Volume & Turning Movements Project

Steering Committee Meeting #6

November 9, 2017

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

CATT Center For Advanced Transportation Technology

NREL National Renewable Energy Laboratory

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Thank you!

WELCOME!

Denise Markow, I-95 Corridor Coalition

Speakers

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Attendees

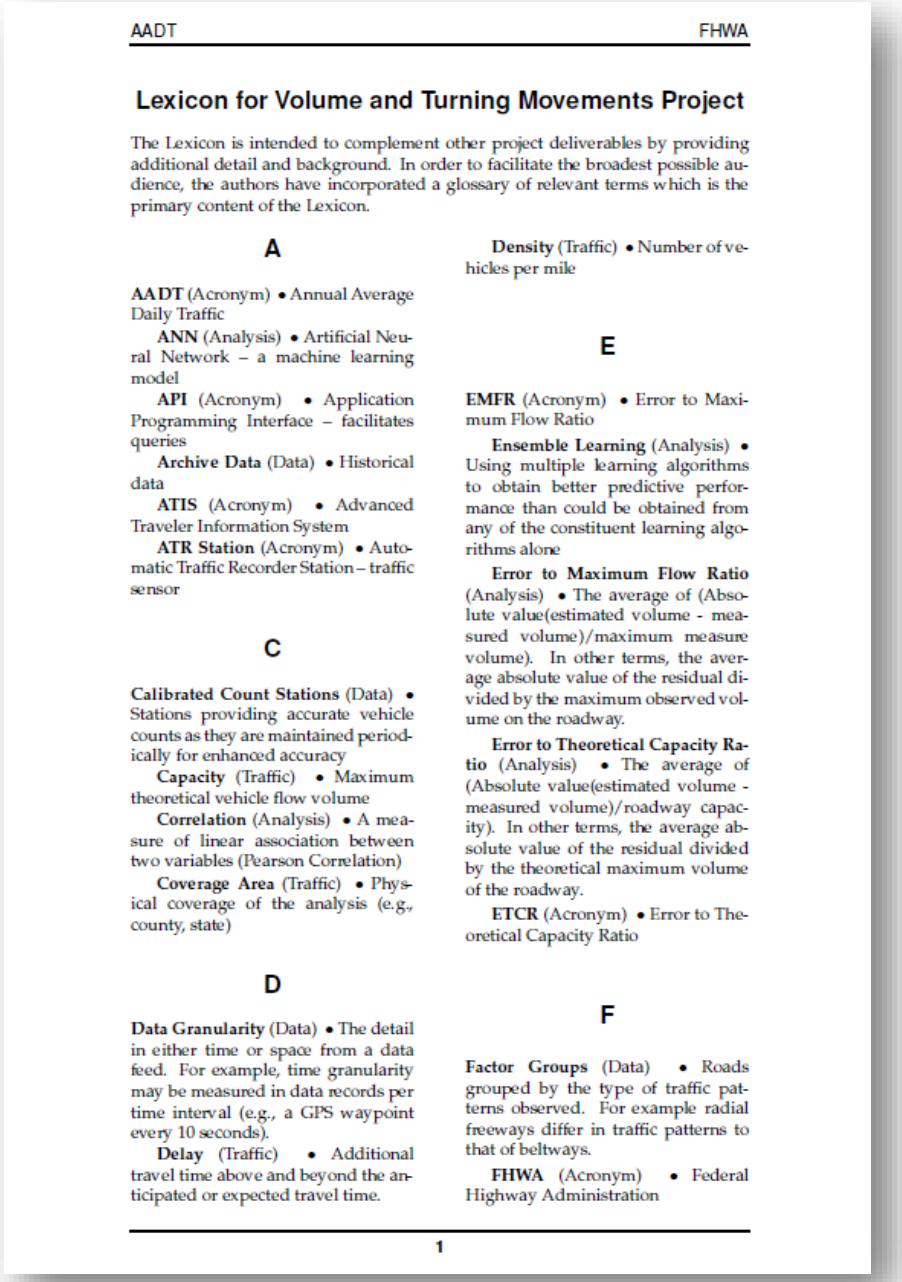
Agencies	
Colorado DOT	NJTPA
District DOT	NREL
Durham MPO (NC)	Pennsylvania DOT
FHWA	Port Authority NY & NJ
Georgia DOT	South Carolina DOT
HERE	Texas A&M Transportation Institute
I-95 Corridor Coalition	TomTom
INRIX	UMD CATT
Maryland DOT/MdSHA	USDOT - BTS
MWCOG	Virginia DOT
New Hampshire DOT	

Agenda

	Topic	Speaker
1	Welcome & Project Status Update	Denise Markow, I-95 Corridor Coalition Stan Young, NREL
2	Spotlight Presentation: Traffic Volume Estimation using INRIX GPS traces: Updated Maryland Results and New Datasets	Zach Vander Laan, UMD CATT
3	TTI MnDOT Study Review	Shawn Turner, TTI
4	State DOT Feedback - shaping future direction	Steering Committee members
5	Next Steps & Wrap Up	Stan Young, NREL Denise Markow, I-95 Corridor Coalition

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.



Lexicon for Volume and Turning Movements Project

The Lexicon is intended to complement other project deliverables by providing additional detail and background. In order to facilitate the broadest possible audience, the authors have incorporated a glossary of relevant terms which is the primary content of the Lexicon.

A

AADT (Acronym) • Annual Average Daily Traffic

ANN (Analysis) • Artificial Neural Network – a machine learning model

API (Acronym) • Application Programming Interface – facilitates queries

Archive Data (Data) • Historical data

ATIS (Acronym) • Advanced Traveler Information System

ATR Station (Acronym) • Automatic Traffic Recorder Station – traffic sensor

C

Calibrated Count Stations (Data) • Stations providing accurate vehicle counts as they are maintained periodically for enhanced accuracy

Capacity (Traffic) • Maximum theoretical vehicle flow volume

Correlation (Analysis) • A measure of linear association between two variables (Pearson Correlation)

Coverage Area (Traffic) • Physical coverage of the analysis (e.g., county, state)

D

Data Granularity (Data) • The detail in either time or space from a data feed. For example, time granularity may be measured in data records per time interval (e.g., a GPS waypoint every 10 seconds).

Delay (Traffic) • Additional travel time above and beyond the anticipated or expected travel time.

Density (Traffic) • Number of vehicles per mile

E

EMFR (Acronym) • Error to Maximum Flow Ratio

Ensemble Learning (Analysis) • Using multiple learning algorithms to obtain better predictive performance than could be obtained from any of the constituent learning algorithms alone

Error to Maximum Flow Ratio (Analysis) • The average of (Absolute value(estimated volume - measured volume)/maximum measure volume). In other terms, the average absolute value of the residual divided by the maximum observed volume on the roadway.

Error to Theoretical Capacity Ratio (Analysis) • The average of (Absolute value(estimated volume - measured volume)/roadway capacity). In other terms, the average absolute value of the residual divided by the theoretical maximum volume of the roadway.

ETCR (Acronym) • Error to Theoretical Capacity Ratio

F

Factor Groups (Data) • Roads grouped by the type of traffic patterns observed. For example radial freeways differ in traffic patterns to that of beltways.

FHWA (Acronym) • Federal Highway Administration

Project Goal

Accelerate the timeframe to a viable volume and turning movement data feed ---

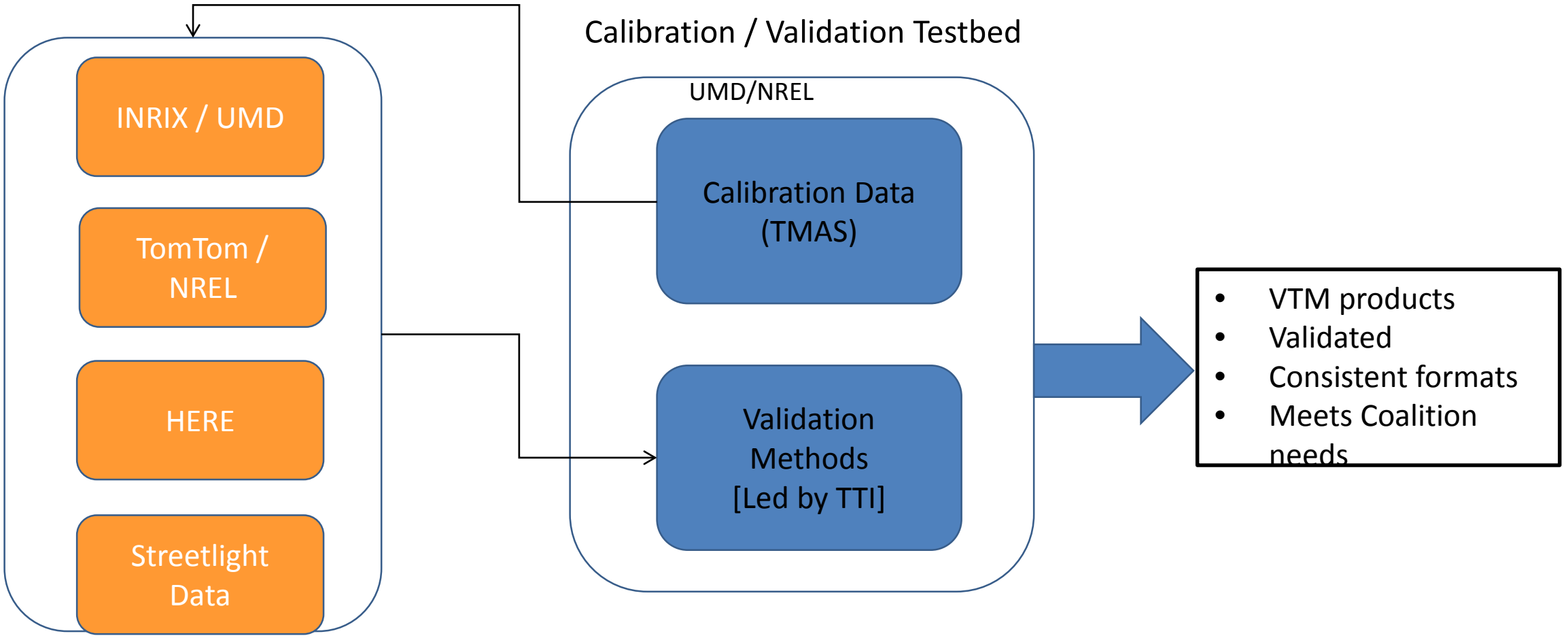
- Anywhere/anytime on the network
- Archive and real-time
- Freeway and Non-Freeway

Insure that initial data products meet members' information needs for operations, performance measurement, and planning.

