

# *Monitoring and Assessing Arterial Traffic Performance*

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# Outline

- ▶ Outsource Probe Data Quality
  - ▶ Multi-Vendor, Freeways, & Arterials
- ▶ Completing the Picture ... Arterial Performance Measures
  - ▶ Possible to measure - not model
  - ▶ Re-identification and High-Res technologies
  - ▶ FOUR key measures to bank on
- ▶ And Beyond ...



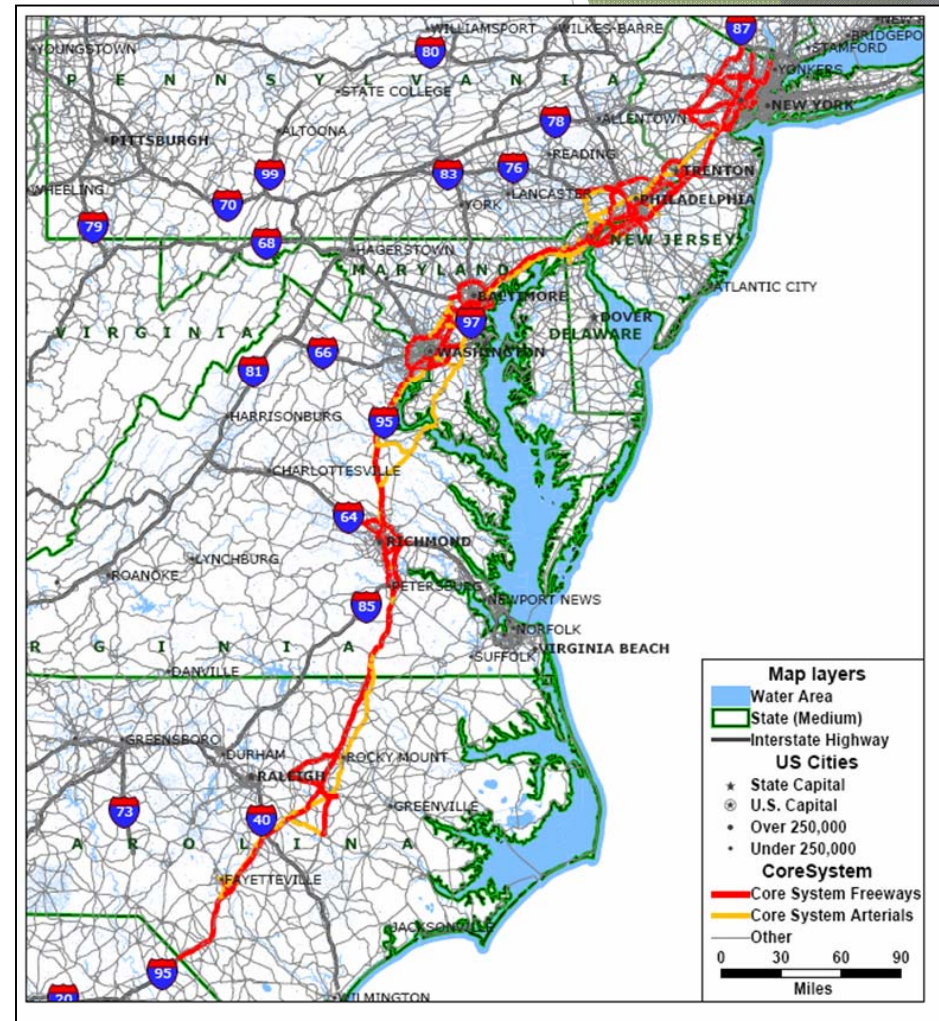
# I-95 Vehicle Probe Project

## ► Phase I (2008-2014)

- First Probe-based Traffic System
- Specifications-based, validated
- Licensing - one buys, all share
- Began 2.5K miles, grew to 40K
- Travel time on signs, 511 systems, operational awareness, performance measures

## ► Phase II (2014 forward)

- All of the above
- Better quality, less cost
- Data market place (Multiple-vendors)
- Emphasis on arterials and latency
- 42.5K miles and growing
- Map-21 Performance Measures



# I-95 Vehicle Probe Project

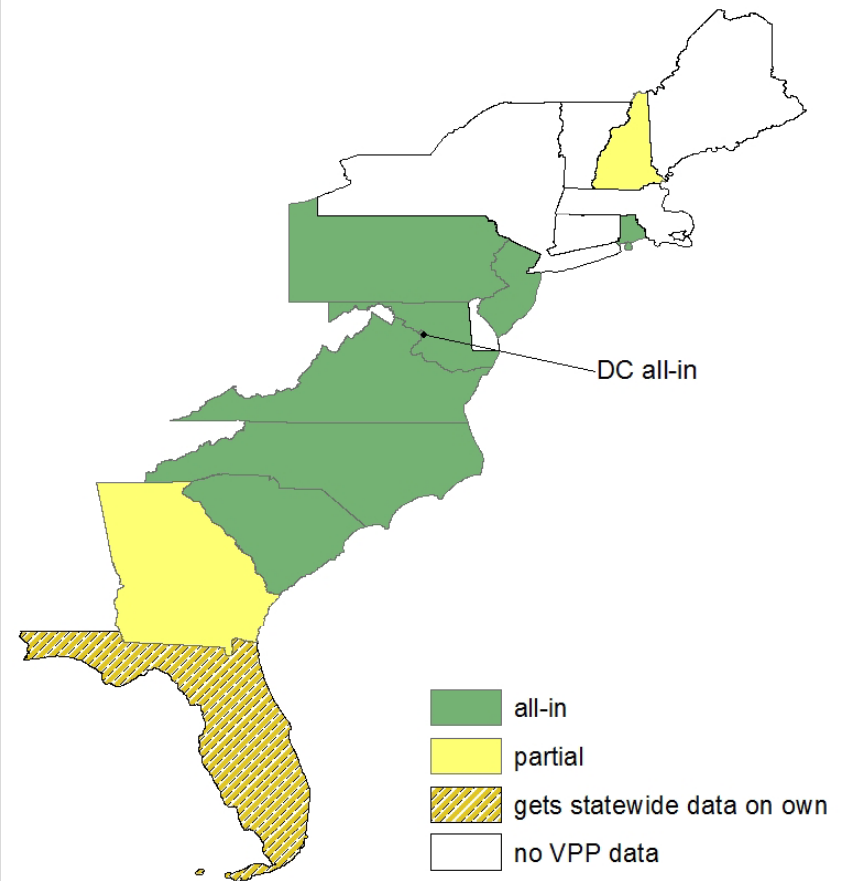
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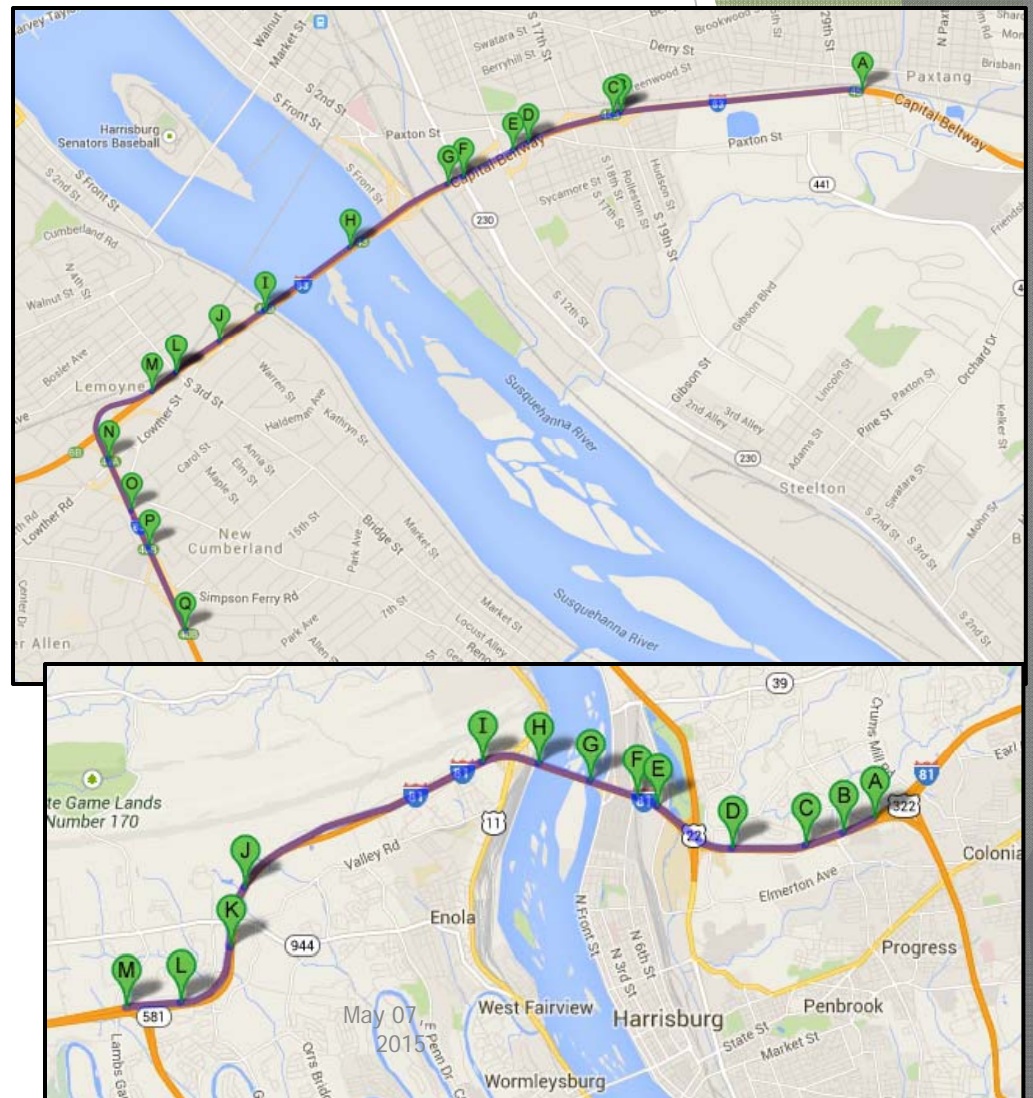
### VPPII April 2015 State Coverage



