Bike Ped Data Collection & Monitoring Multi-state Workgroup
Background for September 2020 Colloquium

Monitoring and Modeling Bicycle and Pedestrian Traffic

April 1, 2020

HUMPHREY SCHOOL
OF PUBLIC AFFAIRS

UNIVERSITY OF MINNESOTA
Driven to Discover℠

Monitoring and Modeling Bicycle and Pedestrian Traffic

- Purpose & Objectives
  - Share information about monitoring and modeling bicycle and pedestrian traffic
  - Plan for September 2020 colloquium on monitoring programs
- Outline for talk
  - Workgroup questions
  - Monitoring approaches and methods (FHWA)
  - Analysis and extrapolation of monitoring data
  - Examples
- Approach
  - Discussion/conversation: interruptions welcome

Your Questions

- Monitoring Technology and Approaches
  1. Worth investing in Eco-Counters? What's your experience and thoughts on TRAFx counters?
  2. Is there a different approach for user counts on bike lanes?
  3. How can we modify our data collection method so that it is more relevant to CT DOT needs?
  4. Short Duration Count Methods- Should the counters be out for 1 or 2 weeks at a time?
- Data Analyses, Extrapolation, and Interpretation
  1. What was your methodology on deciding site location for counters?
  2. How do we calculate VMT on trails?
  3. Are there recognizable use patterns that align with trail types?
  4. How do we extrapolate statewide use, or use on other multi-use trails, from 3 years of CT Trail Census data?
  5. Developing accurate calculation for out and back users since not all uses are out and back.

Recent Guidance for Counting, Estimating Demand

- National Bike and Ped Documentation Project
- FHWA Traffic Monitoring Guide (2013) Ch. 4 Non-motorized Traffic
- NCHRP 770 Estimating Bicycling and Walking for Planning and Project Development: A Guidebook (2014)
- NCHRP 7-19 Methods and Technologies for Pedestrian and Bicycle Volume Data Collection (2014)

FHWA Traffic Monitoring Guide

- Objective: two key performance measures
  - Average annual daily traffic (AADT, AADB, AADP)
  - Vehicle miles traveled (VMT, BMT)
- Approach for Bikes & Peds
  - Mirror approach for vehicles
  - Establish network of permanent and short-duration monitoring sites
  - Use adjustment factors from reference sites to extrapolate short-duration counts
- Challenges in Nonmotorized Monitoring
  - Traffic variability, technology, resources
  - Different perspectives: recreation/trail managers focus on visits and visitors, not traffic or trail miles traveled

FHWA Traffic Monitoring Guide

Permanent Continuous Monitoring	Short Duration Monitoring
1. Review existing continuous count program	1. Select count locations
2. Develop inventory of available continuous count locations and equipment	2. Select type of count (segment vs intersection)
3. Determine the traffic patterns to be monitored	3. Determine duration of counts
4. Establish seasonal pattern groups	4. Determine method of counting (automated vs. manual)
5. Determine number of continuous count locations	5. Determine number of count s
6. Select specific count locations	6. Evaluate counts (QA/QC)
7. Compute adjustment factors	7. Apply factors (occlusion, time of day, day of week, monthly, seasonal)

The Technical Challenge: Inexpensive, Accurate Commercially-Available Counters

EQUIPMENT	TECHNOLOGY	VENDOR AND MODEL
Bicycle Counter – Portable - roads	Pneumatic Tubes	Metro Count MC 5600
Bicycle Counter – Permanent - roads	Inductive Loops	Eco Counter ZELT Inductive loops
Bicycle Counter – Permanent - roads	Inductive Loops	Eco Counter ZELT Inductive loops
Pedestrian Counter – Portable - trails	Microwave	Chambers Electronics RBBP7
Bicycle AND Pedestrian Counter – Permanent - trails	Passive Infrared and Inductive Loops	Eco Counter MULTI

Examples of Counters

Eco Counter ZELT

Inductive Loop – Bicycles: Shoulder or Bike Lane

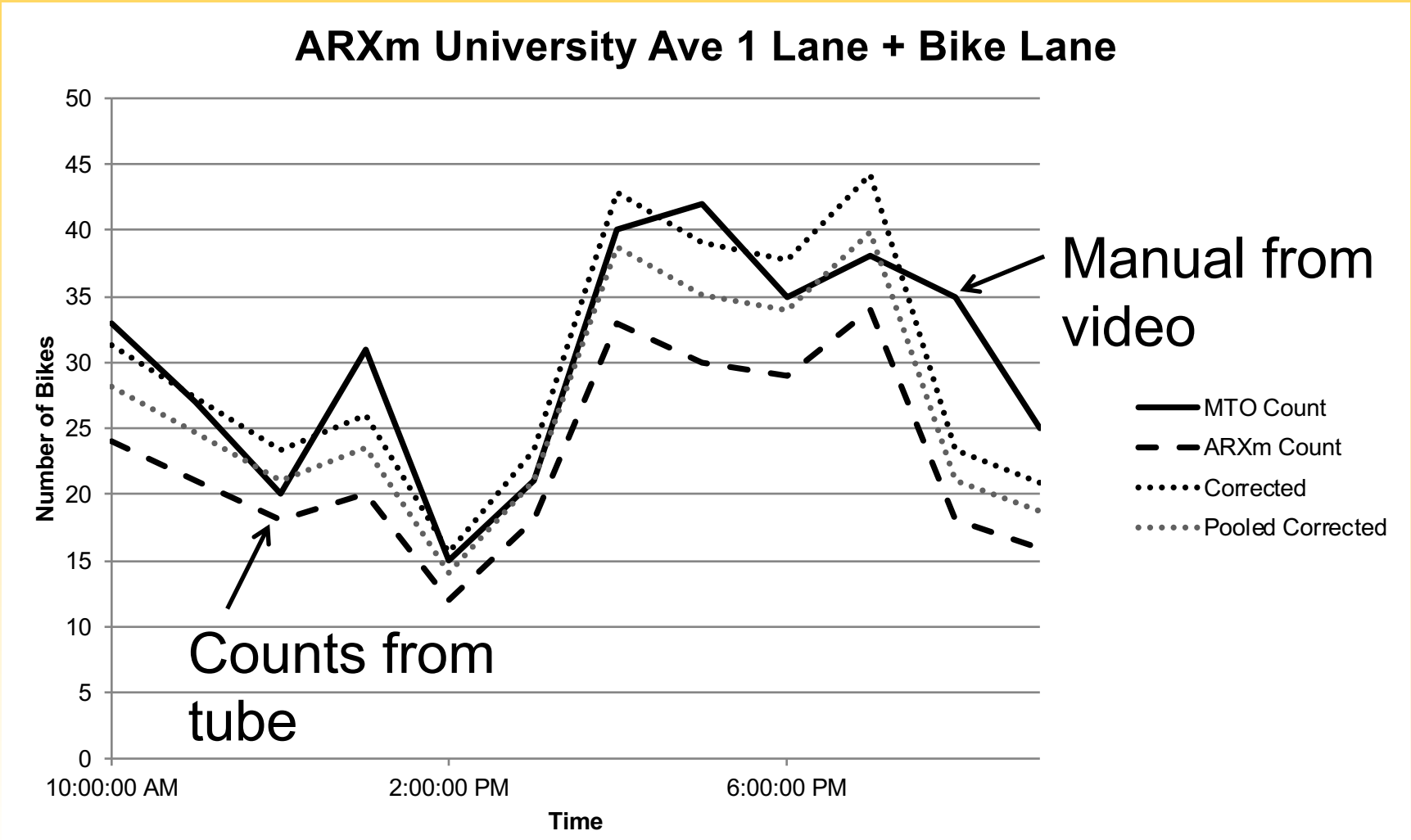
Metro Count MC 5600

Pneumatic Tubes - Bicycles

Chambers Electronics

Microwave – Pedestrians

Validation: Site-Specific and Pooled Adjustment Equations



Validation Results Mixed

- Higher accuracy with lower traffic and fewer lanes
- Correction factors to adjust for systematic error (occlusion)
- Use of (pneumatic tube) counters potentially cost-effective (limited training required)
- Applicability depends on decision-making context

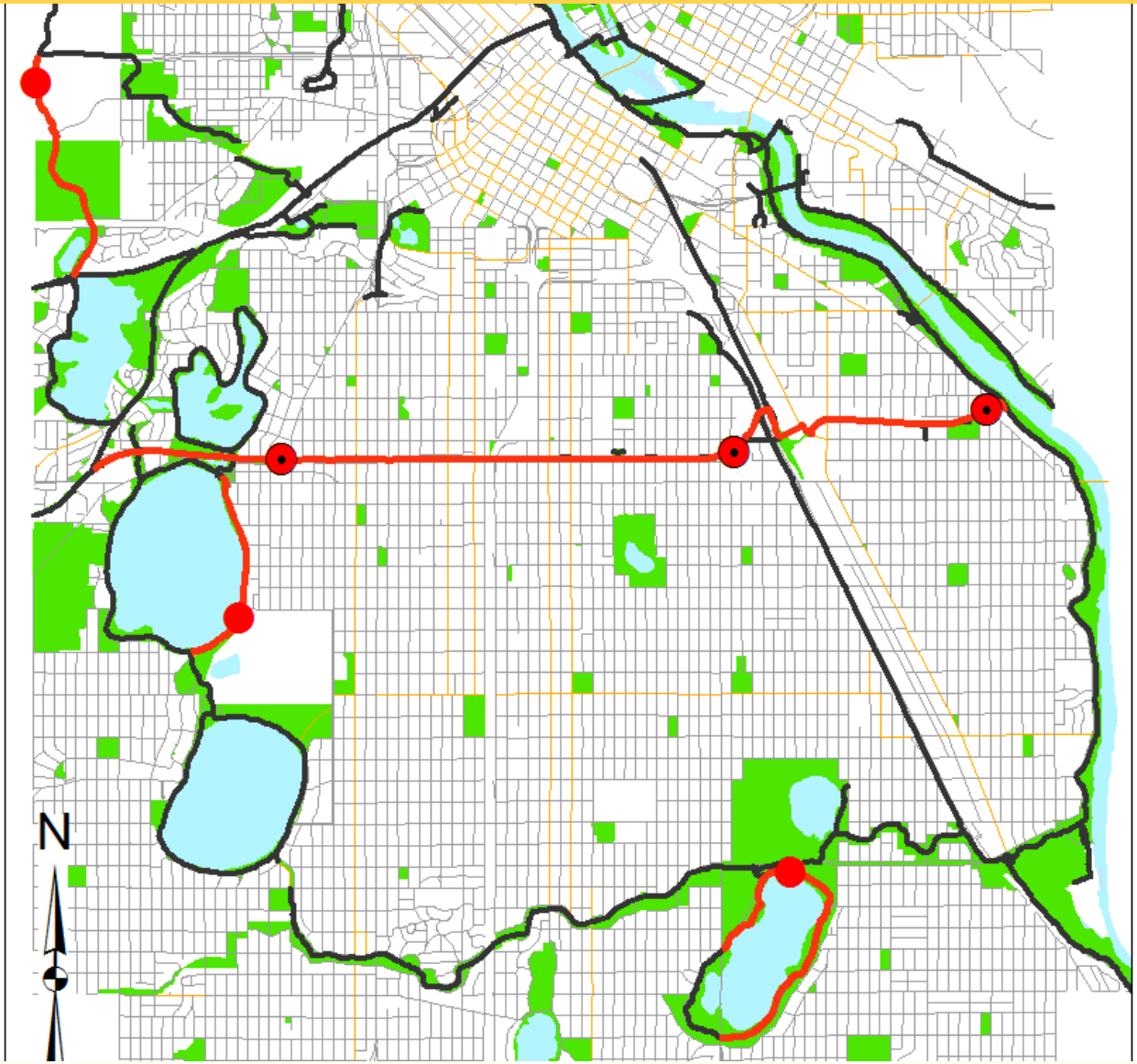
Continuous Automated Monitoring

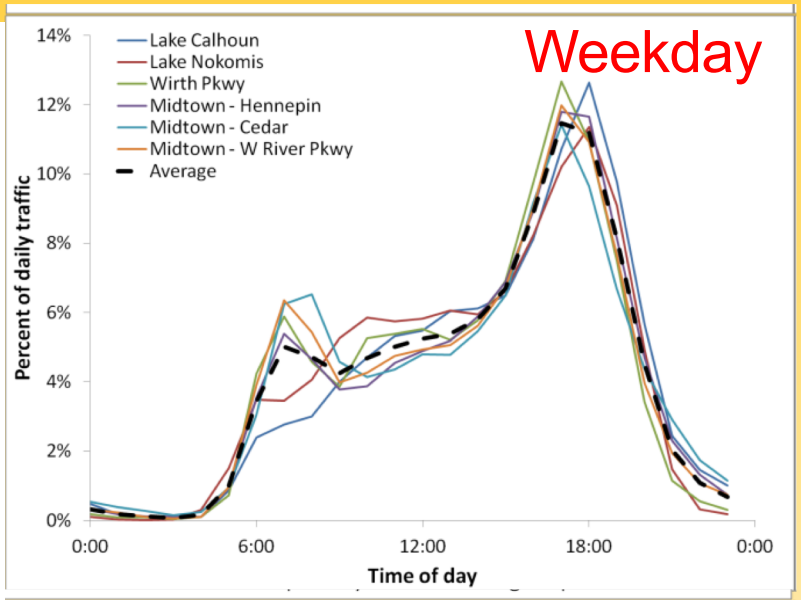
- Technologies evolving rapid
- Many factors affect accuracy
  - Occlusion (simultaneous users) a problem
- Very accurate bike counts with inductive loops
- Less accurate counts with pneumatic tubes
- Know most about trails, streets, sidewalks
- Most people on sidewalks, streets, trails

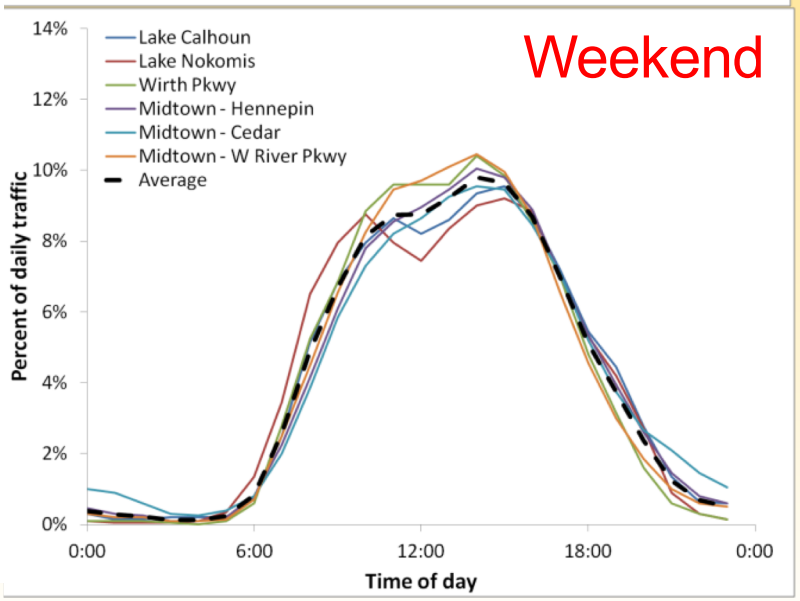
Performance Measures for Urban Trails

- Motivation
  - *How does traffic vary on our trail network?*
- Approach
  - Adapt procedures for traffic monitoring outlined in FHWA TMG (2013)
    - Reference monitoring locations
    - Short duration monitoring locations