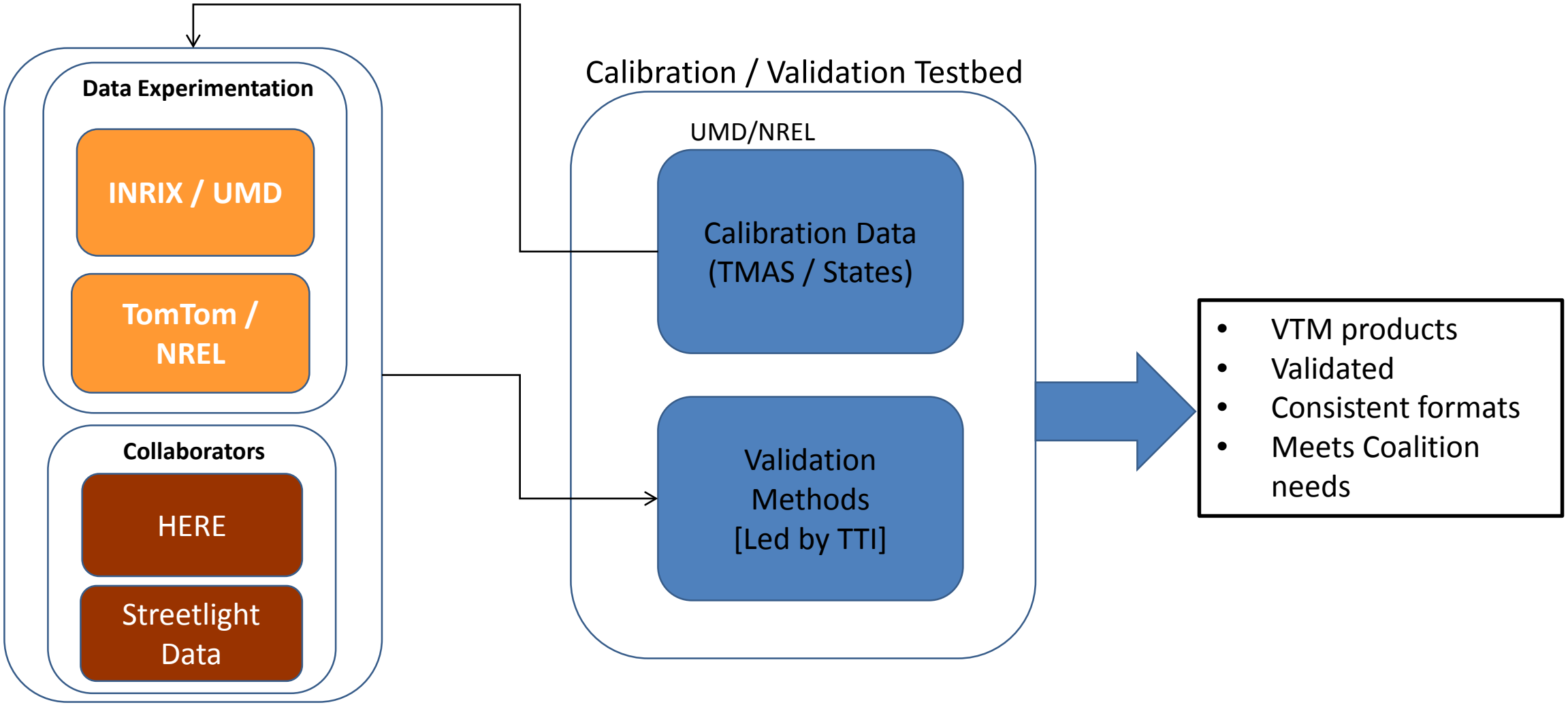
Objectives - Original

- 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

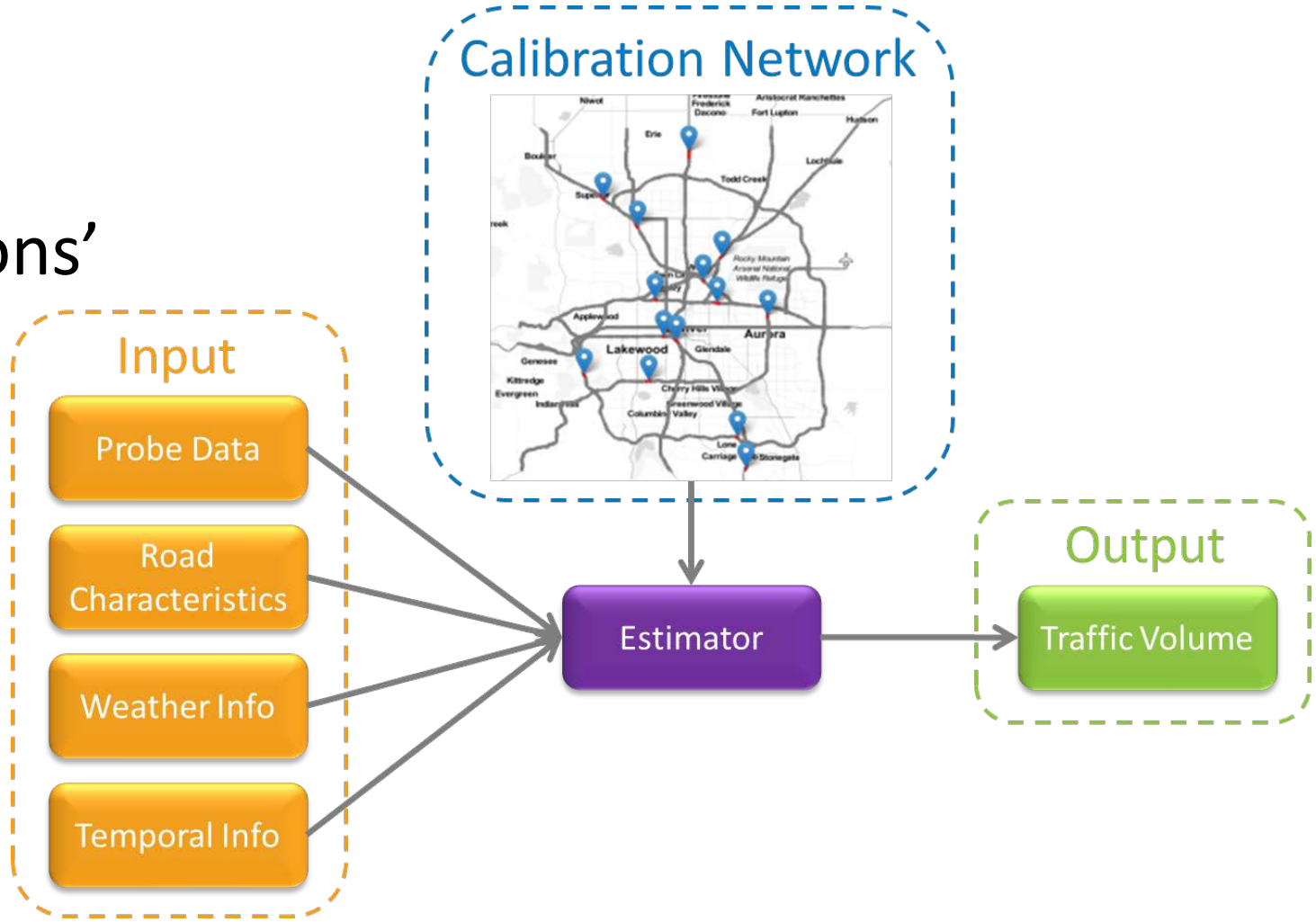


Status of Project – Nov 2017



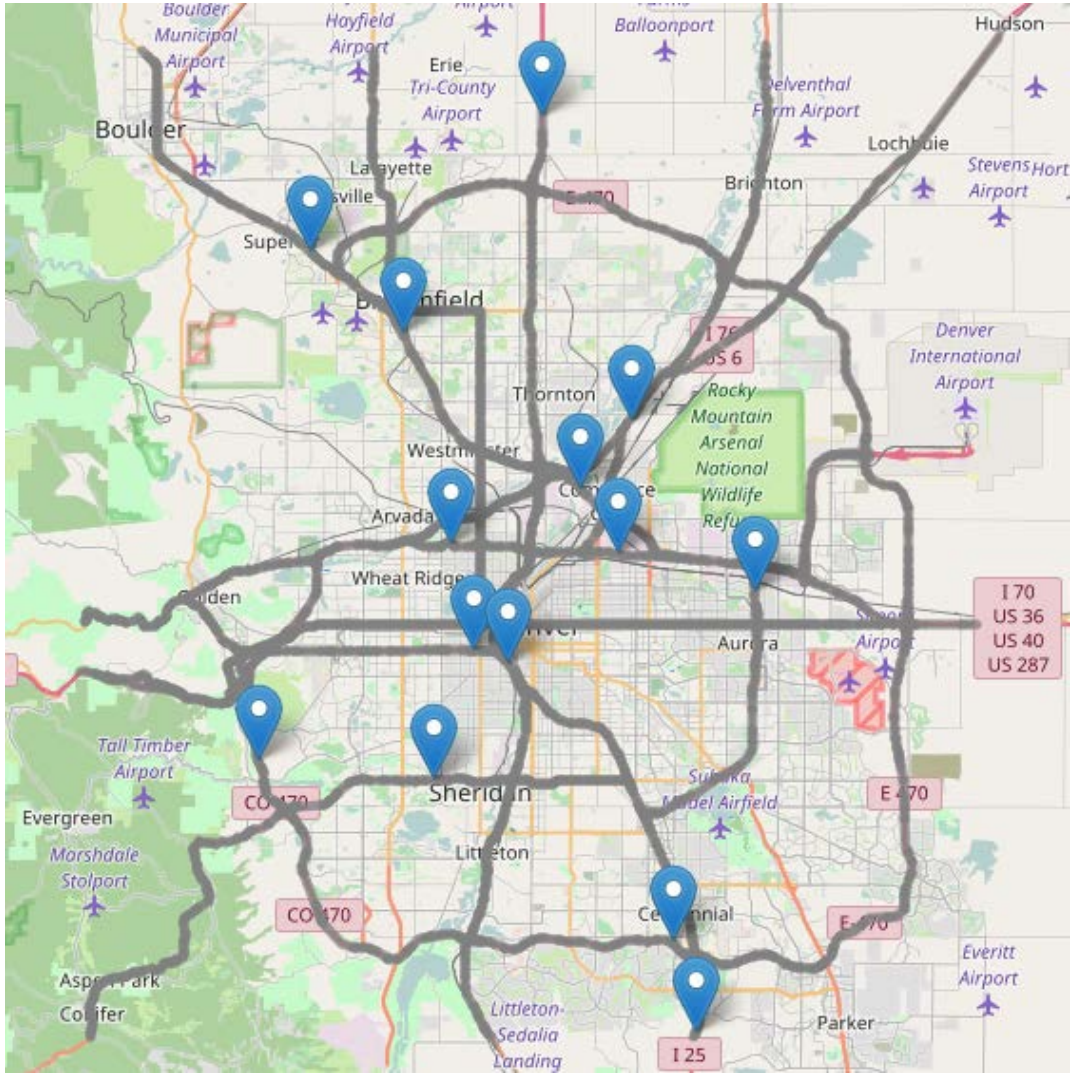
Visualizing the Solution

- 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

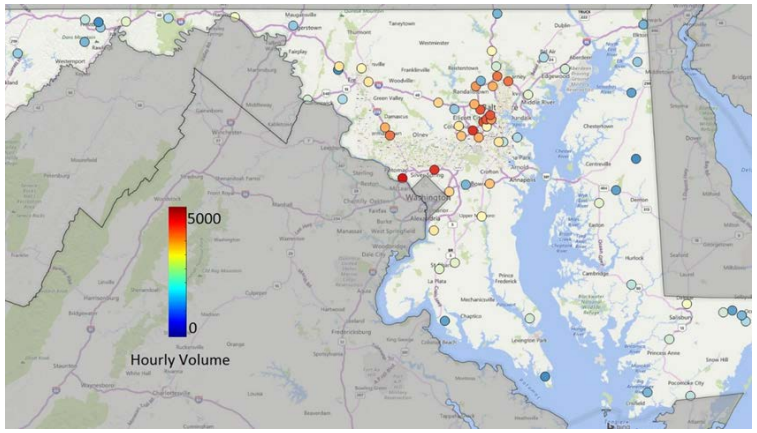
VTM Steering Committee Meeting
November 9, 2017

Today's Presentation

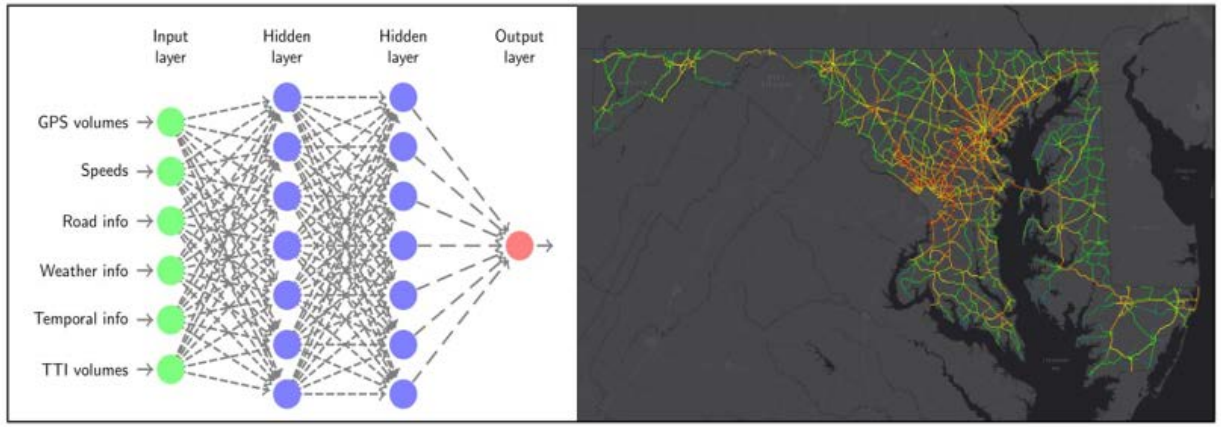
- Objectives and updates
- Maryland analysis
  - GPS dataset
  - Regression Models
  - Results