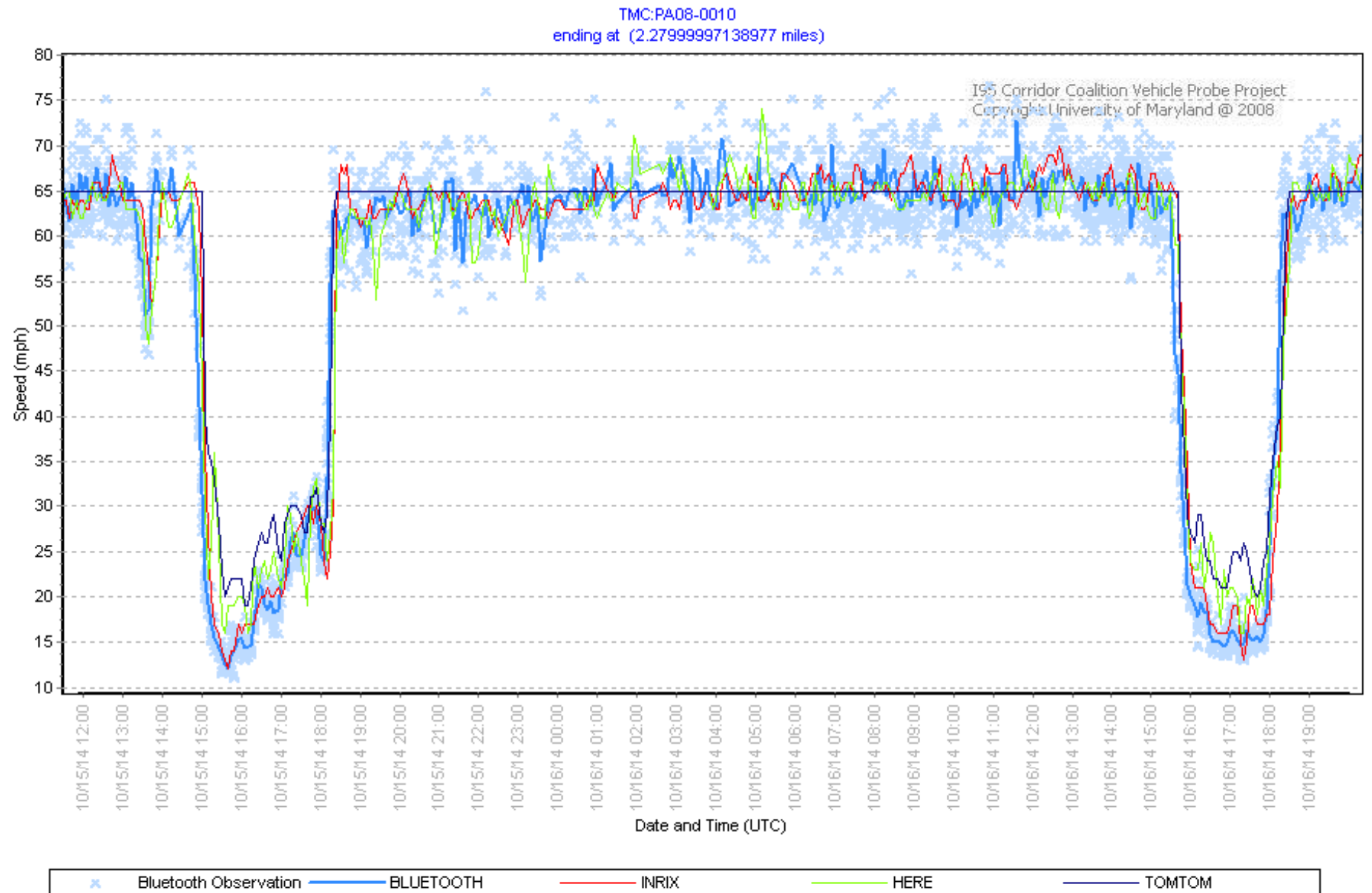


# First Multi-Vendor Freeway Validation I-83 & I-81 Harrisburg, Oct 2014

- ▶ PA-08
  - ▶ 14 Segments
  - ▶ 31.3 miles
- ▶ Data collection
  - ▶ 2300 to 2555 total hrs
  - ▶ 71 to 80 hrs [0-30]
  - ▶ 53 to 66 hrs [30-45]
- ▶ AASE
  - ▶ 2.1 to 4.1 mph [0-30]
  - ▶ 3.1 to 5.8 mph [30-45]



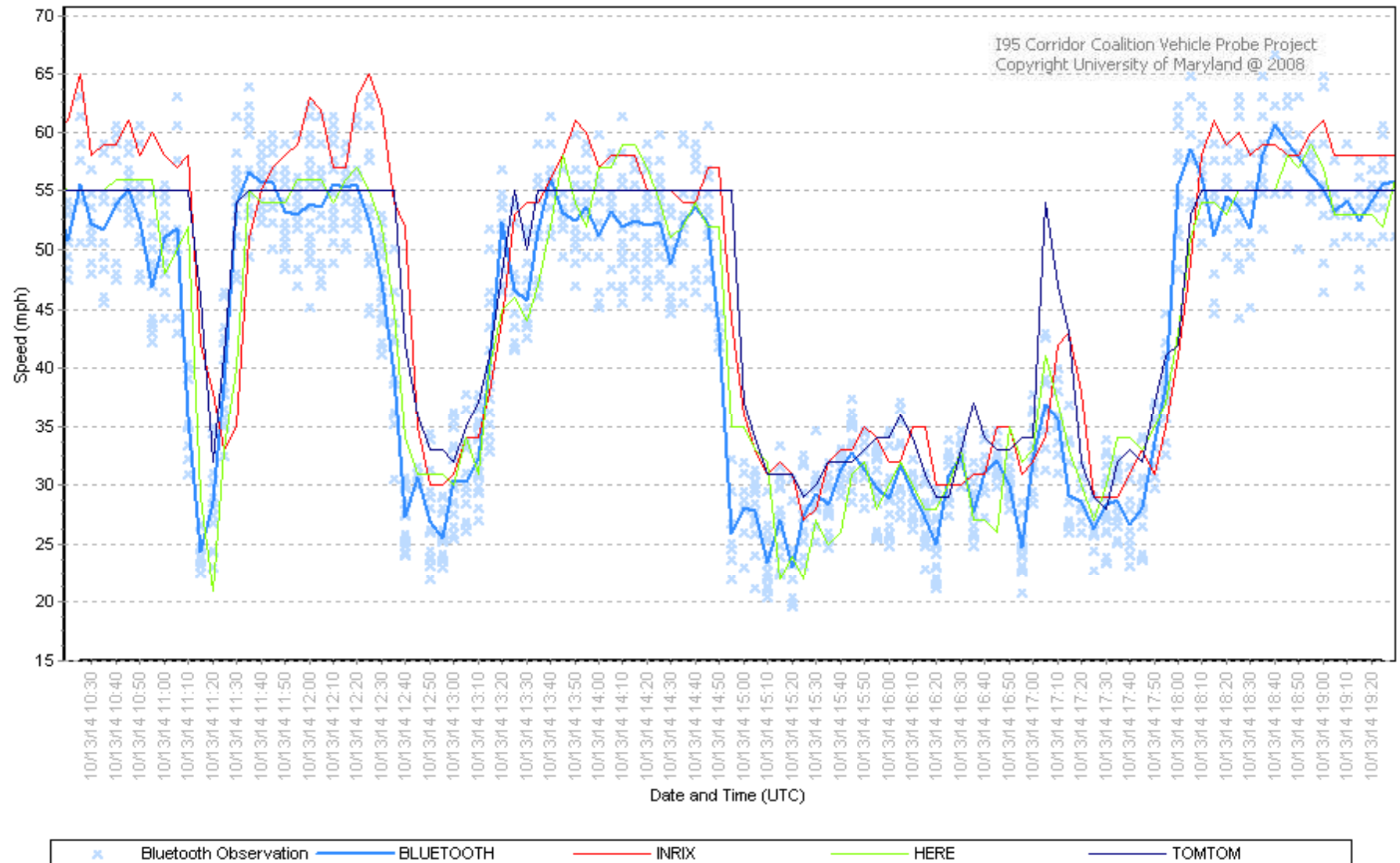
# PM Peak Hour (Oct 15-16, 2014)



