tbody>
</table>

*Median error metrics*
**Goal:** Develop flags to highlight unusual input data and output model estimates

- **Flag 1** - based on GPS input data (key model “ingredient”)
  - *Typical:* Observed GPS counts within X std. dev of mean GPS counts during same day of week and hour
  - *Low:* Less than *Typical* range
  - *High:* Greater than *Typical* range

- **Flag 2** - based on output model estimates
  - *Typical:* Observed hourly estimates within X std. dev of mean estimates during same day of week and hour
  - *Low:* Less than *Typical* range
  - *High:* Greater than *Typical* range
New Hampshire Dataset (Q3 2017)

Data needed at all TMCs

- **GPS probe data** (INRIX)
  - 7M trips, 595M waypoints
  - Penetration rate: 2.3% median
  - Snapped to base map

- **Probe speeds** (RITIS, various vendors)

- **Road characteristics**
  - # lanes, speed limit, facility type, etc.

- **Weather**

- **TTI hourly volume estimates** (Optional)

Corresponding Florida dataset (Q4 2016)

- **GPS probe data** (INRIX)
  - 75M trips, 3.4B waypoints
  - Penetration rate: 2.1% median
  - Snapped to base map
# New Hampshire: Model Comparisons

<table>
<thead>
<tr>
<th>Model</th>
<th>R2</th>
<th>MAPE</th>
<th>EMFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida</td>
<td>0.77</td>
<td>34%</td>
<td>8%</td>
</tr>
<tr>
<td>Base (trained on NH data only)</td>
<td>0.83</td>
<td>28%</td>
<td>7%</td>
</tr>
<tr>
<td>Transfer Learning (FL model fine tuned w/ NH data)</td>
<td>0.83</td>
<td>24%</td>
<td>7%</td>
</tr>
<tr>
<td>Extended (trained on NH and FL data combined)</td>
<td>0.84</td>
<td>27%</td>
<td>7%</td>
</tr>
</tbody>
</table>
New Hampshire Results: Summary

→ Overall median error metrics:
  • $R^2 = 0.84$
  • MAPE = 27%
  • EMFR = 7%

Summary
Promising model performance, even over a variety of scenarios

Observations
  • ↑ Road class = ↑ Accuracy
  • ↑ Avg. hourly volume = ↑ Accuracy
  • ↑ Avg. hourly GPS counts = ↑ Accuracy

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<th>EMFR (%)</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRC 1 (Interstates)</td>
<td>0.84</td>
<td>21</td>
<td>7</td>
<td>65,728</td>
</tr>
<tr>
<td>FRC 2 (Other Freeways &amp; Expressways)</td>
<td>0.83</td>
<td>30</td>
<td>7</td>
<td>84,307</td>
</tr>
<tr>
<td>FRC 3 &amp; 4 (Other principal &amp; minor arterials)</td>
<td>0.86</td>
<td>29</td>
<td>7</td>
<td>25,369</td>
</tr>
</tbody>
</table>

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<tr>
<th>Hourly Volume (vph)</th>
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<th>MAPE (%)</th>
<th>EMFR (%)</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1k</td>
<td>0.84</td>
<td>30</td>
<td>7</td>
<td>38,771</td>
</tr>
<tr>
<td>1k-2k</td>
<td>0.86</td>
<td>20</td>
<td>8</td>
<td>10,394</td>
</tr>
<tr>
<td>2k-3k</td>
<td>0.86</td>
<td>18</td>
<td>7</td>
<td>65,728</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Avg probe counts / hr</th>
<th>R2</th>
<th>MAPE (%)</th>
<th>EMFR (%)</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low [0-5]</td>
<td>0.81</td>
<td>32</td>
<td>7</td>
<td>60,182</td>
</tr>
<tr>
<td>Medium [6-17]</td>
<td>0.85</td>
<td>25</td>
<td>7</td>
<td>57,524</td>
</tr>
<tr>
<td>High [17-145]</td>
<td>0.86</td>
<td>21</td>
<td>6</td>
<td>57,698</td>
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</tbody>
</table>
New Hampshire Statewide Model

• Apply trained model to entire road network
  − Requires 3 months of hourly input data at ~2k TMCs
  − Generate hourly volume estimates at each input time/location
## New Hampshire: AADT & AAWDT Estimation

<table>
<thead>
<tr>
<th>Measure (VPD)</th>
<th>$R^2$</th>
<th>MAPE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT</td>
<td>0.87</td>
<td>17</td>
</tr>
<tr>
<td>AAWDT</td>
<td>0.86</td>
<td>18</td>
</tr>
</tbody>
</table>

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Experiments with Training Dataset

• When Florida dataset is combined with only 2 weeks of New Hampshire data for training, model predictions are reasonably good!

• Over time, only small amount of data for each new geography is needed to create powerful models!

