I-95CC *VTM Phase II Update*
Ubiquitous Traffic Volume from Probe Data

Volume Estimation using Machine Learning Approaches & Probe Vehicle Data: Case Study in Harrisburg, PA

April 21, 2020

CATT Center For Advanced Transportation Technology

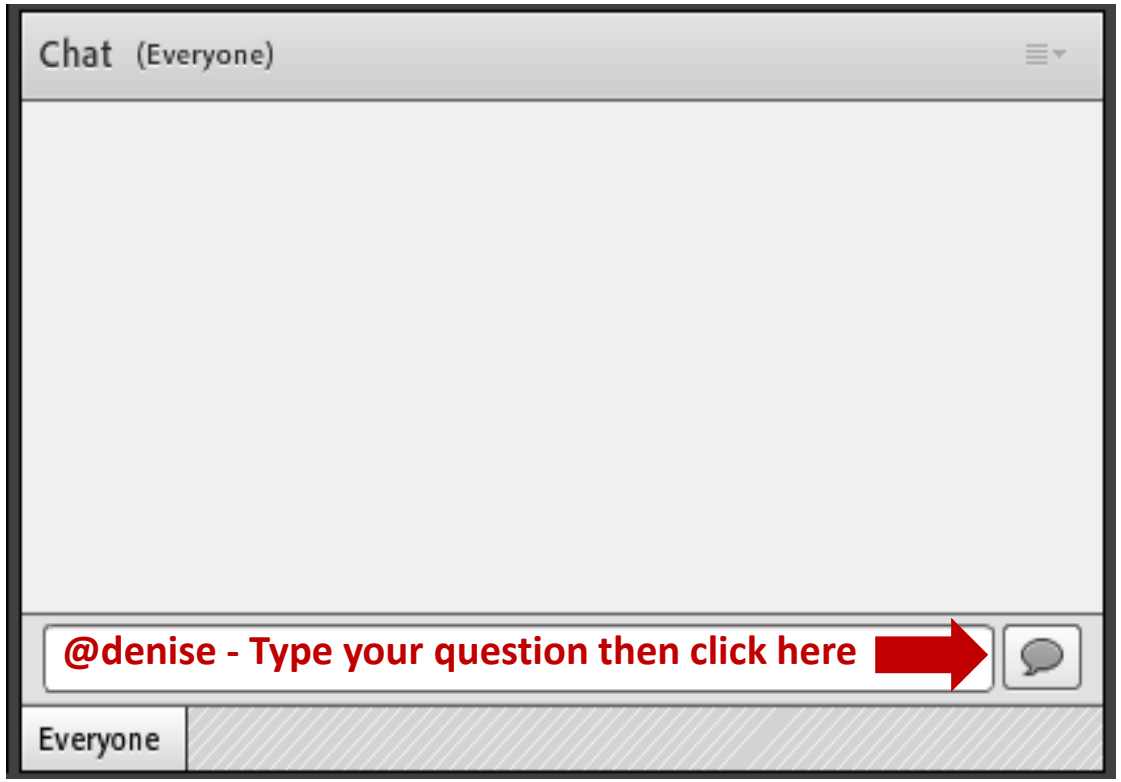
NREL National Renewable Energy Laboratory

Webinar & Audio Information

- The call-in phone number is:
- **Participants will be in “Listen Only” mode throughout the webinar**
- Please press *0 to speak to an operator for questions regarding audio.
- This webinar will be recorded.
- Presentations will be posted to the I-95 Corridor Coalition website. Participants will receive a link to the presentations after they are posted.

Asking Questions

- Please pose your questions using the **chat box**
- Questions will be monitored then answered by the speakers either at the end of their presentation or at the end of the webinar
- Please direct your question to the appropriate speaker



Welcome & Introductions

Denise Markow, PE

I-95 Corridor Coalition

TSMO Director

The Coalition is changing…

New name, new logo, more states
- renewed and stronger
commitment to our members!

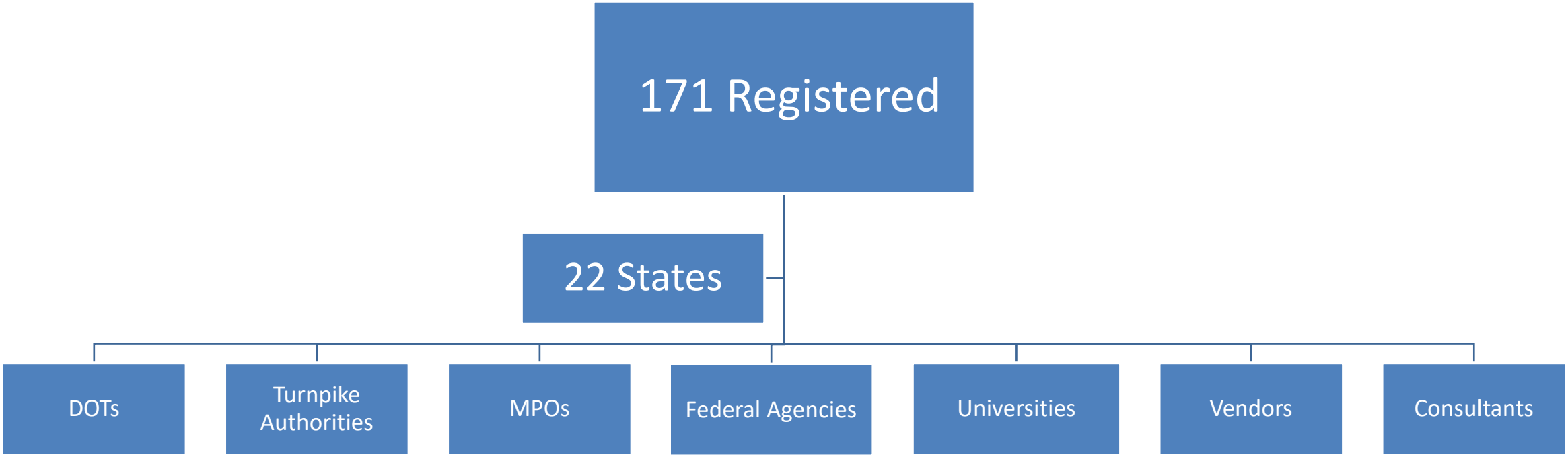
THE EASTERN
TRANSPORTATION
COALITION

CONNECTING FOR SOLUTIONS

Agenda

Time	Topic	Speaker
10:30am-10:40am	Introductions & Welcome	Denise Markow, PE, I-95 Corridor Coalition
10:40am -10:45am	Overview / Objectives	Stan Young, PhD, PE, NREL
11:00am-11:15am	NREL Freeway Results – Harrisburg, Pennsylvania Freeway Results – TomTom Data	Yi Hou, PhD - NREL
11:15am-11:30am	UMD Freeway Results – Traffic Volume Estimation Using GPS Traces: Greater Harrisburg	Kaveh Sadabadi, PhD, UMD CATT
11:30am-11:40am	Lower class roads work & TN & NC status	Stan Young, PhD, PE, NREL
11:40am-12:00pm	Discussion, Questions & Wrap Up	All

I-95 Corridor Coalition Sponsored Event



Project Brief

VTM – Ubiquitous Traffic Volume from Probe Data

"Taking it from the Lab to the Street"

The Eastern Transportation Coalition (formerly I-95 Corridor Coalition)

A new frontier in probe data & analytics

The Eastern Transportation Coalition (**formerly I-95 Corridor Coalition**) sponsored research to achieve accurate volume estimates through outsourced probe data for both operations and planning purposes.

Phase II is now on track to commercialize this data

For many agencies, network-wide volume data remains a key missing dimension for complete and actionable situational awareness, accurately assessing transportation system performance and developing targeted, cost-effective mobility projects and programs.

Phase II tasks in process:

- ❑ *Testing implementation of Phase I with agency partners*
- ❑ *Confirming volume estimates can be used for AADT, ADT and real-time operations applications*
- ❑ *Expanding calibration to arterials and low volume roads*
- ❑ *Quantifying acceptable error bounds / thresholds for planning uses and for operations*
- ❑ *Exploring if probe data can be used to test accuracy of non-ATR counters*
- ❑ *Summarize lessons learned and tips to address conflation needs*

From Point Data → **Ubiquitous Traffic Volume Data**

THE EASTERN TRANSPORTATION COALITION

Phase I Accomplishments

- ❑ Created a practical and logical framework for the delivery of probe-based volume estimates.
- ❑ Developed methods to ensure and measure the accuracy of the volume estimator.
- ❑ Developed the algorithms and methods using machine learning.

Co-Principal Investigators

Kaveh Sadabadi
Center for Advanced Transportation Technology
kfarokhi@umd.edu

Venu Garikapati
National Renewable Energy Laboratory
Venu.Garikapati@nrel.gov

Coalition Contact

Denise Markow
dmarkow@umd.edu

Get involved in a pilot study!

For information, contact:
Stanley.Young@nrel.gov

April 2020

CATT Center For Advanced Transportation Technology | THE EASTERN TRANSPORTATION COALITION | NREL

VTM – Ubiquitous Traffic Volume from Probe Data

"Taking it from the Lab to the Street"

The Eastern Transportation Coalition (formerly I-95 Corridor Coalition)

Why do we need more and better volume data?


Operations

Forecasts (special events)

Operations
- ❑ Detect real-time traffic volume in the network
- ❑ Traffic volume during inclement weather, special events

Planning & Performance measures
- ❑ Assess user costs
- ❑ Utilization of existing capacity
- ❑ AADTs – measured, not modeled


Performance Measures

Economic & Energy assessment
- ❑ Estimate economic impact of congestion
- ❑ Quantify VMT and energy use


Planning

What our members are saying

"Having robust estimated volume data derived from probe data would be a tremendous asset for DVRPC, complementing the speed and travel time data we're already using from the VPP Project to facilitate analysis of our entire road network, including problem identification, project development, and comprehensive, accurate system performance evaluation."

Jesse Buerk
Capital Project Development Manager
Delaware Valley Regional Planning Commission

dvrpc

April 2020

Speakers

Stanley Young, PhD, PE
National Renewable Energy Laboratory
(NREL)
Stanley.young@nrel.gov

Yi Hou, PhD
National Renewable Energy Laboratory
(NREL)
Yi.Hou@nrel.gov

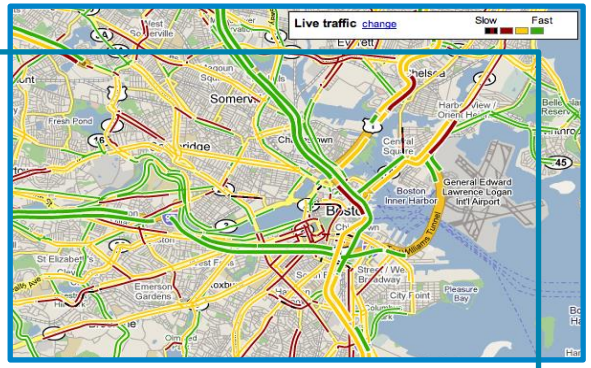
Kaveh Sadabadi, PhD
Center for Advanced Transportation Technology - University of Maryland
(UMD CATT)
kfarokhi@umd.edu

Why Do We Need More and Better Volume Data?

- **Operation**
  - Detect real-time traffic volume in the network
  - Traffic volume during inclement weather and special events
- **Planning & Performance measure**
  - Assess user costs
  - Utilization of existing capacity
  - AADTs – measured, not modeled
- **Economic and energy assessment**
  - Estimate economic impact of congestion
  - Quantify VMT and energy use


Planning


Operations



Performance Measures

Forecasts (special events)

Objective: Traffic Volumes Everywhere at All Times

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 every road

Methodology – Scaling/Conflating Probe Data Observations

Calibration Network

Input

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

Estimator
Machine Learning Techniques

Output

Traffic Volume Everywhere and All Times: Both real-time and historic

Phases of Research

Phase I

- I-95 Corridor Coalition Volume-Turning Movement Research Initiative

Phase II

- Prototype Phase – ‘Getting from the Lab to the Streets’
  - Chattanooga, TN; Harrisburg, PA; Colorado; North Carolina (AADT) & Others
  - **Partners TEST the data**

How we estimate accuracy – Cross Validation

- Repeat this for N times
  - N-1 stations are used for model training
  - 1 station is used for model validation
- Find model hyperparameters that yield the best estimation results
- Train a model using all training data and test model on test data

1st iteration

2nd iteration

3rd iteration

...

Nth iteration

Model Evaluation Criteria

- Error to Maximum Flow Ratio (EMFR)
  - Reflects error relative to the max volume observed, lower is better

$$\text{EMFR} = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|V_i - \widehat{V}_i\right|}{V_{max}}$$

- Coefficient of Determination (R^2)
  - Explanatory power of model
  - Between 0 and 1, higher is better

$$R^2 = 1 - \frac{(\widehat{V}_i - V_i)^2}{(V_i - \bar{V})^2}$$

- Symmetric Mean Absolute Percentage Error (SMAPE)
  - Reflects error relative to measured volume, lower is better,

$$\text{SMAPE} = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|V_i - \widehat{V}_i\right|}{(V_i + \widehat{V}_i)/2}$$

- Mean Absolute Error (MAE)
  - Reflects simple magnitude of error, independent of the actual volume , lower is better

$$\text{MAE} = \frac{1}{N}\sum_{i=1}^{N}\left|V_i - \widehat{V}_i\right|$$

How Good is Good Enough?

Traffic Engineer

- **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)

Statistician/ Planner

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

Highway Operations

- **Error to Capacity (ETCR) or Max Flow (EMFR)**
  - < 10% becomes useful < 5% is target
  - {For highway operations, reflective of capacity constraint situations}

MAPE is Volume Dependent!

AADT Range	Decreasing (-)	Increasing (-)
0 - 19	-100%	400%
20 - 49	-40%	50%
50 - 99	-30%	40%
100 - 299	-25%	30%
300 - 999	-20%	25%
1000 – 4,999	-15%	20%
5,000 – 49,999	-10%	15%
50,000+	-10%	10%

MNDOT Example

Freeway Results – Compare and Contrast

	NREL	UMD
Data Input	TomTom reported # of probes per segment	INRIX Trip Data
Model Region	Harrisburg Region	Statewide, with Harrisburg sub-select
Calibration/Validation Source	Data input: Continuous Count Stations	
Model Type	XGBoost Tree Learning	Neural Network
Probe Mix	Light Duty Vehicles	Light, Medium, Heavy Duty Vehicles
Penetration Rate	~12%	~ 6 to 7%
Results	**Freeway results comparable – consistent with other research, ~5% EMFR, >90% R^2**	

Harrisburg, Pennsylvania
Freeway Results
NREL – TomTom Data

*Preliminary Results

Input Variables

TomTom vehicle probe data	• Probe vehicle counts, Hourly average speed
Weather	• Temperature, precipitation, wind, snow
Road characteristics	• Functional road class, speed limit, longitude, latitude, number of lanes
Temporal information	• Month, day of week, hour of day

Data for Model Training

- July 1st to Dec 31th, 2018
- 8 Stations
- 57,023 observations

FRC Class	# of CCSs
Interstate	6
Freeway / Expressway	1
Principal Arterial	1

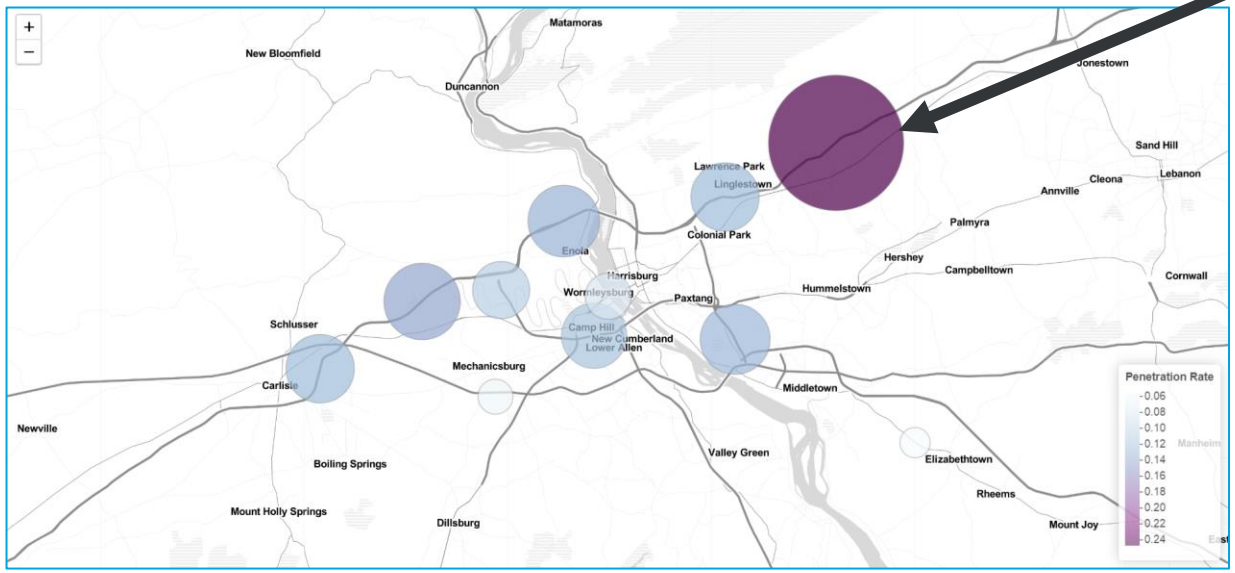
Note: 3.5 stations worth of continuous count data were excluded:
- 3 stations on lower class roads (FRC 4)
- The south direction of station 701