  - Comparison with previous results & conclusion
- New datasets
  - Florida
  - Rhode Island

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:

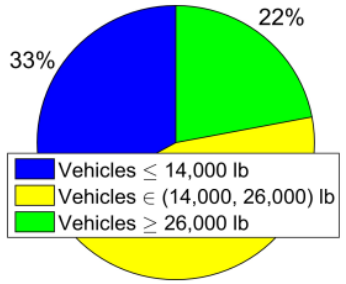
- Feature engineering
  - TTI volume estimates as a model input
- Model selection
  - using a recurrent neural network to take advantage of temporal patterns in data
- 10 additional ATR stations (mostly low-volume)

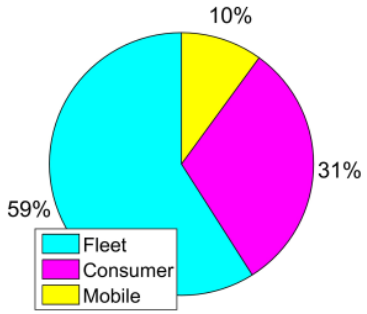
Goals

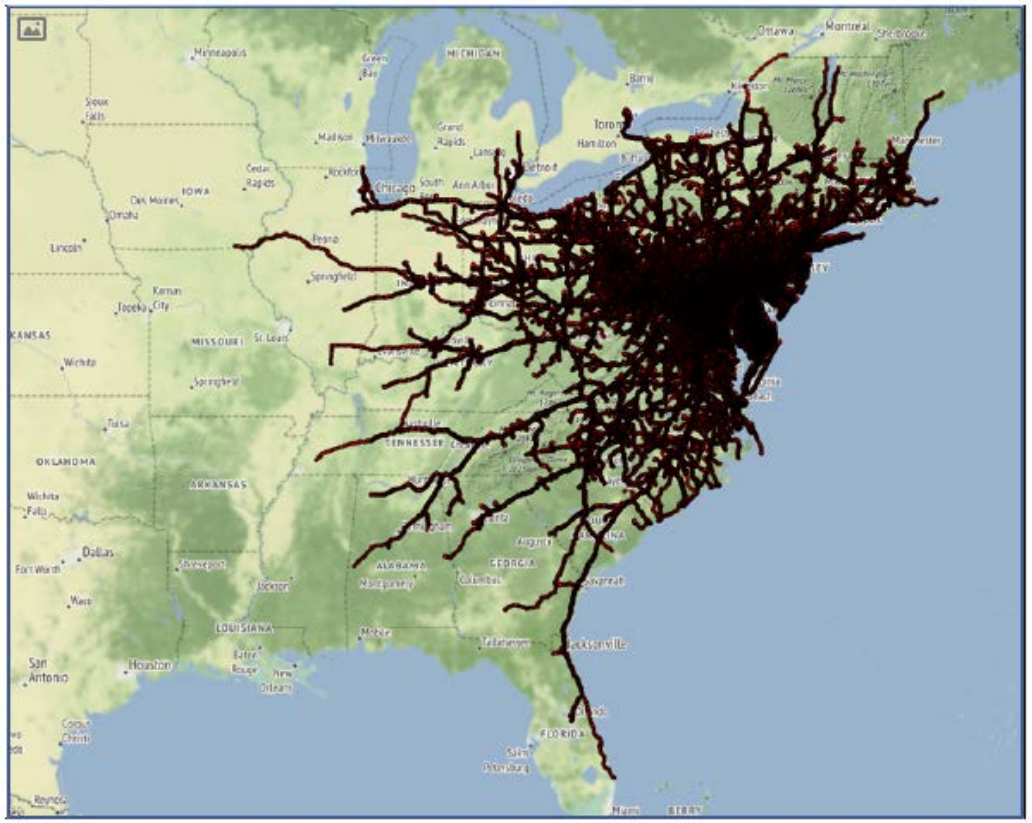
- Quantify current model performance
- Compare current and previous results