• Potentially, the statewide traffic count data collection (and its associated cost) can be optimized!

<table>
<thead>
<tr>
<th></th>
<th>R²</th>
<th>MAPE</th>
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<tbody>
<tr>
<td></td>
<td>2 w.</td>
<td>3 mo.</td>
</tr>
<tr>
<td>Base</td>
<td>mean</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>0.77</td>
</tr>
<tr>
<td>Extended</td>
<td>mean</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>0.81</td>
</tr>
</tbody>
</table>
Summary

- Analysis on Florida and New Hampshire datasets are complete
- Hourly volume estimates:
  - Estimates meet requirements for most planning and operational purposes
  - Estimation quality improves with road class and actual volumes (number of probes)
  - Developed sensible flags to identify unusual behavior of input to and output from the models
- AADT and AAWDT estimates:
  - High level of accuracy
  - Consistent with expectations along major highways and urban areas
- Freight volumes
  - Initial results are promising, especially on FRC1 roads
- Model and data transferability
  - It is possible to leverage larger datasets in developing models for smaller geographies
Questions

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Zachary Vander Laan
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August 16, 2018
NREL
Insights from VTM Error Analysis

August 16, 2018
Volume Error Analysis
Colorado Roadways
both Freeways and Off-freeways

(a) Symmetric MAPE
(b) Training Bounds & Data Filtering
(c) Performance during unusual events

August 2018
National Renewable Energy Lab
Yi Hou, Venu Garikapati, Stan Young
Symmetric Mean Absolute Percentage Error

• Issues with Mean Absolute Percentage Error (MAPE)
  o Inflates error at small observed values and can not be used if there are zero values
  o No upper limit to the percentage error – can go to infinity
    – Anything averaged with infinity is infinity

• Symmetric MAPE
  o Overcomes the issues with MAPE
  o Provide a result between 0% to 200%

\[
\text{SMAPE} = \frac{100\%}{N} \sum_{i=1}^{N} \frac{|V_i - \hat{V}_i|}{(|V_i| + |\hat{V}_i|)/2}
\]

\[
\text{MAPE} = \frac{100\%}{N} \sum_{i=1}^{N} \left| \frac{V_i - \hat{V}_i}{V_i} \right|
\]
• Results exceed the survey expectation: ETCR<10%
• All have very similar accuracy
• XGBoost is the most computational efficient

<table>
<thead>
<tr>
<th>Model</th>
<th>MAPE</th>
<th>SMAPE</th>
<th>ETCR</th>
<th>R2</th>
<th>Training Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF</td>
<td>17.8%</td>
<td>16.6%</td>
<td>5.2%</td>
<td>0.92</td>
<td>73s</td>
</tr>
<tr>
<td>GBM</td>
<td>18.3%</td>
<td>17.4%</td>
<td>4.8%</td>
<td>0.93</td>
<td>124s</td>
</tr>
<tr>
<td>XGBoost</td>
<td>17.7%</td>
<td>17.2%</td>
<td>5.3%</td>
<td>0.91</td>
<td>13s</td>
</tr>
</tbody>
</table>
Model Results Comparison – Colorado Off-Freeways

- Much more accurate than linear regression and AADT based methods

<table>
<thead>
<tr>
<th>Model</th>
<th>MAPE*</th>
<th>SMAPE</th>
<th>MAE</th>
<th>EMFR</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>XGBoost</td>
<td>50.6%</td>
<td>34.0%</td>
<td>89.2</td>
<td>13.2%</td>
<td>0.88</td>
</tr>
<tr>
<td>Linear</td>
<td>314.7%</td>
<td>68.1%</td>
<td>153.1</td>
<td>29.5%</td>
<td>0.80</td>
</tr>
<tr>
<td>AADT Based Method</td>
<td>161.7%</td>
<td>76.0%</td>
<td>304.4</td>
<td>26.5%</td>
<td>0.16</td>
</tr>
</tbody>
</table>

*The results include extreme low volume

- Further examine MAPE and EMFR for volume > 20 vehs/hr

<table>
<thead>
<tr>
<th>Model</th>
<th>MAPE (Vol&gt;20)</th>
<th>SMAPE (Vol&gt;20)</th>
<th>EMFR (Vol&gt;20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XGBoost</td>
<td>29.7%</td>
<td>27.4%</td>
<td>10.8%</td>
</tr>
<tr>
<td>Linear Regression</td>
<td>90.4%</td>
<td>50.4%</td>
<td>20.8%</td>
</tr>
<tr>
<td>AADT Based Method</td>
<td>124.9%</td>
<td>63.8%</td>
<td>28.1%</td>
</tr>
</tbody>
</table>

- Need to look at accuracy in volume ranges
Volume Error Analysis
Colorado Roadways
both Freeways and Off-freeways