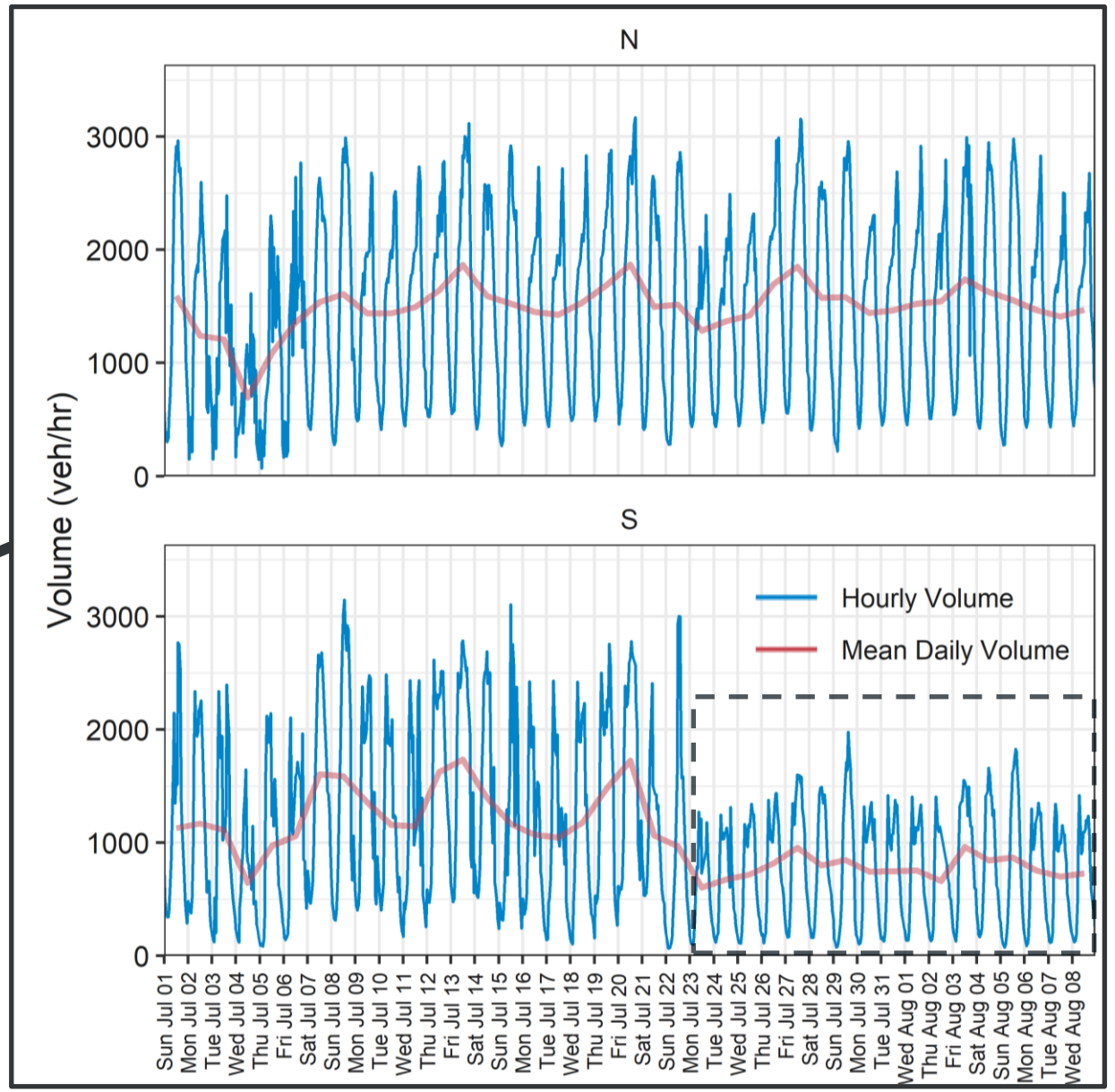
Average Traffic Volume by Station

Note: The circle sizes also scale with volume

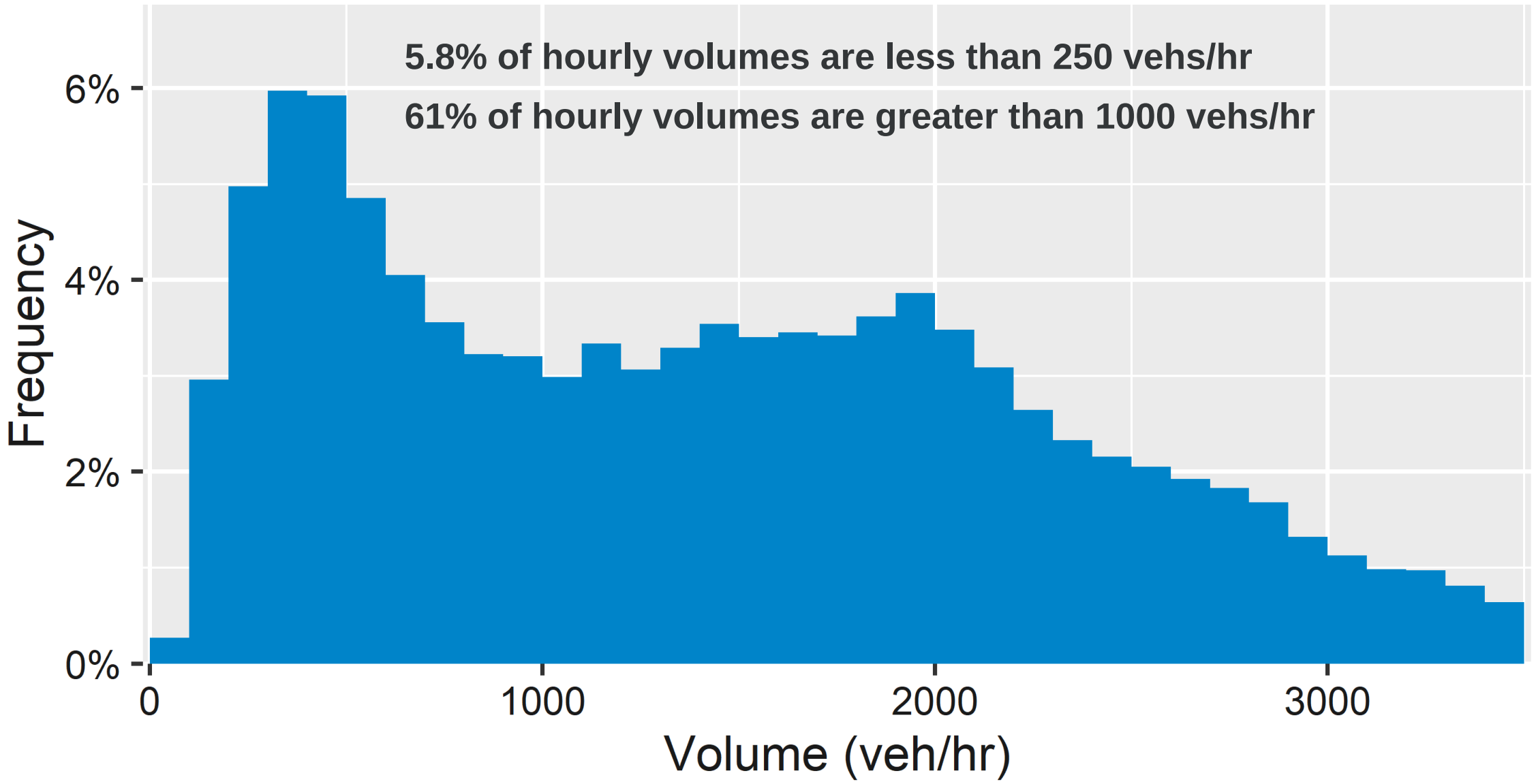
Station 701 Southbound

- Anomaly on southbound at station 701 was detected
- Station 701 southbound was excluded from the model training