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

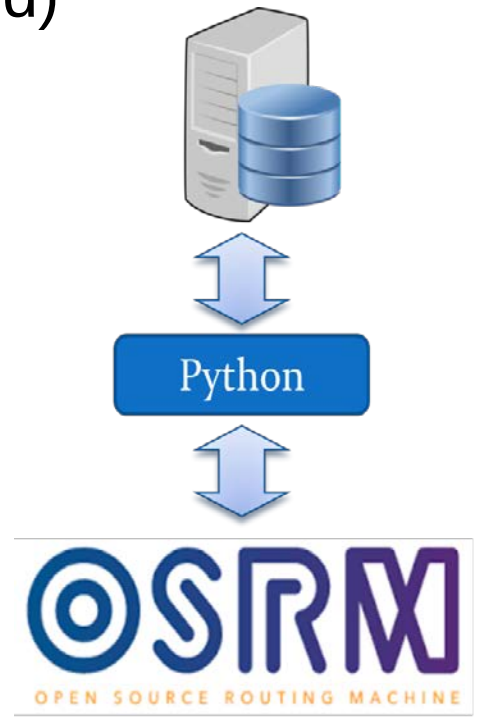


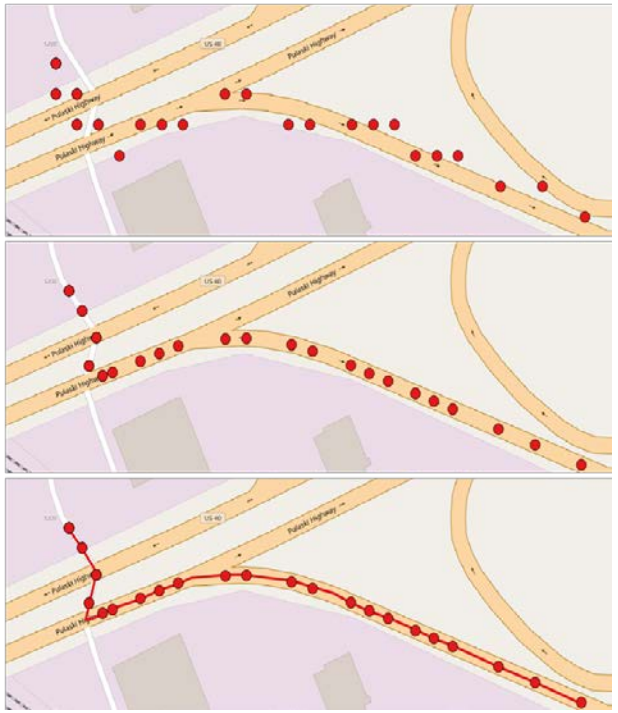




Waypoint Snapping and Map Matching

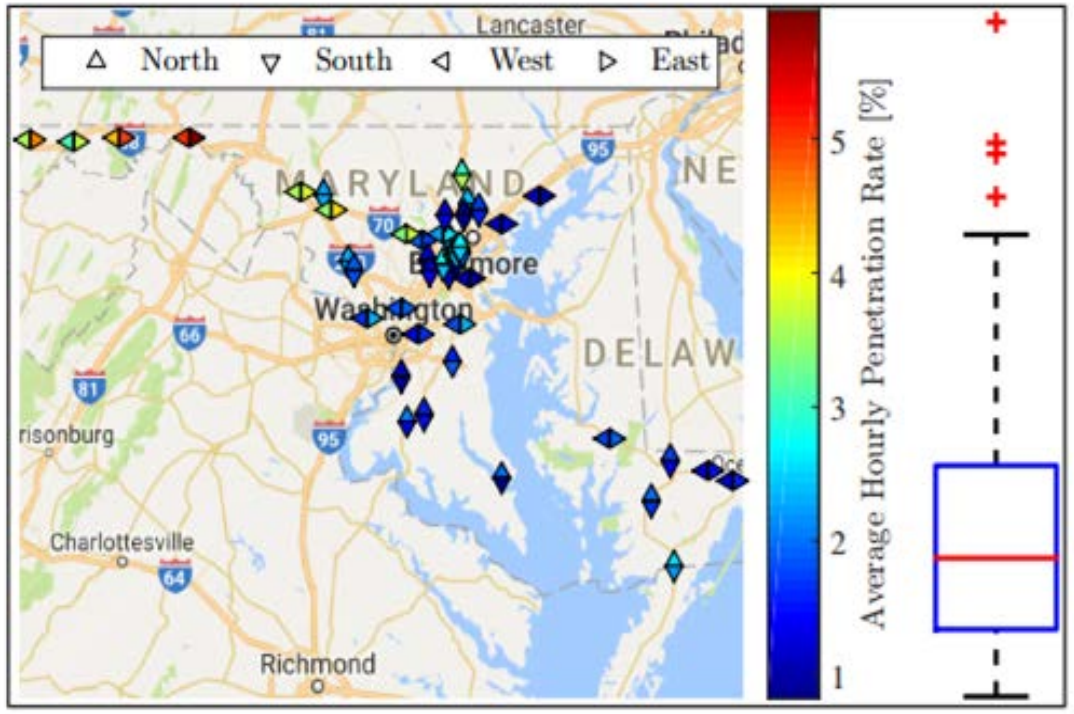
- Waypoints only identified by lat/lon, but need to be associated with road network
  - No longer the case with most recent INRIX data (i.e., Florida, Rhode Island)
- Two step process
  - Snapping
  - Map matching
- OpenStreetMap tools used
- Requires significant amount of fine-tuning





GPS Penetration Rates

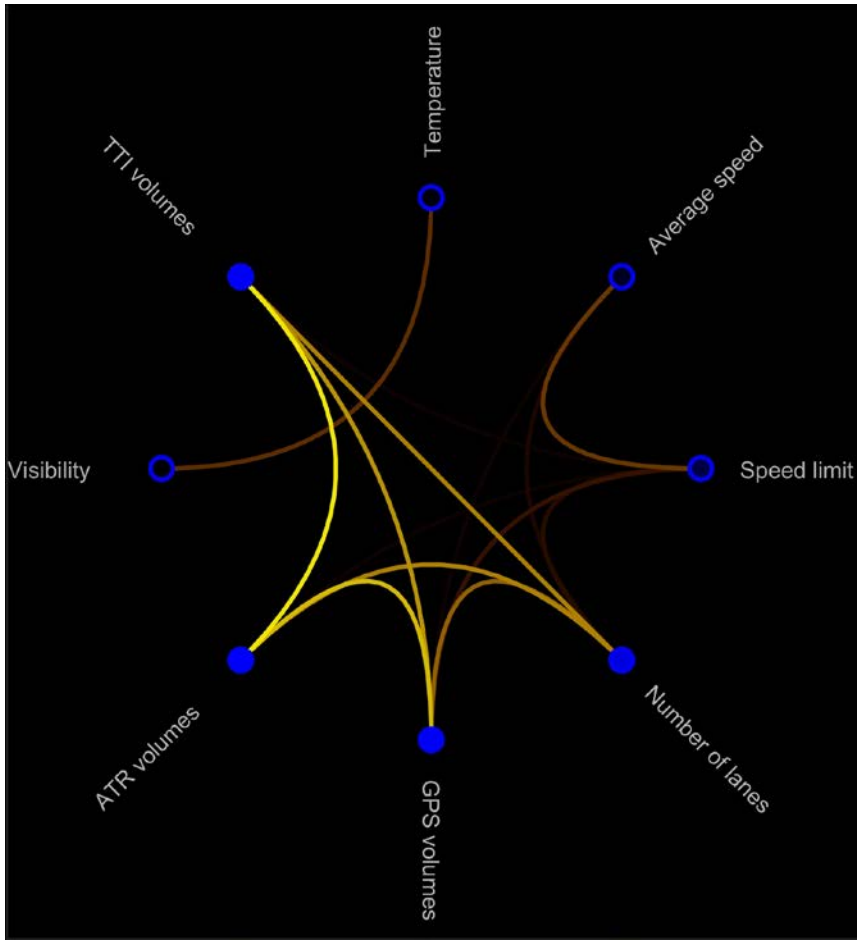
- Hourly penetration rates of GPS traces are computed at 45 ATR locations over the 4 month period



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

Other Data & Correlations

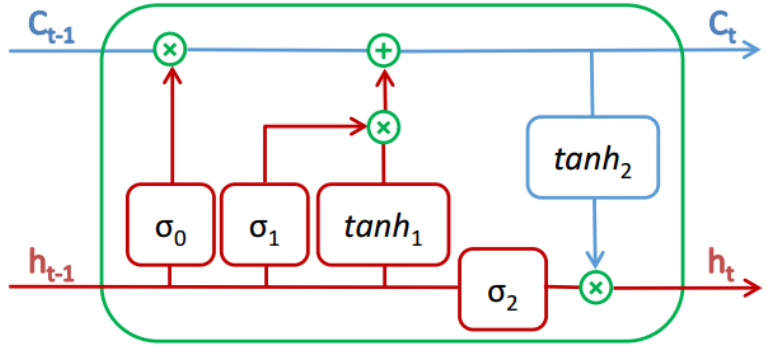
- Speed data from RITIS
- Road characteristics
  - Type of the road (IS,US,MD)
  - Number of lanes
  - Speed limit
  - Directions separated
- Weather data
  - Temperature, humidity, pressure, visibility, wind speed, precipitation
- Temporal characteristics
  - Hour of day, weekday/Sat/Sun, federal holiday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



Yellow/magenta: +/- correlation

Machine Learning Regression Models

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



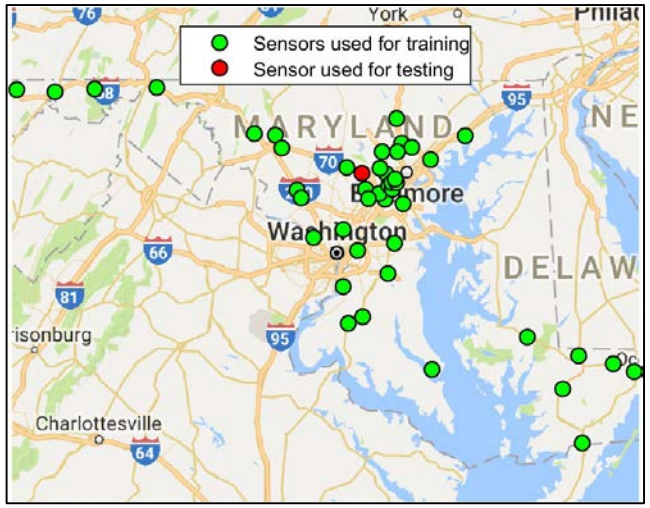
LSTM Cell

- 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

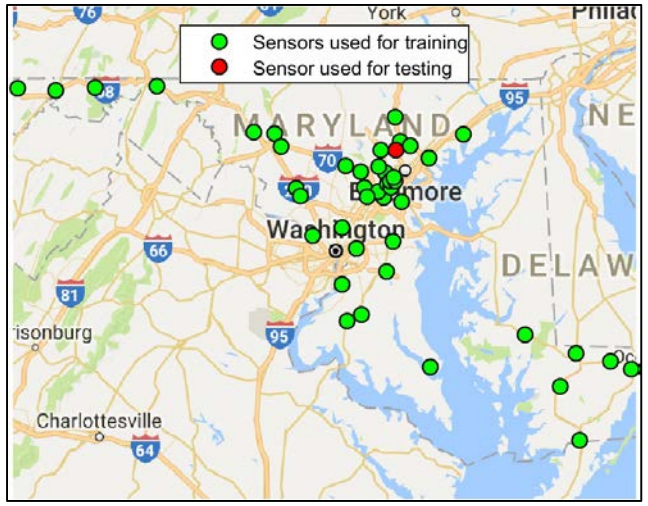
- Implementation
  - TensorFlow ™
  - Train models on dedicated computer with GPU