# Non-recurring Congestion

## Oct 13, 2014 10 AM to 7 PM

TMC:PA08-0006  
ending at (1.28999996185303 miles)





# Arterial Probe Data Quality Study

## 2013 - mid 2014

State / Set ID	Road Number	Road Name	Validation Date Span	# of Segments	# of Through Lanes	AADT Range (in 1000s)	Length* (mile)	# Signals / Density	# of Access Points	Median Barrier	Speed Limit (mph)
NJ-11	US-1	Trenton Fwy, Brunswick Pike	Sep 10 - 24, 2013	10	2-4	33 - 90	14.2	10 / 0.7	112	Yes	55
	NJ-42	Black Horse Pike		8	2	25-54	12.5	23 / 1.8	260	Yes	45-50
	US-130	Burlington Pike		10	3	42	14.3	28 / 2.0	229	Yes	50
NJ-12	NJ-38	Kaighn Ave.	Nov 5-19, 2013	16	2-4	32-80	24.5	44 / 1.8	235	Yes	50
	NJ-73	Palmyra Bridge Rd.		18	2-4	33-74	23.9	41 / 1.7	236	Yes	45-55
PA-05	US-1	Lincoln Highway	Dec 3 - 14, 2013	28	2 - 3+3	21 - 100	30.62	107 / 3.5	178	Yes	40 - 50
	US-322	Conchester Highway		6	1-2	22 - 34	14.28	7 / 0.5	48	No	35 - 45
PA-06	PA-611	Easton Rd	Jan 9 - 22, 2014	10	2-4	18-31	6.7	21 / 3.13	98	NO	40-45
	PA-611	Old York Rd		8	1-2	21-28	7.2	24 / 3.5	105	Partial	45-48
	PA-611	N Broad St		16	2-4	21-28	7.2	24 / 3.5	105	Partial	45-48
VA-07	VA-7	Leesburg Pike and Harry Byrd Hwy	April 5-16, 2014	30	2-4	20-30	10.0	10 / 0.3	100	Yes	45
	US-29	Lee Hwy (S Washington St)		4	2	20-30	10.0	10 / 0.3	100	Yes	45
VA-08	US-29	Lee Hwy	May 8-19, 2014	26	2-4	20-30	10.0	10 / 0.3	100	Yes	45
MD-08	MD-140	Reistertown Rd	June 5-14, 2014	12	1 - 3	20-30	10.0	10 / 0.3	100	Yes	45
		Baltimore Blvd		6	2 - 4	20-30	10.0	10 / 0.3	100	Yes	45

- 9 Case Studies from 2013-14
- Spans NJ through NC
- Test extent of probe data  
20K AADT to 50K AADT  
4 - 6 lanes  
0.5 to 4 signals per mile
- Objective: Reference case studies

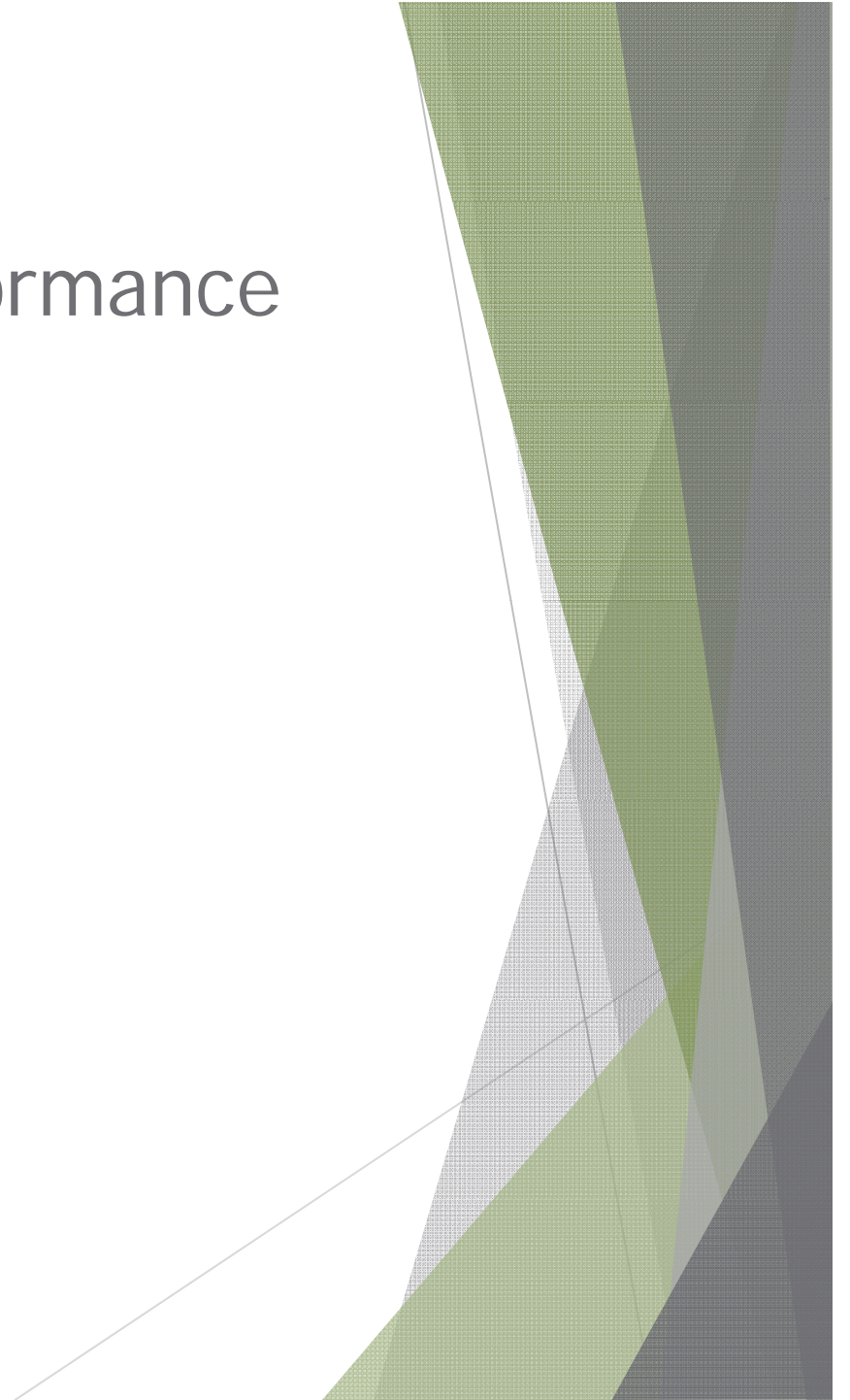
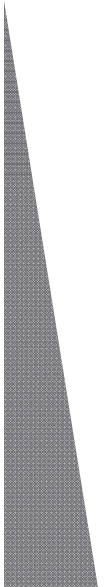


# Arterial Probe Data Recommendations

✓ RECOMMENDED	🔑 SHOULD BE TESTED	✗ NOT RECOMMENDED
<ul style="list-style-type: none"><li>• <math>\leq 1</math> signal per mile</li><li>• AADT &gt; 40,000 vpd (2-way)</li><li>• Limited curb cuts</li></ul> <p><b>Principal Arterials</b> Likely to have accurate probe data...</p>	<ul style="list-style-type: none"><li>• 1 to 2 signals per mile</li><li>• AADT 20K to 40K vpd (2-way)</li><li>• Moderate number of curb cuts</li></ul> <p><b>Minor Arterials</b> Possibly accurate probe data...</p>	<ul style="list-style-type: none"><li>• <math>\geq 2</math> signals per mile</li><li>• AADT &lt; 20K (2-way) - low volume</li><li>• Substantial number of curb cuts</li></ul> <p><b>Major Collectors</b> Unlikely probe data is accurate...</p>

- Data quality most correlated to signal density
- Consistent positive bias at low speeds
  - As probe data improves, delay will increase
- Other issues / challenges:
  - Severe queuing, multi-cycle failures
  - Optimistic bias in bi-modal traffic
  - Insensitive to signal timing changes
- Data Quality will improve
  - Increased probe density
  - Point pair processing (true travel time sampling)

# Shifting Gears - Measuring Arterial Performance



# Roadmap for Arterial Management Systems

- ▶ Arterial Performance Measures are fundamentally different than Freeway Performance Measures
- ▶ Until now, arterial measurement has been too costly, and performance had to be modeled.
- ▶ New technology has enabled first generation large scale performance assessment
  - ▶ Re-identification data, High-Resolution Controller data
- ▶ From a DATA perspective, we are NOW (2015) with arterials, where we were in 2008/9 with freeways
- ▶ Significant opportunity - significant challenge
  - ▶ Common language, lexicon, tools
  - ▶ Bridge culture divide between traffic, planning and operations



# Technologies Enabling Arterial Management Systems

## Re-identification

## High-Res Signal Data

Both enabled by consumer wireless communication and big data processing.