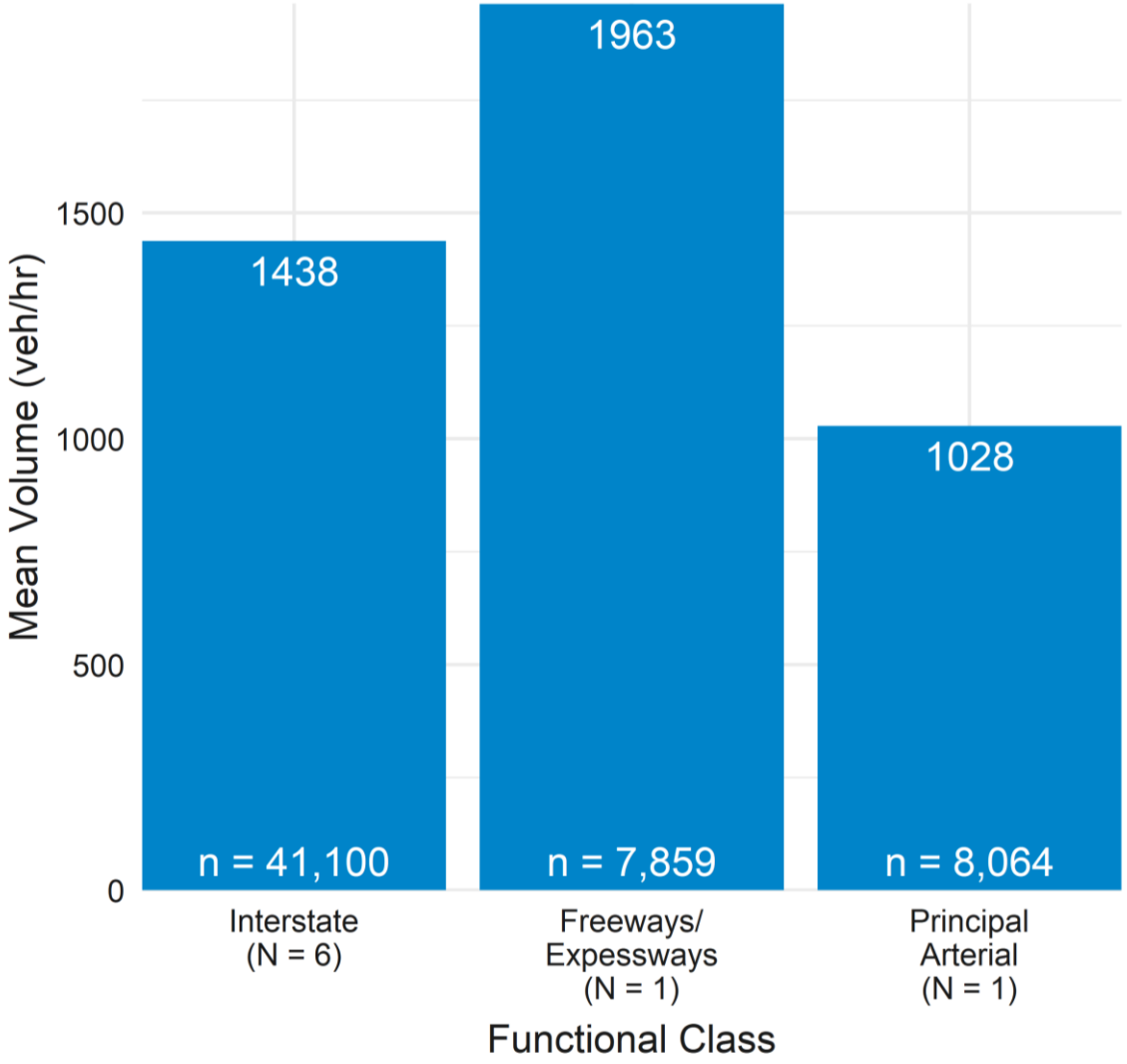


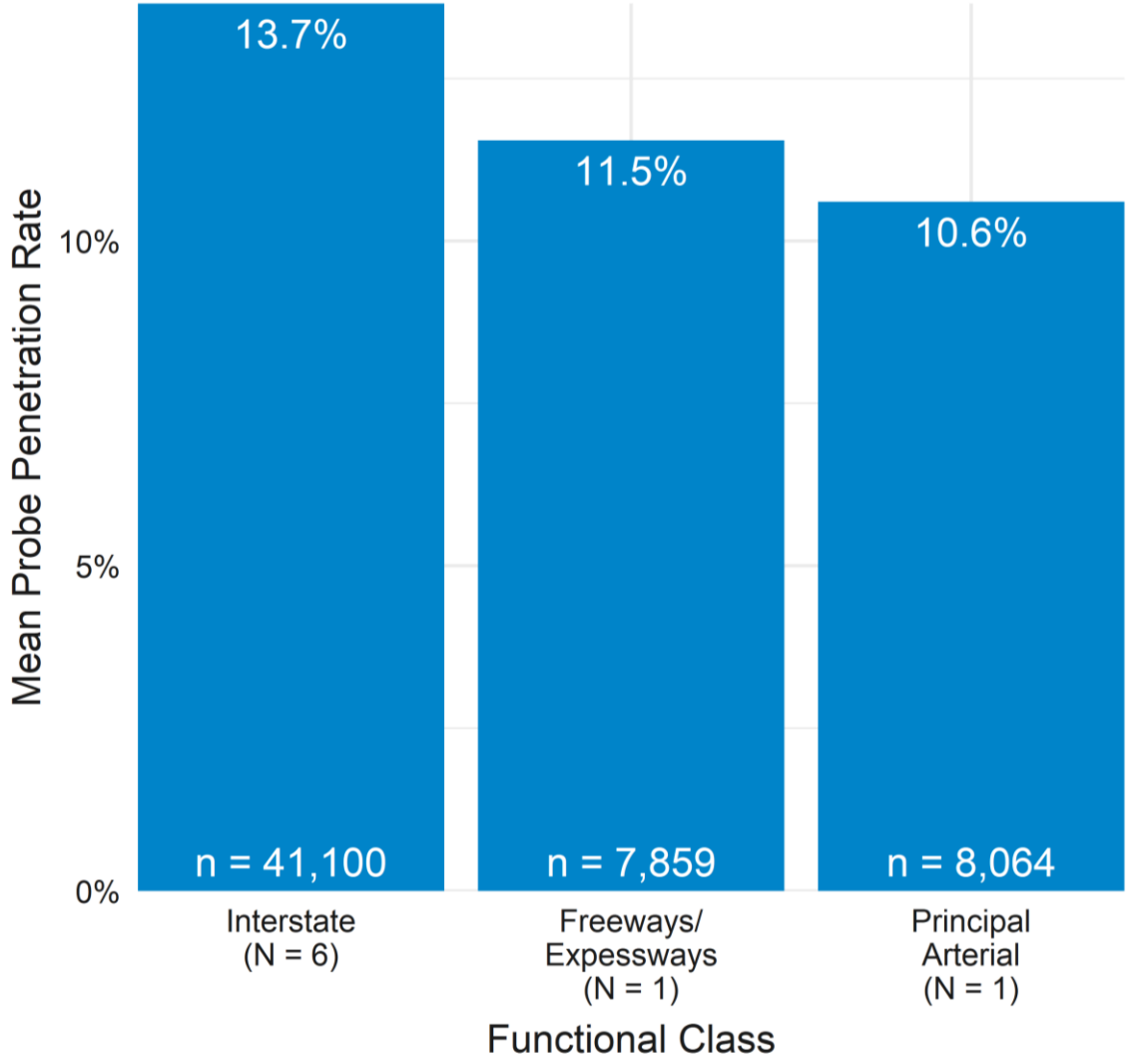


Freeway & Interstate Volume Distribution

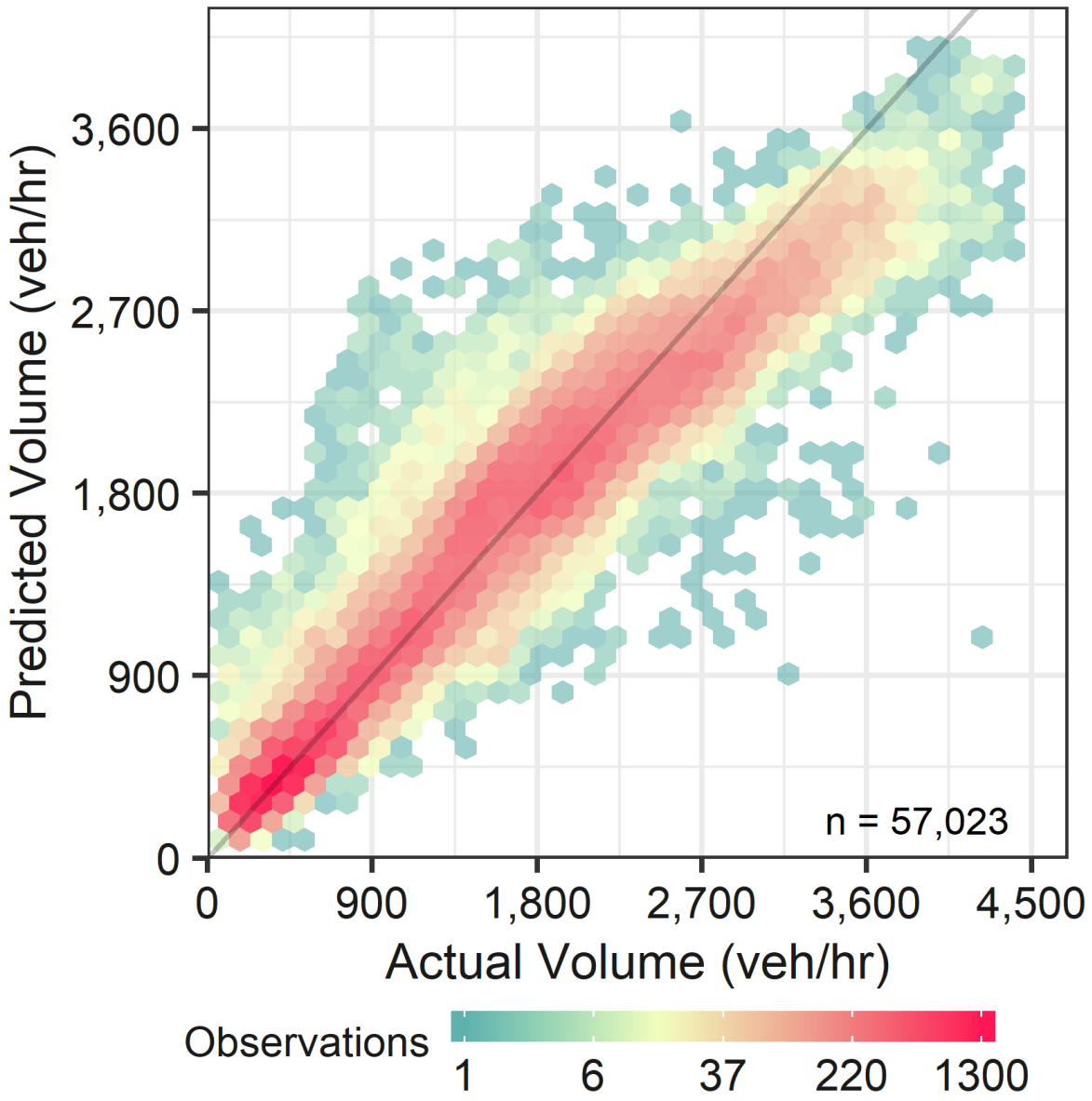


Mean Volume & Probe Penetration by Road Class

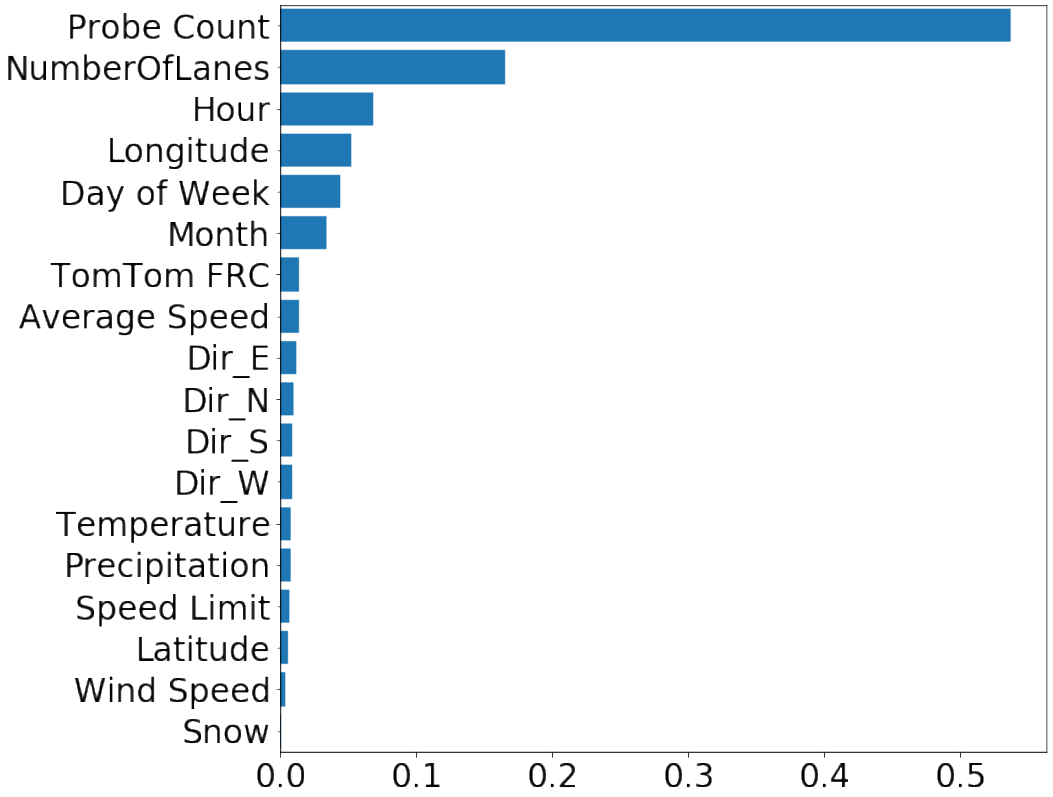




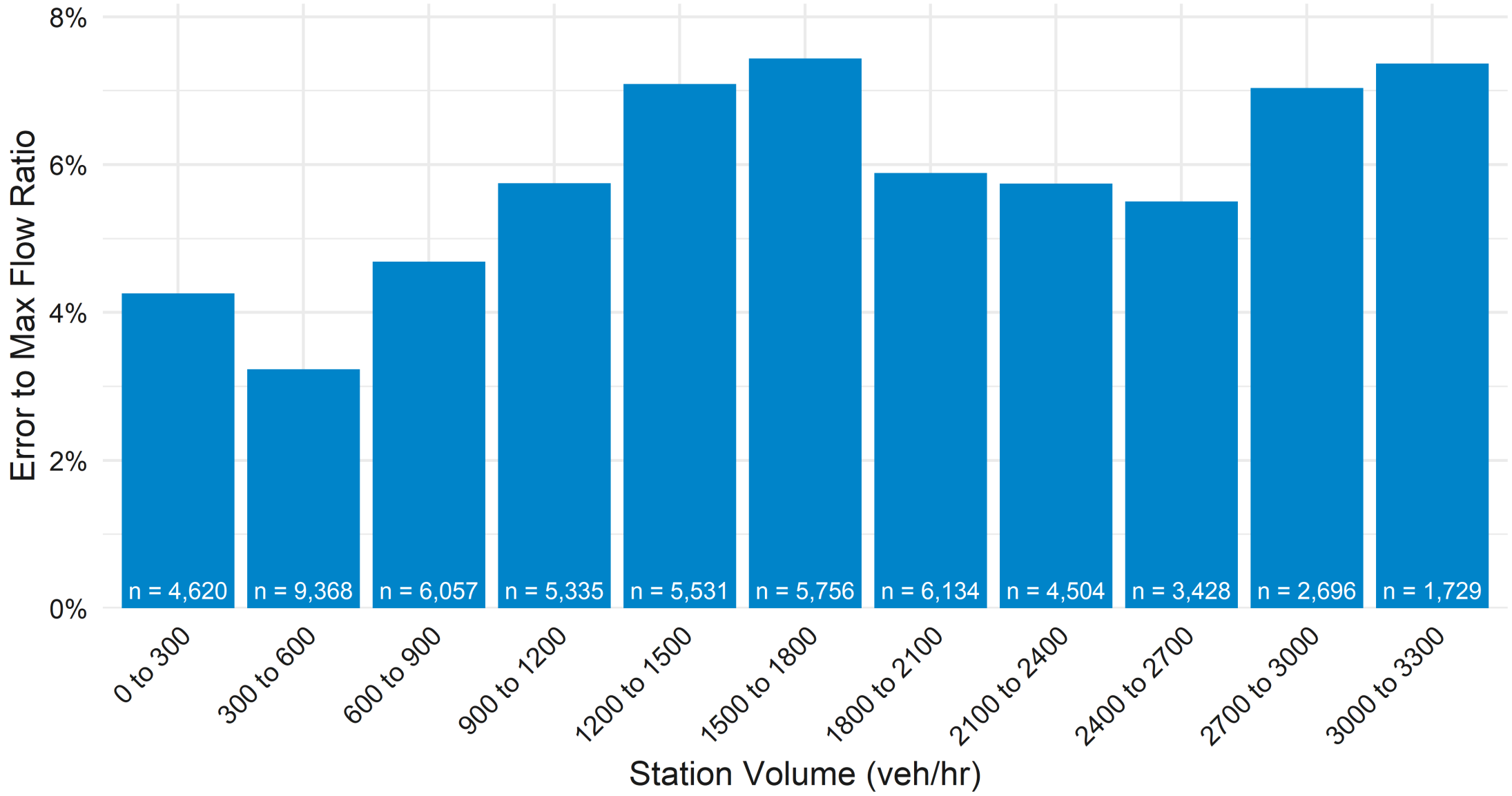
Freeway Volume Estimation Results



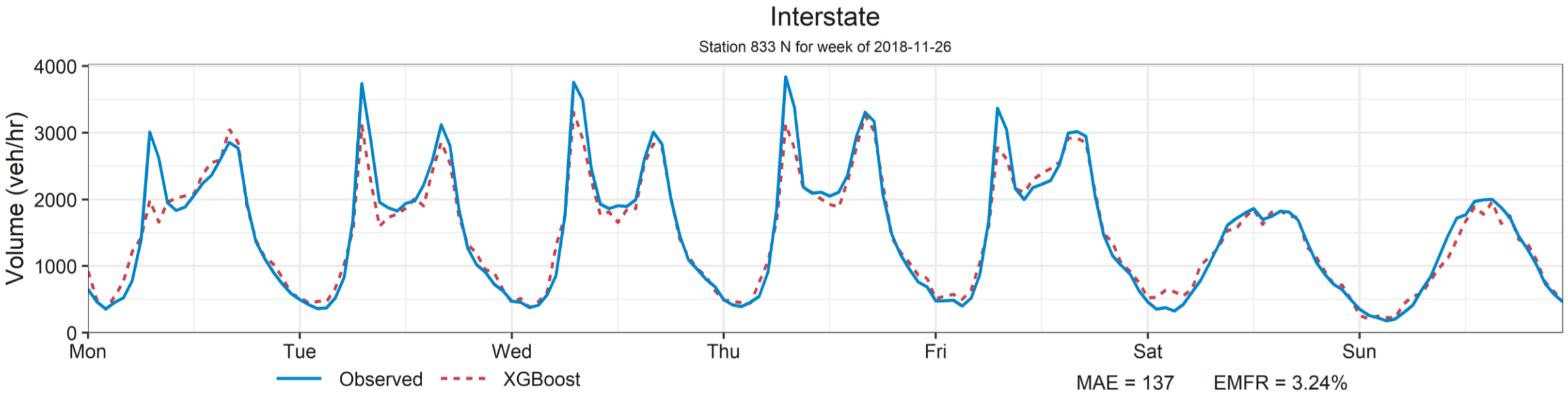
R2	MAE (veh/hr)	SMAPE	EMFR
0.91	194	16.9%	5.7%

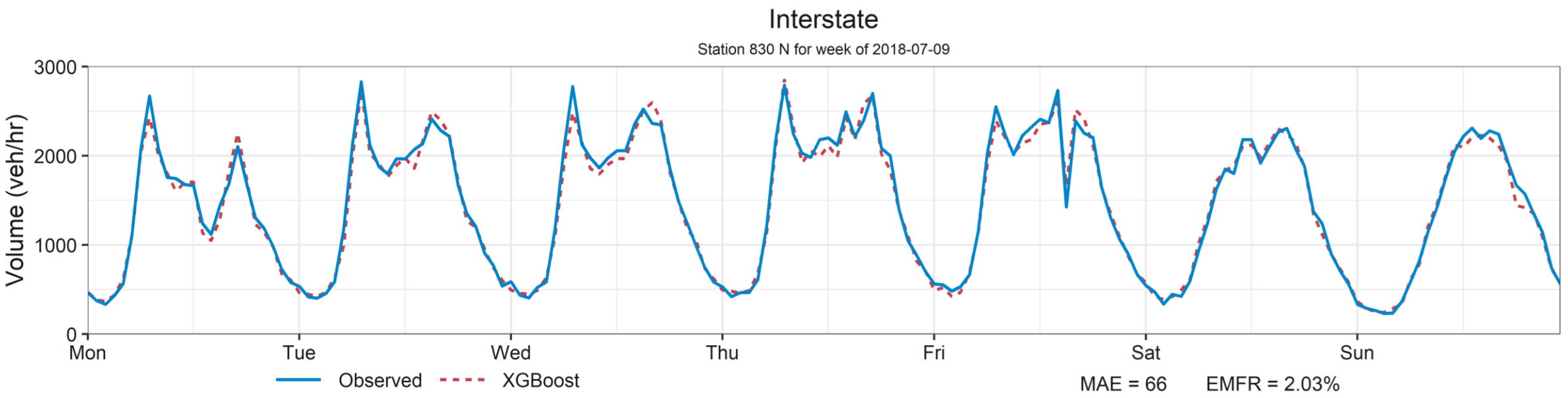


EMFR vs Volume (Freeway)