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



1st Iteration



2nd Iteration

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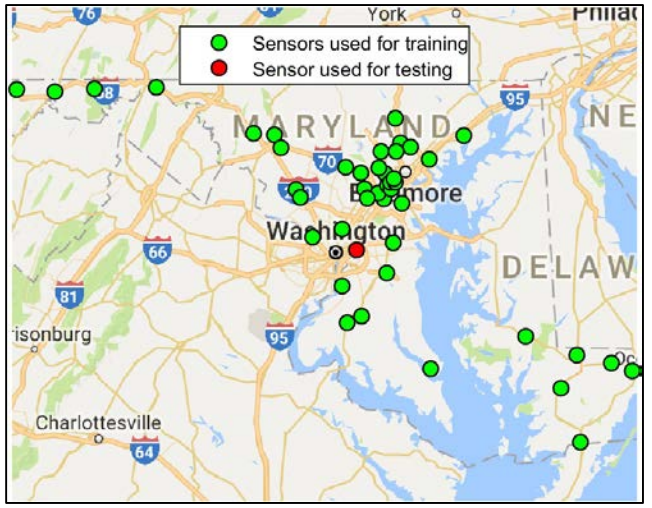
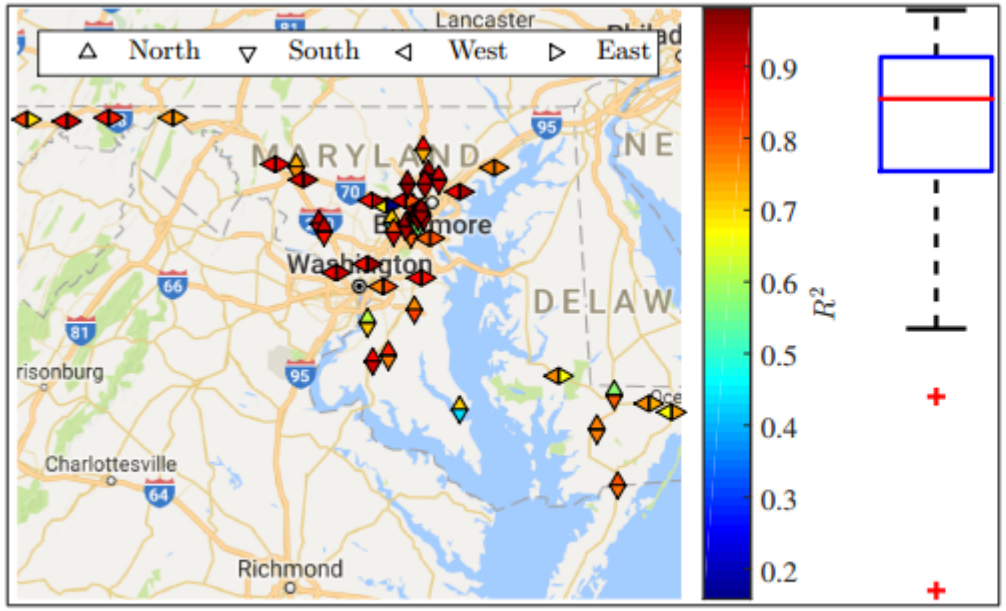


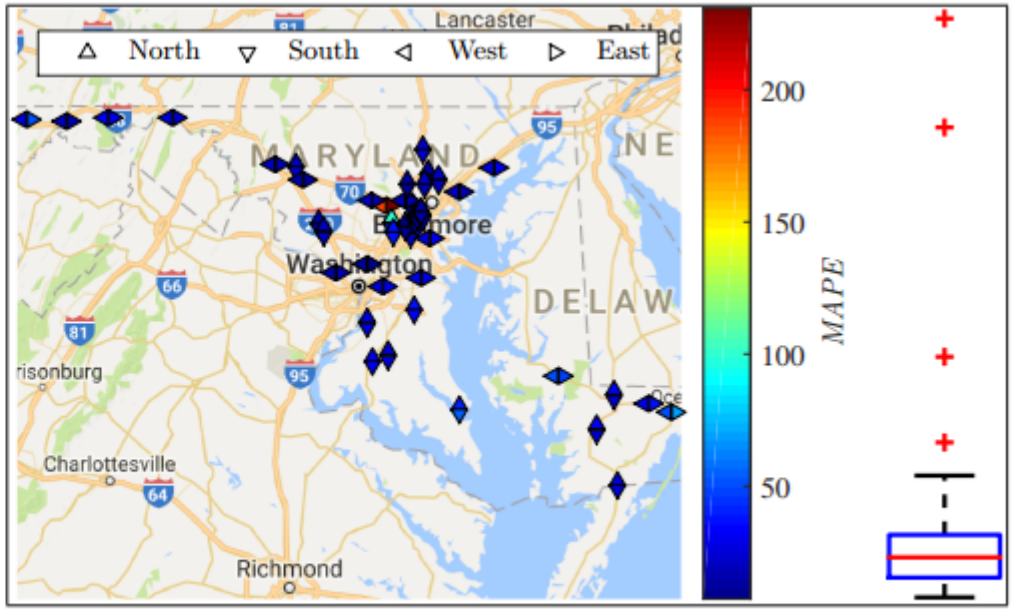
45th Iteration

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%



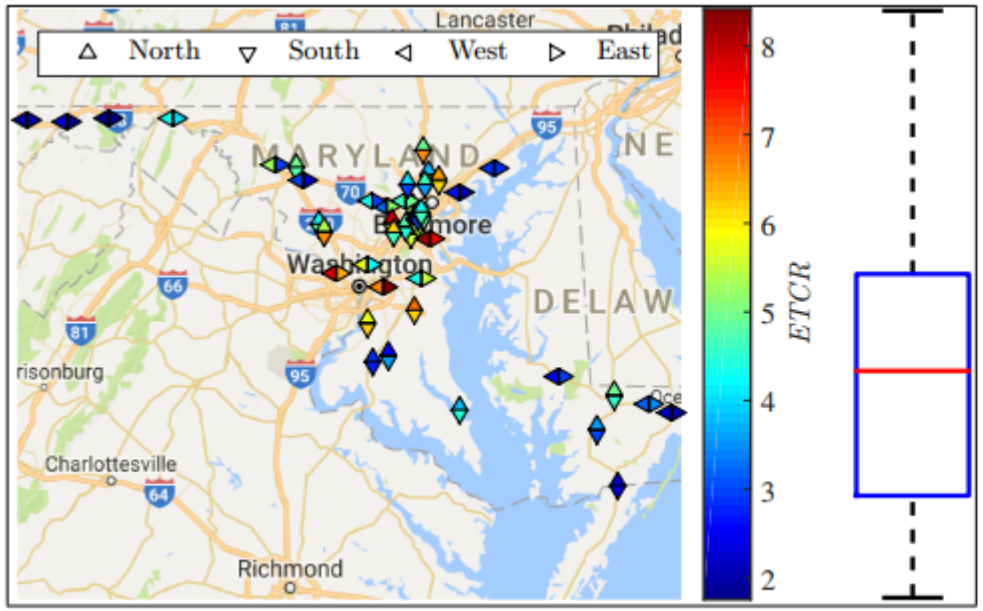
(a) R^2 for test locations



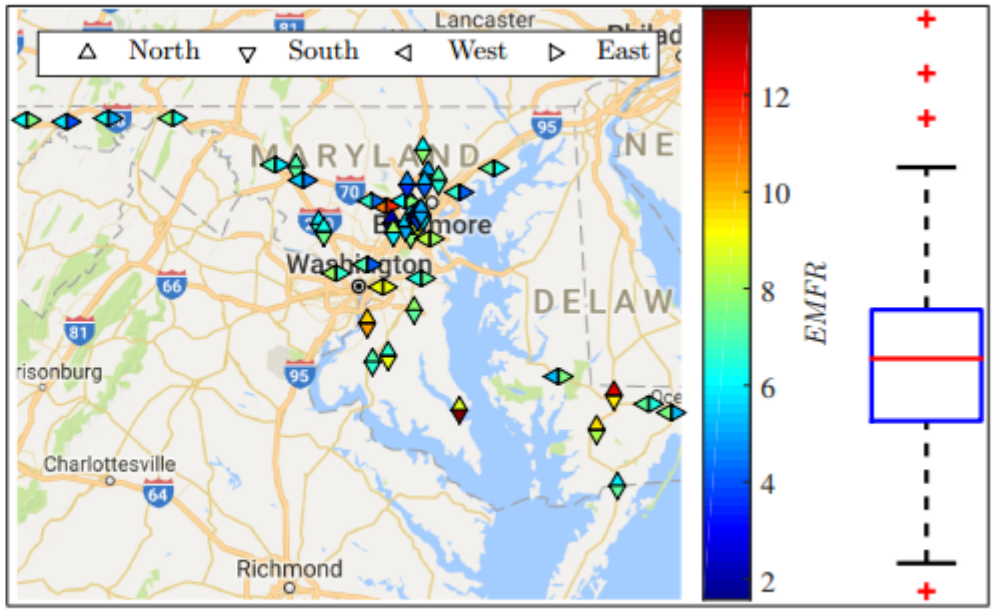
(b) $MAPE$ for test locations

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%



(c) *ETCR* for test locations



(d) *EMFR* for test locations

Results: Current Model Summary

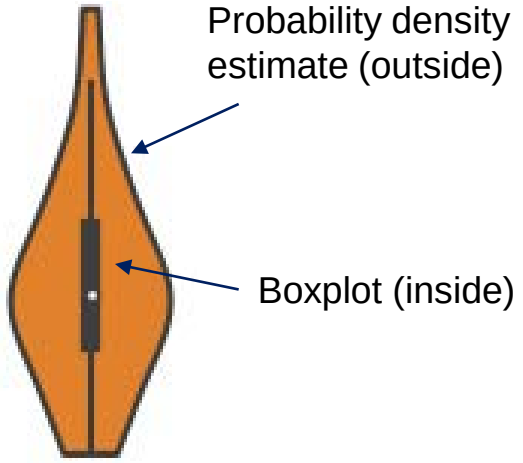
Description	R2	MAPE (%)	ETCR (%)	EMFR (%)	Observations
Day (6am-8pm)	0.58	17.9	5.7	8.5	93,282
Night (8pm-6am)	0.82	26.4	2.0	3.4	64,758
Peak (7am-9am & 4pm-6pm)	0.62	20.0	6.4	9.4	26,858
Off-peak	0.86	23.0	3.6	5.6	131,182
Hourly volume (0-1000)	0.76	28.9	3.0	7.2	68,460
Hourly volume (1000-2000)	0.84	25.1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