Reference locations

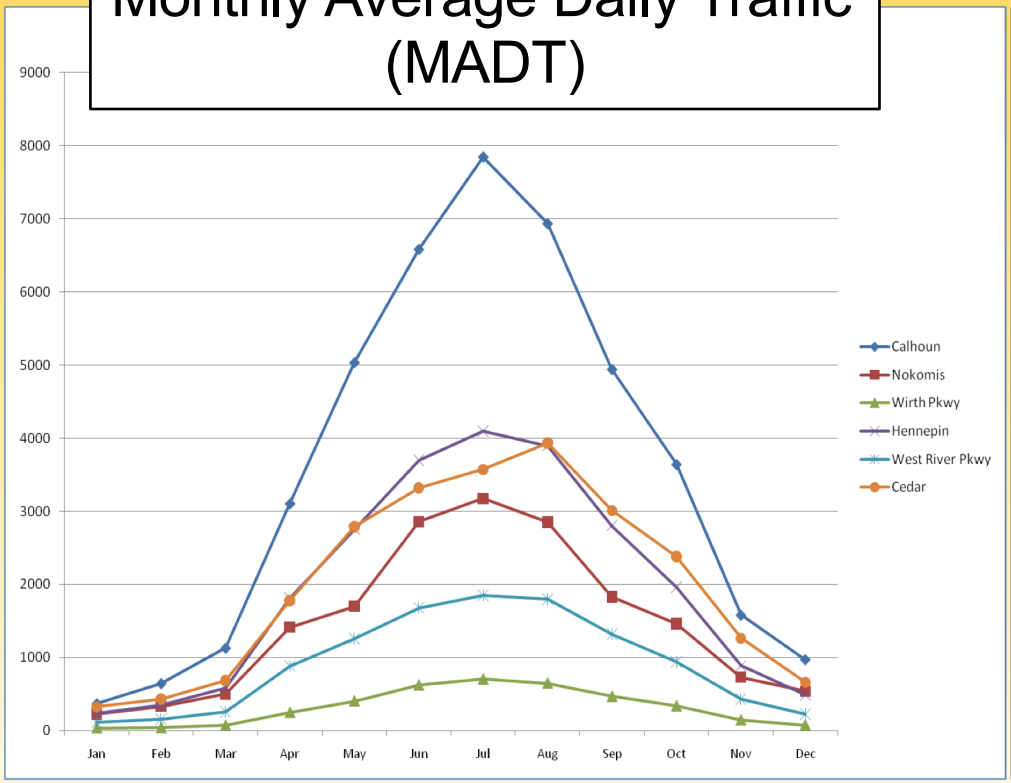




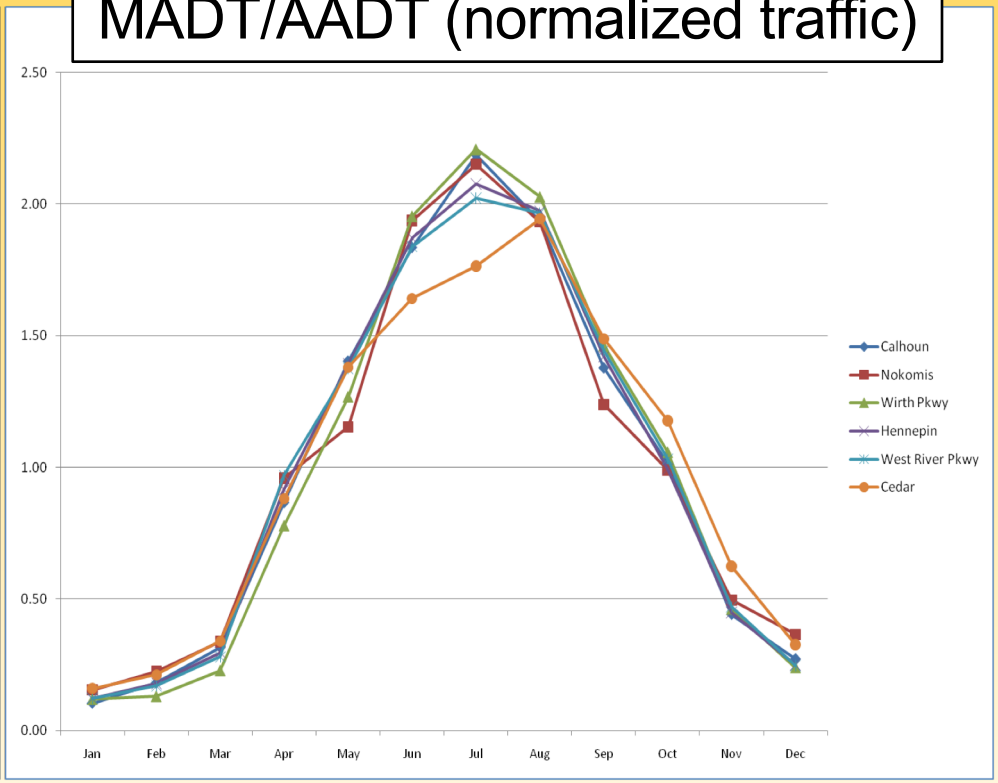


Reference locations

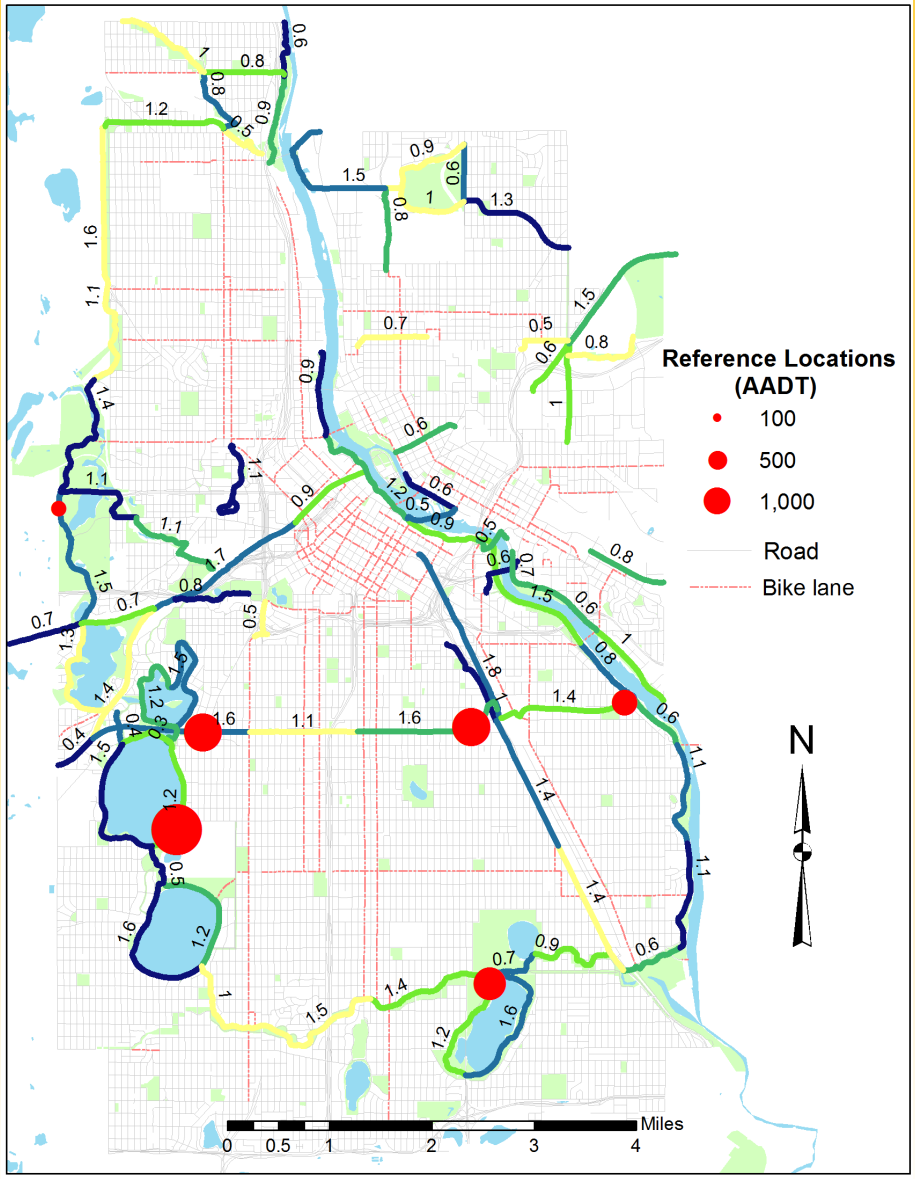
Monthly Average Daily Traffic (MADT)



MADT/AADT (normalized traffic)

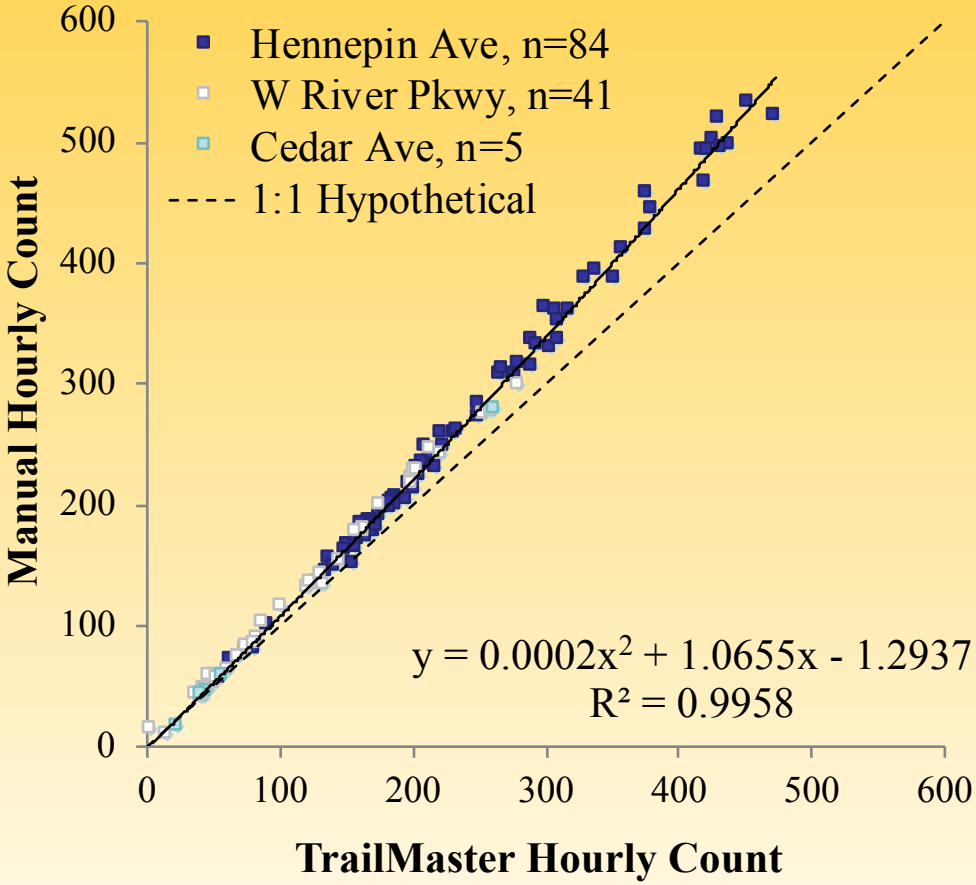


Designing a count campaign



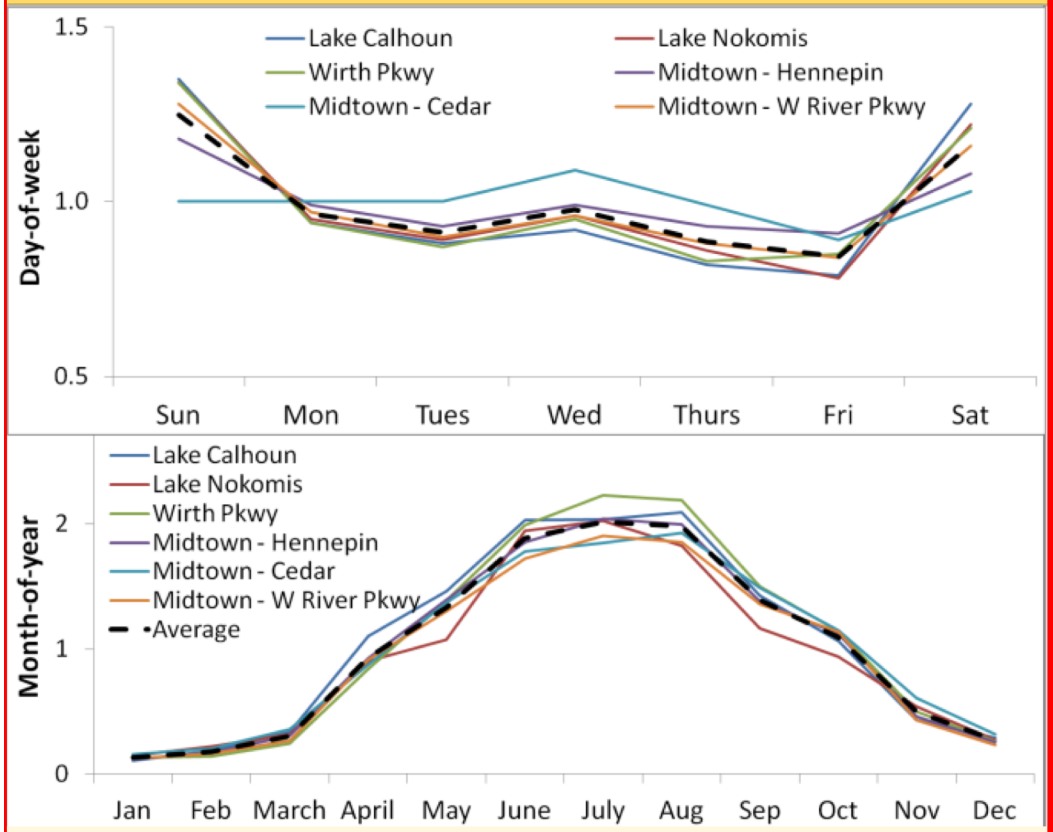
No. of segments = 82
Sum = ~80 miles
Mean = 0.98 miles
Min = 0.17 miles
Max = 1.8 miles

Count equipment: mixed-mode

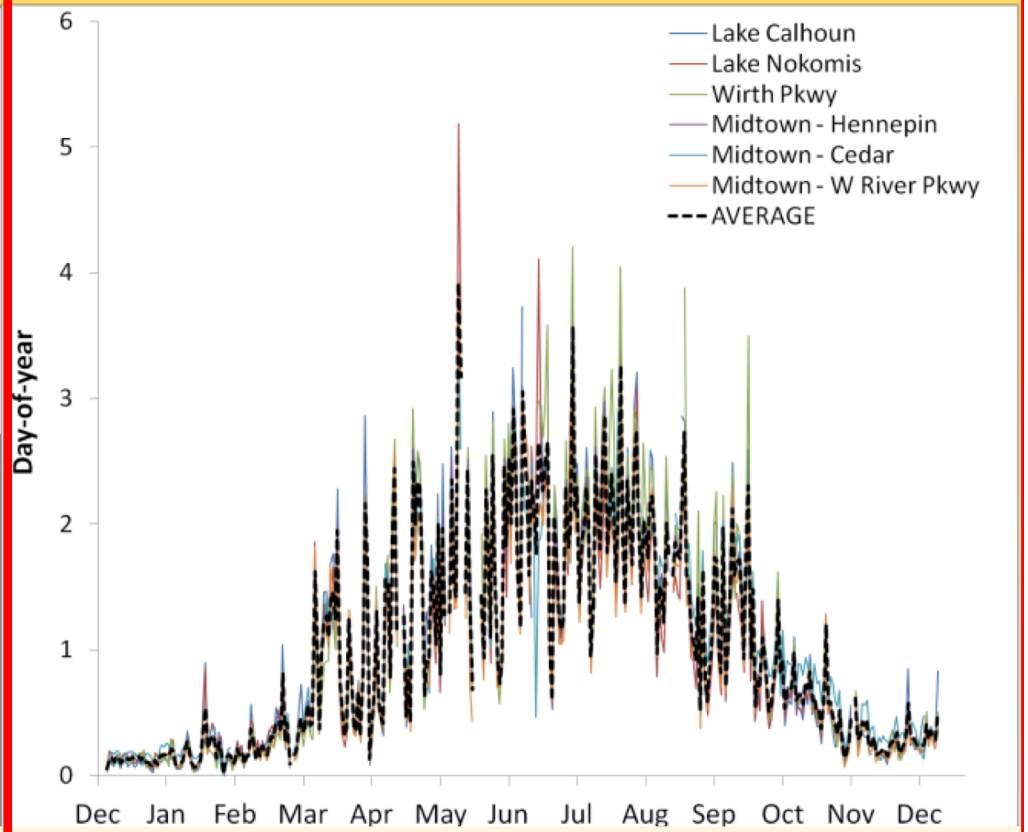


Scaling factors

Approach 1: "Traditional"