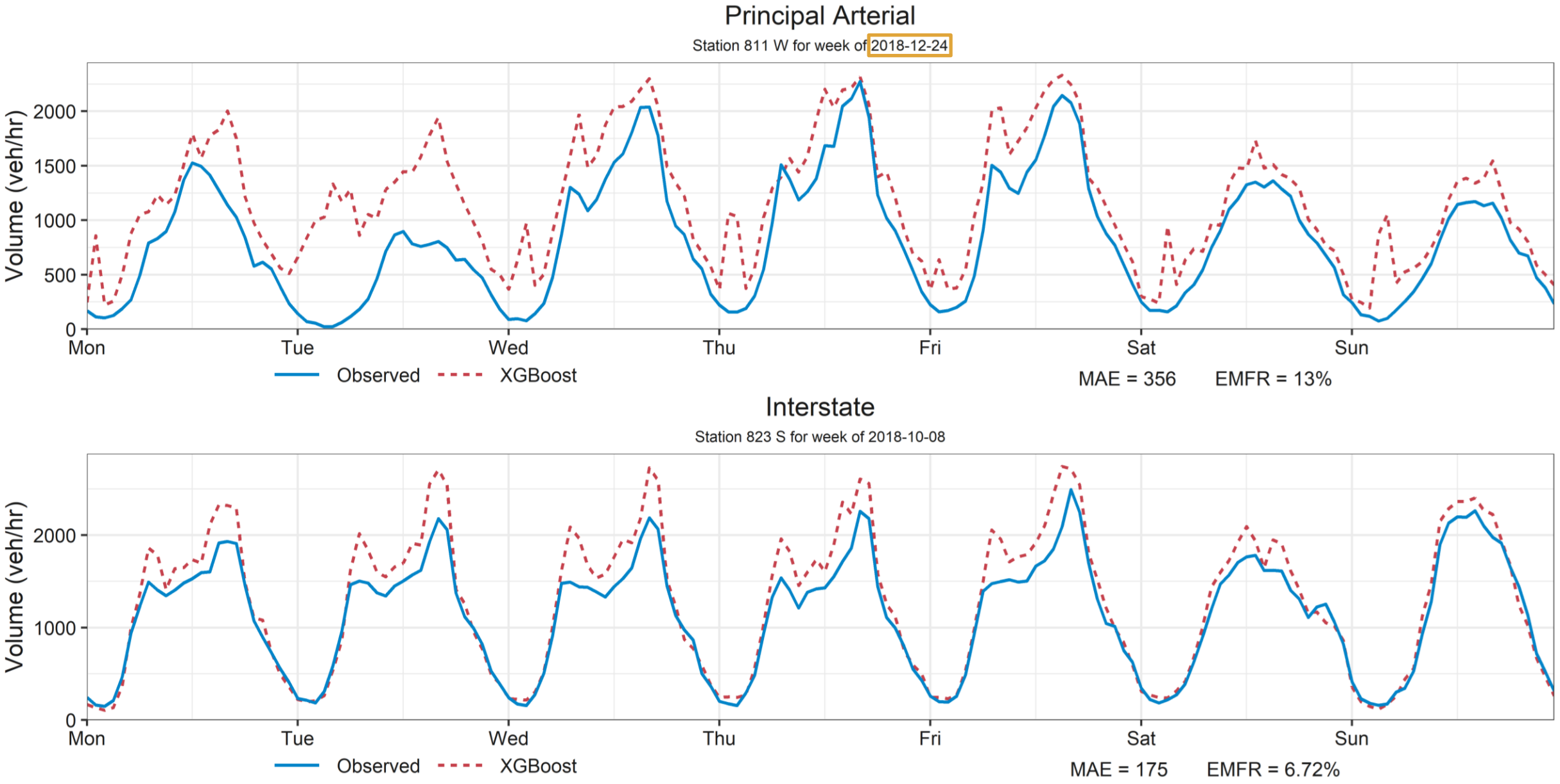


Weekly Predictions: Low Errors





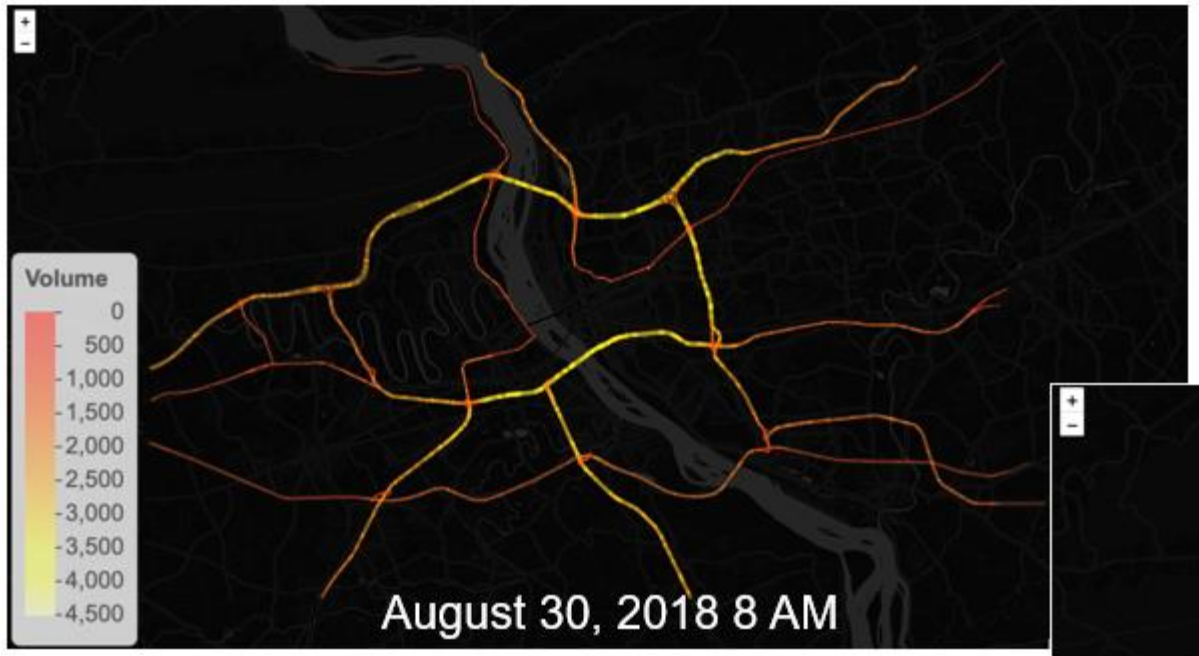
Weekly Predictions: Higher Errors

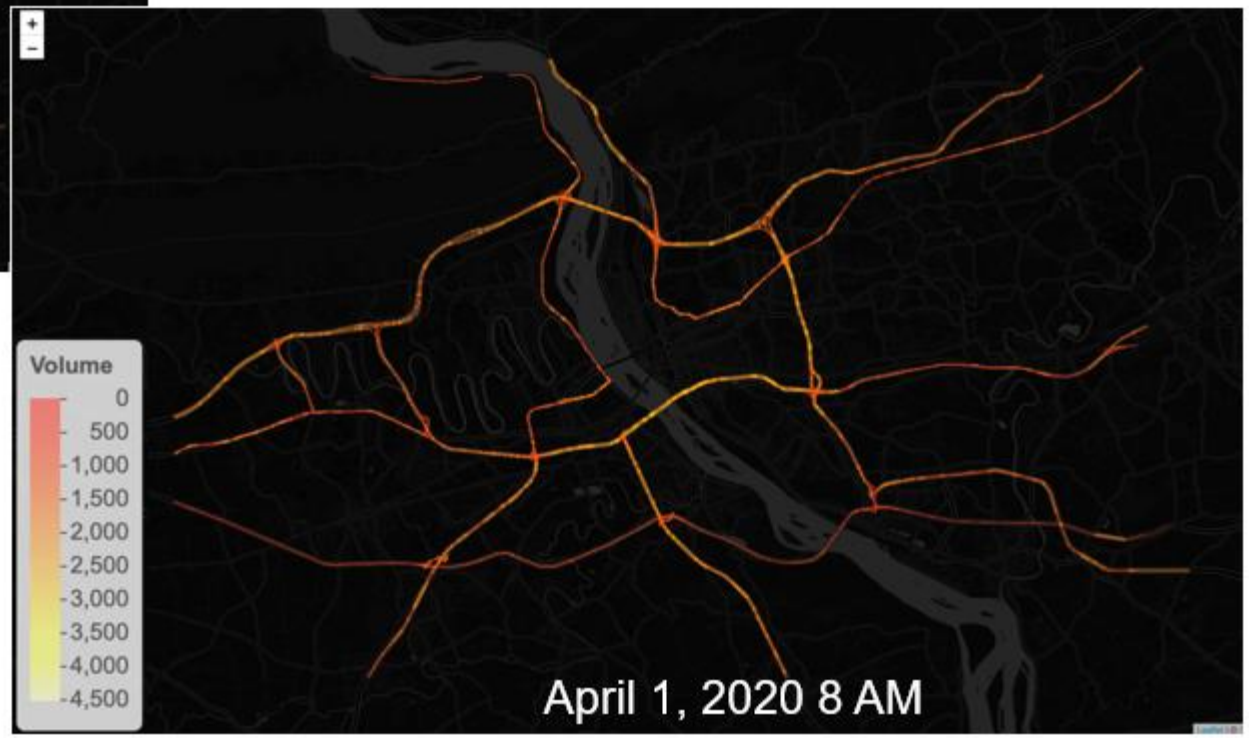


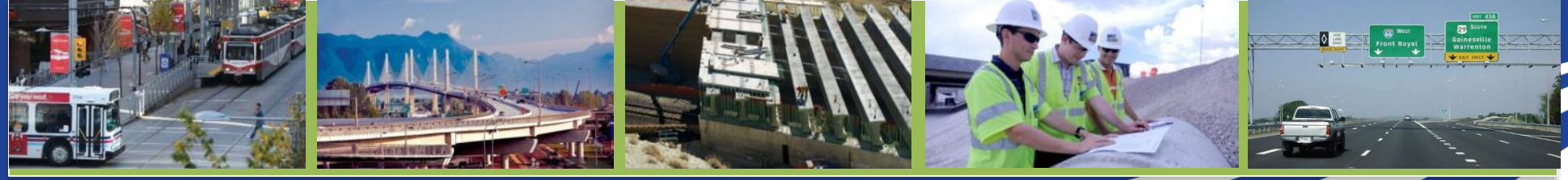
Traffic Volume of Different Hour of Day

Traffic Volume of Different Hour of Day

Impacts of COVID – Harrisburg, PA







Traffic Volume Estimation Using GPS Traces: Greater Harrisburg

Analysis Performed by:
Przemyslaw Sekula psekula@umd.edu and
Zachary Vander Laan zvanderl@umd.edu

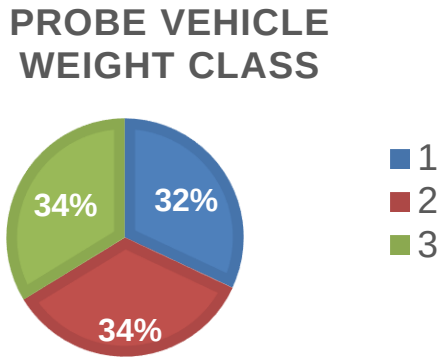
Presented by:
Kaveh Farokhi Sadabadi kfarokhi@umd.edu

April 21, 2020

Data Sources

Input Data (network-wide)

- **GPS probe data** (INRIX)
  - 44.5M trips
  - New “paths” dataset
    - Routed to OSM network
    - Balanced vehicle types
  - Penetration Rate: ~6-7%
- **Probe speeds** (INRIX)
- **Road characteristics** (HPMS & OSM)
  - # lanes, speed limit, road class, etc.
- **Weather**
- **Temporal Info**

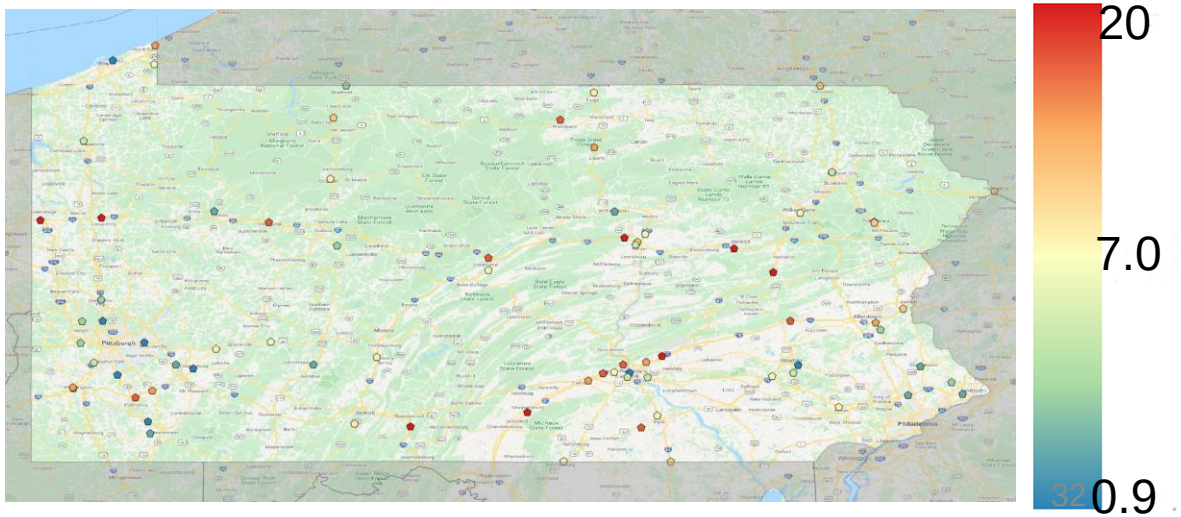


1: cars / light-duty trucks
2: medium-duty trucks
3: heavy-duty trucks

Calibration Data (specific locations)

- **Traffic Counts (permanent CCS & short-term)**
  - Used for model training / evaluation
  - Used to estimate probe penetration rate

Probe Penetration Rates: 1-19% (Median = 6.55)

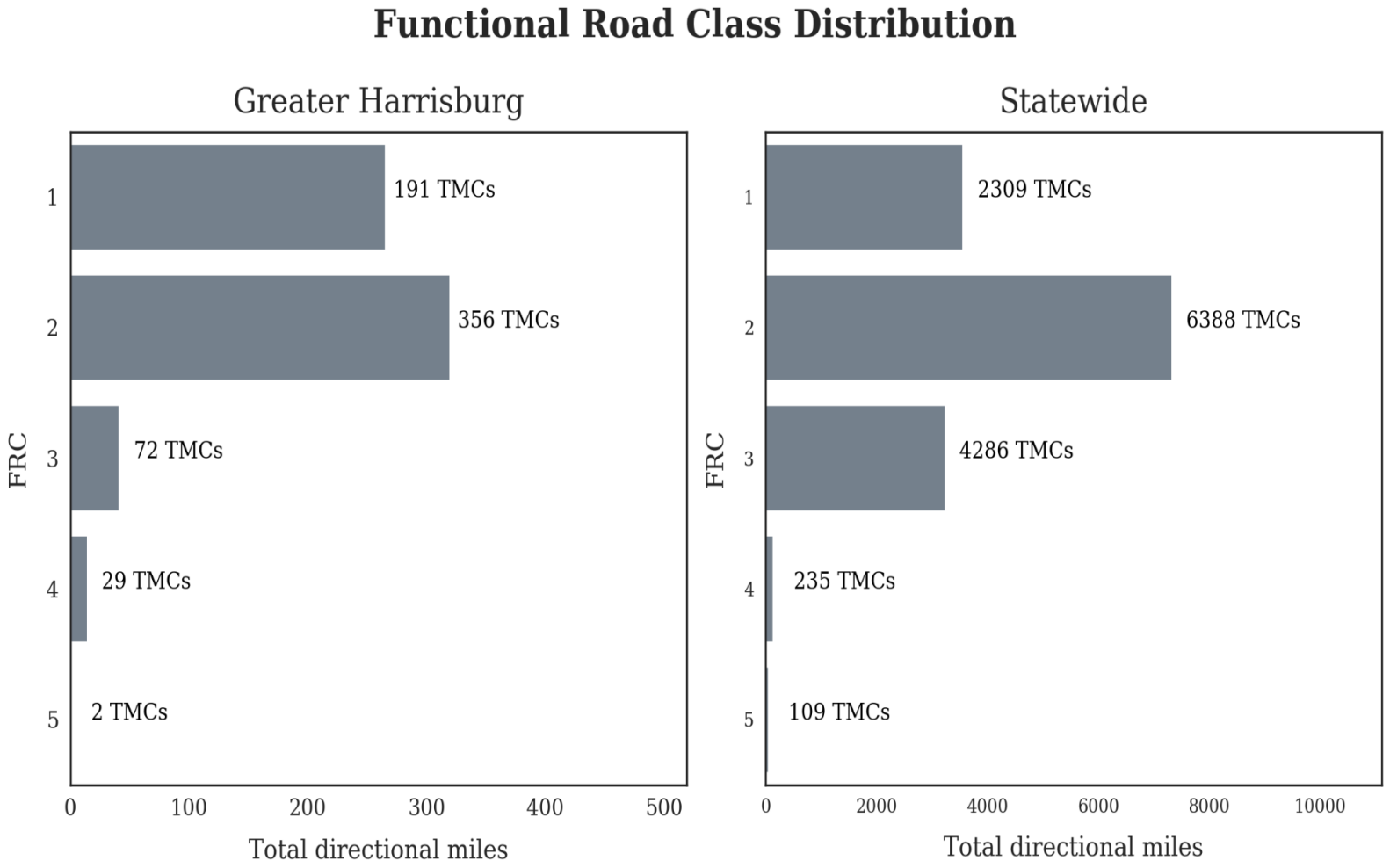


Road Network: FRC

- Road Network used for analysis is primarily FRC 1-3
- Greater Harrisburg Region is mostly FRC 1 and 2

FRC Description

1: Interstates
2: Other freeways & expressways
3: Principal Arterials
4-5: Minor arterials



Continuous Count Stations: FRC

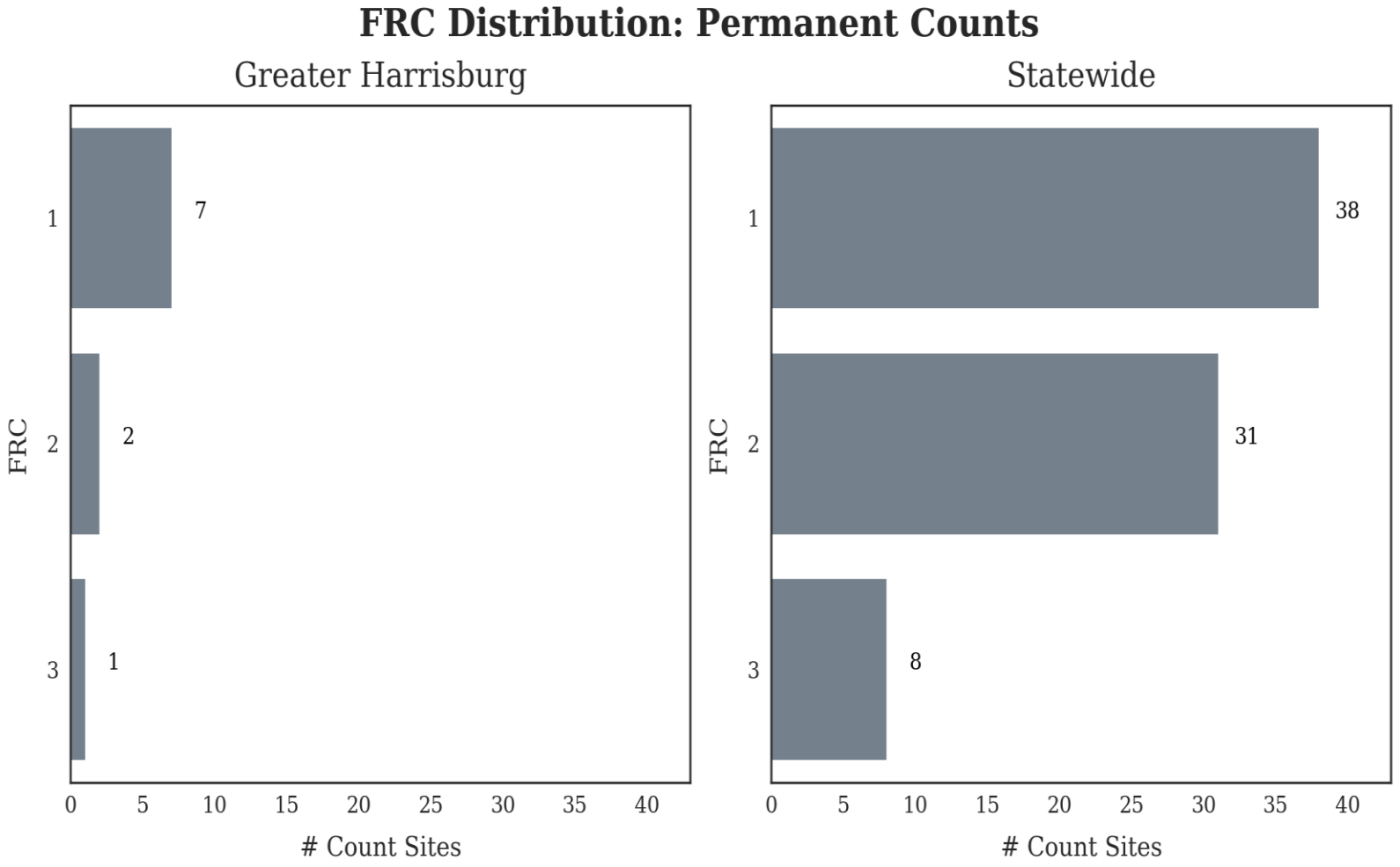
<u>Statewide</u> (300k hours):