* Median values

Current Model Accuracy vs. GPS Volumes

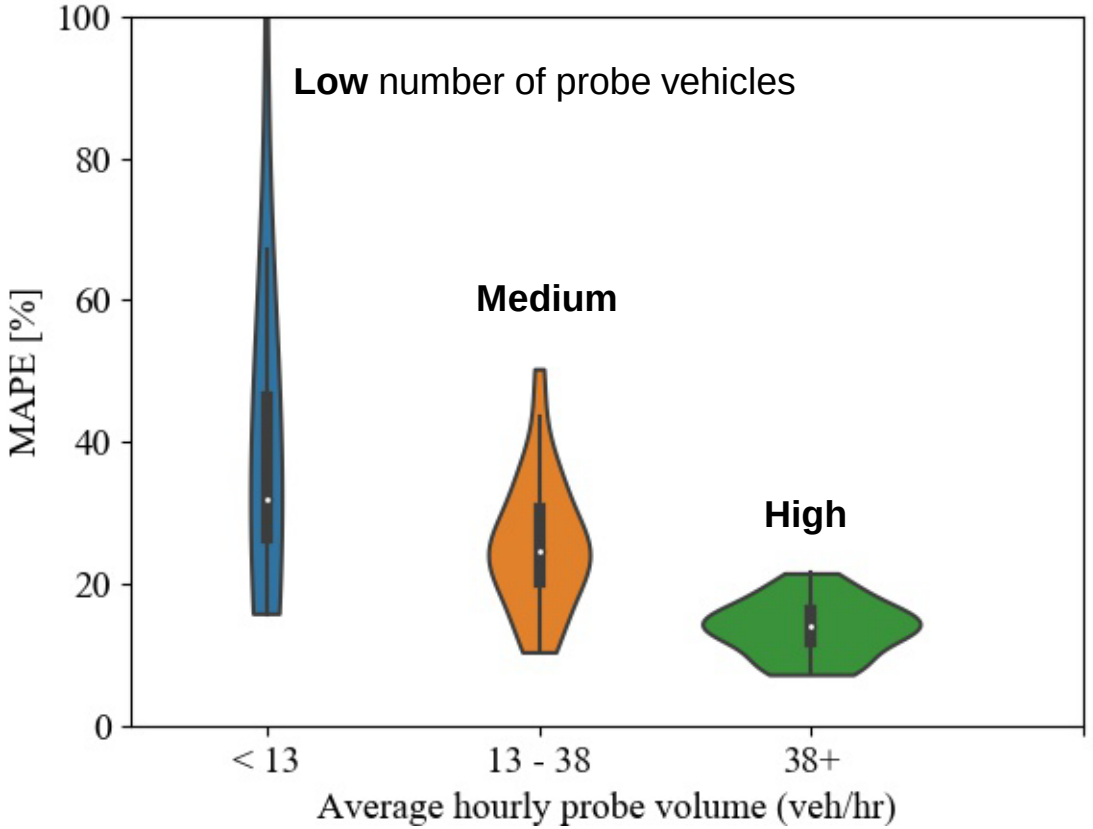
Q: How is model performance impacted by number of GPS probe vehicles?

- 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



Sample violin plot

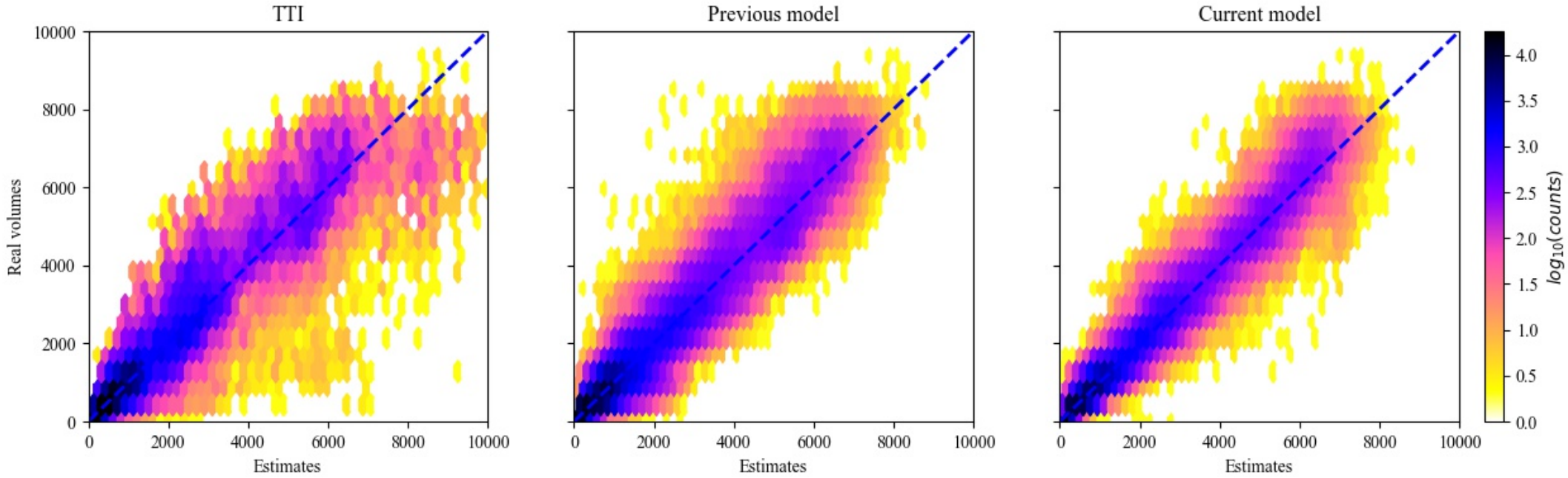
Current Model Accuracy vs. GPS Volumes



- Higher average hourly GPS volumes = higher accuracy, fewer outliers

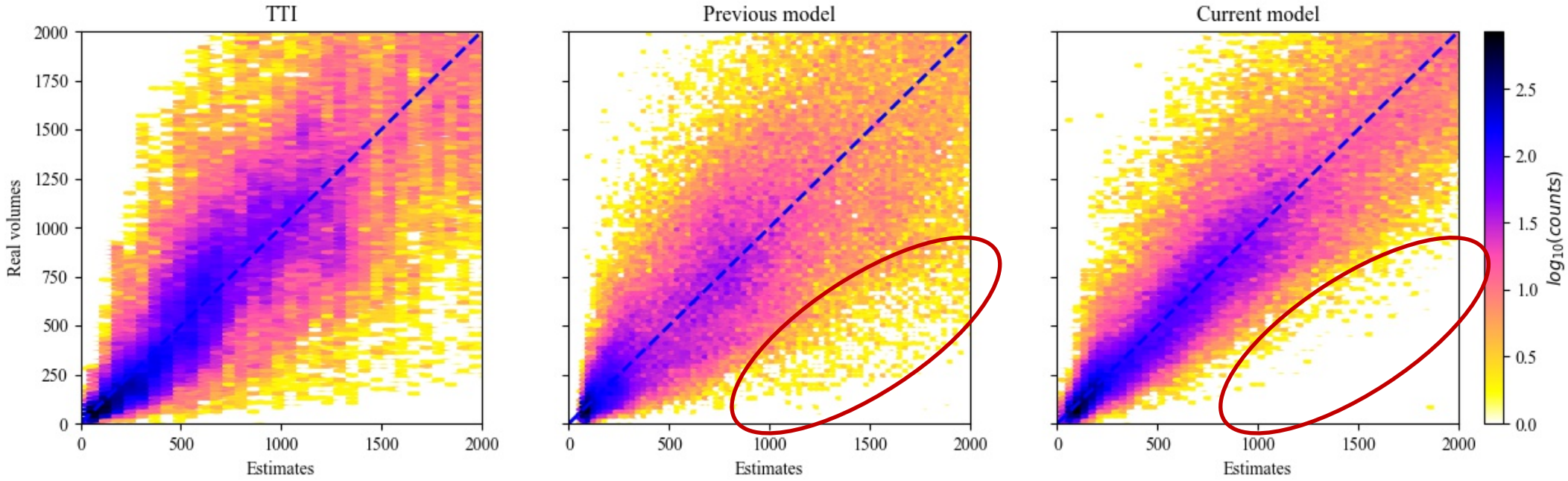
Current vs Previous Model (1/4)

- 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)

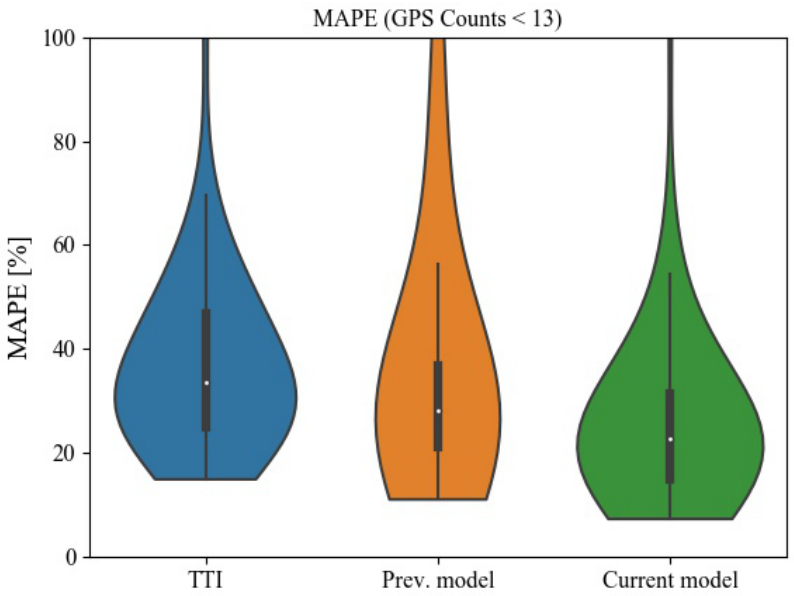
- Focus on lower-volume region (0 - 2000 vph)
- Previous model has a number of outliers at low volumes (circled)
- Current model much better in the circled region, and more concentrated about 45-degree line