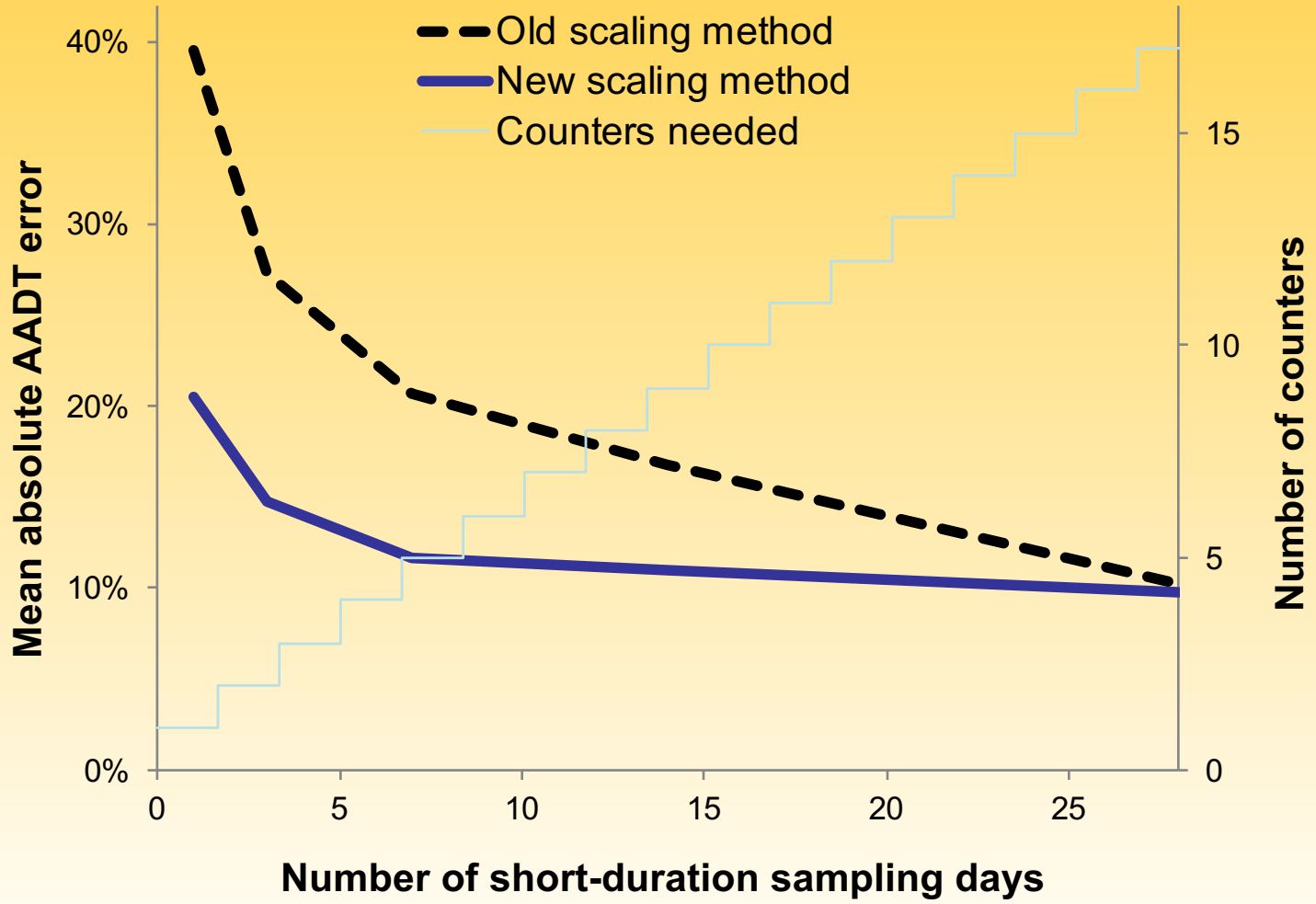
Approach 2: "New"



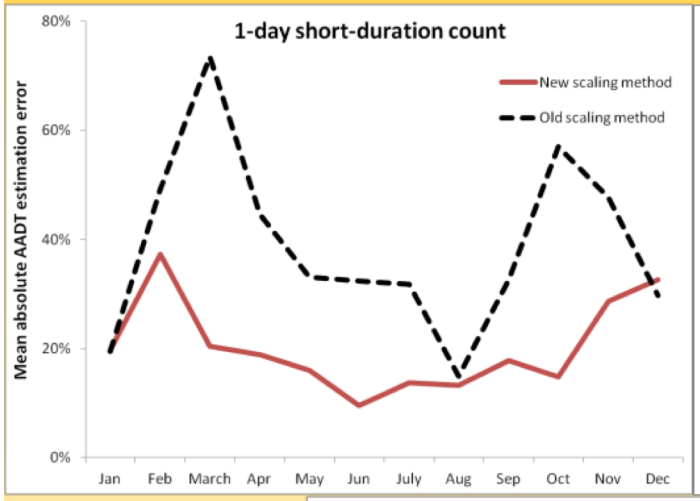
Comparing Factoring (extrapolation) Methods

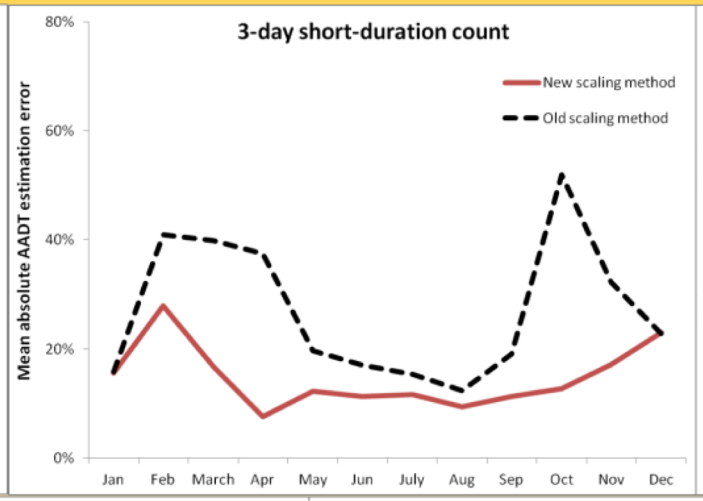
- Compute traditional (day-of-week, month-of-year) and new day-of-year factors for five of six reference sites
- Randomly select 50 different 1 day, 3 day, 5 day, 7 day, 14 day, 30 day counts from sixth site
- Use both factoring approaches to estimate AADTT and trail miles traveled for sixth site
- Compare extrapolation error from two factoring approaches

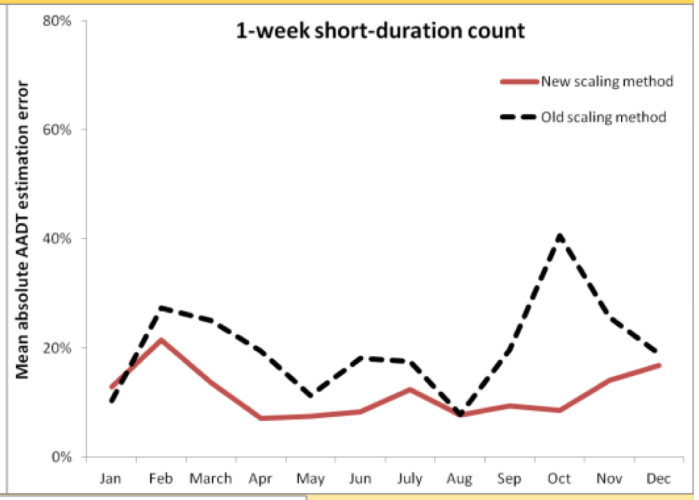
Day-of-Year Factors Reduce Extrapolation Error

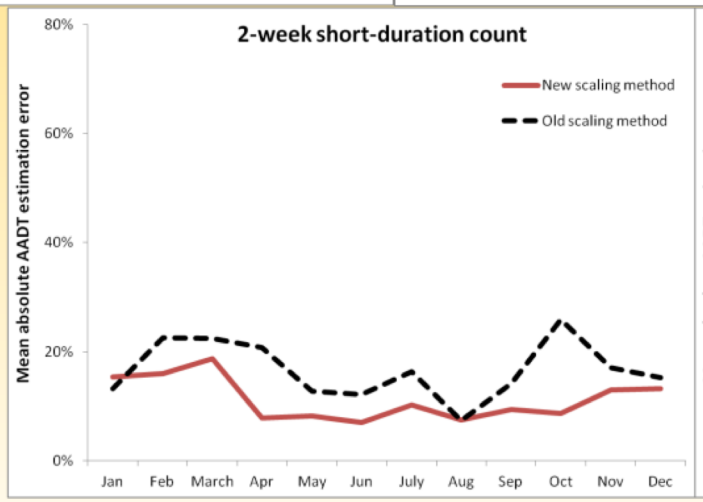


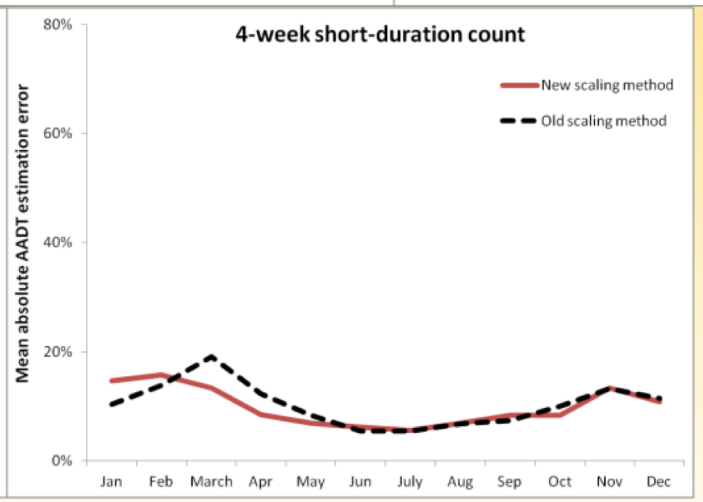
Sampling from April to October Minimizes Extrapolation Error



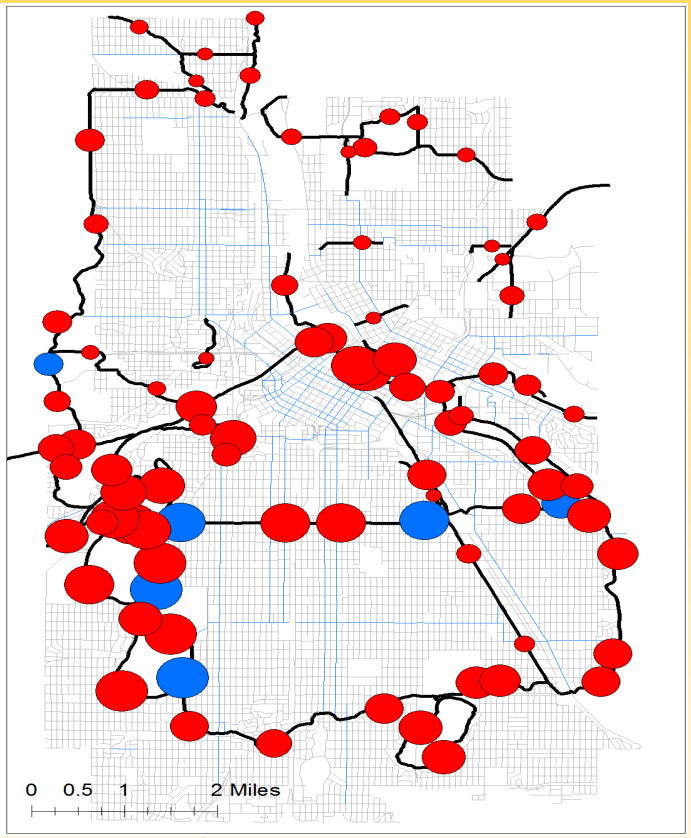




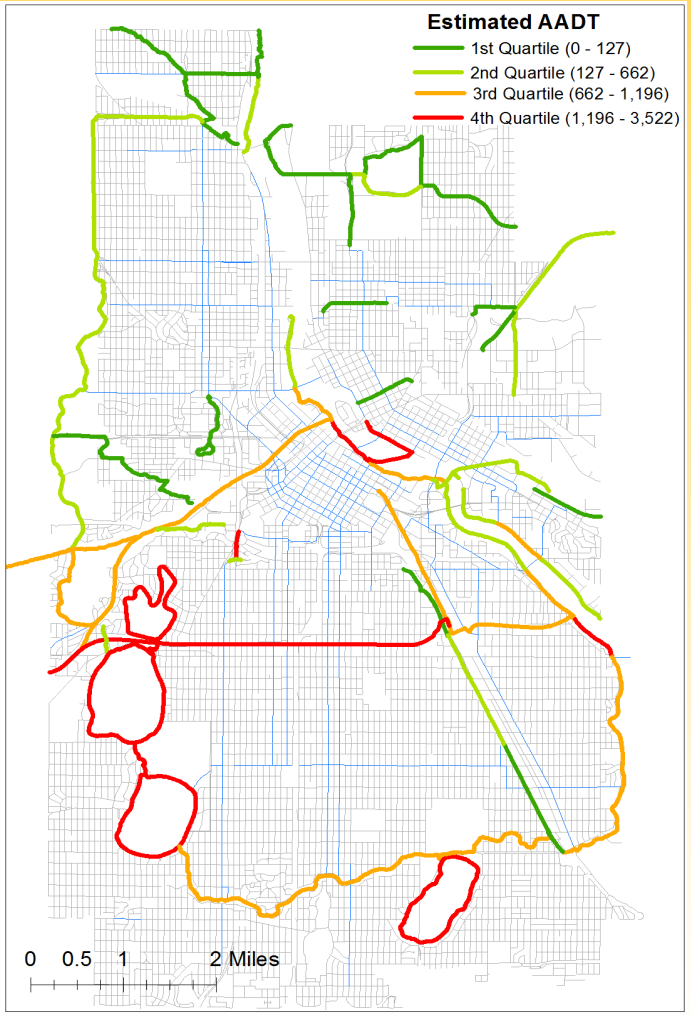




Estimating Performance Measures: AADT and Trail Miles Traveled in Minneapolis

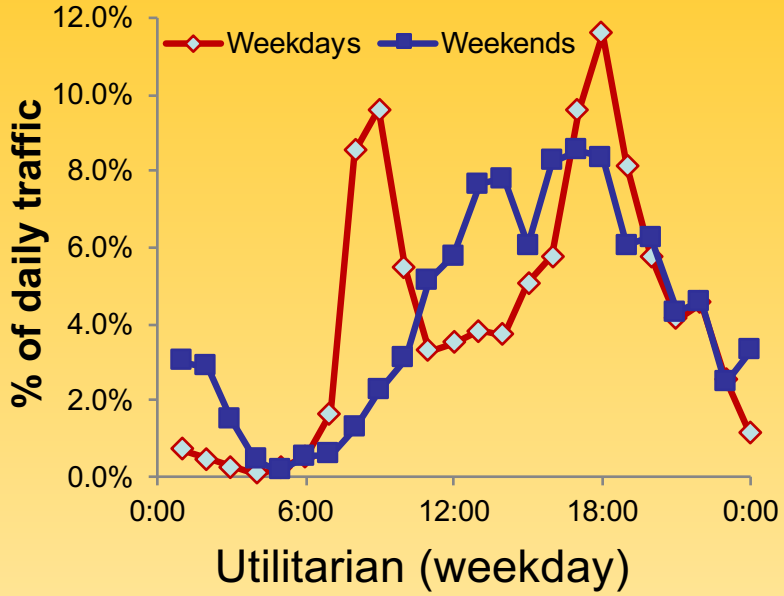


- 6 reference sites
- 7 day short duration counts on each segment



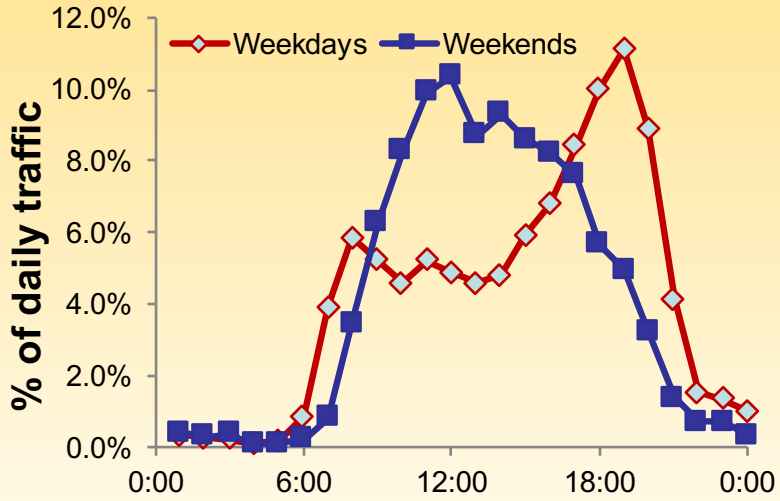
Segment AADT	
Mean	954
Median	750
Max	3,728
Min	39

> 28 million miles traveled on 80 mile trail network in 2013:

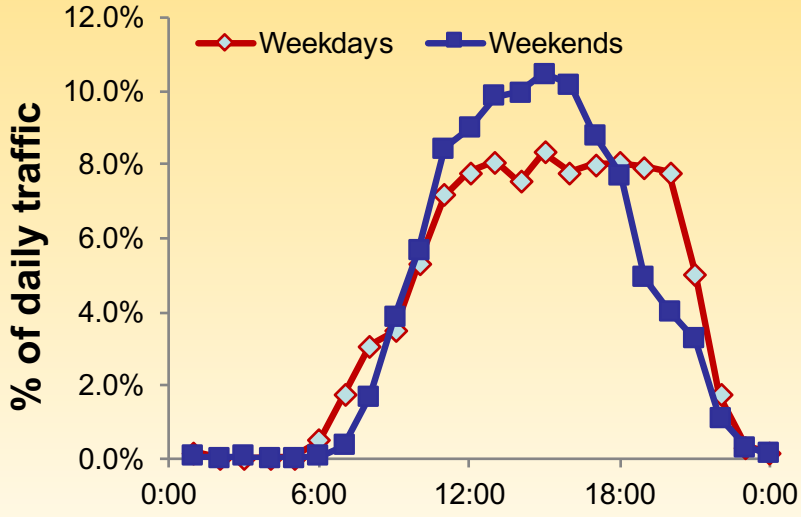


Utilitarian (weekday)

Short-duration monitoring identified three different traffic patterns (factor groups). Need new reference monitoring sites.