- 77 CCS locations
- FRC 1-3, with majority of stations being FRC 1 and 2

<u>GH Region</u> (35k hours):

- 10 CCS locations
- 7 out of 10 are FRC 1

→ Use <u>statewide</u> CCS data to calibrate the model to ensure it learns patterns on FRC 2 and 3



Results:
Greater Harrisburg (hourly volumes)

→ Overall median error metrics:

- R2 = 0.90
- MAPE = 14%
- SMAPE = 14%
- EMFR = 5.8%

Summary

Promising model performance, even over a variety of scenarios

Observations

- ↑ Road class = ↑ Accuracy
- ↑ Avg. hourly volume = ↑ Accuracy

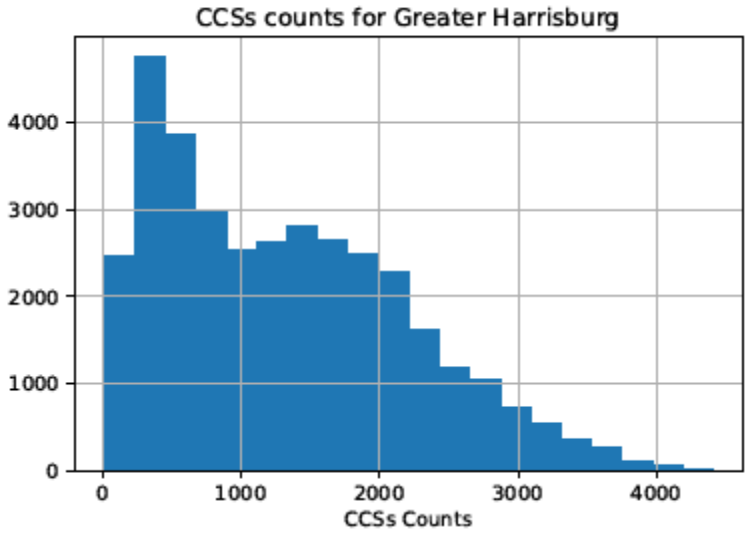
Median Error Metrics by Scenario

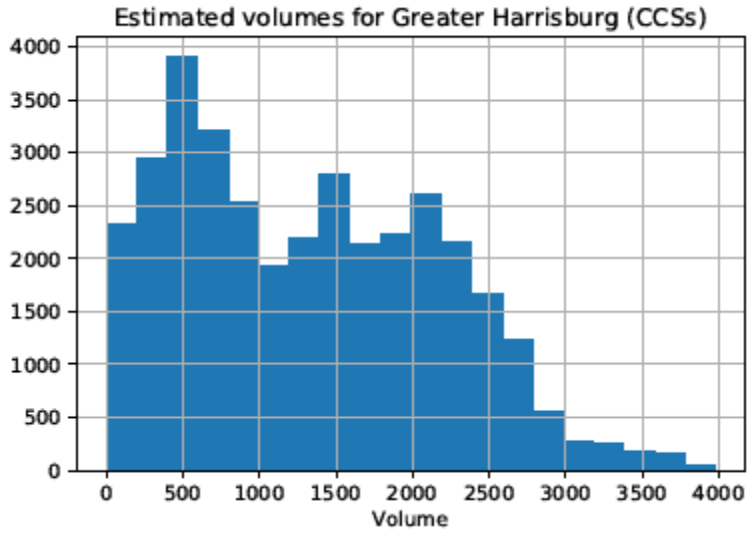
Road Classification	R2	MAPE (%)	SMAPE (%)	EMFR (%)	Obs
FRC 1 (Interstates)	0.90	13	13	5.7	23695
FRC 2 (Other Freeways & Expressways)	0.91	17	15	6.1	8122
FRC 3 & 4 (Other principal & minor arterials)	0.70	30	37	6.9	3089

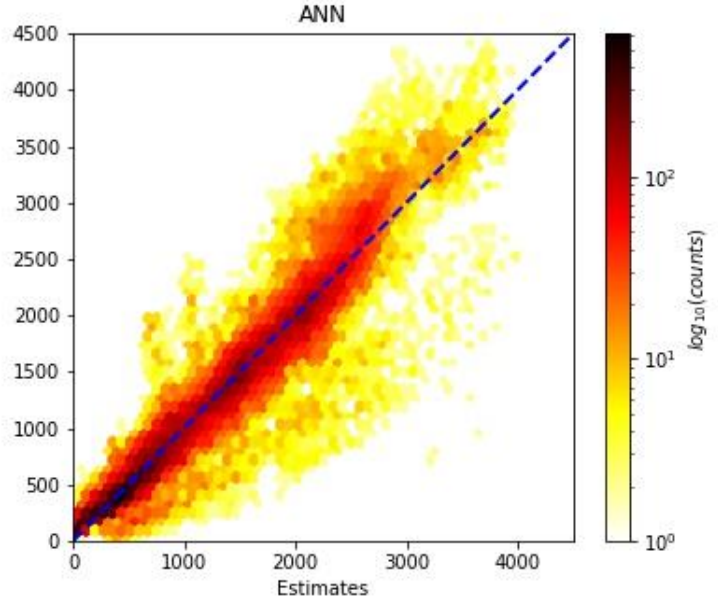
Avg probe counts / hr	R2	MAPE (%)	SMAPE (%)	EMFR (%)	Obs
"Low" [0-77]	0.91	16	22	6.0	13,376
"Medium" [77-150]	0.88	19	15	5.9	12,278
"High" [150-191]	0.89	12	13	5.7	9,252

Hourly Volume (vph)	R2	MAPE (%)	SMAPE (%)	EMFR (%)	Obs
0-1k	0.72	27	32	6.9	5,255
1k-2k	0.92	13	13	5.5	29,259
2k+	0.84	13	14	7.1	392

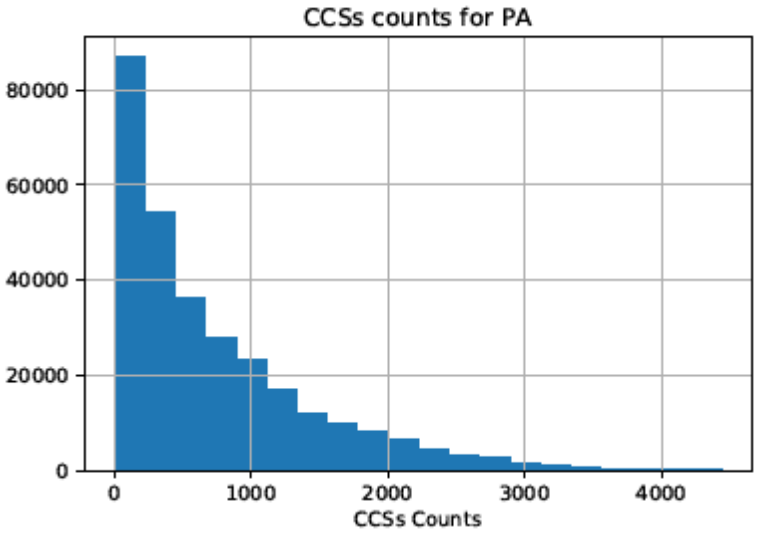
Observed vs. Estimates: Greater Harrisburg (hourly volumes)

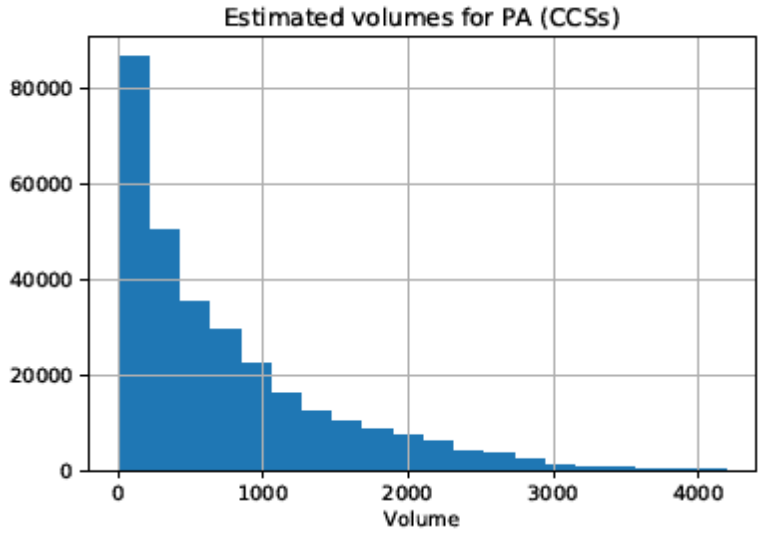


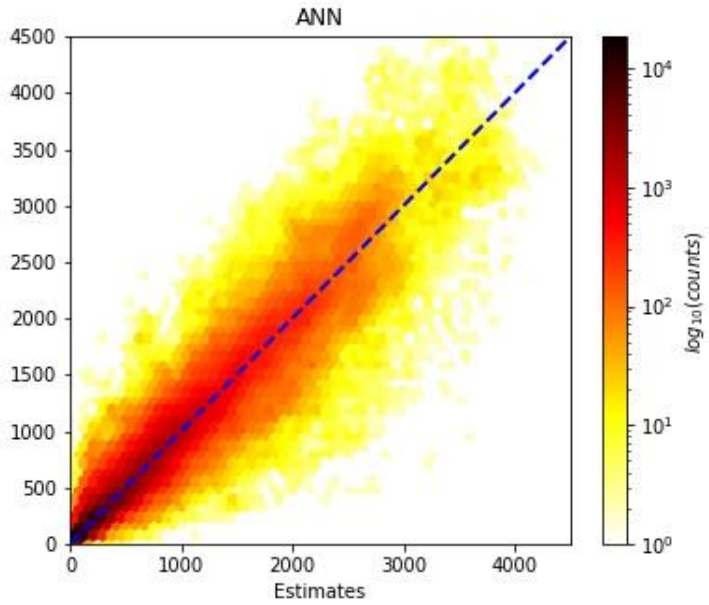




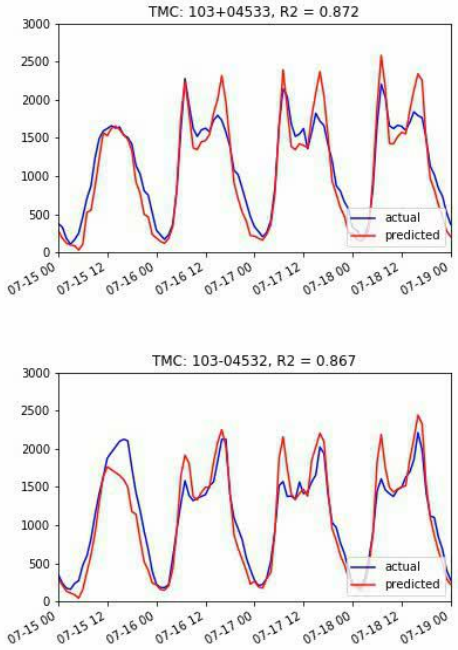
Observed vs. Estimates: Statewide (hourly volumes)

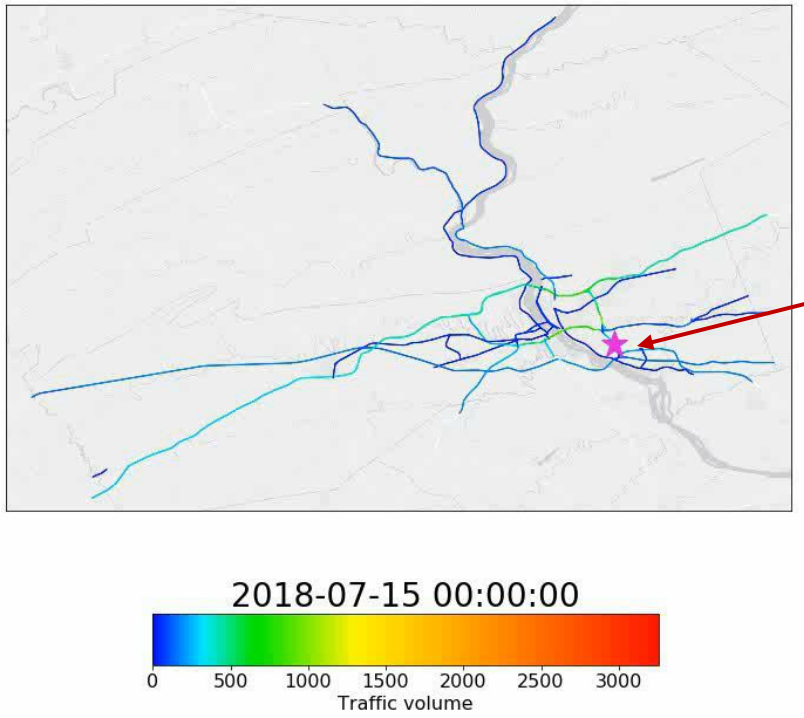






Greater Harrisburg - visualization



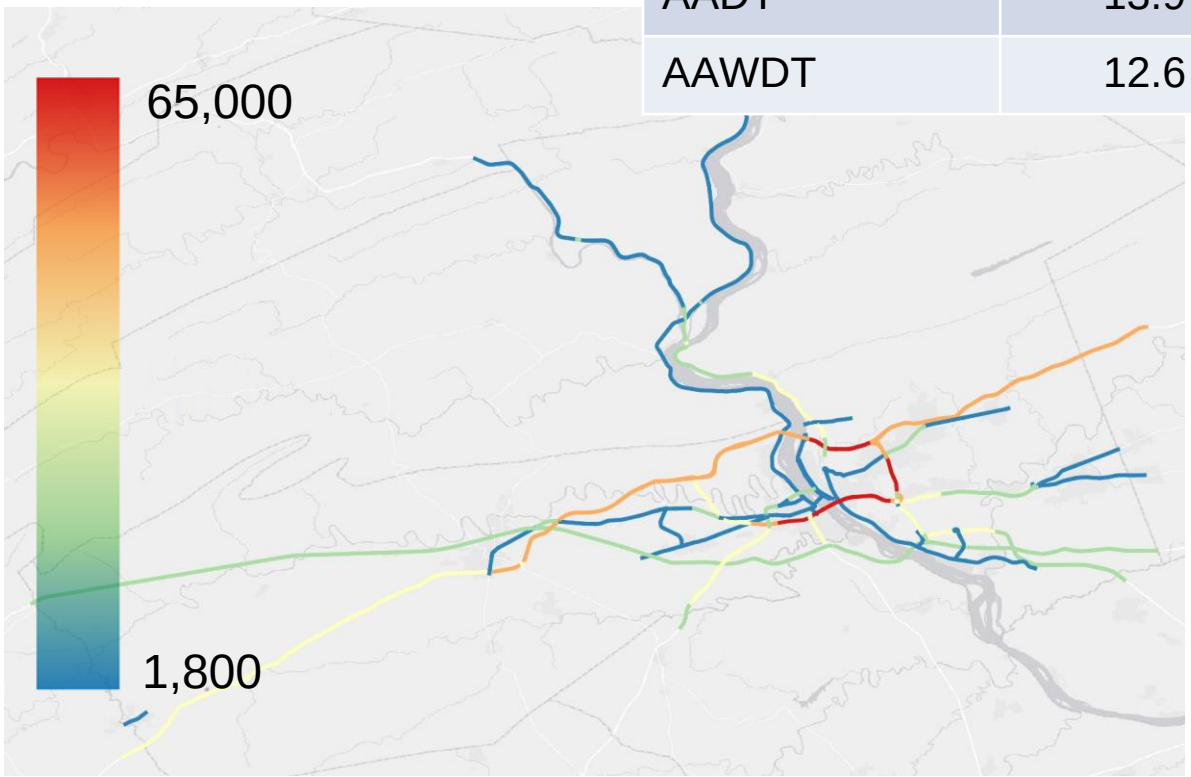


Continuous count station selected that exhibits typical (median) model performance