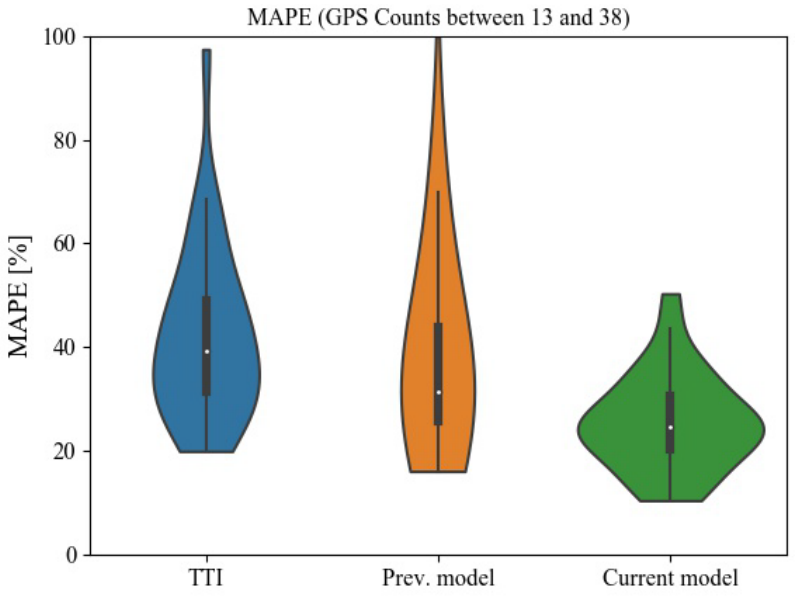
Current vs Previous Model (3/4)

- All models have outliers for low GPS counts
- Current model most accurate, has fewest outliers at all 3 GPS probe intensity levels

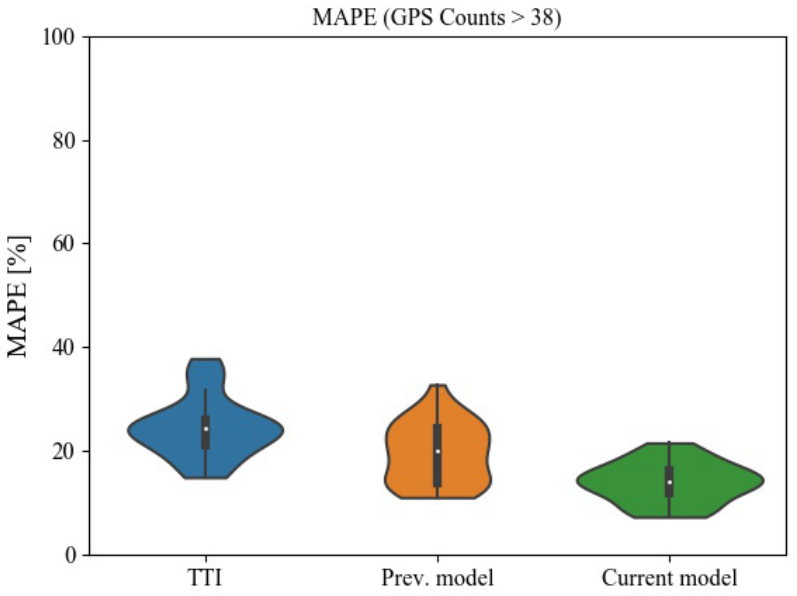
Low number of probe vehicles



Medium number of probe vehicles



High number of probe vehicles



Current vs Previous Model (4/4)

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

Median Error Metrics				
Model	**R2**	**MAPE (%)**	**ETCR (%)**	**EMFR (%)**
TTI	0.70	33.7	5.8	9.1
Previous	0.76	28.2	5.3	7.8
Current	0.86	22.8	4.3	6.5

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

Current Model Improvement (%)				
Baseline Model	**R2**	**MAPE (%)**	**ETCR (%)**	**EMFR (%)**
TTI	22.9	32.3	25.9	28.6
Previous	13.2	19.1	18.9	16.7

Maryland Summary

- 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

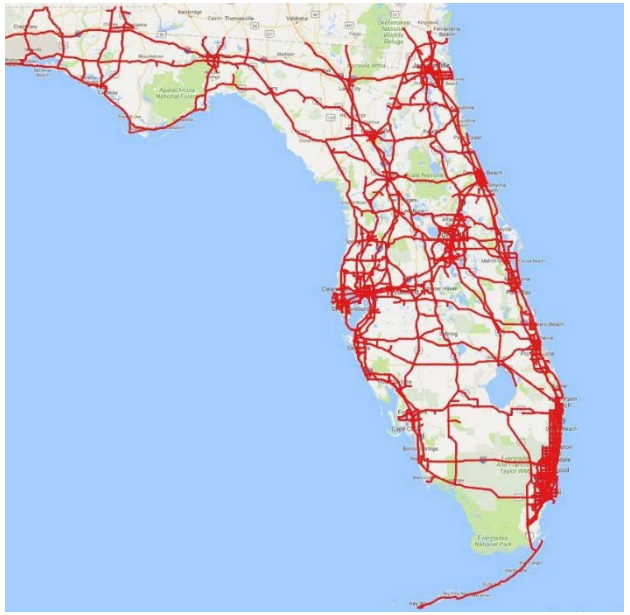
- Estimation accuracy is highly dependent on the number of GPS probe vehicles
  - Penetration rates will likely increase over time

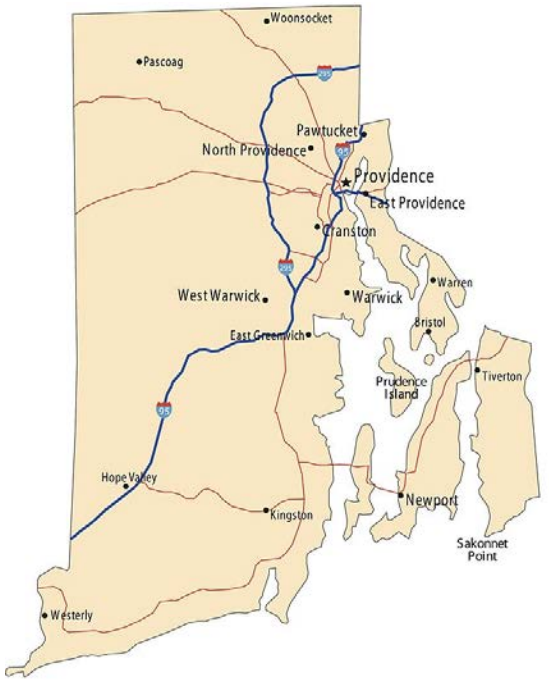
New Datasets: Florida and Rhode Island

- INRIX Q4 2016 data obtained for Florida and Rhode Island
- Waypoints snapped to XD segments → 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

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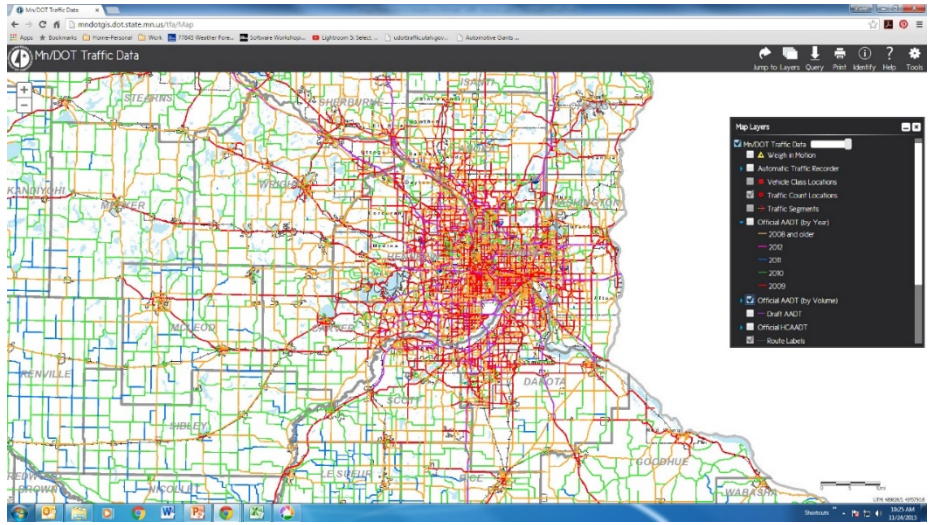
Texas A&M Transportation Institute



Using Mobile Device Samples to Estimate Annual Average Traffic Volumes in MN

Shawn Turner, P.E.