(a) Symmetric MAPE
(b) Training Bounds & Data Filtering
(c) Performance during unusual events

Are the large errors at high volumes due to lack of appropriate training data?
MAPE of Different Volume Range – Colorado Freeways
MAPE of Different Volume Range – Colorado Freeways

Anticipated – Statistical Expectation
Residual vs. Probe Count
Residual vs. Probe Count – Colorado Freeways
Residual vs. Probe Count

Outside bounds of training
Residual vs. Probe Count

Data issues zero reported probes
Data quality
Volume Error Analysis
Colorado Roadways
both Freeways and Off-freeways

(a) Symmetric MAPE
(b) Training Bounds & Data Filtering
(c) Performance during unusual events

How well does method perform during unusual events and conditions?
Error by Observed Volume Percentile Across Locations

Observed Volume Data

Group volumes by location, day of week, and hour of day

<table>
<thead>
<tr>
<th>Location1</th>
<th>Weekdays</th>
<th>0:00 – 1:00am</th>
<th>0% - 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location1</td>
<td>Weekdays</td>
<td>1:00 – 2:00am</td>
<td>0% - 5%</td>
</tr>
<tr>
<td>Location1</td>
<td>Weekends</td>
<td>0:00 – 1:00am</td>
<td>0% - 5%</td>
</tr>
<tr>
<td>Location14</td>
<td>Weekends</td>
<td>23:00 – 24:00 pm</td>
<td>0% - 5%</td>
</tr>
</tbody>
</table>

Error Measures

<table>
<thead>
<tr>
<th>Location1</th>
<th>Weekdays</th>
<th>0:00 – 1:00am</th>
<th>5% - 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location1</td>
<td>Weekdays</td>
<td>1:00 – 2:00am</td>
<td>5% - 50%</td>
</tr>
<tr>
<td>Location1</td>
<td>Weekends</td>
<td>0:00 – 1:00am</td>
<td>5% - 50%</td>
</tr>
<tr>
<td>Location14</td>
<td>Weekends</td>
<td>23:00 – 24:00 pm</td>
<td>5% - 50%</td>
</tr>
</tbody>
</table>

Error Measures

<table>
<thead>
<tr>
<th>Location1</th>
<th>Weekdays</th>
<th>0:00 – 1:00am</th>
<th>50% - 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location1</td>
<td>Weekdays</td>
<td>1:00 – 2:00am</td>
<td>50% - 95%</td>
</tr>
<tr>
<td>Location1</td>
<td>Weekends</td>
<td>0:00 – 1:00am</td>
<td>50% - 95%</td>
</tr>
<tr>
<td>Location14</td>
<td>Weekends</td>
<td>23:00 – 24:00 pm</td>
<td>50% - 95%</td>
</tr>
</tbody>
</table>

Error Measures

<table>
<thead>
<tr>
<th>Location1</th>
<th>Weekdays</th>
<th>0:00 – 1:00am</th>
<th>95% - 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location1</td>
<td>Weekdays</td>
<td>1:00 – 2:00am</td>
<td>95% - 100%</td>
</tr>
<tr>
<td>Location1</td>
<td>Weekends</td>
<td>0:00 – 1:00am</td>
<td>95% - 100%</td>
</tr>
<tr>
<td>Location14</td>
<td>Weekends</td>
<td>23:00 – 24:00 pm</td>
<td>95% - 100%</td>
</tr>
</tbody>
</table>
Error by Volume Percentile Across Locations

- Model performs as good as normal conditions when observed volume are above 95th percentile.
- For volumes lower than 5th percentile, MAPE and SMAPE are slightly higher than other conditions.

<table>
<thead>
<tr>
<th>Percentile of Volume</th>
<th>MAPE</th>
<th>SMAPE</th>
<th>MAE</th>
<th>ECR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% - 5%</td>
<td>25.5%</td>
<td>20.2%</td>
<td>273.9</td>
<td>4.2%</td>
</tr>
<tr>
<td>5% - 50%</td>
<td>18.2%</td>
<td>17.4%</td>
<td>326.7</td>
<td>4.9%</td>
</tr>
<tr>
<td>50% - 95%</td>
<td>16.2%</td>
<td>16.6%</td>
<td>385.1</td>
<td>5.7%</td>
</tr>
<tr>
<td>95% - 100%</td>
<td>16.3%</td>
<td>17.2%</td>
<td>438.9</td>
<td>6.4%</td>
</tr>
</tbody>
</table>
Error by Standard Deviation Across Locations