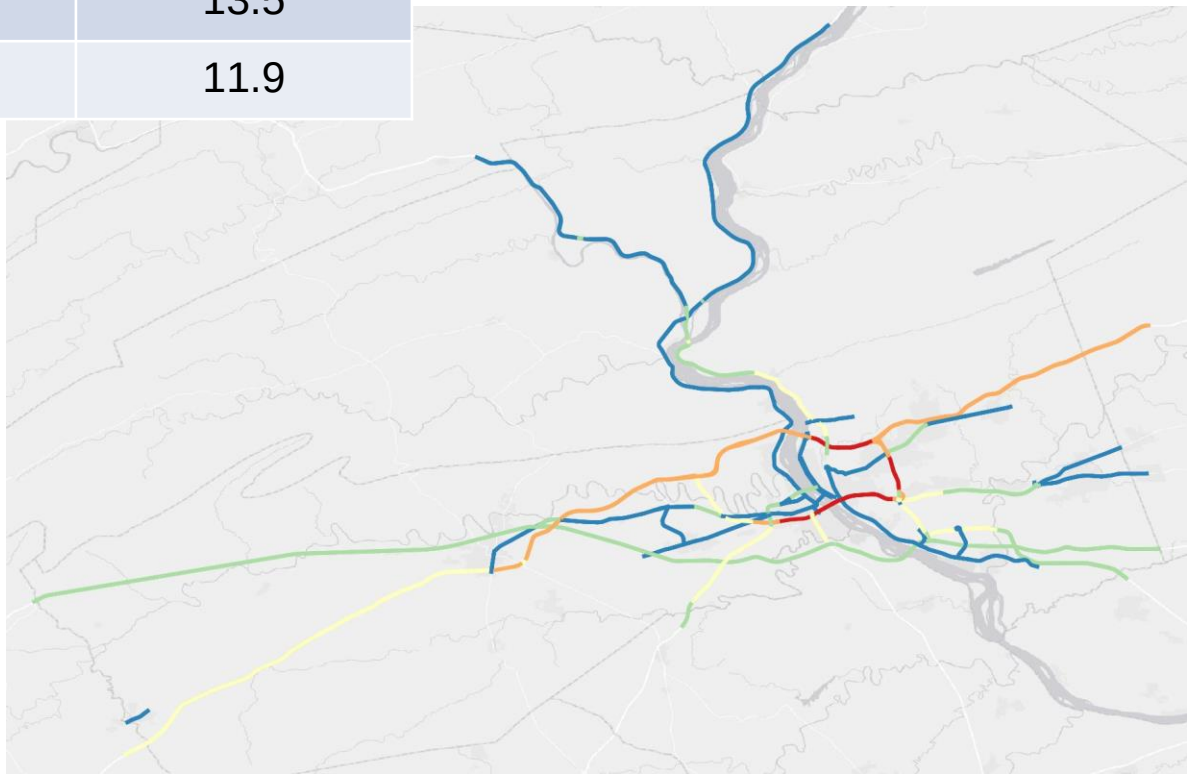
AADT & AAWDT Estimation

Measure (VPD)	MAPE [%]	SMAPE (%)
AADT	13.9	13.5
AAWDT	12.6	11.9

AADT



AAWDT



Freeway Results – Compare and Contrast

	NREL	UMD
Data Input	TomTom reported # of probes per segment	INRIX Trip Data
Model Region	Harrisburg Region	Statewide, with Harrisburg sub-select
Calibration/Validation Source	Data input: Continuous Count Stations	
Model Type	XGBoost Tree Learning	Neural Network
Probe Mix	Light Duty Vehicles	Light, Medium, Heavy Duty Vehicles
Penetration Rate	~12%	~ 6 to 7%
Results	**Freeway results comparable – consistent with other research, ~5% EMFR, >90% R^2**	

Harrisburg, Pennsylvania
Off-freeway Results

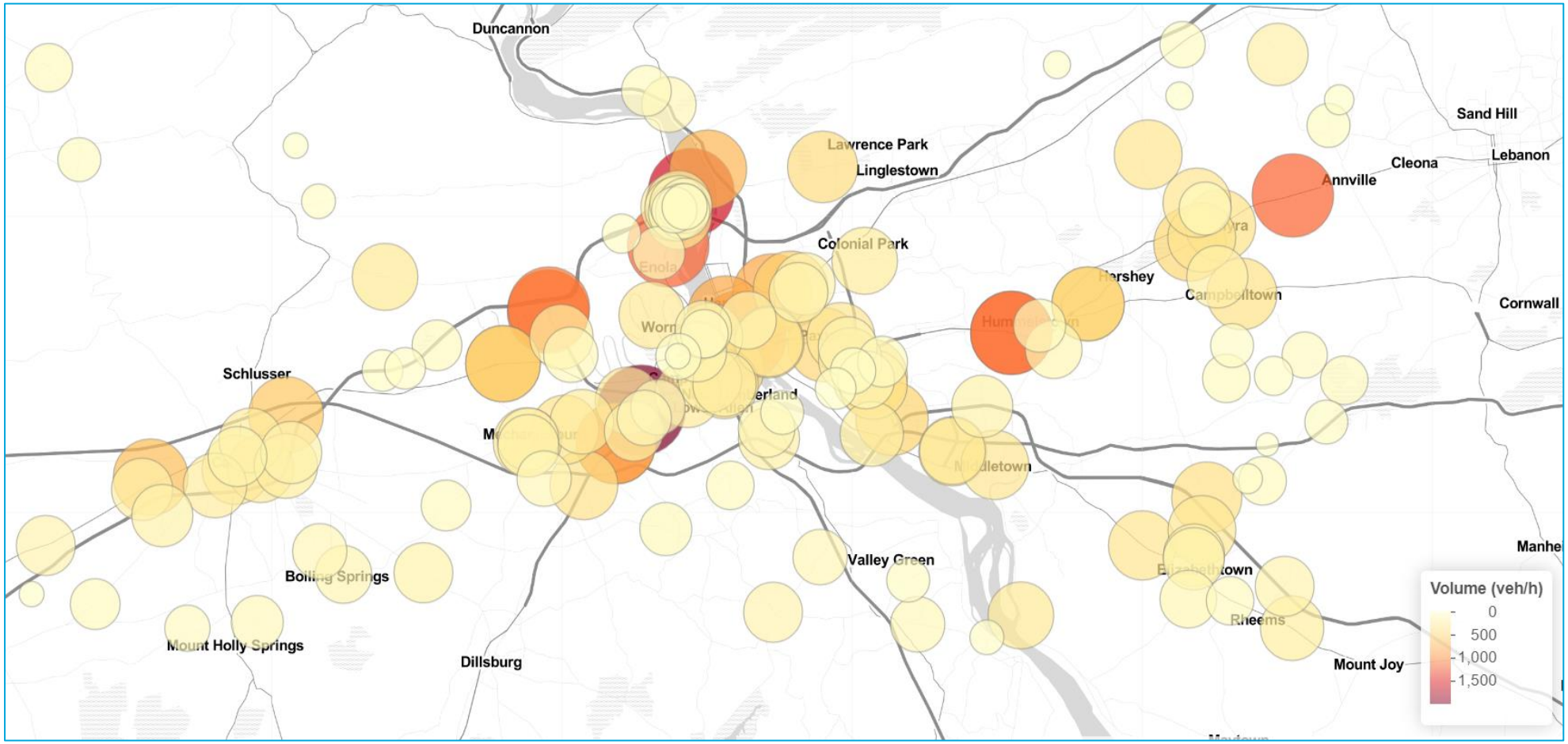
*Preliminary Results

Harrisburg Off-freeway Station Volumes

- July 1st - Dec 31th, 2018
- 156 Stations-24 hr count
- 2855/684 Train/Test Hours

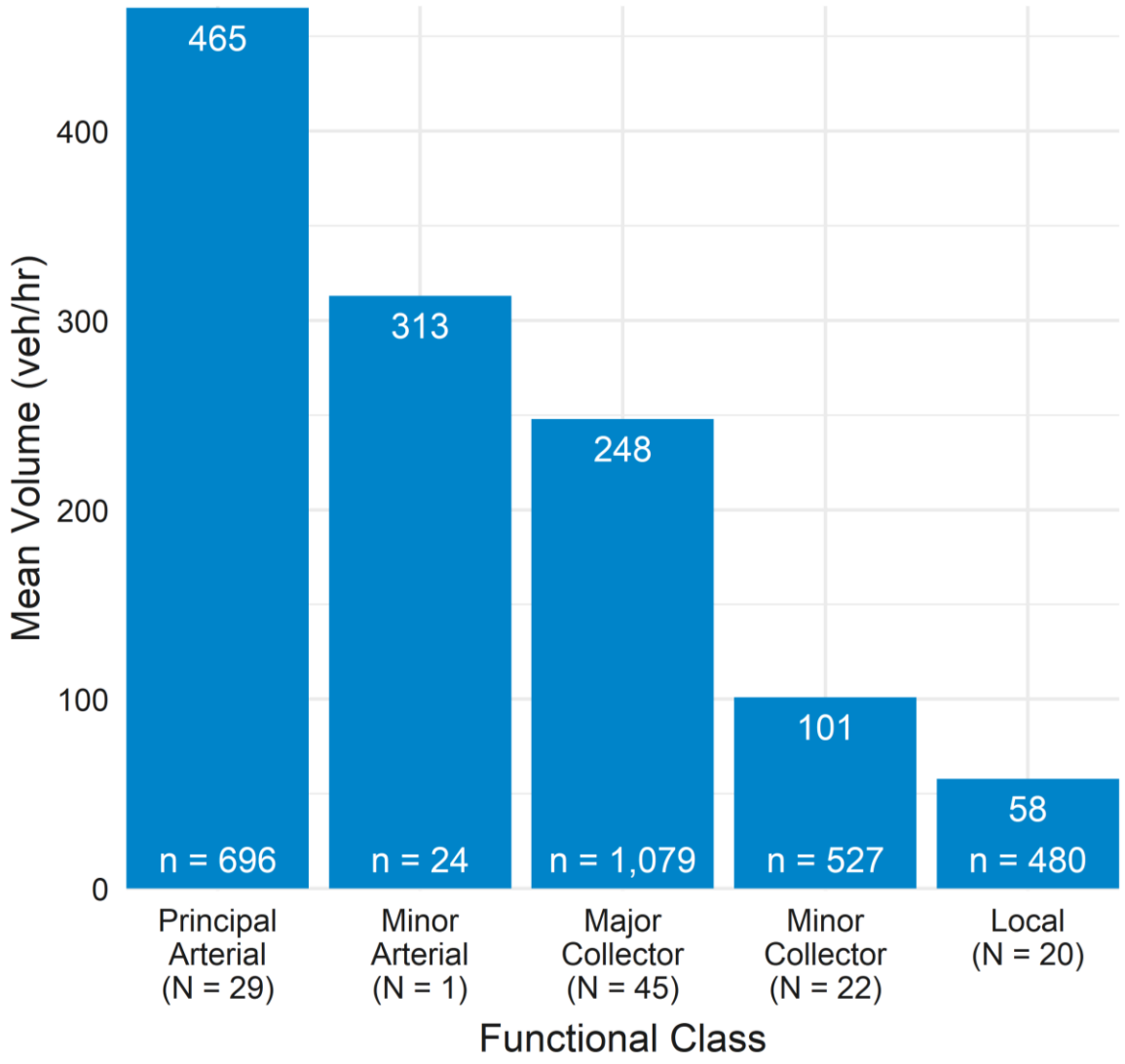
FRC Class	# of CCSs
Principal Arterial	36
Minor Arterial	1
Major Collector	64
Minor Collector	30
Local	25

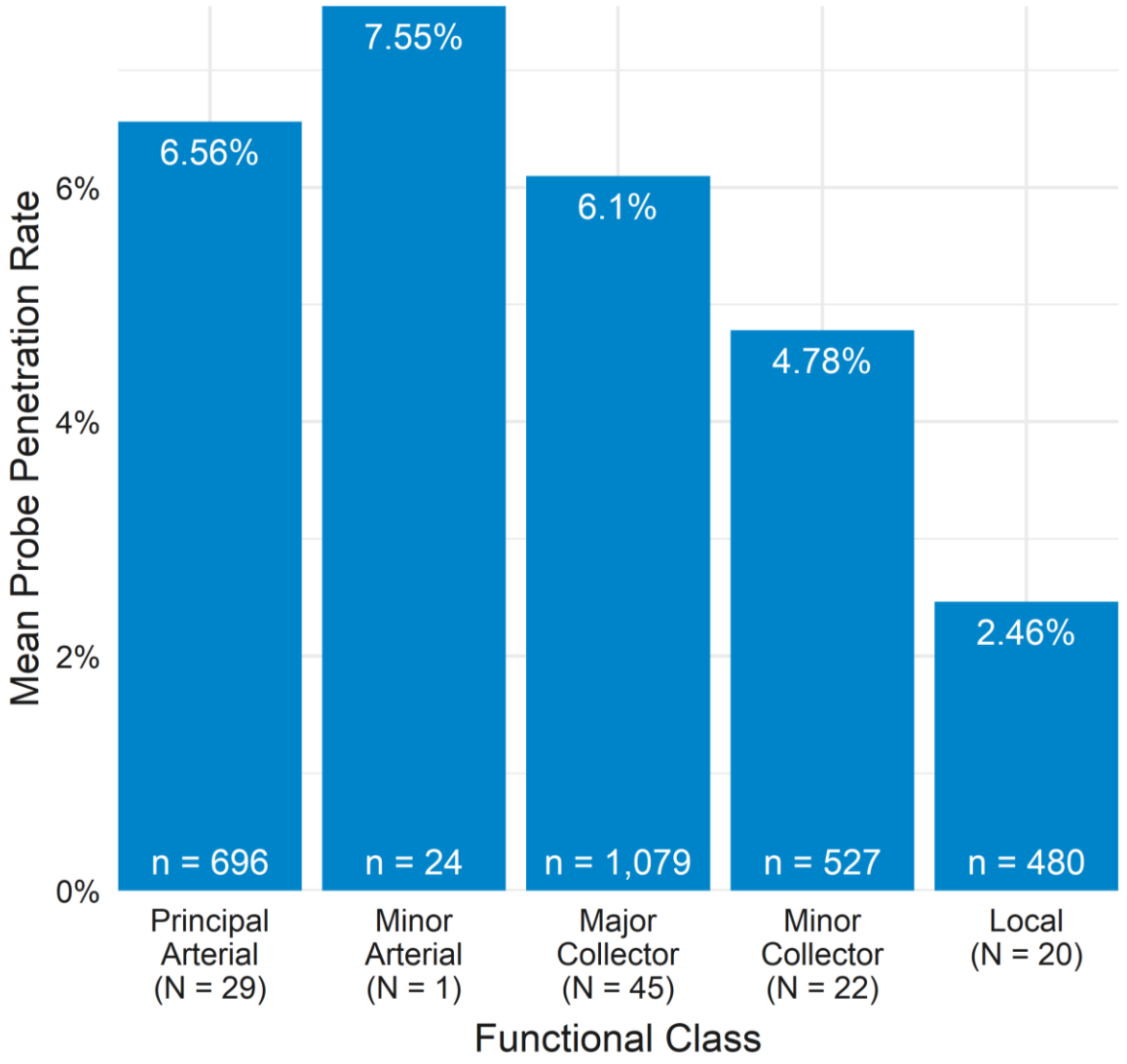
Average Traffic Volume by Location



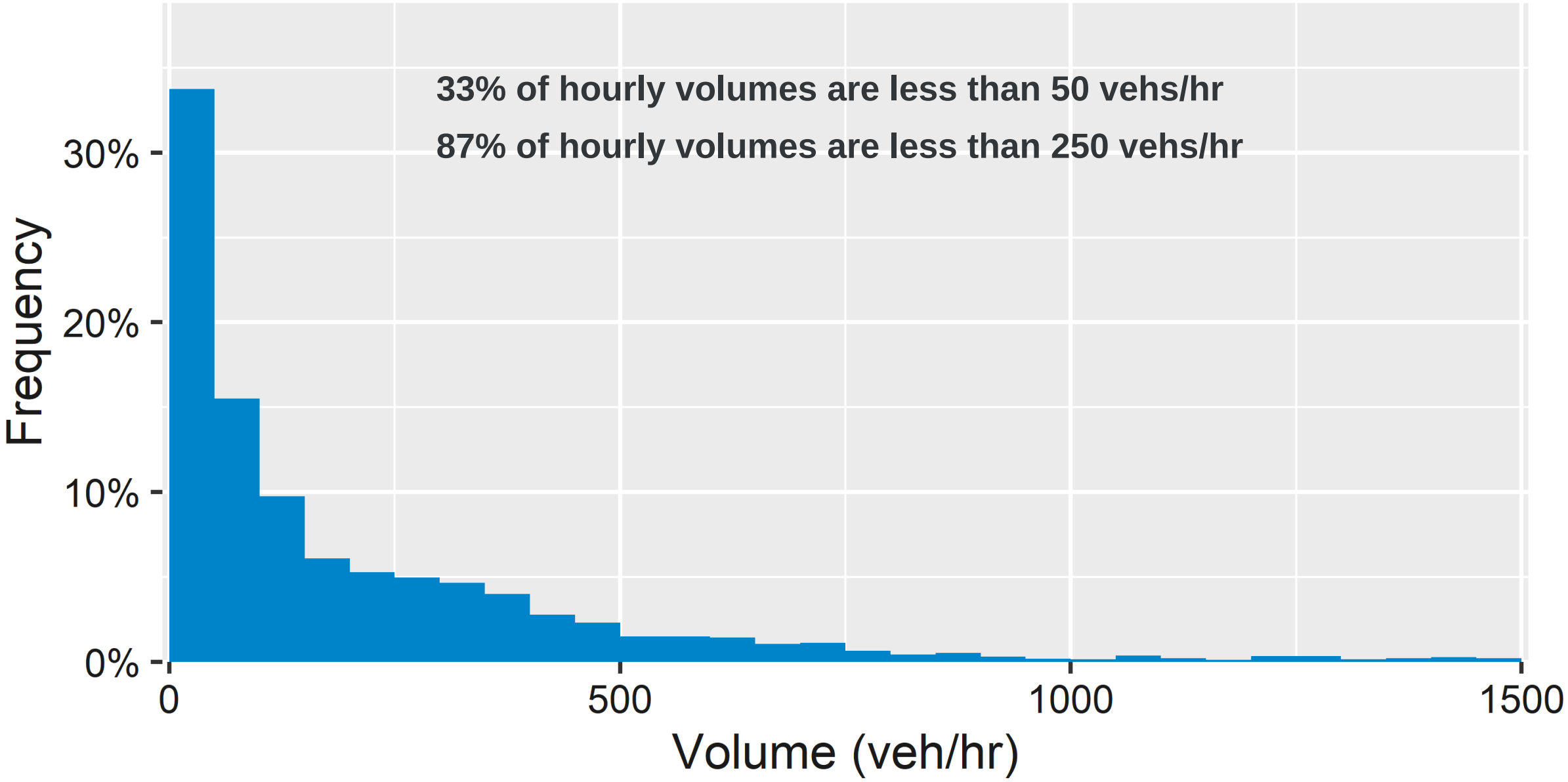
*Note: The circle sizes also scale with volume