Mixed Recreational – Utilitarian
(all current reference locations)



Recreational

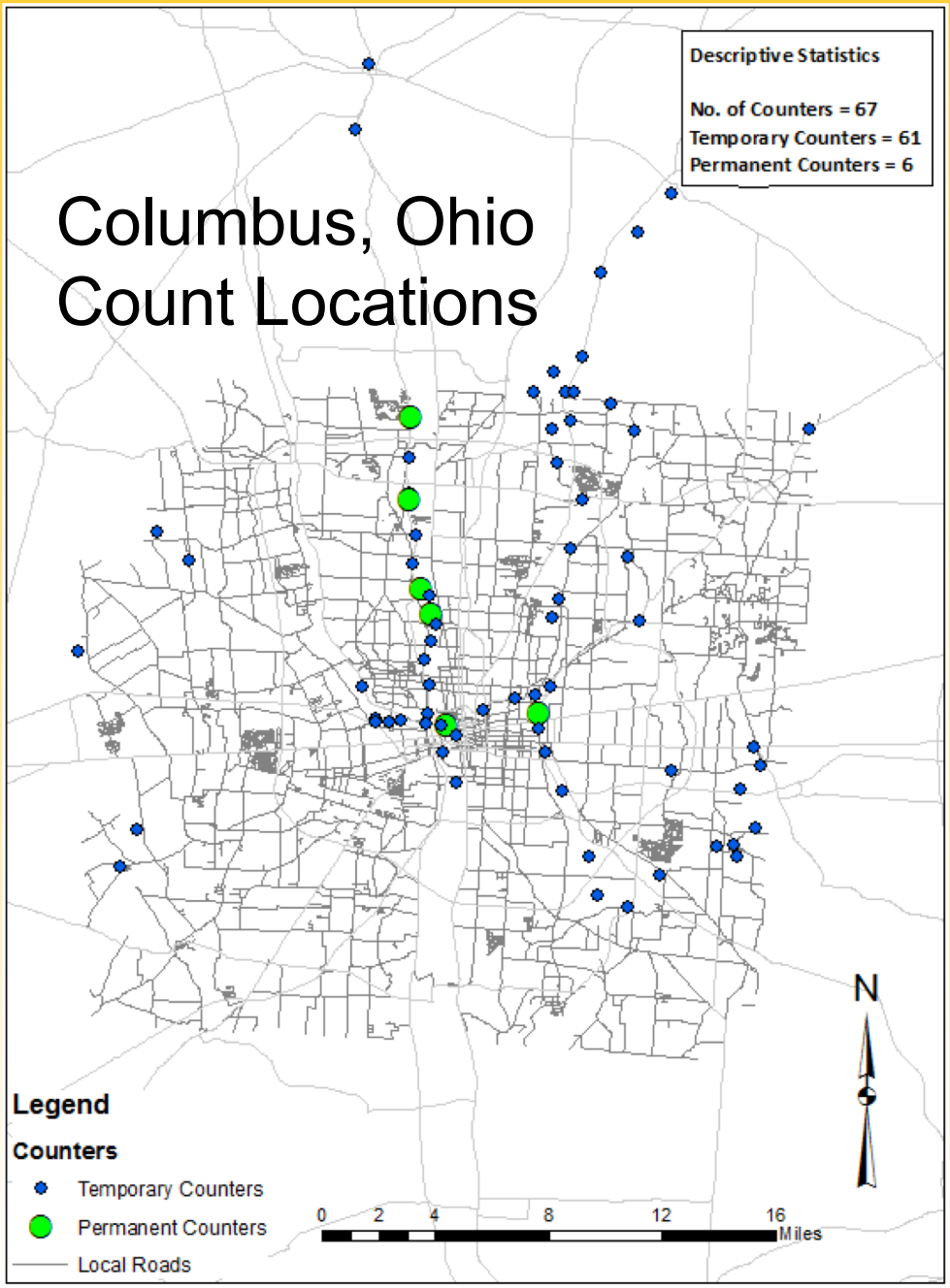
Conclusions

1. Possible to estimate AADT and TMT for trail network.
2. Traffic volumes on trails are significant and follow seasonal, daily, and hourly patterns.

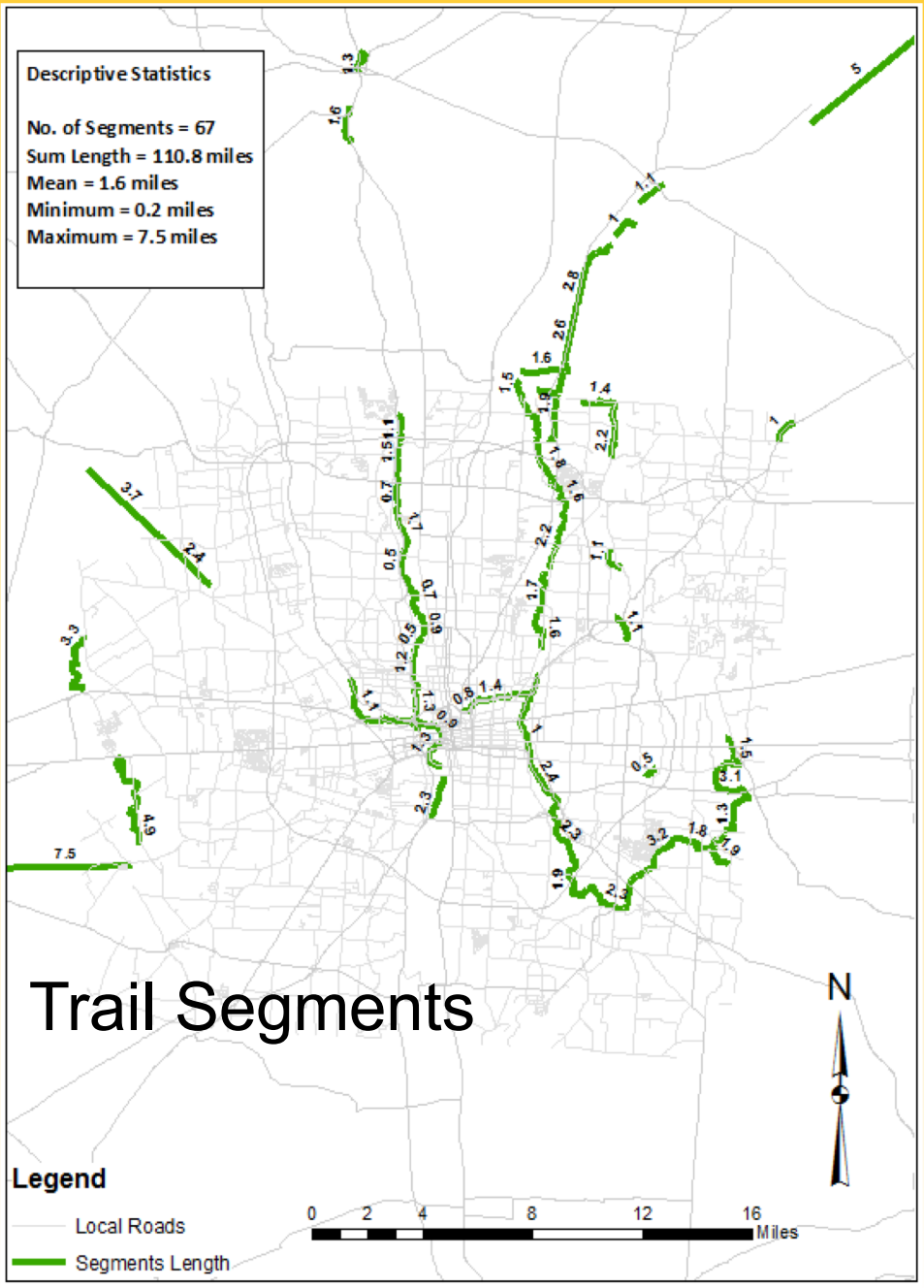
Next steps

1. Relocate reference network (factor groups).
2. Re-assess segment breaks.
3. Monitor bikes and peds separately.
4. Institutionalize monitoring and planning
5. Explore generality of models

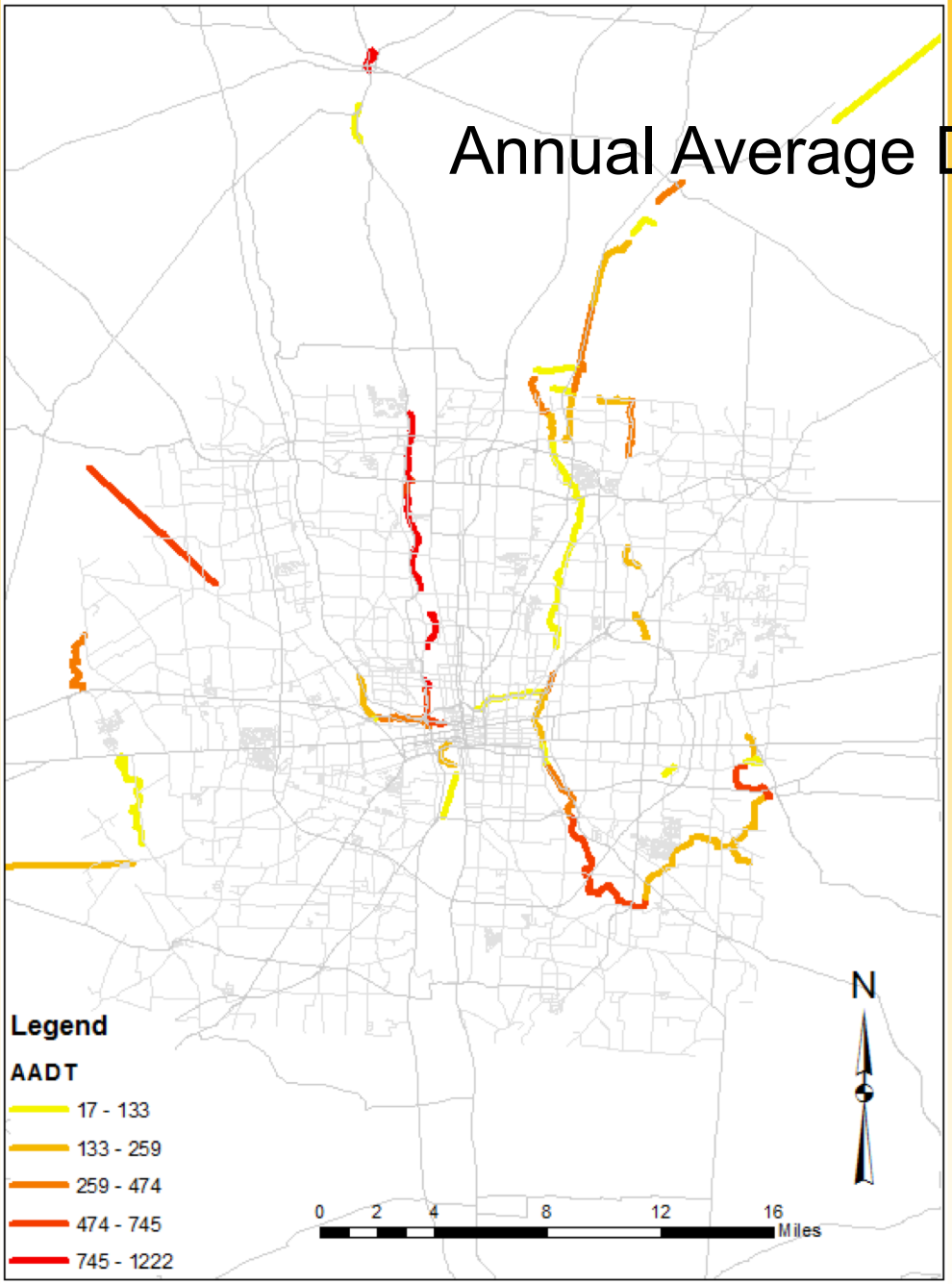
Columbus, Ohio Count Locations

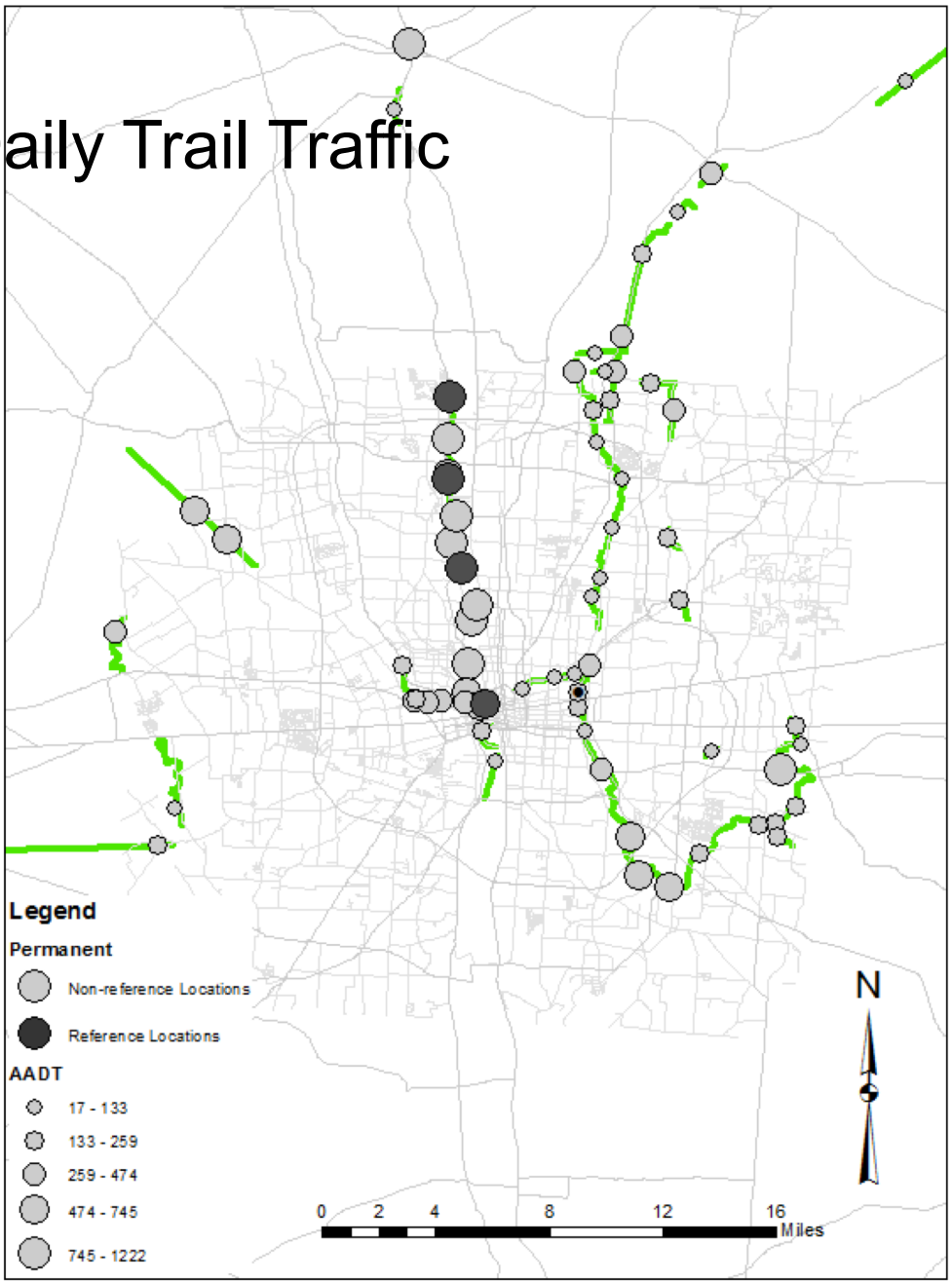


Trail Segments



Annual Average Daily Trail Traffic





Characteristics of Columbus and Minneapolis Networks			
	Minneapolis	Columbus (city)	Columbus (metro, including city)
Trail miles	80	51	110
Reference monitoring sites	6	5	6
Short-duration monitoring sites	80	36	61
Total different monitoring locations	86	41	67
Mean segment length (mile)	0.93	1.25	1.59
Monitoring technology	TrailMaster © active infrared	TRAFx © passive infrared, TrailMaster © active infrared	
Monitoring periods (sampling)	2013	2014	2014
Trail Monitoring Results: Estimates of AADT			
Maximum AADT	3754	1256	1403
Mean AADT	1022	355	330
Median AADT	848	204	217
Minimum AADT	39	20	13