Available Now - Multiple Vendors - Cost Effective

- ▶ Direct samples vehicle travel time (5% for BT)
- ▶ Works best at corridor level
- ▶ Independent of Signal System
- ▶ Provides top-level user experience information
- ▶ Logs *all* actuation and phasing information
- ▶ Works at intersection level
- ▶ Integrated with Signal System
- ▶ Provides detailed intersection analysis and data for optimizing signal system

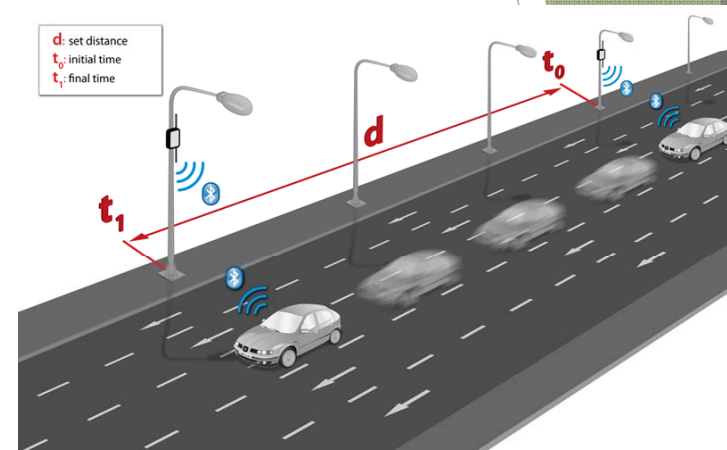
**Not one or the other... but both!**

# Emerging Arterial Performance Measures

- ▶ **Travel Time & Travel Time Reliability** - based on sampled travel time sources
  - ▶ Enabled by re-identification data, later outsourced probe data and connected vehicle data as it matures
  - ▶ Fundamentally linked to the statistical distribution of travel time
- ▶ **Percent Arrivals on Green** - reflects quality progression
  - ▶ Supported by methods such as Purdue Coordination Diagram tools
- ▶ **Split Failures (frequency of occurrences)**
  - ▶ Reflects capacity constraints
  - ▶ Related to GOR / ROR

# Re-Identification Data (Bluetooth)

- ▶ Uses a ID unique to a vehicle (MAC ID of a Bluetooth device inside vehicle)
- ▶ An initial detector identifies when a vehicle enters a corridor by the vehicle's ID
- ▶ Another detector *re-identifies* the vehicle at the end of the corridor
- ▶ Travel time/ speed can be directly calculated from the entry and exit time



Car	MAC address	Entry Time hh:mm:ss	Exit Time hh:mm:ss
1	12-34-56-78-9A-BC	13:10:05	13:15:37
2	48-2C-6A-1E-59-3D	13:10:10	13:15:25

Direct samples of Travel Time

Picture source: libelium.com



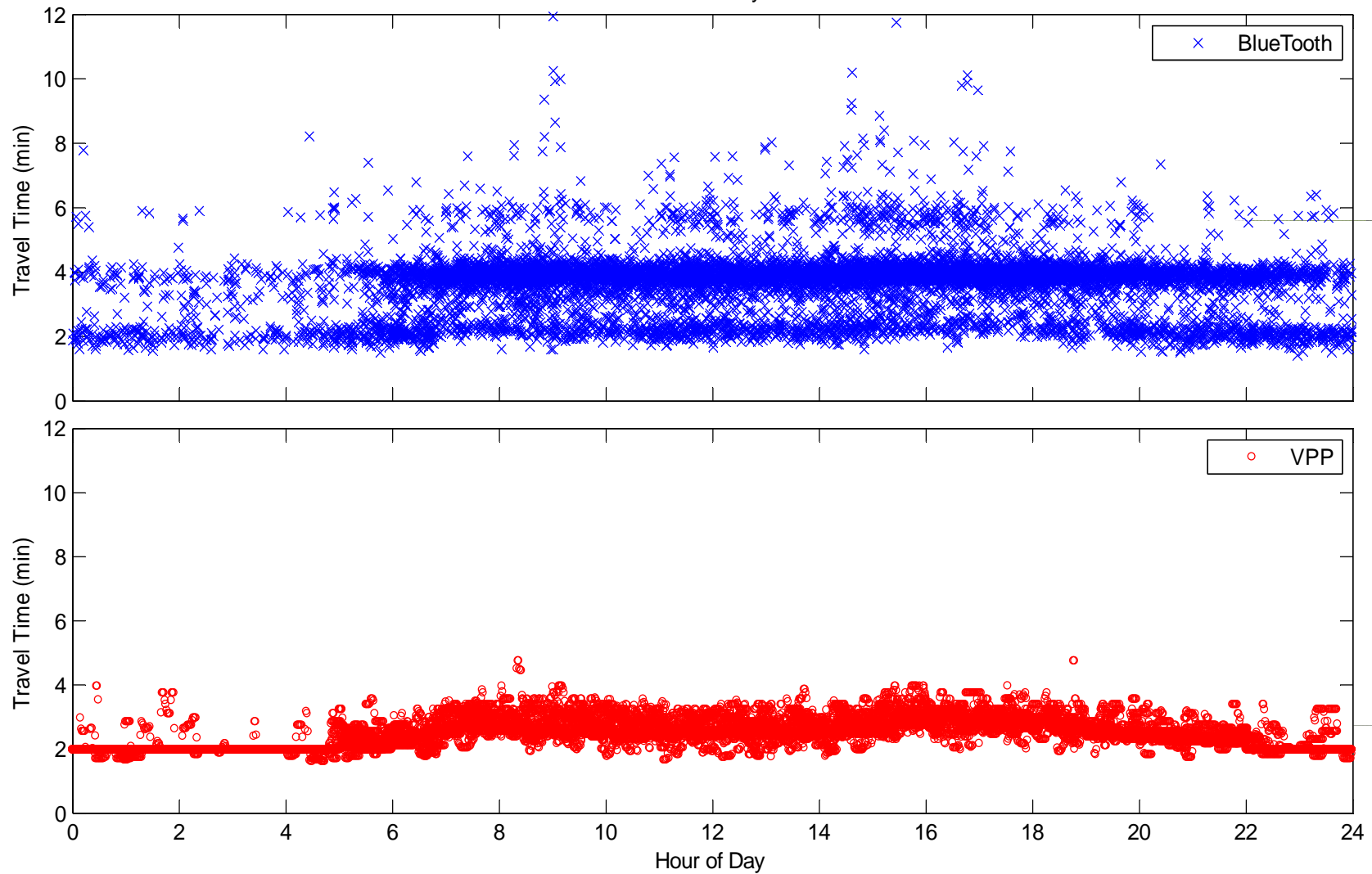
# Travel Time and Travel Time Reliability

- ▶ Based on directly sampled travel time measurements
- ▶ For arterials, can be applied ....
  - ▶ Intersection to intersection
  - ▶ **Corridor based**
  - ▶ Network level, origin to destination
- ▶ Directly reflects concerns of the traveling public
  - ▶ Efficient and predictable travel
- ▶ Measures can be applicable to other modes of travel
  - ▶ Freeway, transit, air, etc.