Mean Volume & Probe Penetration by Road Class

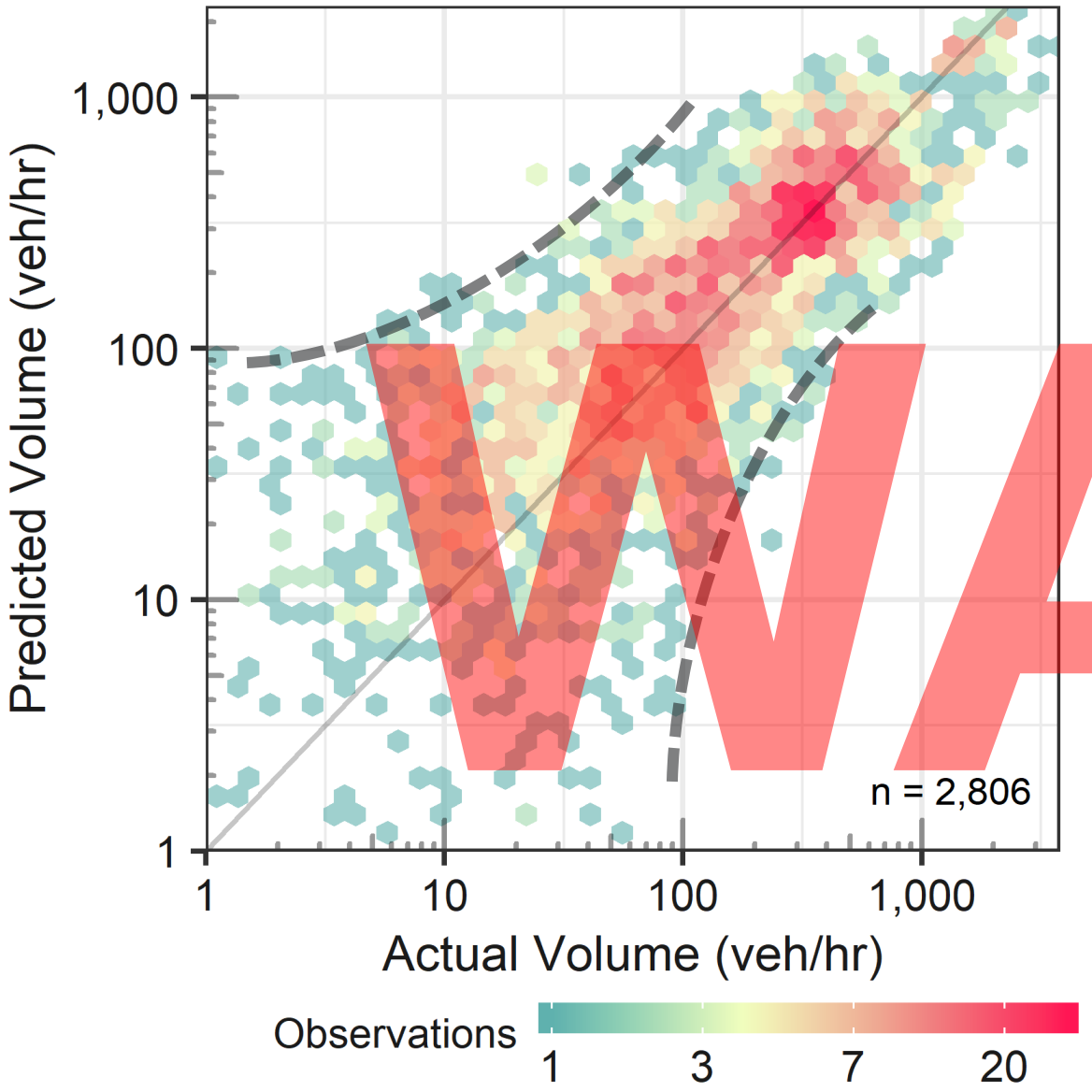




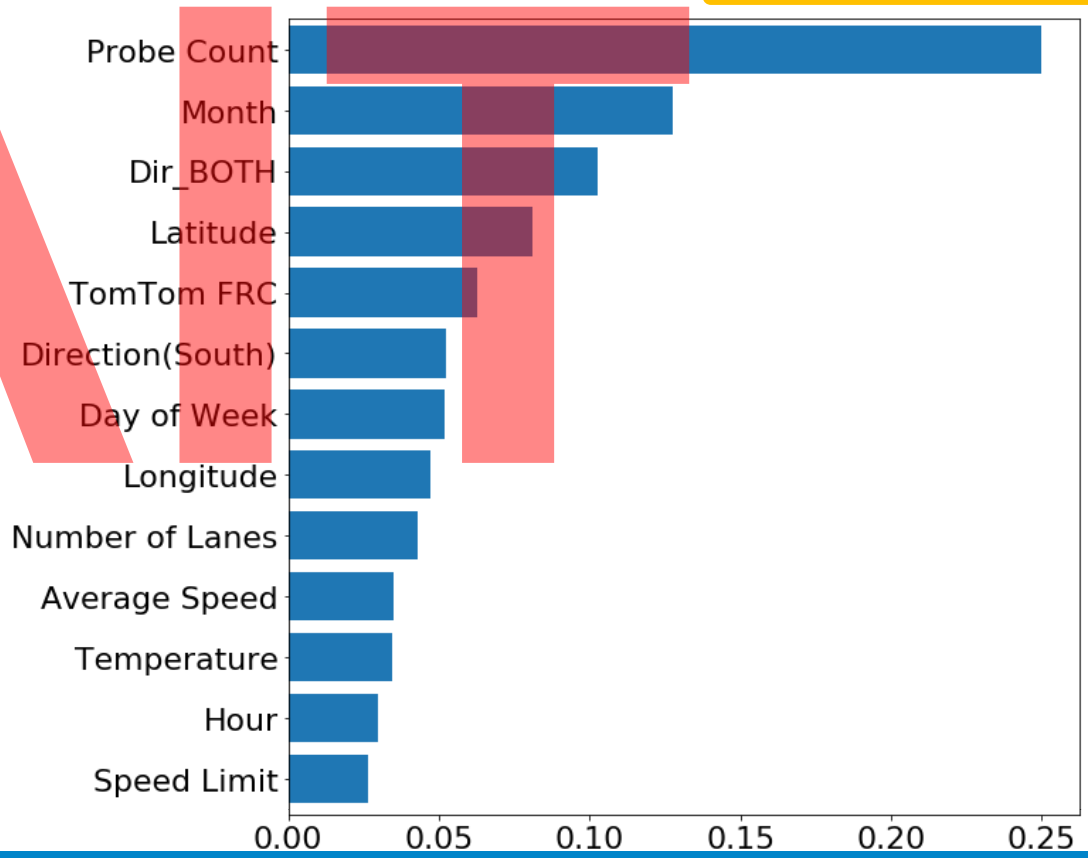
Off-freeway Volume Distribution



Off-freeway Volume Estimation Results



Model	R^2	MAE (veh/hr)	SMAPE	EMFR
XGBoost - Train	0.62	123	70.3%	22.9%
XGBoost - Test	0.72	104	60.1%	20.0%



Issues to resolve -----

1. Some counts bi-directional, some uni-directional
2. Filtering out bad input data
   - Statewide provide large basis for outlier detection
3. Low penetration rate for local roads
4. Large variation in volume

Both UMD and NREL tracking issues in PA

North Carolina Status Update
NREL – TomTom Data

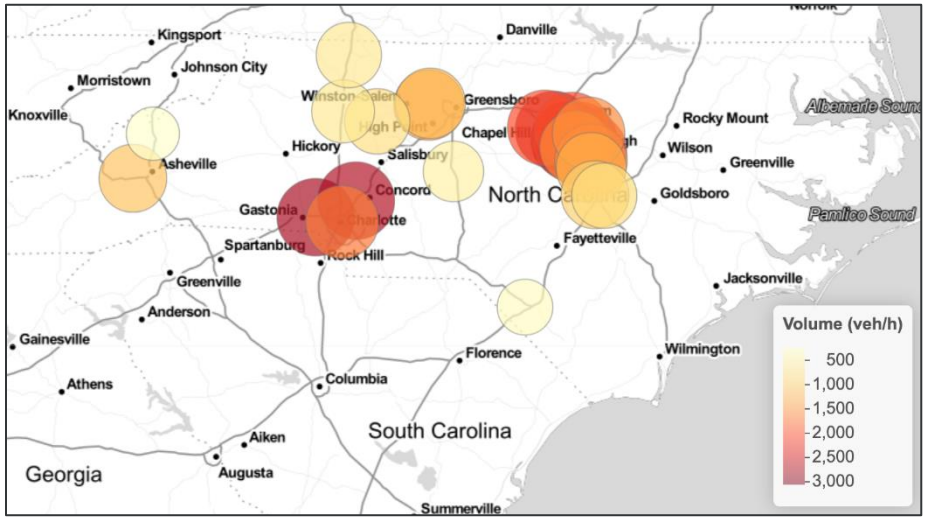
*Preliminary Results

Data for Model Training

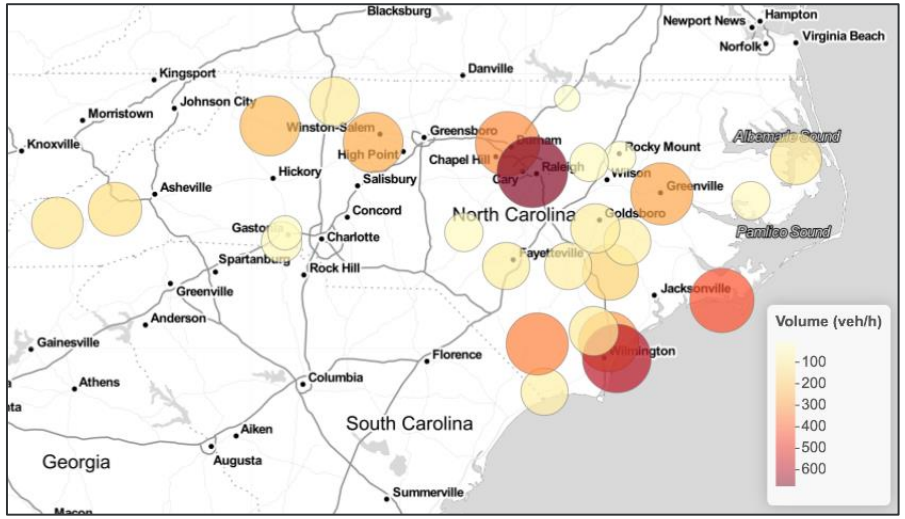
- July 1th to Dec 31th, 2018
- 52 Stations
- 144,923 off-freeway observations
- 185,520 freeway observations

FHWA Functional Class	# of CCSs
Freeways	25
Principal Arterial	5
Minor Arterial	10
Minor and Major Collectors	6
Local	6

Average Traffic Volume by Station



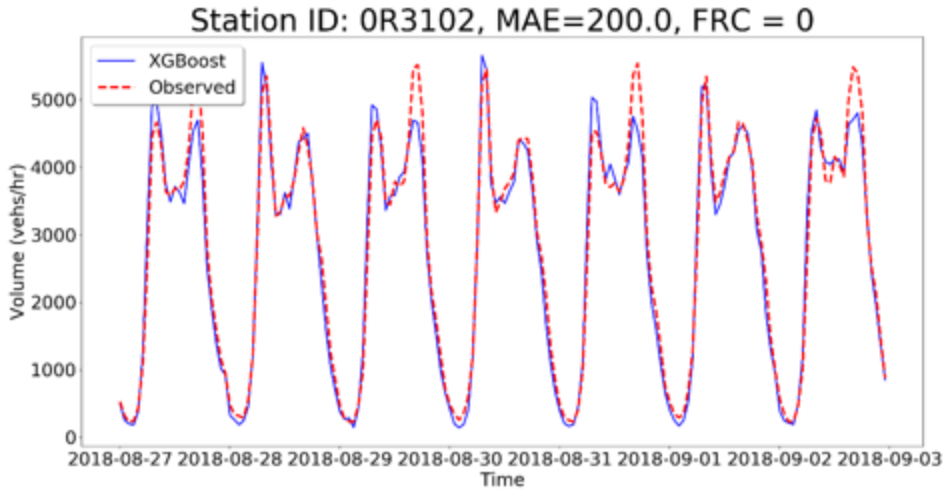
Freeways



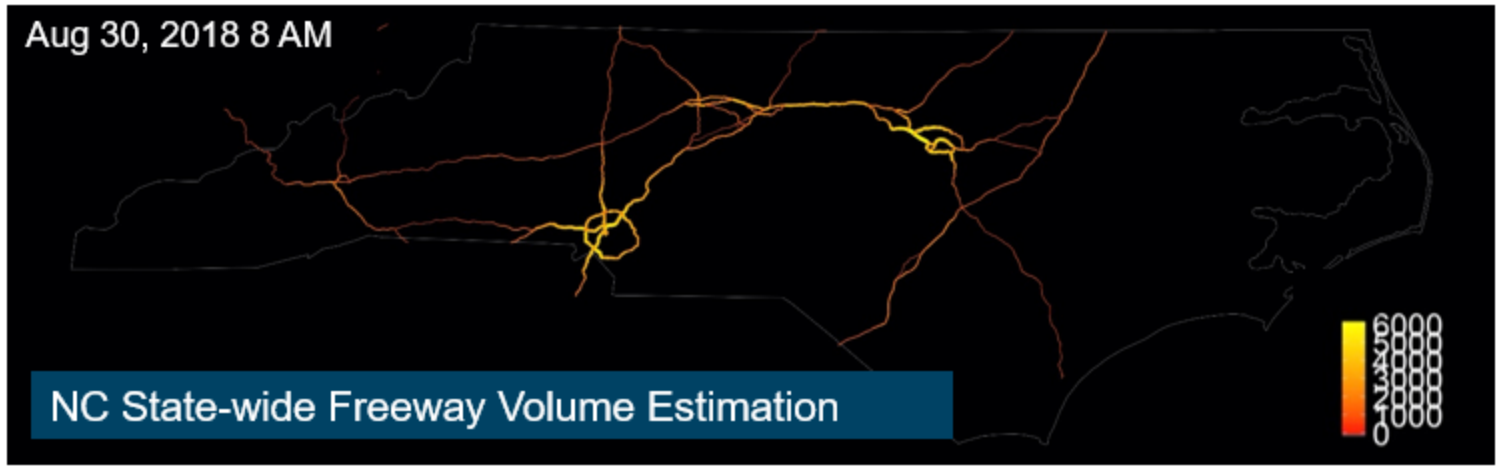
Off-freeways

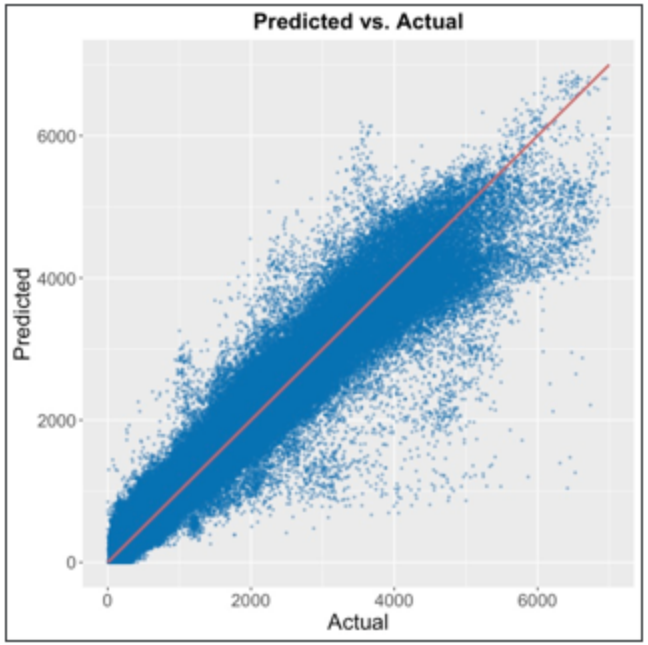
*Note: The circle sizes also scale with volume