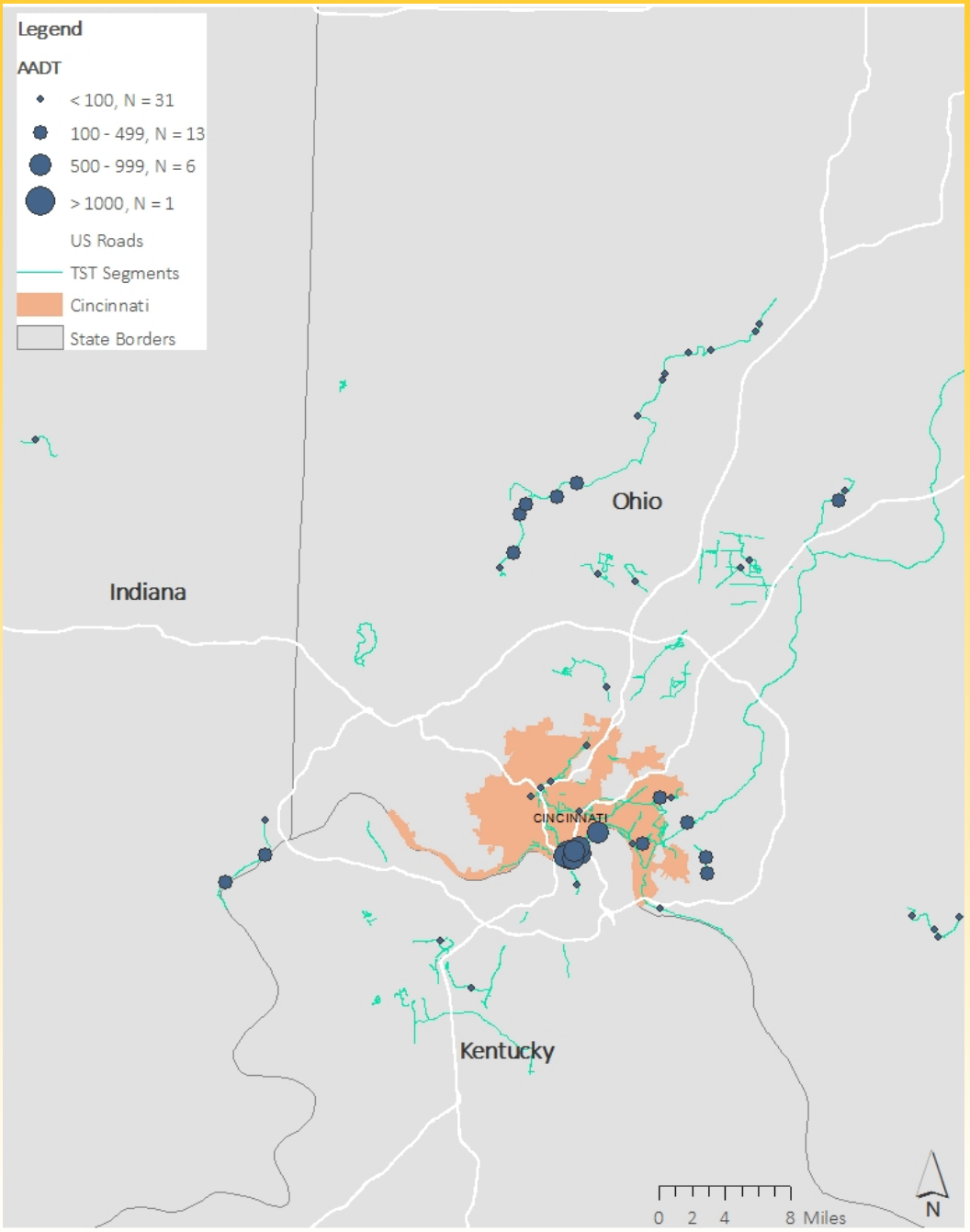
Cincinnati Region

Interact for Health
Tri-State Trails

58 monitoring locations

Integrate network into demand models

Distribute tools (Prince George's County)



Industrial Heartland Trail Coalition

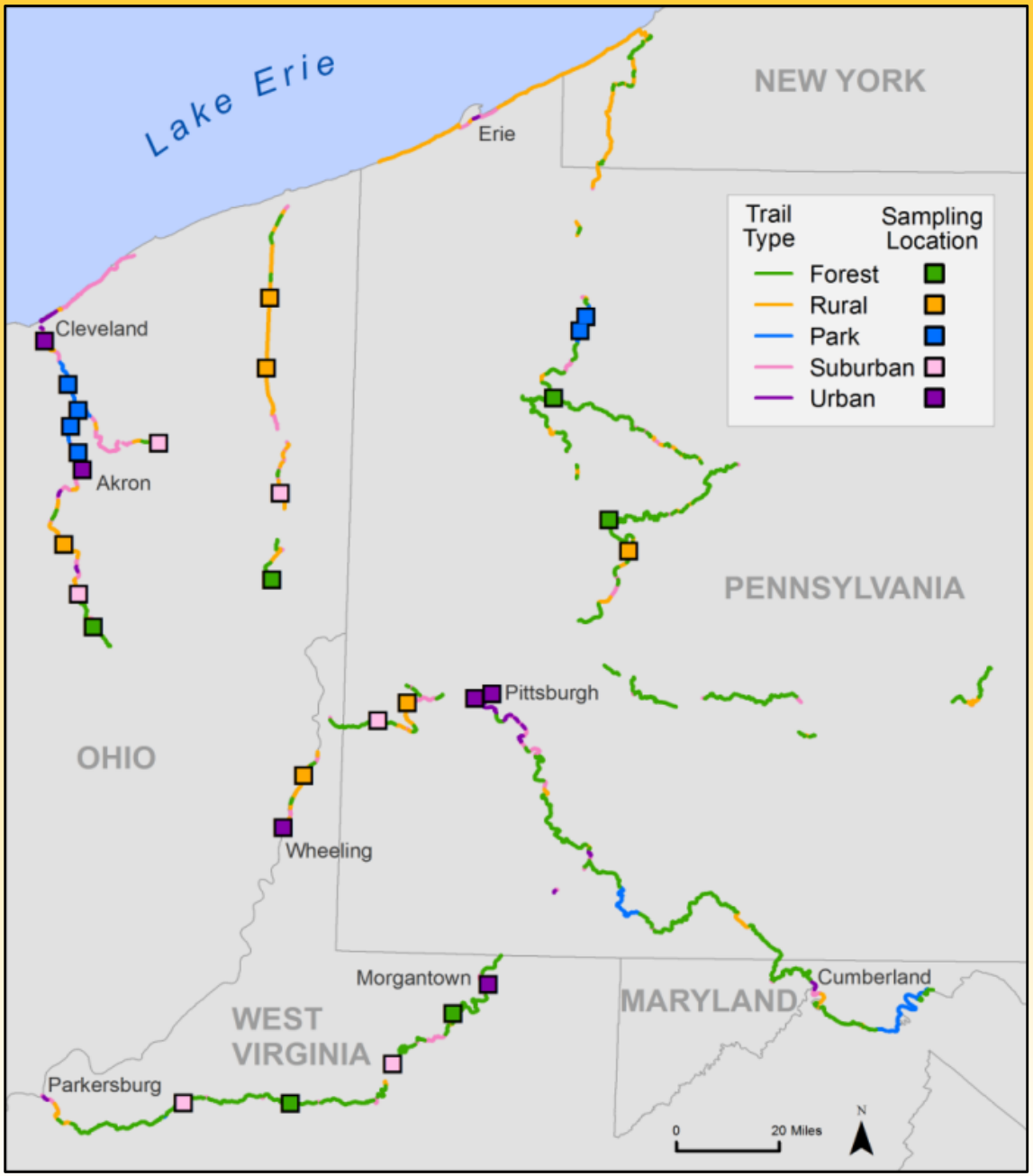
- Regional economic development coalition
  - 100 members
  - Leadership: Rails to Trails Conservancy, National Park Service, and PA Environmental Council
- Trail network
  - Nearly 1000 miles of existing trail
  - Plans to increase network to 1,400 miles
  - 4 states: Ohio, Pennsylvania, W. Virginia, New York
  - 48 counties

Research Objectives

- Estimate performance indicators for 972 mile trail network in 4-state region
- Illustrate application of FHWA *Traffic Monitoring Guide* methods to regional trails
- Help design long-term monitoring plans
- Describe implications for practice
  (*Transportation Research Record 2018)*

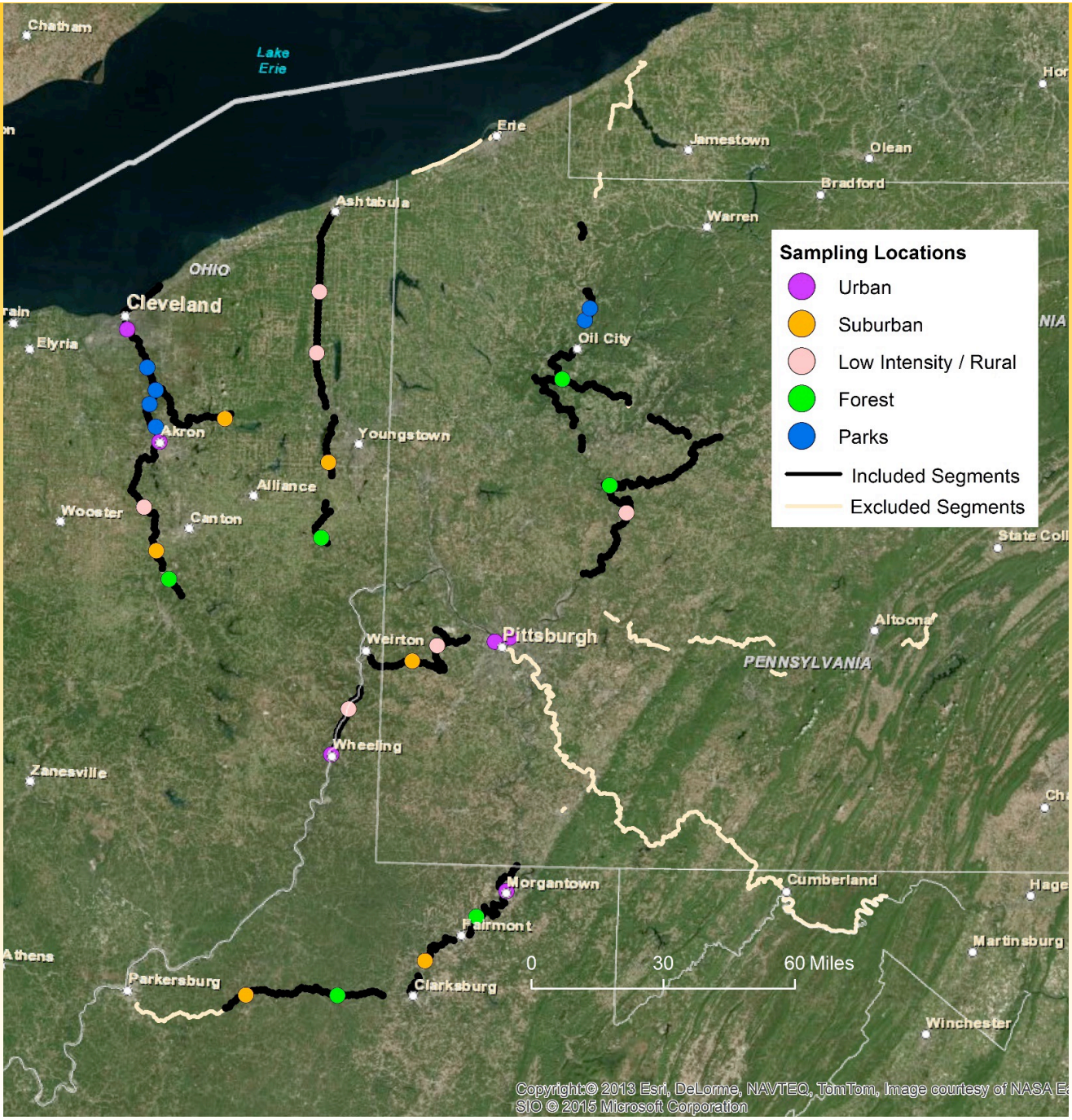
Research Team Approach

- Stratified randomized selection of 30 monitoring sites
- Data collection
  - Passive infrared monitors
  - Goal: minimum one year monitoring data (2015-2016)
- Data quality management
  - Visual inspection of data
  - Flag outliers (> 3 standard deviations above mean)
  - Assess zero counts
  - Impute missing values
- Model daily traffic (30 sites, 5 classes, 1 general model)
- Estimate performance indications
  - Annual average daily trail traffic (AADTT); Trail miles traveled (TMT)
- Determine permanent and short-duration sites



Sampling Approach

- 30 locations
- Stratified randomized selection of sites
- 1,056 potential sample sites (1 mile intervals in network)
- GIS buffers, 16 factors
- Factor analysis, K-means clustering to identify strata
- Five strata: Urban, suburban, rural, forest, parks



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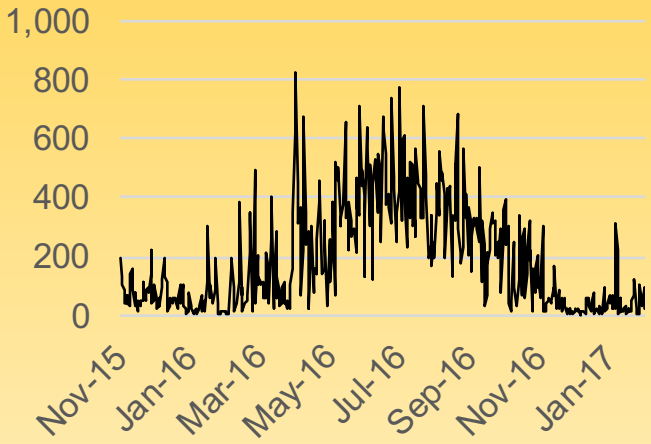
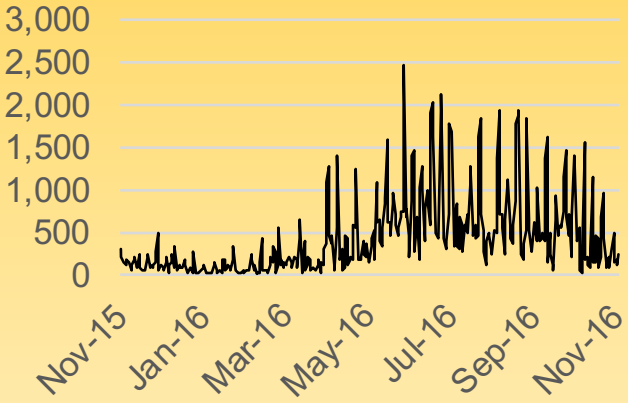
Data Quality Management

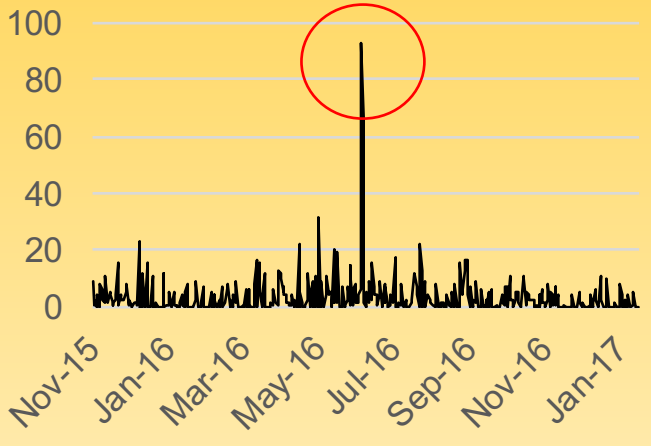
Normal Pattern
Suburban #12



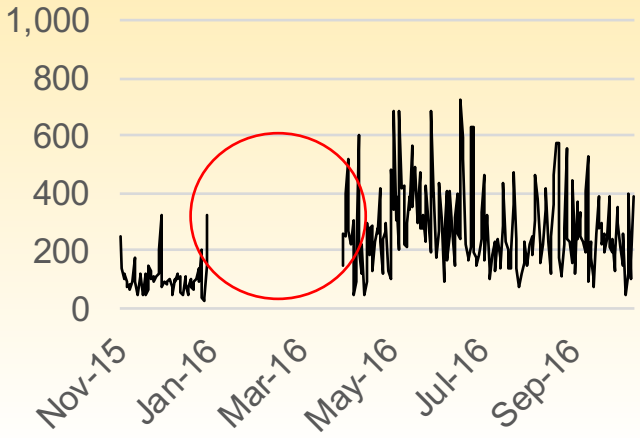
Normal Pattern with Greater Variation
Parks #4



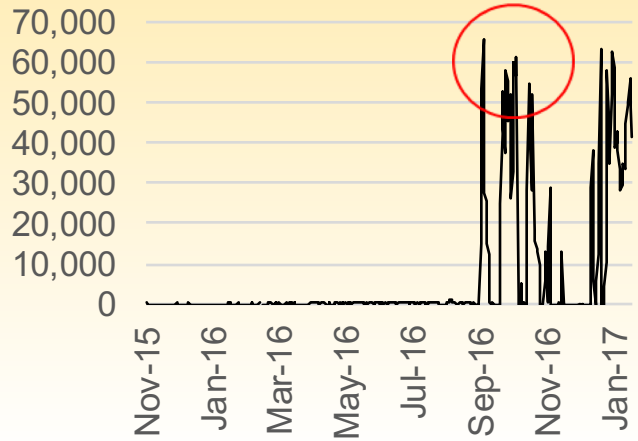
Outliers
Forest #28



Missing Days
Urban #1



Counter with Errors
Suburban #9



- Visual inspection identified problems.
- Missing data.
- Some outliers removed.