# Re-id Travel Time Data Fidelity

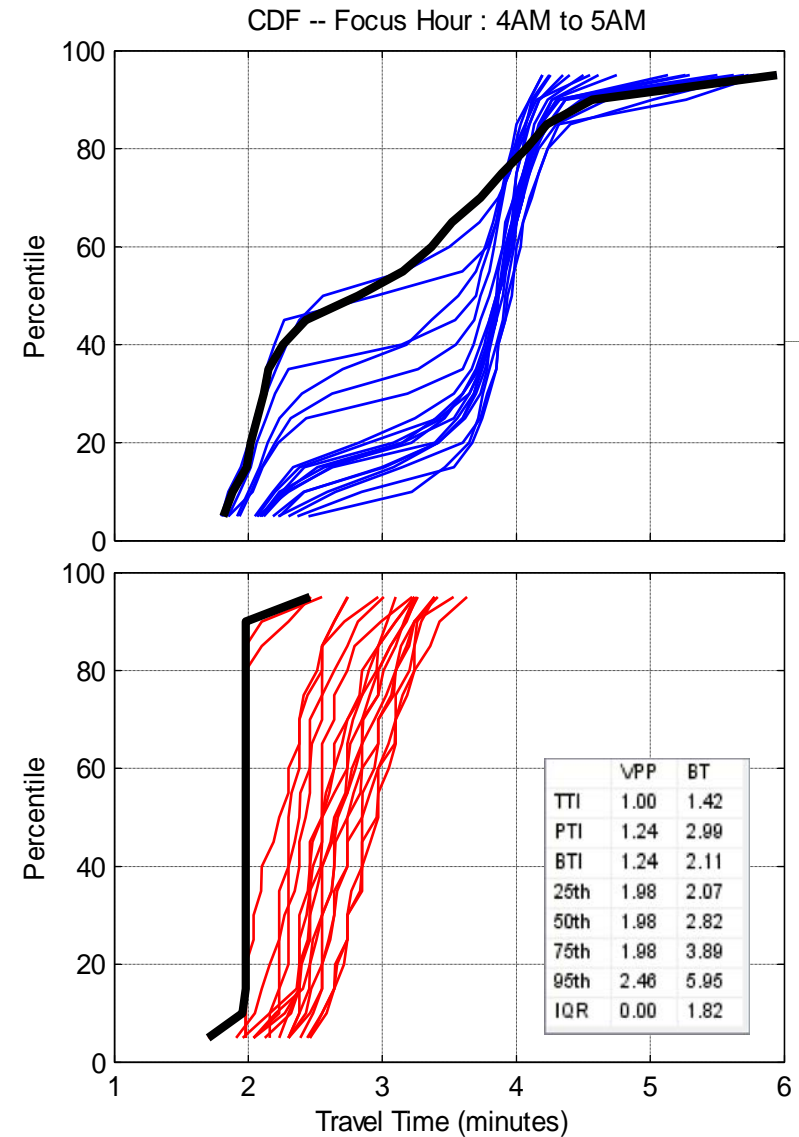
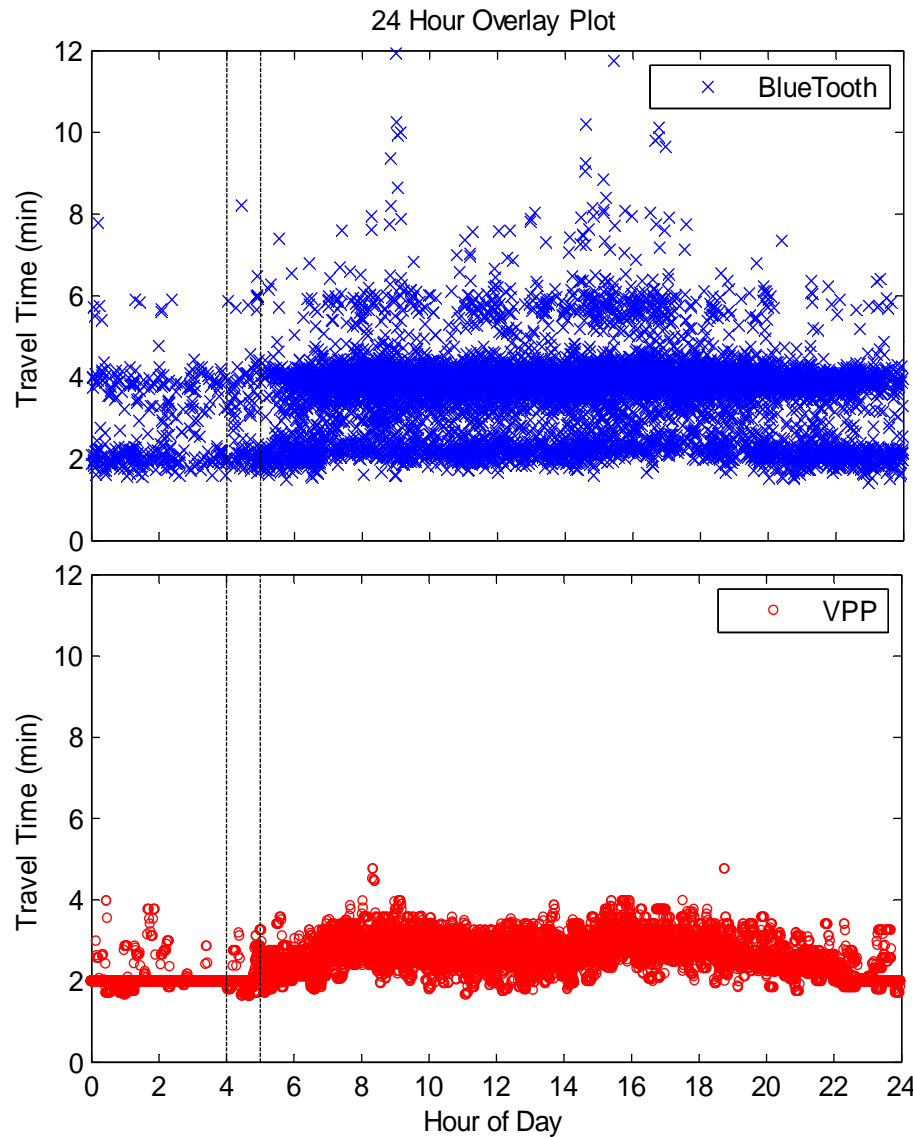
Segment: PA05-0002 B to C Weekdays Only from 12/03-12/17 2013 Length: 1.19 miles