Observed Volume Data

Group volumes by location, day of week, and hour of day

Location 1
- Weekdays
  - 0:00 – 1:00am

Location 1
- Weekdays
  - 1:00 – 2:00am

Location 1
- Weekends
  - 0:00 – 1:00am

Location 14
- Weekends
  - 23:00 – 24:00 pm

Error Measures

$\text{Error by standard deviation across locations}$

$> 3\sigma$

$[2\sigma, 3\sigma]$

$[\sigma, 2\sigma]$

$[0, \sigma]$

$[-\sigma, 0]$

$[-2\sigma, -\sigma]$

$[-3\sigma, -2\sigma]$

$< -3\sigma$
Group volumes by location, day of week, and hour of day

- Location1 Weekdays 0:00 – 1:00am
- Location1 Weekdays 1:00 – 2:00am
- Location1 Weekends 0:00 – 1:00am
- Location14 Weekends 23:00 – 24:00 pm

Error Measures

- $> 3\sigma$
- $[2\sigma, 3\sigma]$
- $[\sigma, 2\sigma]$
- $[0, \sigma]$
- $[-\sigma, 0]$
- $[-2\sigma, -\sigma]$
- $[-3\sigma, -2\sigma]$
- $< -3\sigma$

- Blizzard / Eclipse / Hurricane
- Fatal accident / Special Event / Snow Storm
- Incident / weather
- Regular Traffic

Error by standard deviation across locations
Error by Standard Deviation Across Locations

- SMAPE is consistent for both normal and abnormal conditions, except for two 0.1% tails.
- MAPE is between 15.6% and 22.9% for volumes larger than $\mu-3\sigma$
- Model performs very well for special events and extremely congested conditions.

<table>
<thead>
<tr>
<th>Std. of Volume</th>
<th>Count</th>
<th>MAPE</th>
<th>SMAPE</th>
<th>MAE</th>
<th>ECR</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt;-3\sigma$ (0.1%)</td>
<td>214</td>
<td>42.9%</td>
<td>25.2%</td>
<td>564.5</td>
<td>8.6%</td>
</tr>
<tr>
<td>-3\sigma to -2\sigma (2.1%)</td>
<td>1694</td>
<td>22.9%</td>
<td>18.4%</td>
<td>276.0</td>
<td>4.4%</td>
</tr>
<tr>
<td>-2\sigma to $-\sigma$ (13.6%)</td>
<td>5820</td>
<td>20.9%</td>
<td>18.4%</td>
<td>286.8</td>
<td>4.5%</td>
</tr>
<tr>
<td>-1\sigma to 0 (34.1%)</td>
<td>15896</td>
<td>19.1%</td>
<td>18.0%</td>
<td>278.1</td>
<td>4.2%</td>
</tr>
<tr>
<td>0 to $\sigma$ (34.1%)</td>
<td>22234</td>
<td>15.6%</td>
<td>16.4%</td>
<td>428.6</td>
<td>6.3%</td>
</tr>
<tr>
<td>$\sigma$ to 2\sigma (13.6%)</td>
<td>5390</td>
<td>15.7%</td>
<td>16.4%</td>
<td>398.8</td>
<td>5.8%</td>
</tr>
<tr>
<td>2\sigma to 3\sigma (2.1%)</td>
<td>743</td>
<td>17.8%</td>
<td>18.6%</td>
<td>243.9</td>
<td>3.7%</td>
</tr>
<tr>
<td>$&gt;3\sigma$ (0.1%)</td>
<td>101</td>
<td>21.7%</td>
<td>24.8%</td>
<td>340.1</td>
<td>5.1%</td>
</tr>
</tbody>
</table>
Summary and Future Work

• Symmetric MAPE Implemented
• Error Analysis
  o Training bounds issue confirmed at large volumes
  o Input data filtering issue discovered
  o Next steps – revised methodology for filtering, flagging and better accuracy
• Working towards confidence flag / number & identifying information importance
Future Work – Next Steps
Remaining Analysis Work

• Status of VTM R&D
  o In the homestretch – anticipate closeout end of 2018
  o Small additional research funding extended effort

• Extended work
  o NREL & UMD
    – Continued Metric / Error Analysis / Confidence
  o NREL Focus
    – Analyze additional Coalition state
  o UMD Focus
    – Truck Volumes and vehicle types analysis
• Recall
  o Original VPP – Single vendor, travel times
  o VPP 2.0 – Travel time and speeds
    – Multiple vendor
    – Ancillary products (maps, trace data, etc.)
• Preparing VPP 3.0 (everything in VPP 2.0)
  o Include volume estimates
  o Other emerging capabilities – OD & trace data
• Recommended specs for volume estimates in VPP 3.0 is product/deliverable in VTM research
• Results of call for interest to go ‘from Lab to the Streets’
  o Discussion with several states
    – FL, GA, MD, PA, NH, CO, AL, PANYNJ and others
  o Vendors are responding with custom data packages/services to support volume estimates
• USDOT/FHWA – Pooled fund study
  o New sources of volume data for HPMS
• Other ....

• Contact Denise, Stan, or Kaveh if interested
Final Questions
Thank You!

For Questions, please contact:

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