Data, QAQC Summary

- 30 monitors deployed
- 22 monitors (73%) deployed ≥ 365 days
- 23 monitors (77%) recorded counts for all days deployed; 7 monitors (23%) had missing days
- 3 monitors included counts judged invalid using QAQC checks
- 19 monitors (63%) had valid counts for ≥ 365 days
- 11 monitors (37%) have valid counts < 365 days (116 – 364 days)
- Total days all monitors deployed: 11,127
- Total days with counts: 10,951 (98% of days deployed)
- Total days with valid counts: 10,698 (96% of days deployed)

Site-specific Models of Daily Traffic

(used to impute missing counts)

All Sites Model	
Dependent variable: ADT	137
Average Dew Point	- - -
Average Wind Speed	+++
Maximum Temperature	+++
Maximum Temperature Squared	+++
Precipitation	- - -
Weekend	+++
Spring	+++
Summer	+++
Fall	+++
Constant	+++
Pseudo R2	0.028

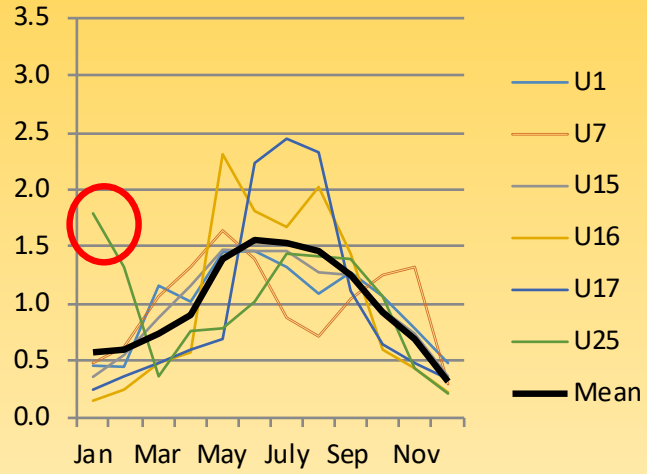
- Negative Binomial Regression
- All Sites Model (n=10,698)
- All variables significant at 1%
- Similar results, site specific models
- Precipitation not significant for urban counters
- Dew point not significant for suburban and parks counters
- Wind speed and max temperature not significant for rural counters
- Seasonal variables are not significant for forest

Monitoring Results

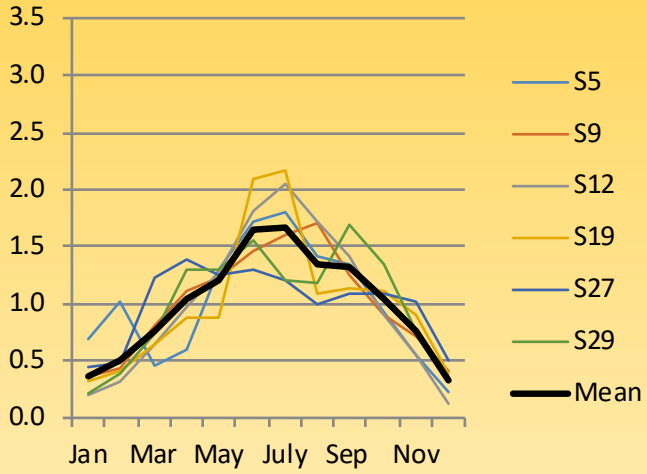
Land Use Strata (6 sites / strata)	Minimum AADTT	Maximum AADTT	Strata Mean AADTT
Forest	4	97	40
Low intensity dev. and rural	20	161	84
Parks	35	597	258
Suburban	31	221	90
Urban	47	506	251

Monthly Factors by Land Use

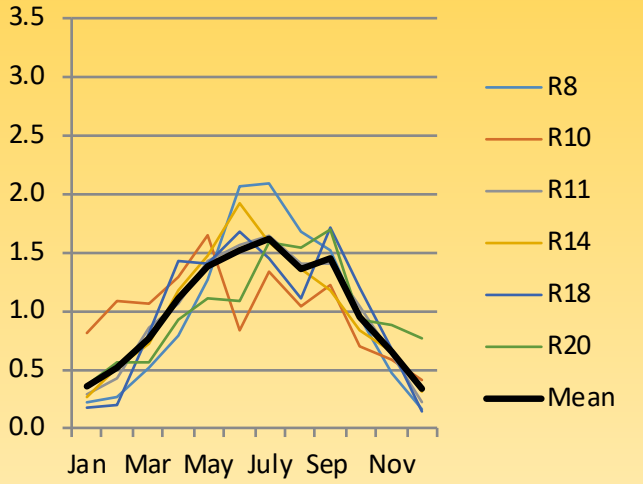
Urban



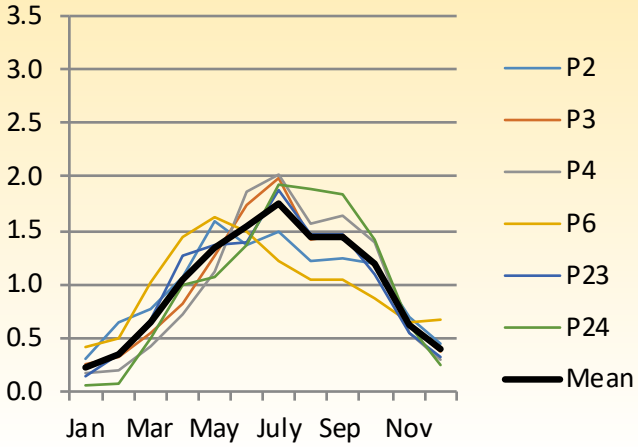
Suburban



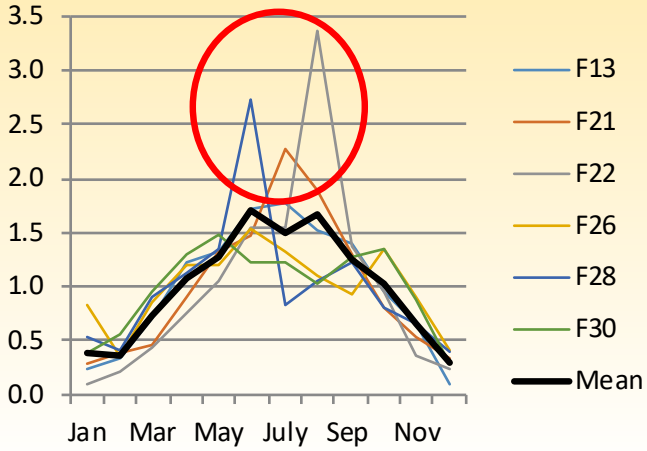
Rural



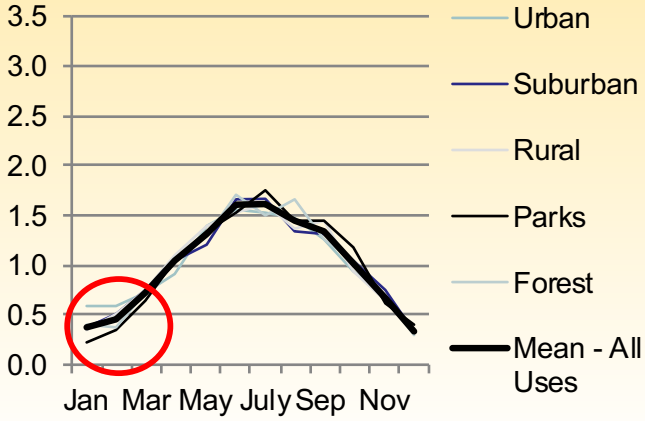
Parks



Forest

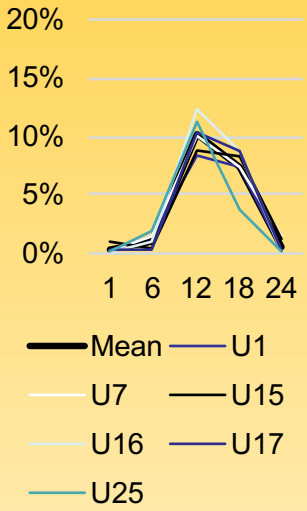


All Sites

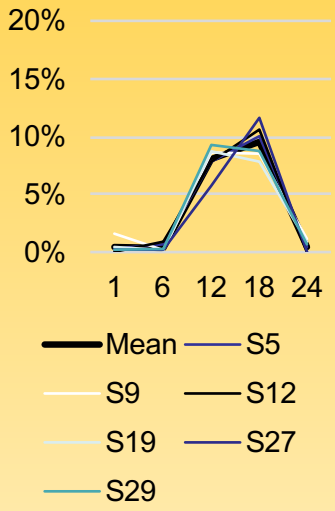


Hourly Factors by Land Use

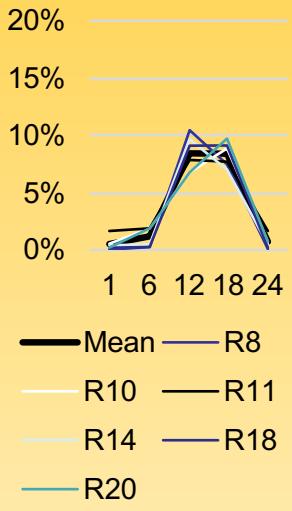
Urban Weekday



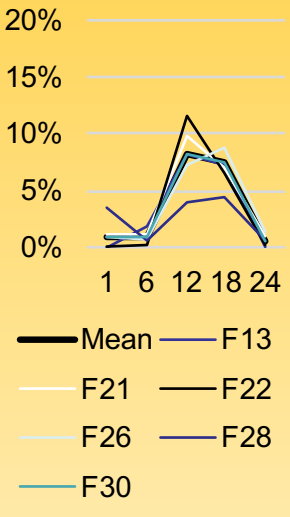
Suburban Weekday



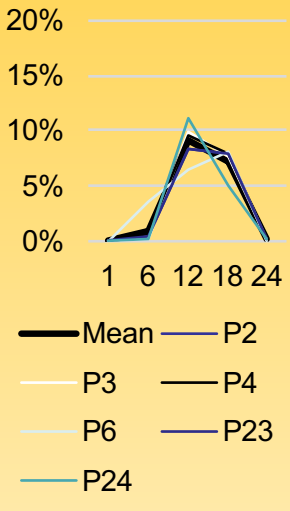
Rural Weekday



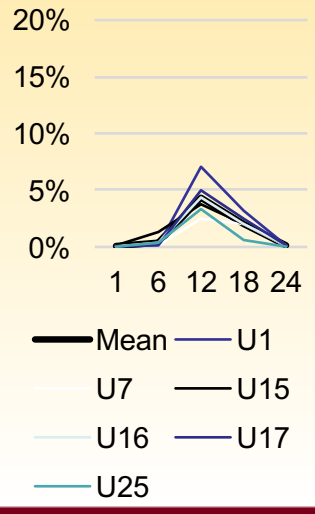
Forest Weekday



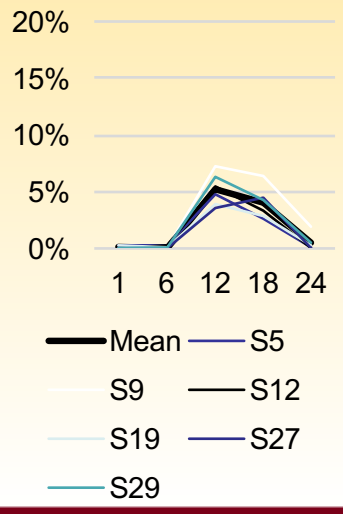
Park Weekday



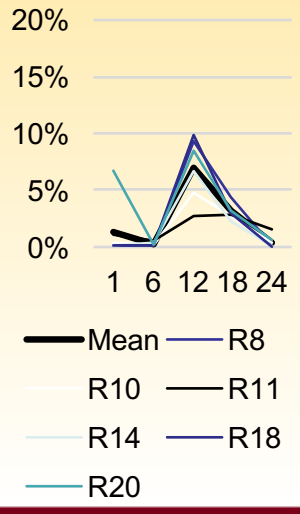
Urban Weekend



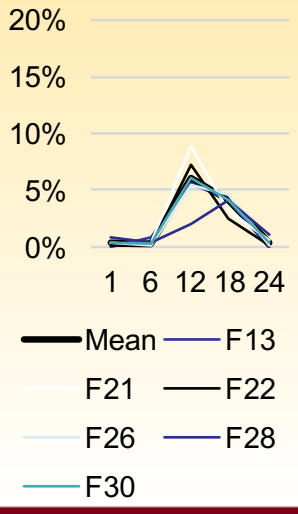
Suburban Weekend



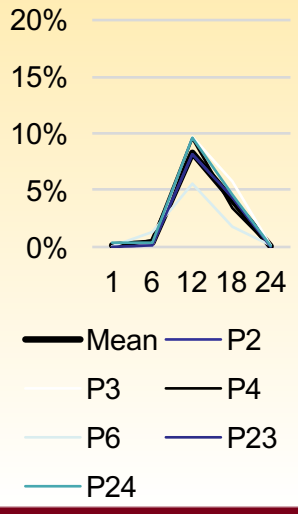
Rural Weekend



Forest Weekend



Park Weekend



Estimation of Performance Indicators

Sample Strata	Number of Sample Points	Estimated Trail Miles	AADT	Estimated Trail Miles Traveled Annually	% of Sample Points (Miles)	% of Miles Traveled
Forest	497	457	40	6,676,000	47%	23%
Low intensity dev. and rural	248	228	84	6,995,000	23%	24%
Parks	72	66	258	6,238,000	7%	21%
Suburban	196	180	90	5,924,000	19%	20%
Urban	43	40	251	3,624,000	4%	12%
Totals	1056	972		29,500,000	100%	100%