24 Hour Overlay Plot



# CFD Statistical Performance Measures

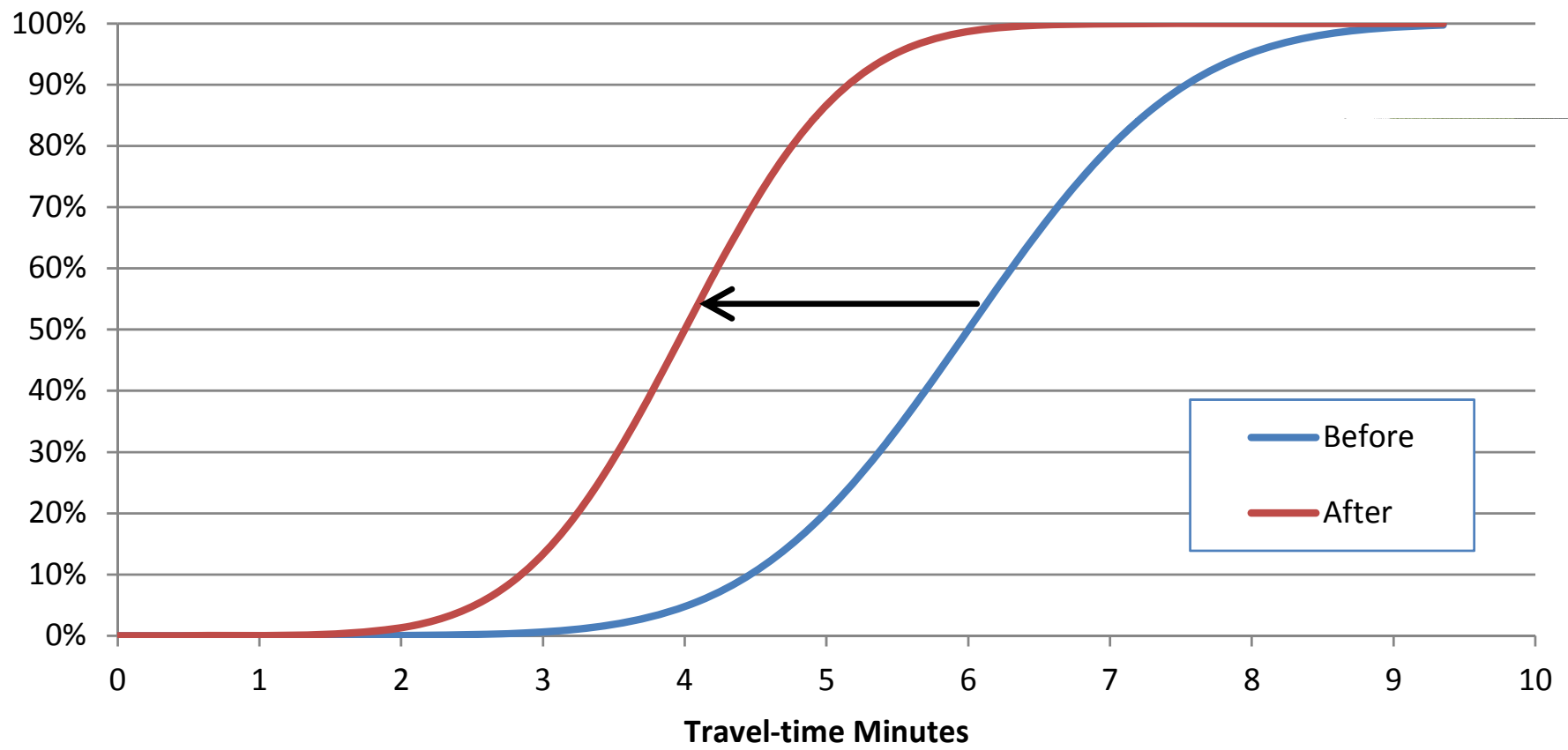
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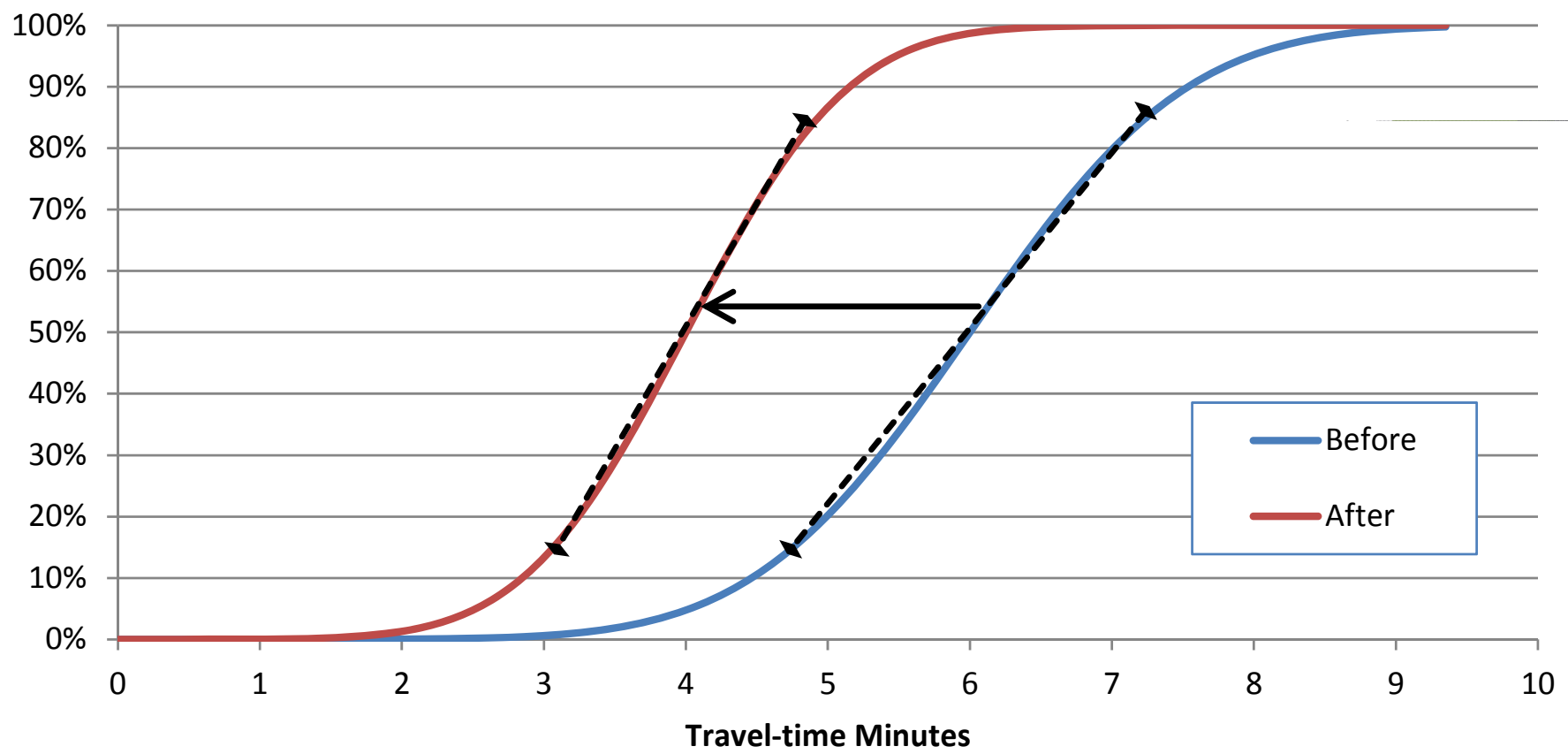
# Travel Time

## Comparative CFD



# Travel Time Reliability

## Comparative CFD



# Percent Arrival on Green (PAG) and Split Failures

## ▶ Percent Arrivals on Green

- ▶ Measure on how effectively signals are coordinated, moving vehicles **through** the system
- ▶ The higher the PAG, ...
  - ▶ Less stops, happier customers
  - ▶ Higher corridor speed , better fuel economy, less emissions
  - ▶ Direct indicator of signal system performance

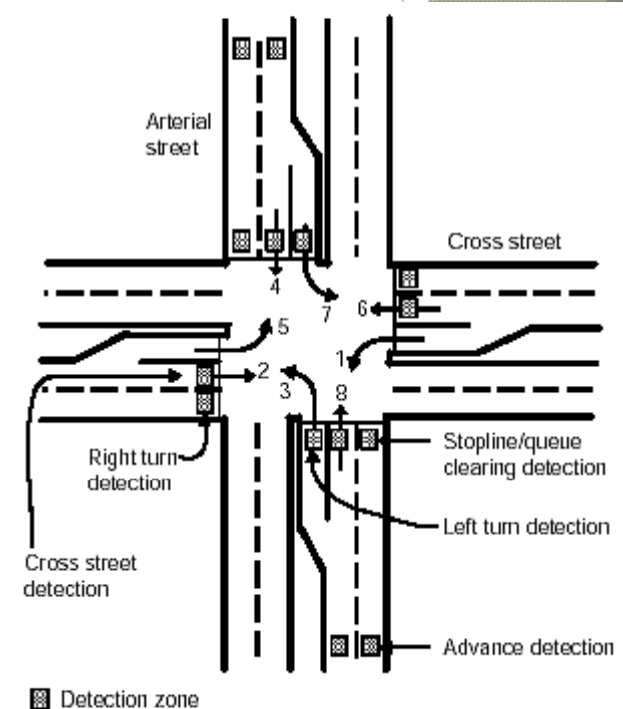
## ▶ Split Failures (i.e. Capacity Constraint)

- ▶ Measures percent of system (time and space) suffering from lack of capacity
- ▶ The 'need more capacity' metric, or 'get off my back' metric, its 'time to spread the pain' metric ...
- ▶ Something more than signal optimization required - capacity/demands need to be addressed



# High Resolution Signal Data

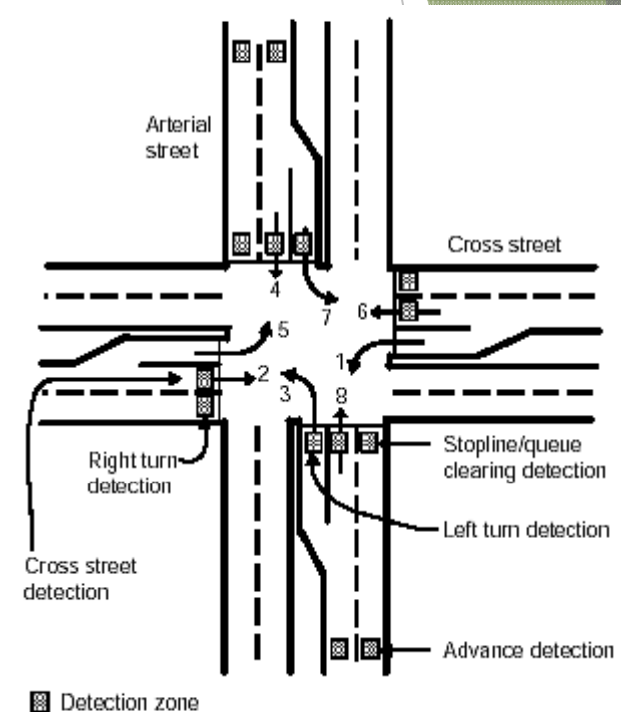
- ▶ Logging of sensor and phase information
- ▶ Data forwarded periodically to central server
- ▶ Applications
  - ▶ Purdue Coordination Diagram
  - ▶ Red-Occupancy Ratio / Green Occupancy Ratio
  - ▶ Volume / Demand Analysis (per movement)
  - ▶ Streamlined Maintenance