Freeway Volume Estimation Results



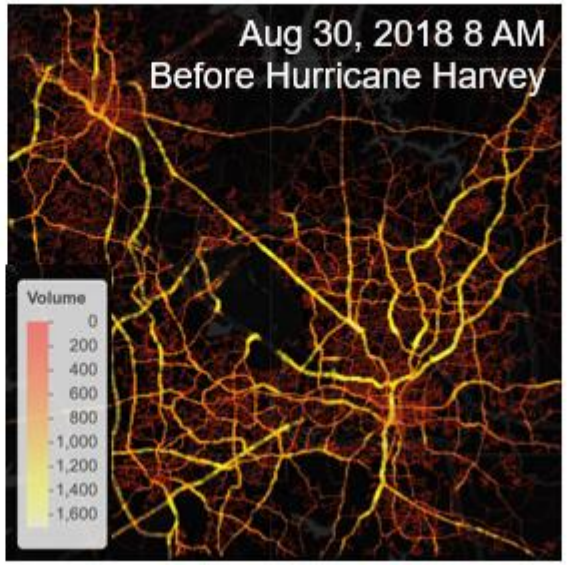
Roadway Type	R2	MAE	WAPE	EMFR
Freeway	0.92	257	15.4%	6.4%

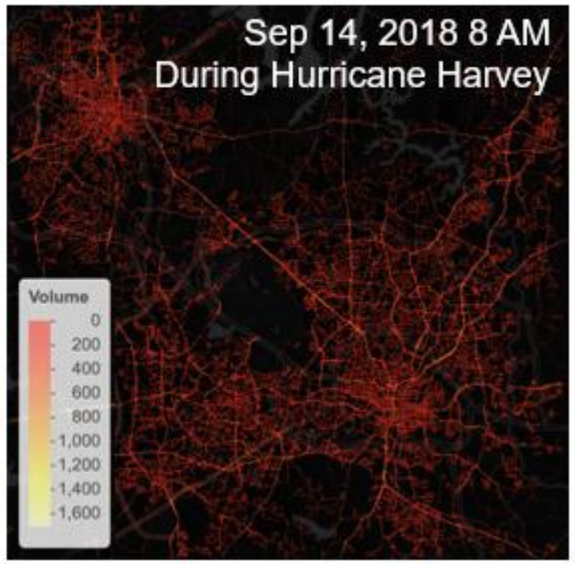


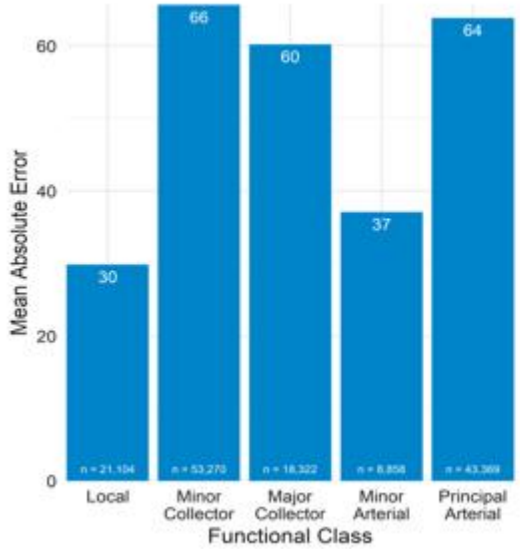


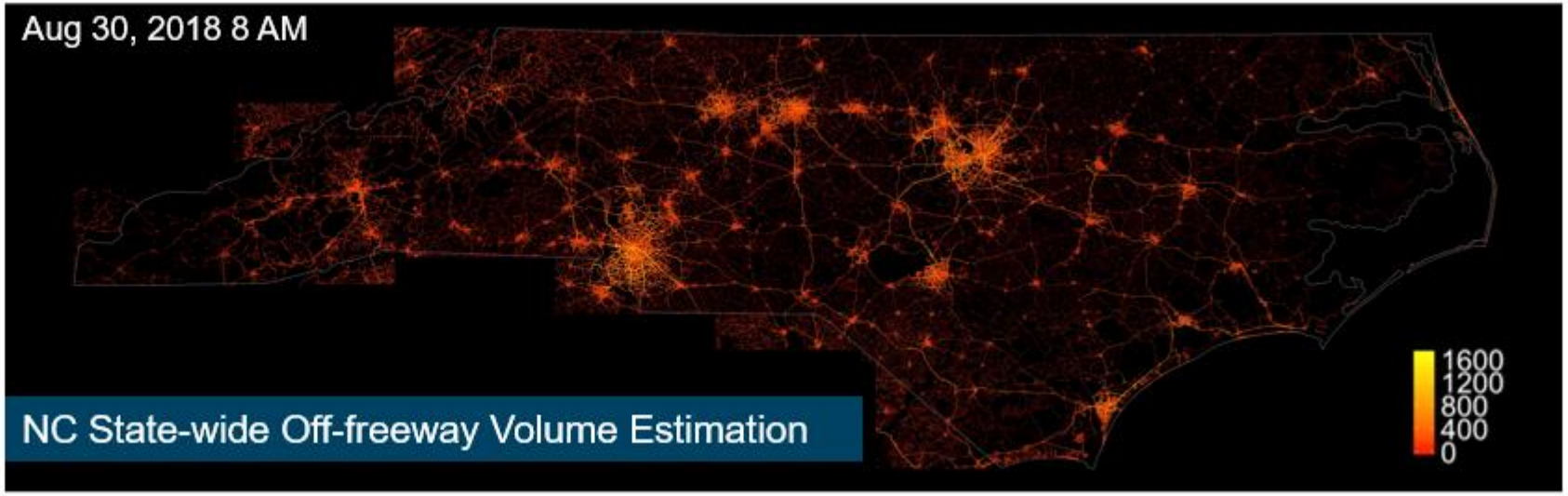
Off-freeway Volume Estimation Results

Roadway Type	R2	MAE	WAPE	EMFR
Off-Freeway	0.87	55	31.6%	13.2%









Next Steps – North Carolina

- **Use NC for testbed for AADT and Continuous / Temp counts**
- NC has broader and more continuous count data than any other state
- Expand North Carolina to12 month study period (Jan – Dec)
- Estimate hourly volumes and AADT for spectrum of functional class roadways from both continuous & temporary counters
- Address questions –
  - What is accuracy of AADT / ADT estimation from probe method?
  - What are the limits/accuracy from using temporary count data

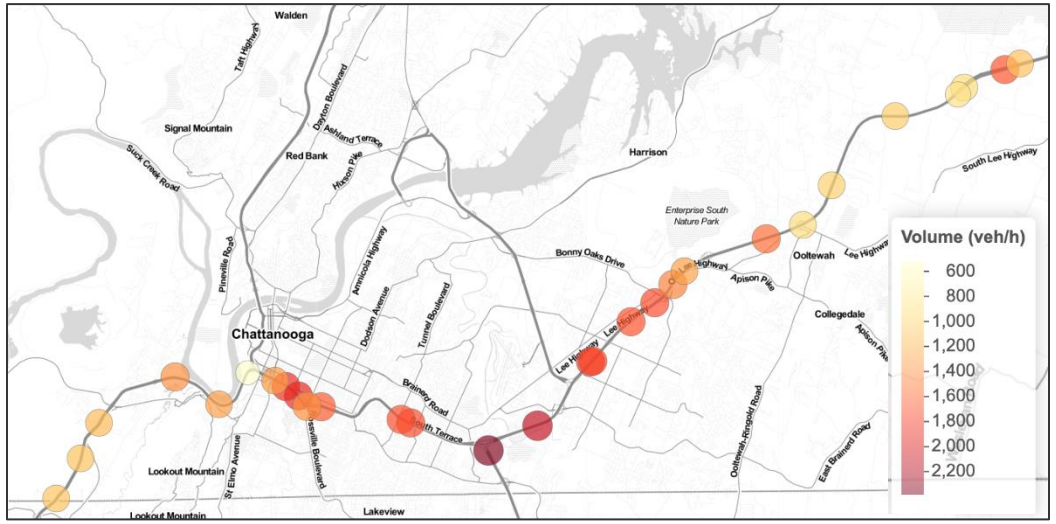
Chattanooga, TN Status Update
NREL – TomTom Data

*Preliminary Results

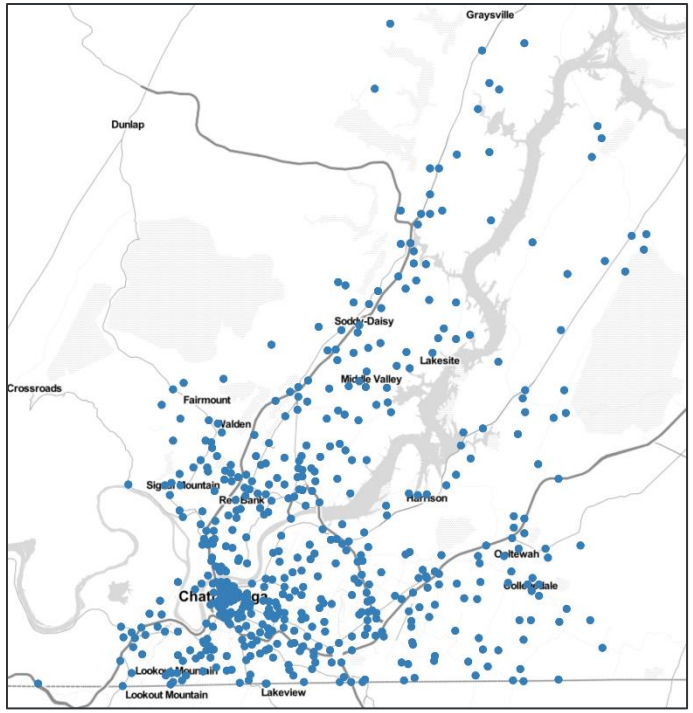
Data for Model Training – from temporary count data

FHWA Functional Class	# of CCSs
Freeways	36
Principal Arterial	55
Minor Arterial	14
Major Collectors	70
Minor Collectors	199
Local	163

	Freeway	Off-freeway
Data Source	RDS	Short-term Counts
Time Period	Jan 1 – Apr 22, 2019	Jan 3 – Jun 5, 2018
# of Stations	36	501
# of Observations	81,918	15,570



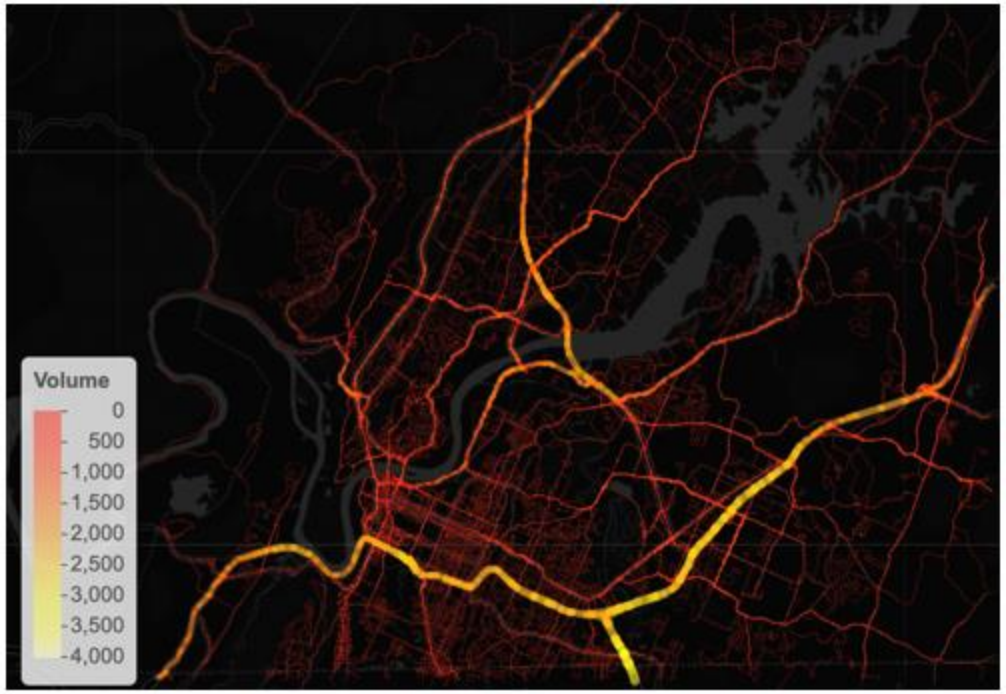
Freeway RDS Data



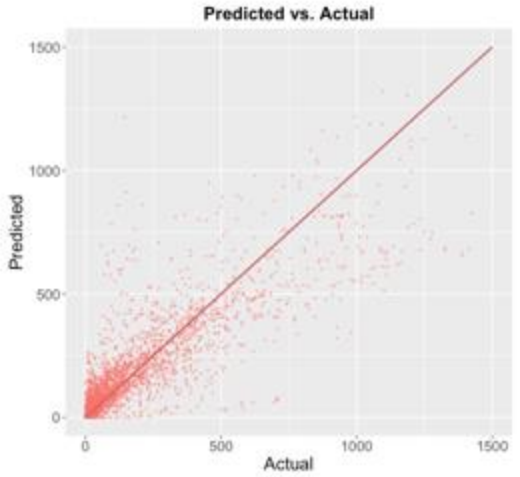
Off-freeway Short-term Count Data

Freeway Volume Estimation Results

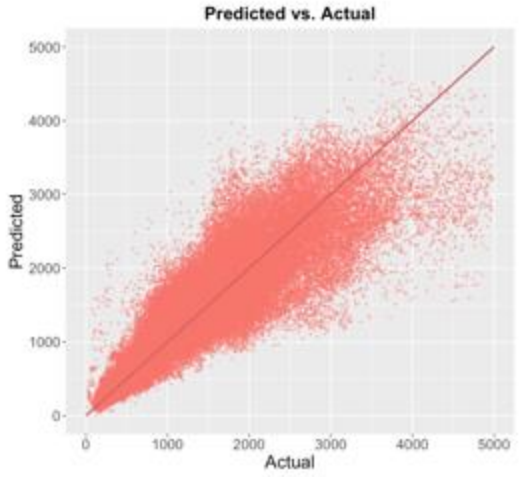
	R2	MAE	WAPE	EMFR
Interstates	0.80	284	20.4%	7.6%
Non-interstates	0.77	81	39.0%	38.2%

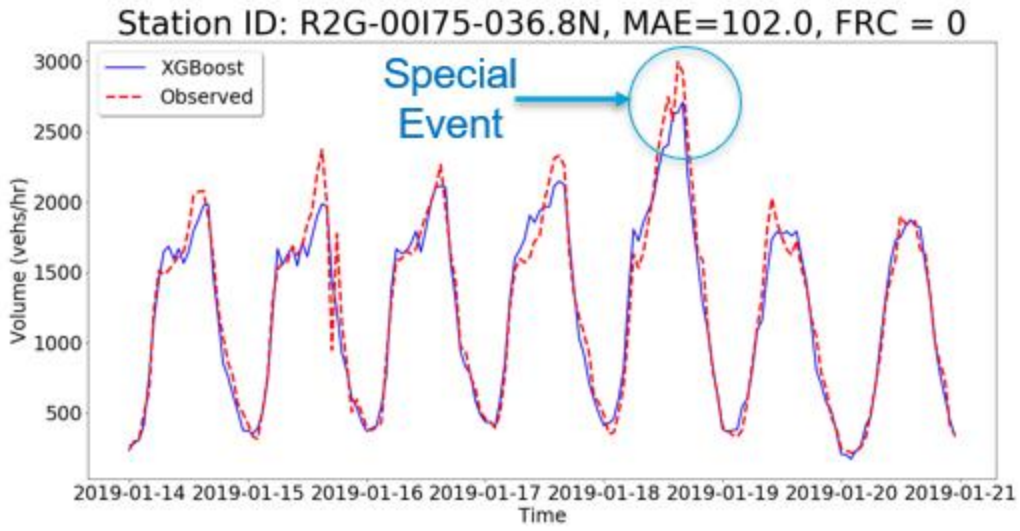


Non-interstates



Interstates





Next Steps – Chattanooga

- QC/QA Input data, primarily temporary counts
- Develop automated processes for doing QC/QA
- Look at state level continuous counters – possible State model, applied at regional scale to overcome data issues

Questions & Wrap Up

Denise Markow, PE

I-95 Corridor Coalition

TSMO Director

Final Questions