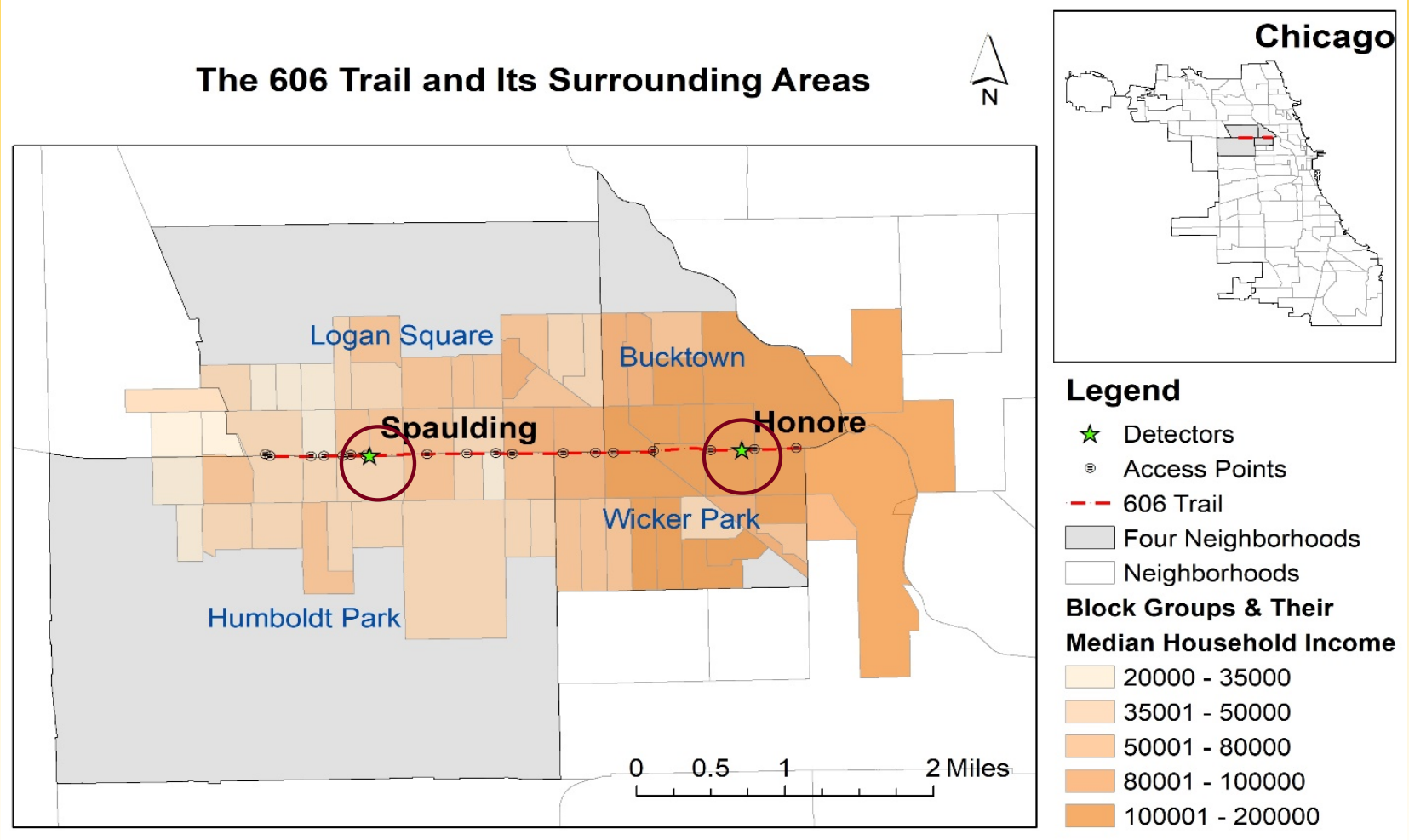
Conclusions

- FHWA principles applicable to regional trail monitoring
- Many practical challenges in monitoring
- Stratified-randomized sampling approach is useful
- QAQC procedures essential for valid estimates
- Daily traffic can be modeled using weather, day-of-week, and season variables
- Monthly average daily traffic patterns converge across land uses (regardless of volume)
- AADTT associated with adjacent land use
- Trail miles traveled substantial: 29.5 million miles / year

The 606 (Bloomingdale Trail)

- Opened in June 2015
- The only multiuse elevated trail in the US
- Cost $95 million
- 15 years of planning and development

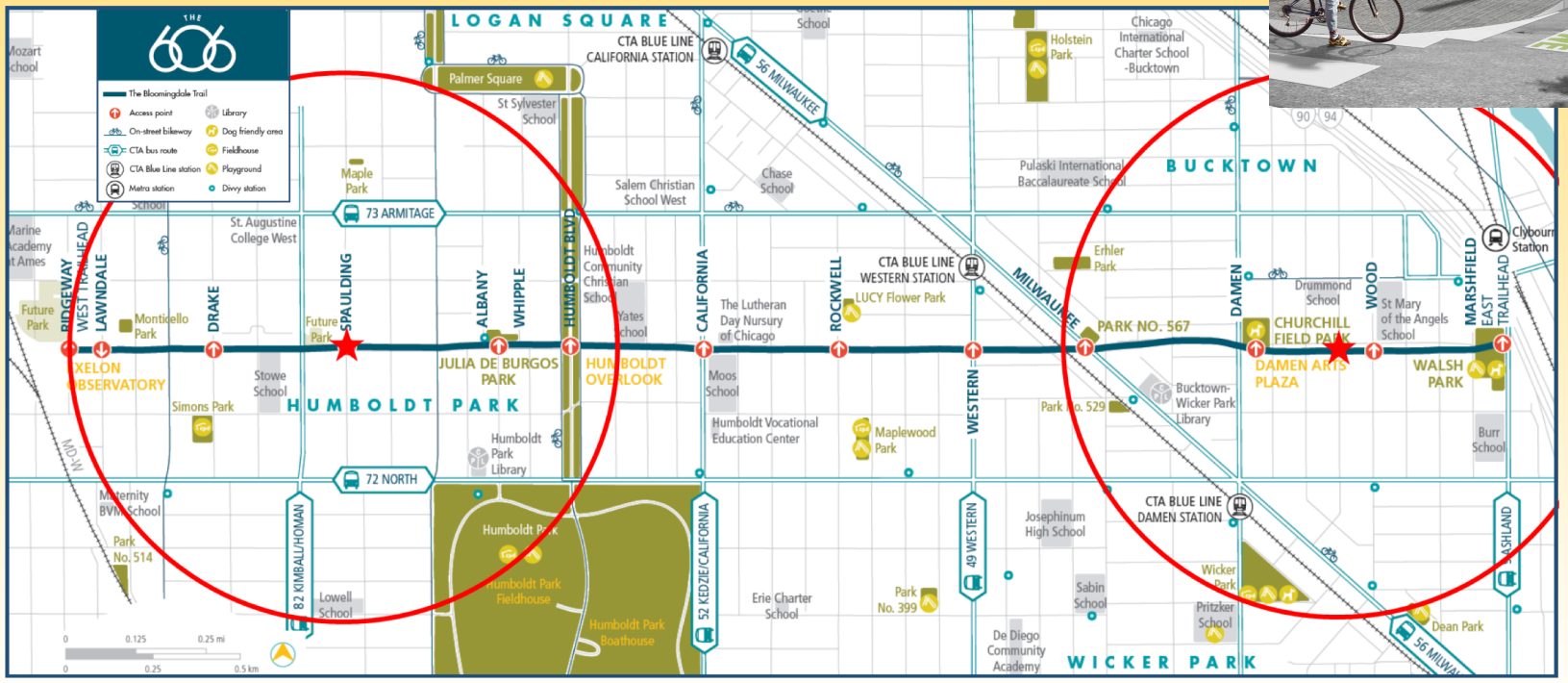
Location of The 606



Before & After

The 606 – Accessible to All Users

- 12 ***access points*** for wheel-based users



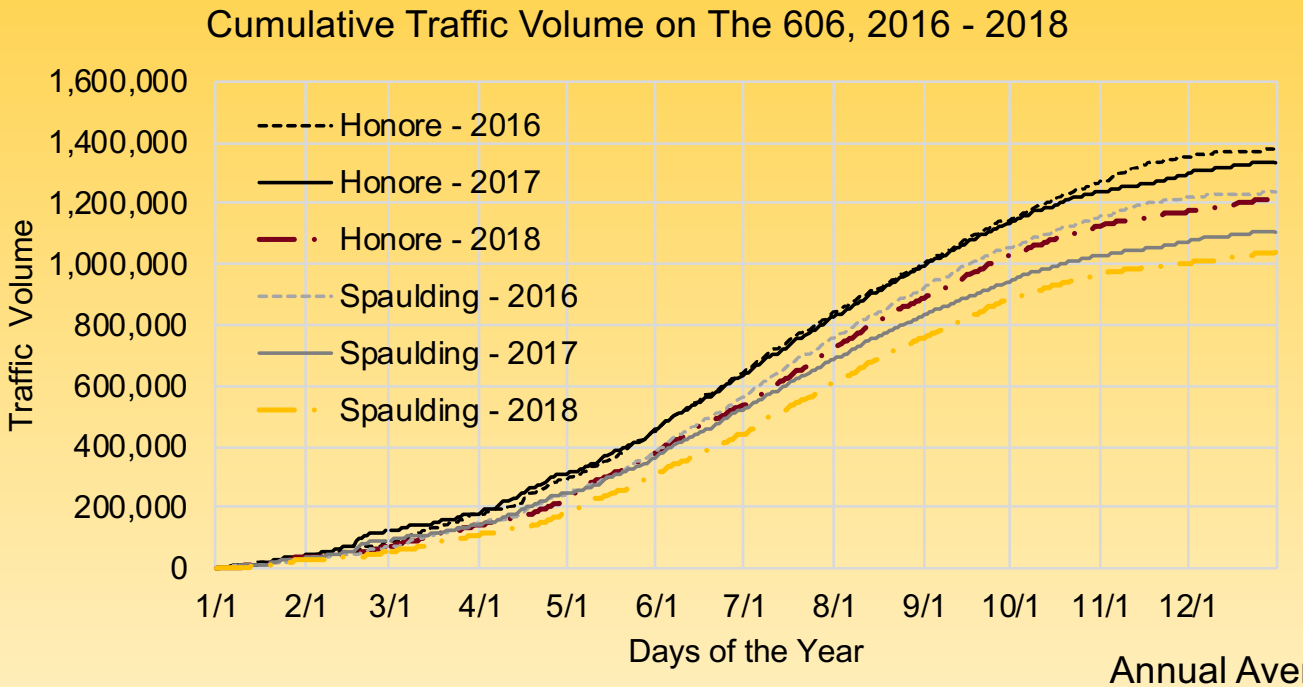
Methods

- Mixed-mode Traffic counts from 1/1/2016 – 12/31/2018
- Monitoring location: Spaulding Avenue and Honore Street

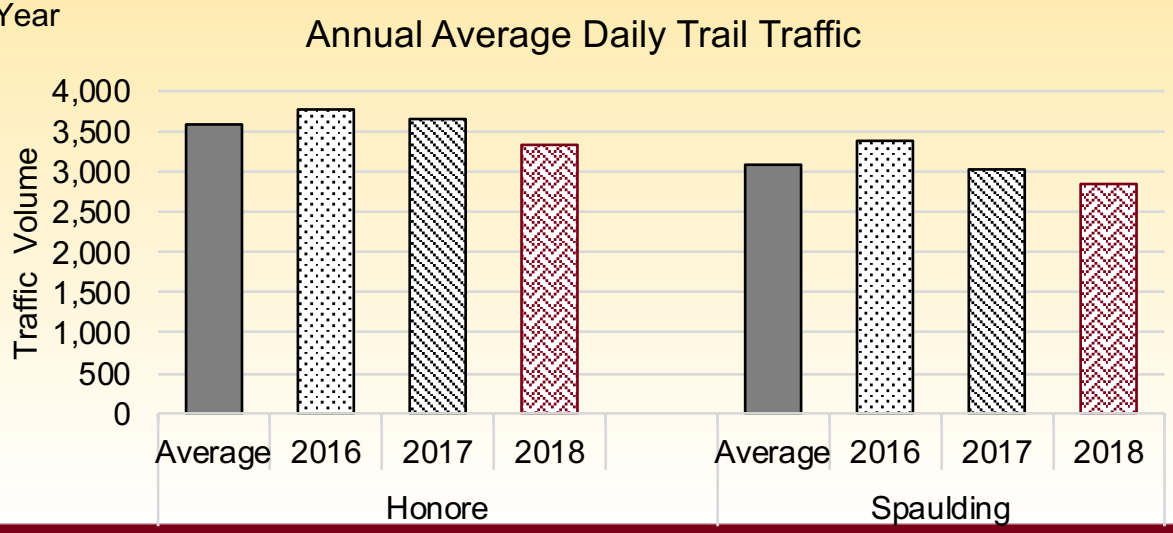
Methods

- Installation of the monitors (2016-present)
- Undercount due to occlusion (field studies)
  - Field studies for calibration factors
- Missing observations due to counter malfunction (imputed with weather models)