Picture Source: FHWA

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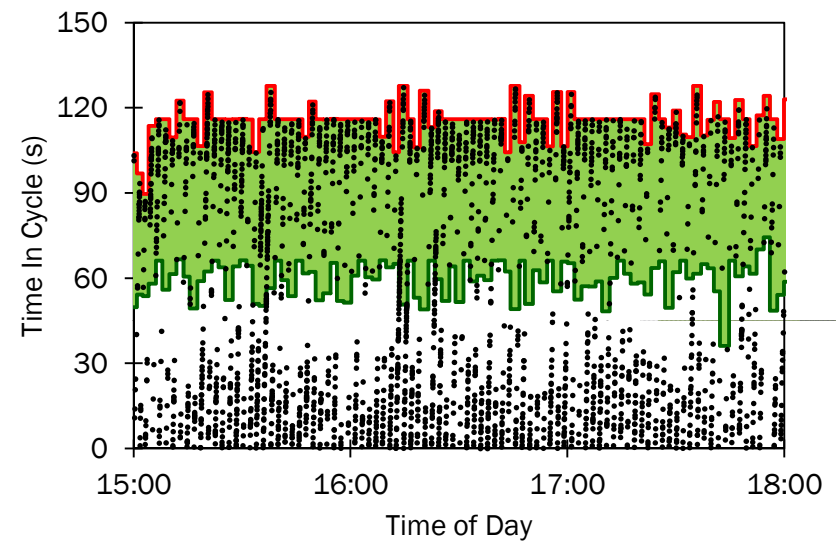
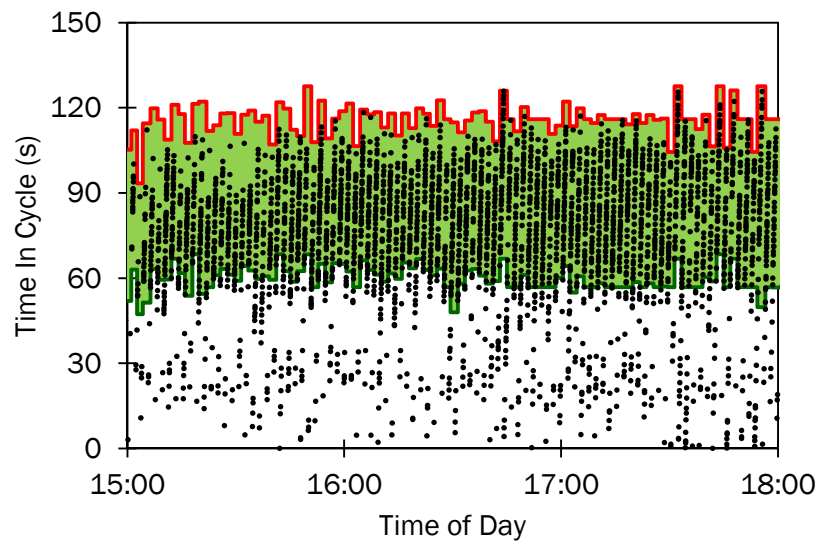


Picture Source: FHWA

**THIS IS CONNECTED INFRASTRUCTURE!!!!**

# Sample Metric - PAGs

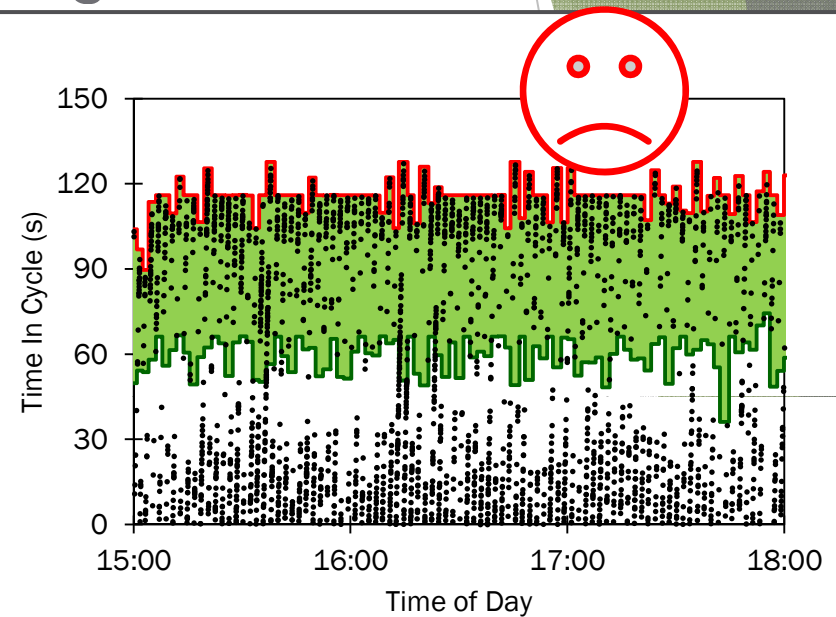
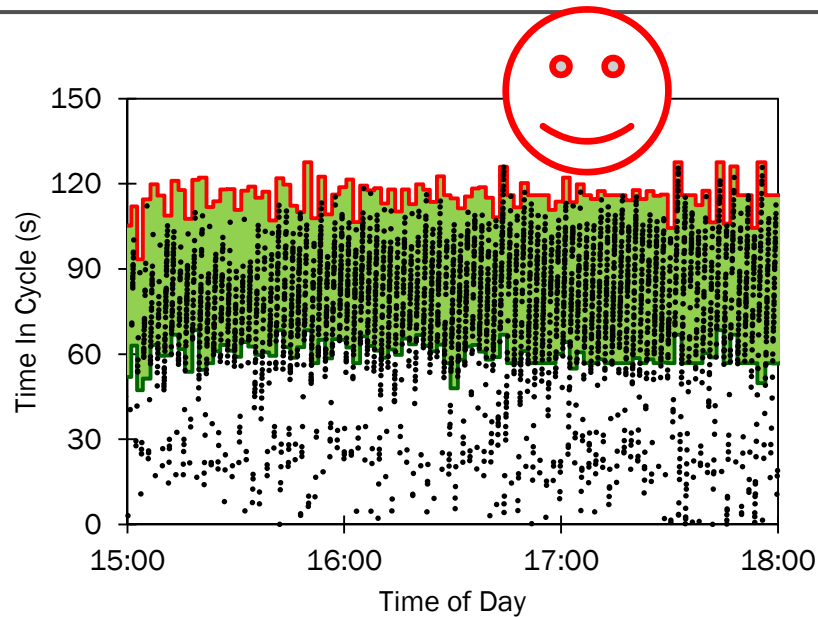
## Purdue Coordination Diagram





# Sample Metric - PAGs

## Purdue Coordination Diagram



# Percent Arrivals on Green in the news!



Salt Lake City 53 °  
Traffic

## The Salt Lake Tribune

WWW.SLTRIB.COM

MAY 21, 2015

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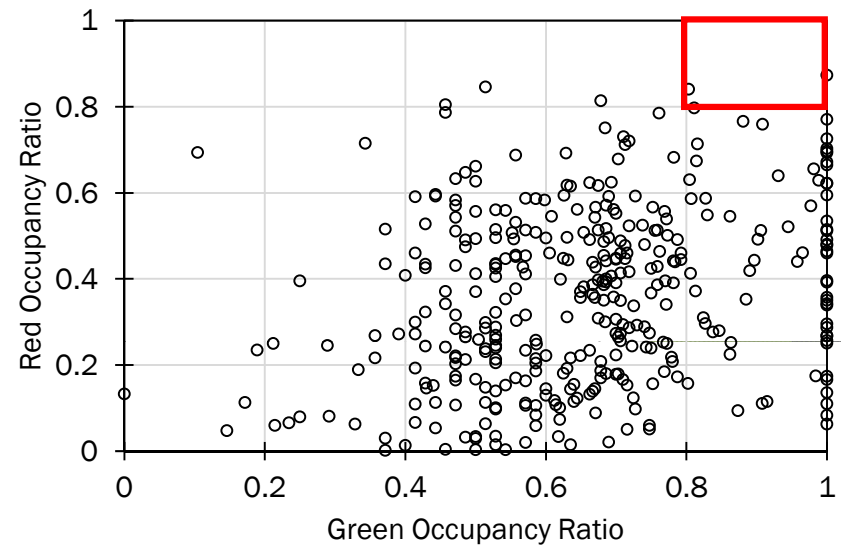
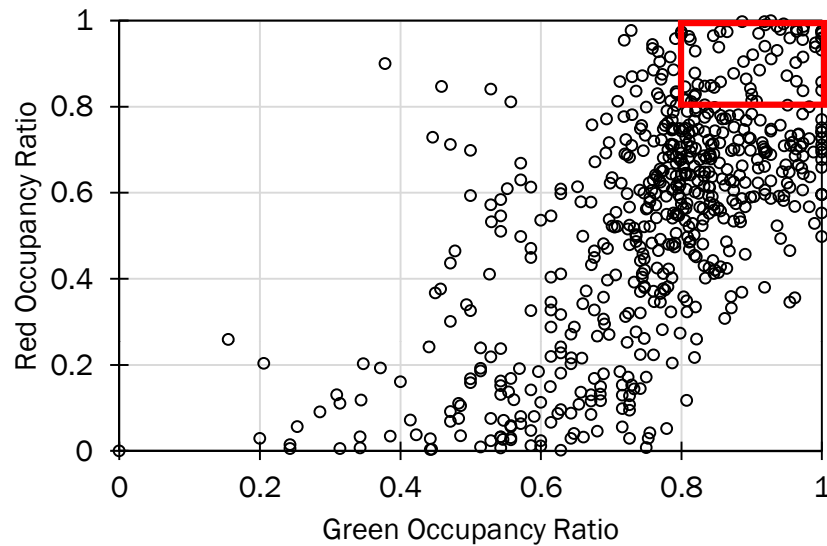
### **Odds of hitting a red light in Utah? Just 1-in-4**