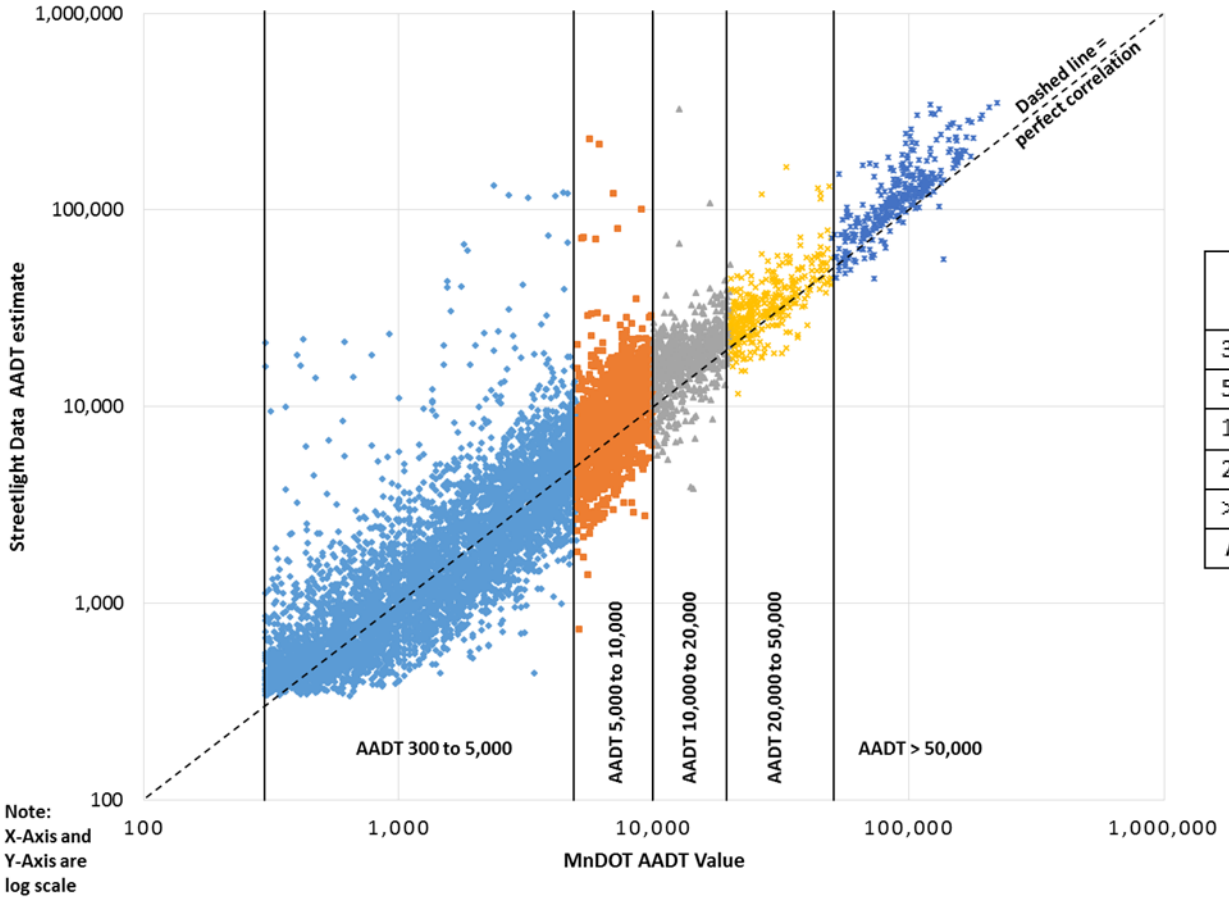
Texas A&M Transportation Institute

I-95 Corridor Coalition Webinar ~ November 9, 2017

Evaluation Synopsis

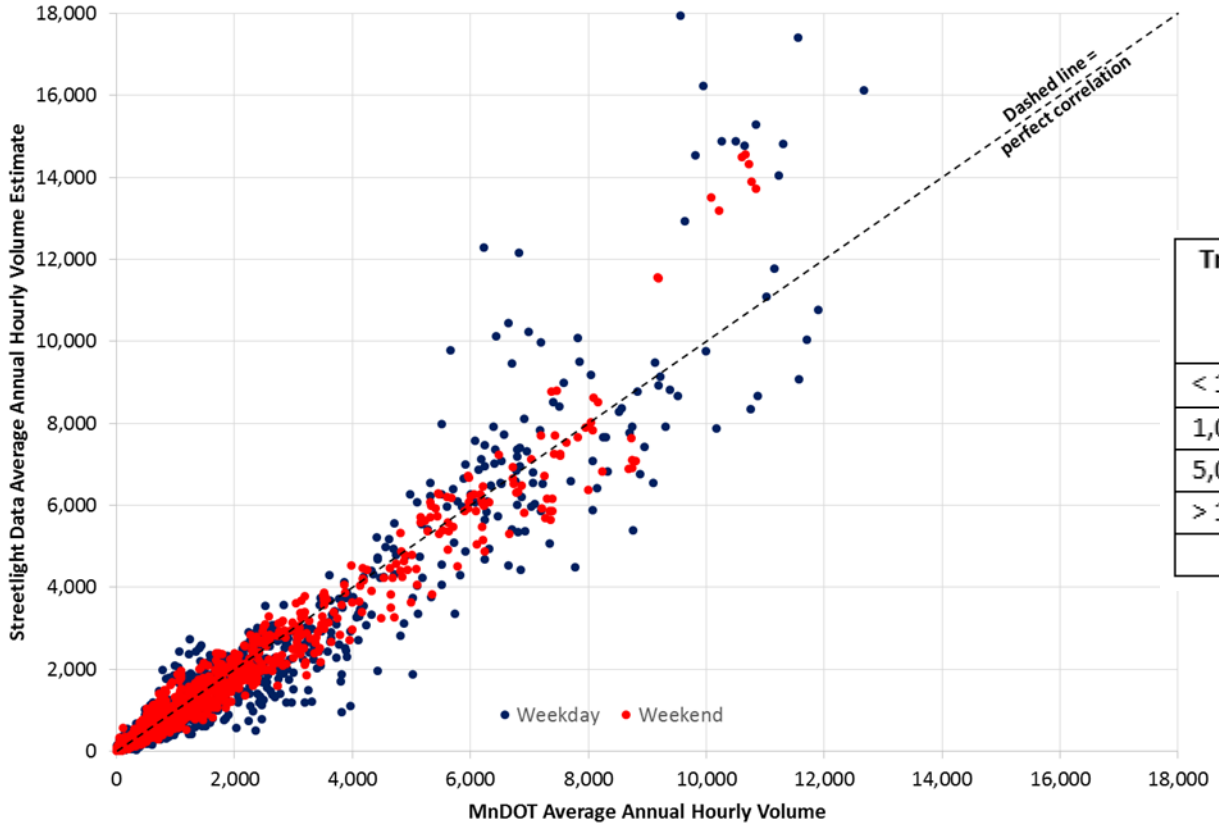
- Multiple companies interested, only StreetLight Data (STL) provided volume estimates
- TTI used MnDOT counts as benchmark
- STL used MnDOT ATRs to calibrate
- Planning-level focus & multiple comparisons:
  - AADT at 7,800+ short duration count locations
  - Avg. annual hourly counts at 69 perm count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

AADT at 7,837 short-duration locations



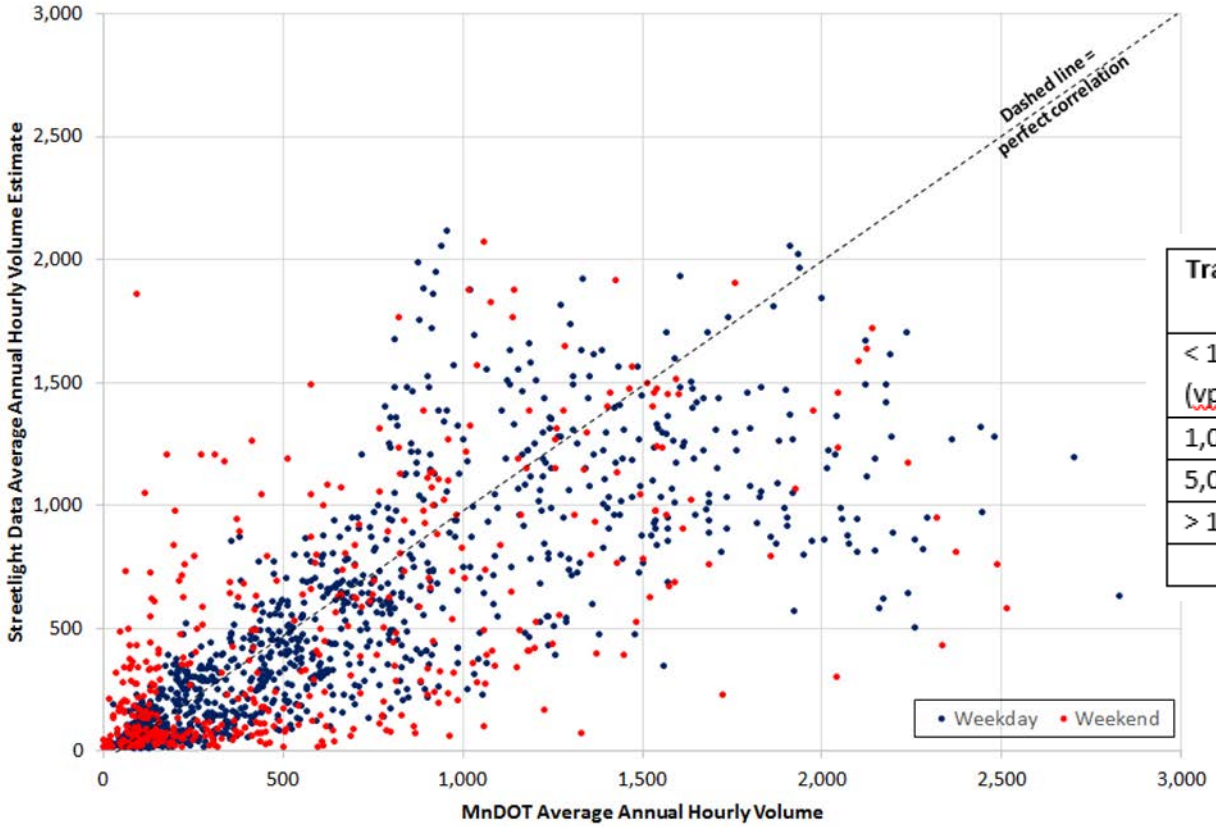
Traffic Volume Level Category	Number of MnDOT Sites	Mean Absolute Percent Error	Mean Absolute Difference	Mean Signed Difference
300 to 5,000 AADT	5,090	68%	1,155	+701
5,000 to 10,000 AADT	1,319	58%	4,023	+2,963
10,000 to 20,000 AADT	759	44%	5,885	+5,043
20,000 to 50,000 AADT	346	29%	8,578	+6,544
> 50,000 AADT	323	34%	34,112	+32,142
All Traffic Levels Combined	7,837	61%	3,782	+3,056

Avg. annual hourly estimates at 69 perm count locations



Traffic Volume Level Category	Number of Hourly Values	Mean Absolute Percent Error	Mean Absolute Difference	Mean Signed Difference
< 1,000 vehicles per hour (vph)	2,129	49%	82	-14
1,000 to 5,000 vph	868	21%	424	-202
5,000 to 10,000 vph	196	16%	1091	4
> 10,000 vph	23	28%	3041	1981
All Traffic Levels Combined	3,216	39%	257	-49

Avg. annual day-of-week hourly estimates at 12 non-public perm count locations



Traffic Volume Level Category	Number of Hourly Values	Mean Absolute Percent Error	Mean Absolute Difference	Mean Signed Difference
< 1,000 vehicles per hour (vph)	1,247	53%	165	-63
1,000 to 5,000 vph	334	34%	535	-433
5,000 to 10,000 vph	0	-	-	-
> 10,000 vph	0	-	-	-
All Traffic Levels Combined	1,581	49%	243	-141

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

1 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

2 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:

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