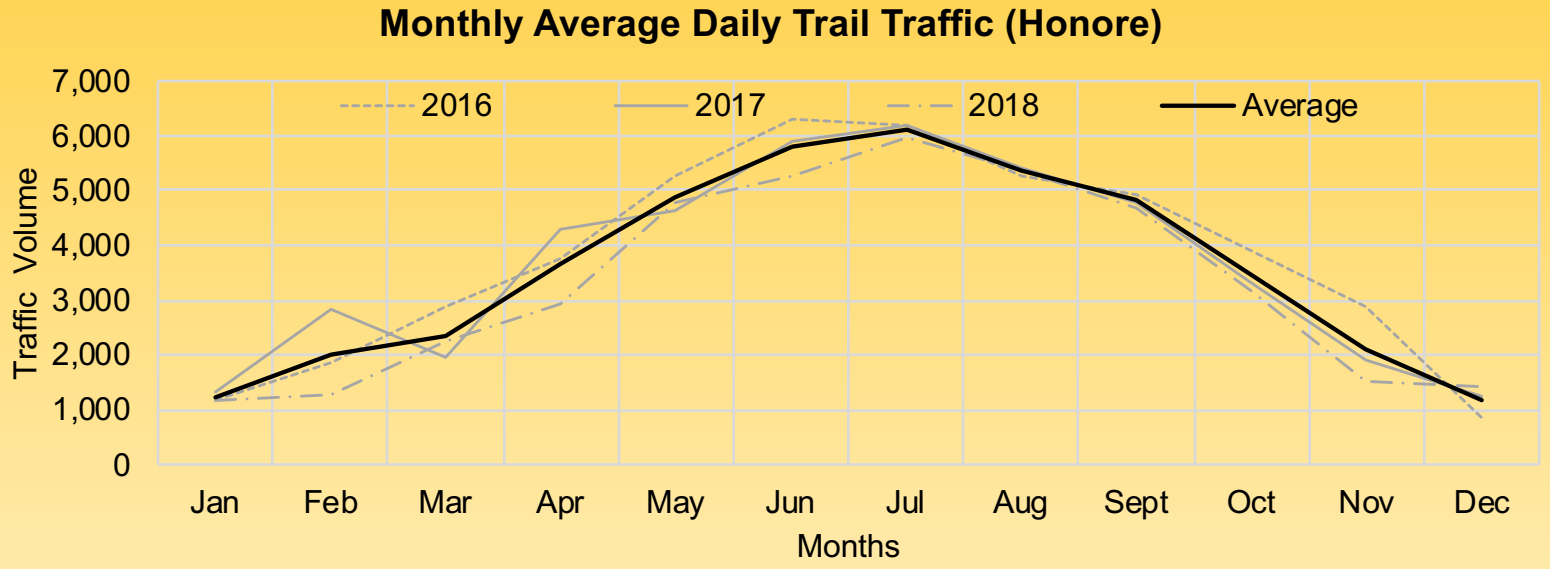
Total Use of 606 Declined

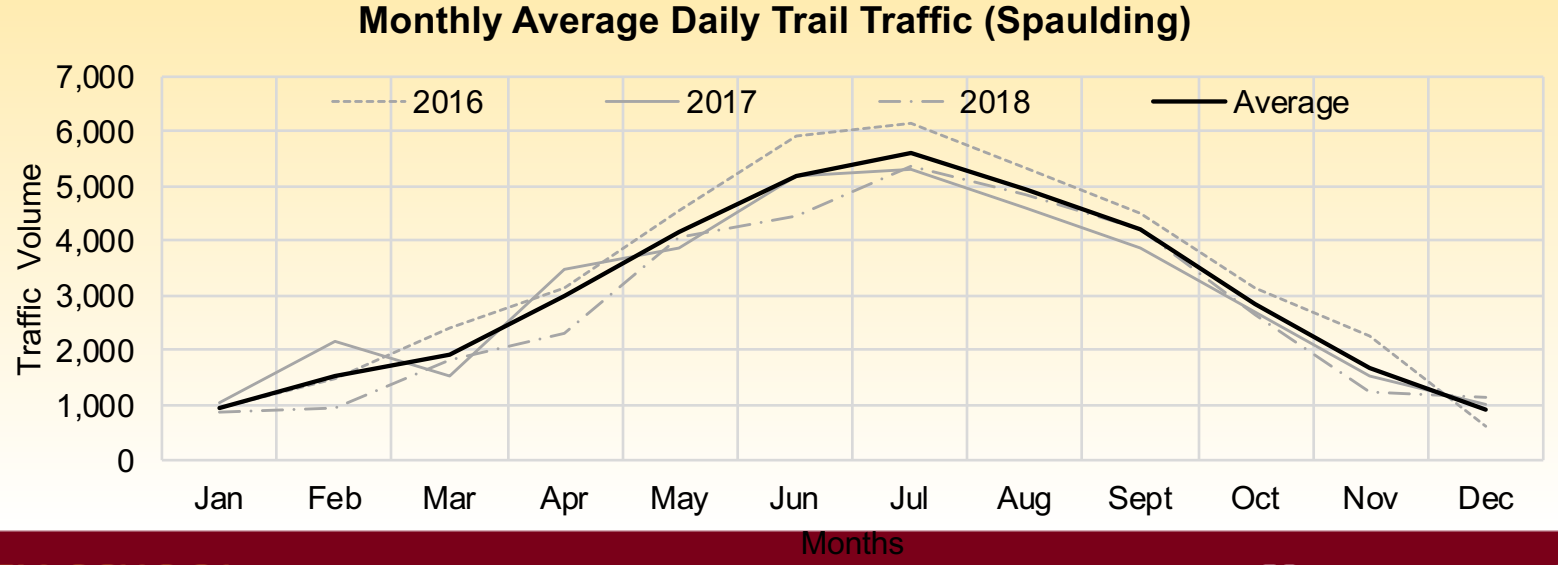


- Honore: - 11.9%
- Spaulding: - 16.1%

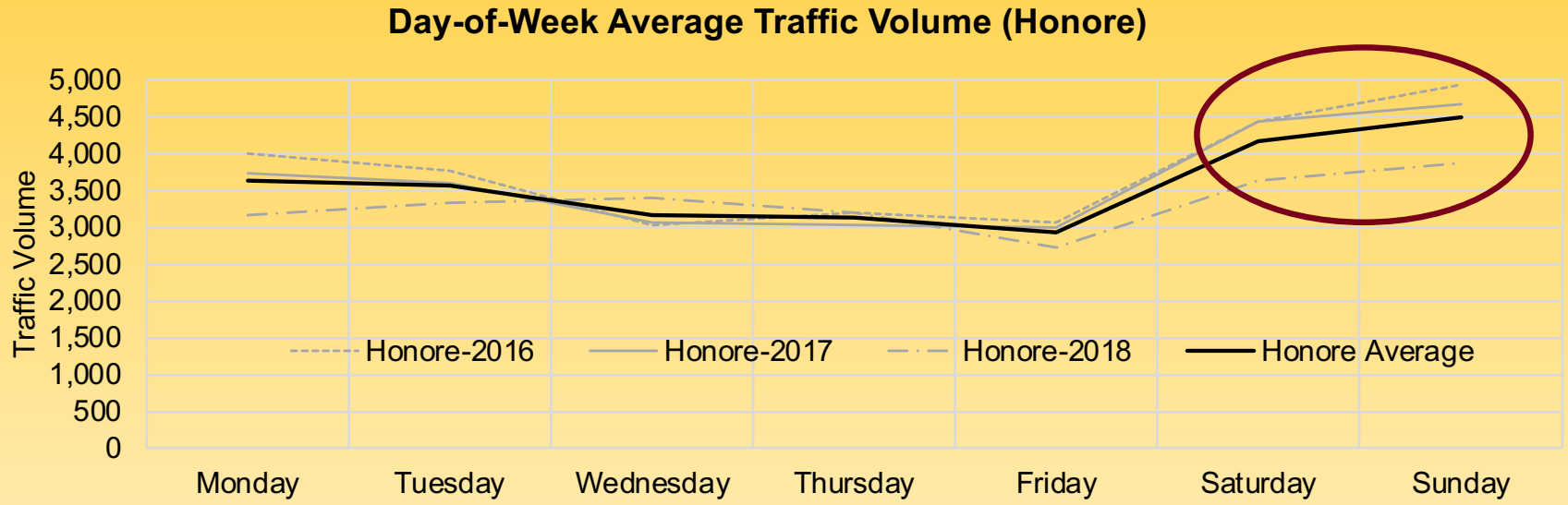


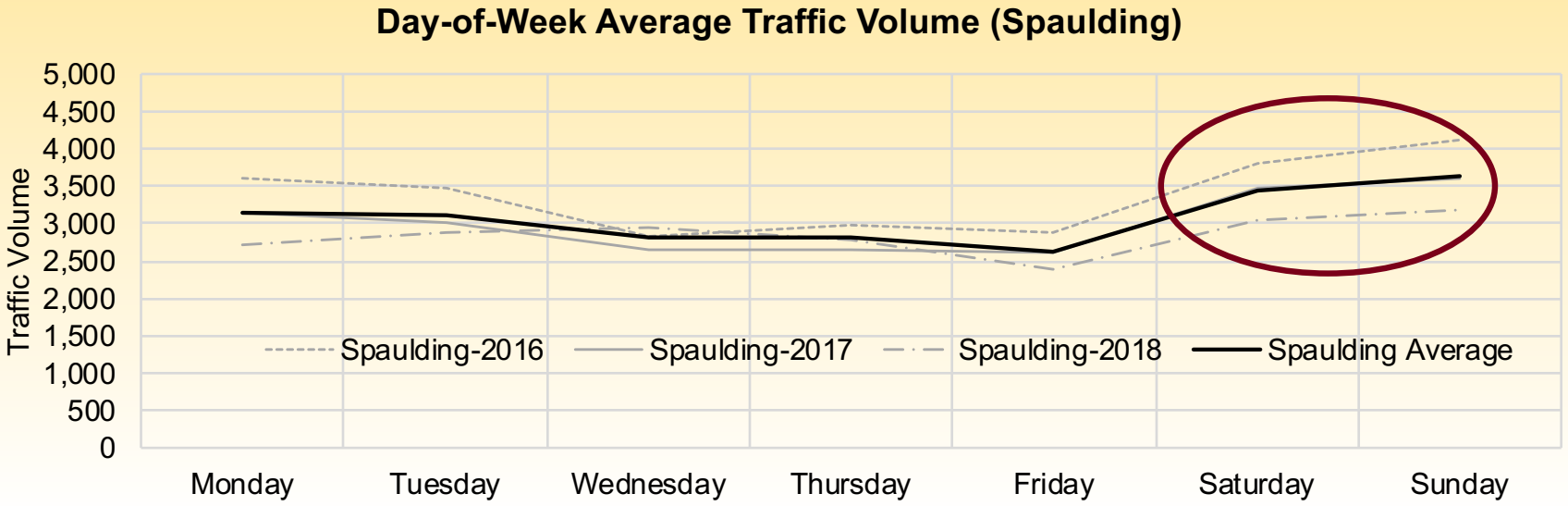
Seasonal Pattern of Monthly Average Daily Trail Traffic



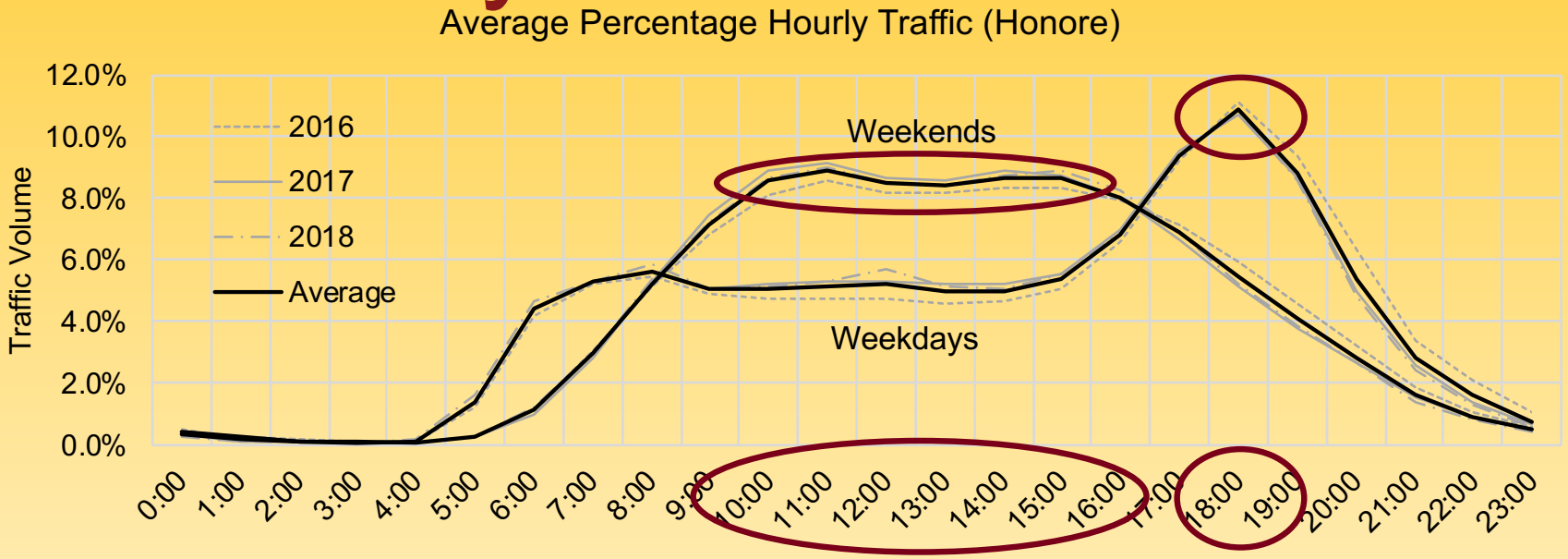


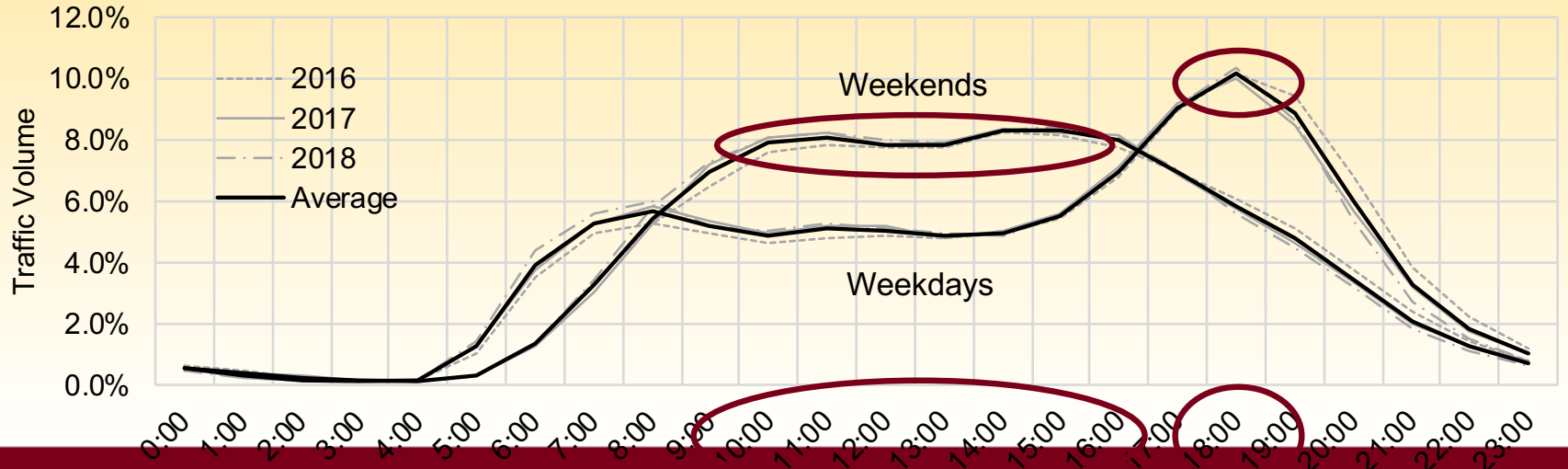
Day-of-Week Patterns





Hourly Traffic Patterns





Observations about the 606

- The 606 is heavily used
- Use decreased in both 2017 & 2018
  - Larger decrease in 2018
  - Larger decrease on the segment in less affluent neighborhood (Spaulding)
- Temporal patterns of use did not change substantially

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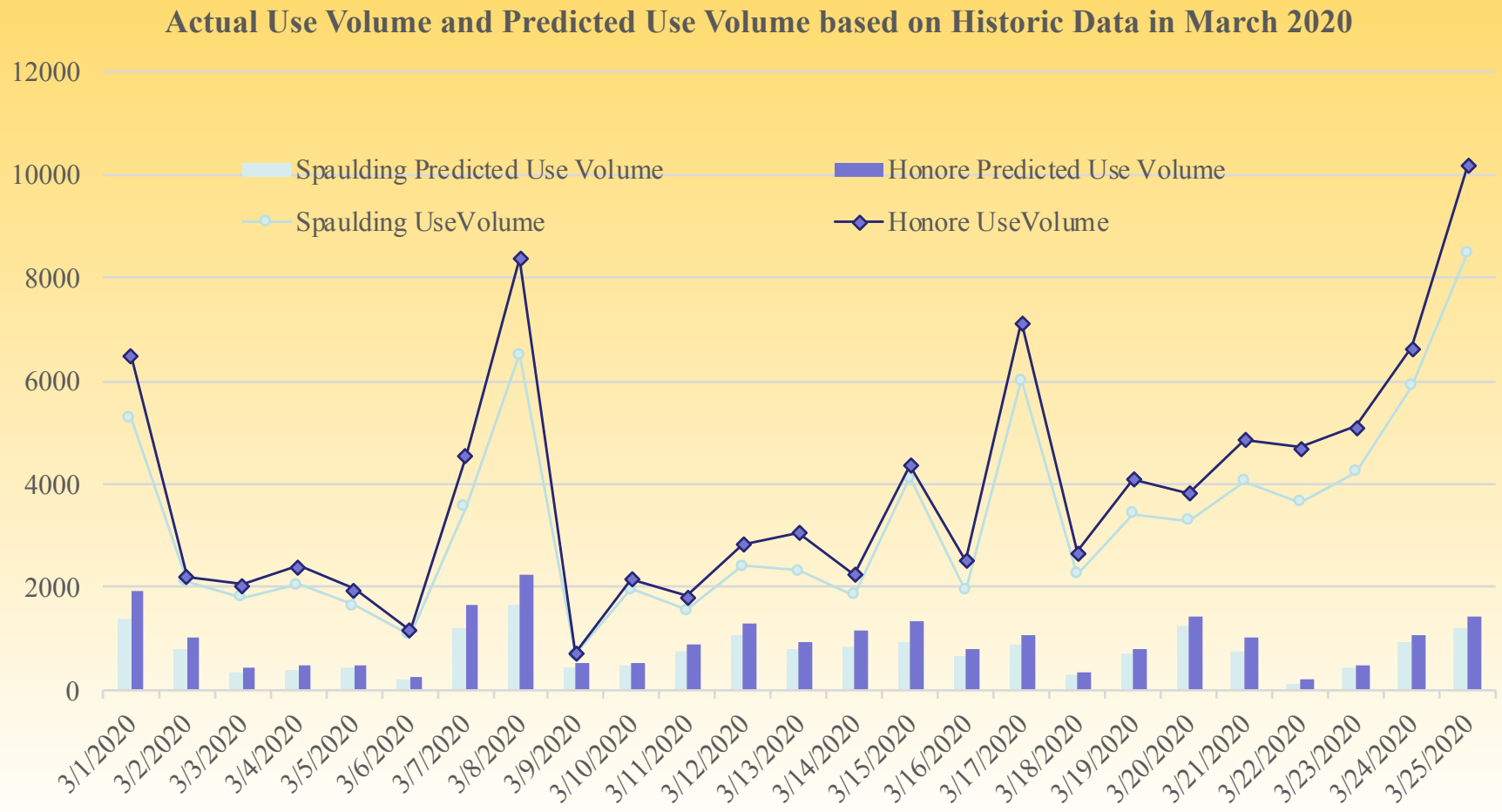
Use Peaked With Shelter at Home; 606 Subsequently Closed



Your Questions

- Monitoring Technology and Approaches
  1. Worth investing in Eco-Counters? What's your experience and thoughts on TRAFx counters?
  2. Is there a different approach for user counts on bike lanes?
  3. How can we modify our data collection method so that it is more relevant to CT DOT needs?
  4. Short Duration Count Methods- Should the counters be out for 1 or 2 weeks at a time?
- Data Analyses, Extrapolation, and Interpretation
  1. What was your methodology on deciding site location for counters?
  2. How do we calculate VMT on trails?
  3. Are there recognizable use patterns that align with trail types?
  4. How do we extrapolate statewide use, or use on other multi-use trails, from 3 years of CT Trail Census data?
  5. Developing accurate calculation for out and back users since not all uses are out and back.

Questions?

Thank you!