By Lee Davidson The Salt Lake Tribune

Published December 23, 2013 10:04 pm

# Sample Metric - Intersection

## Movement Capacity Analysis (ROR - GOR)

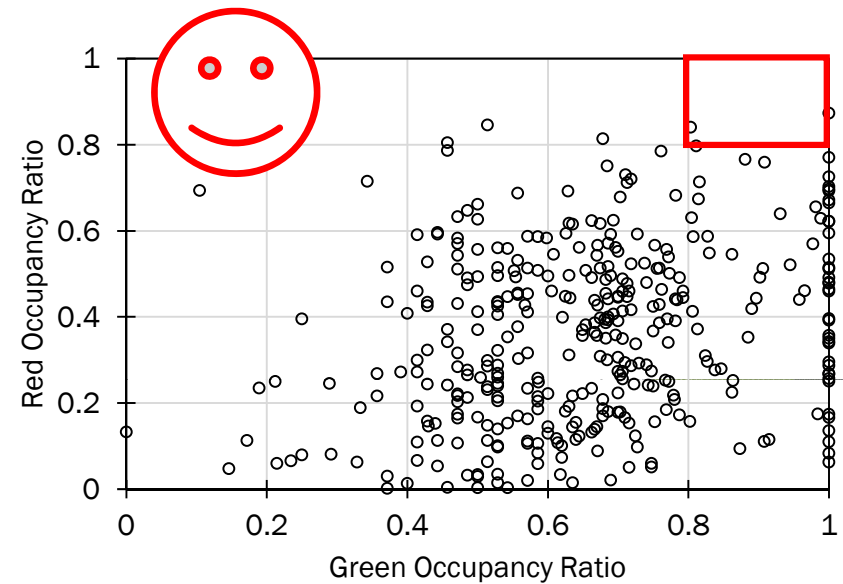
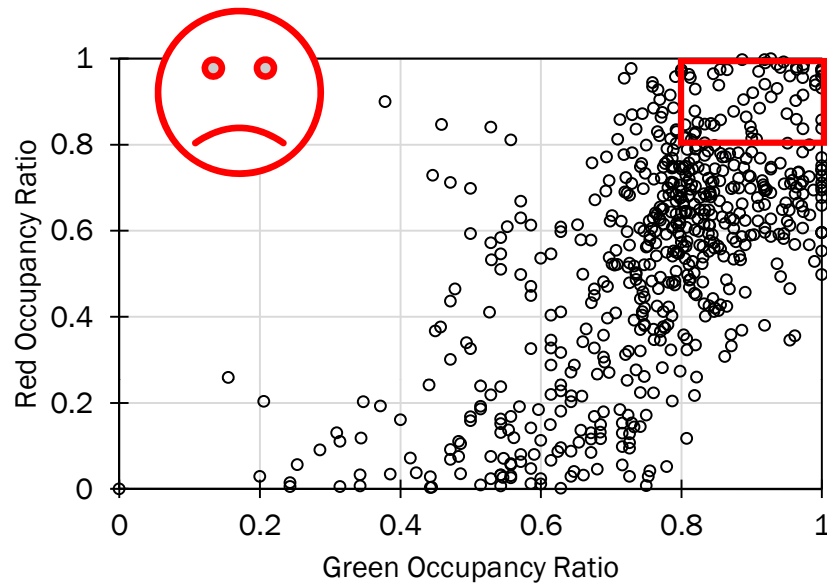


Purdue Univ.



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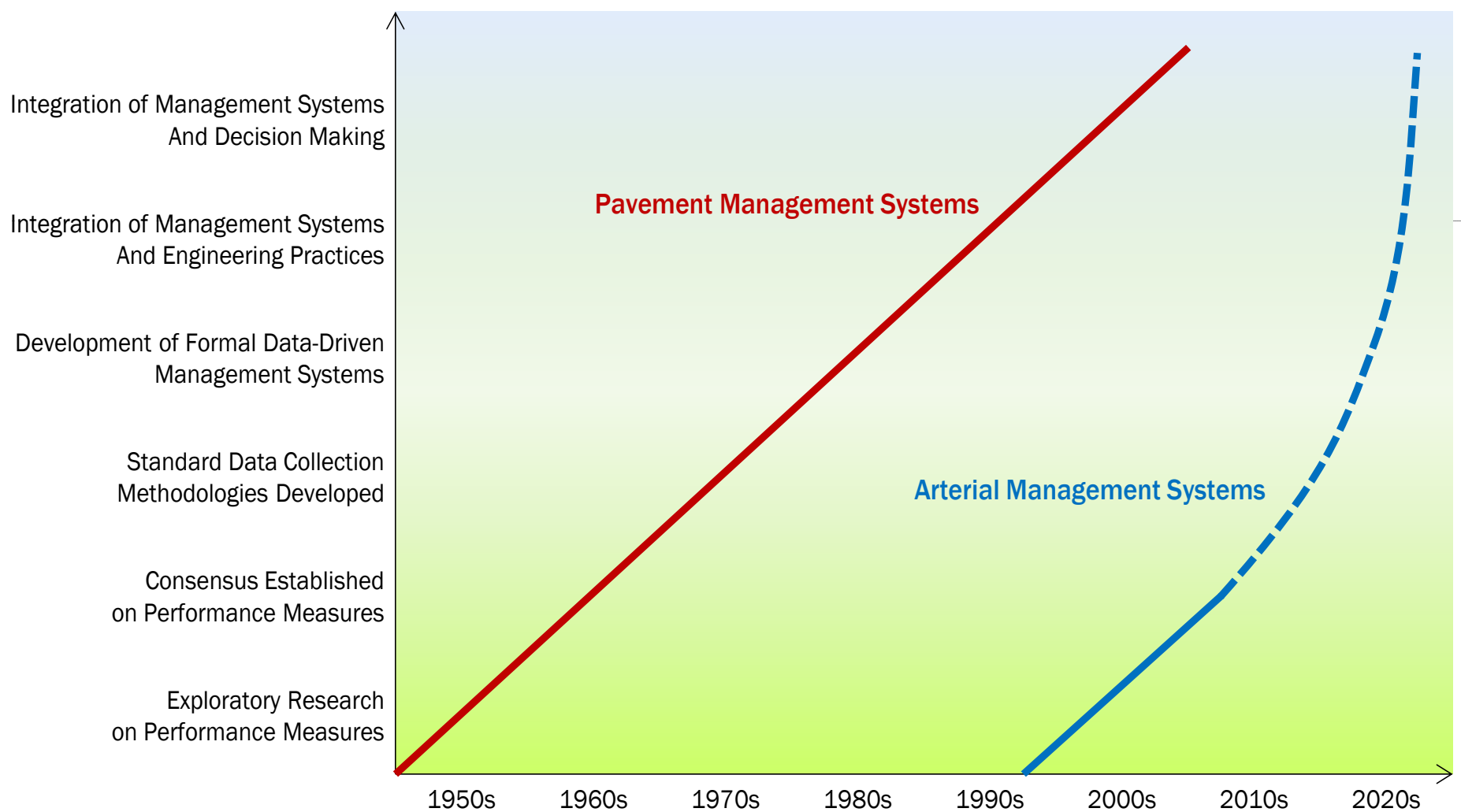


Purdue Univ.

# Frequency of Split Failures

- ▶ Indicator of oversaturation
  - ▶ When demand overruns capacity
- ▶ Indicates when additional capacity or demand management is required
- ▶ Also known as the metric for ....
  - ▶ 'Get off my back, nothing left to do'
  - ▶ 'Time to share the pain'
  - ▶ 'Give me another lane if you want this solved'

# Current State of Arterial Management Systems (AMS)

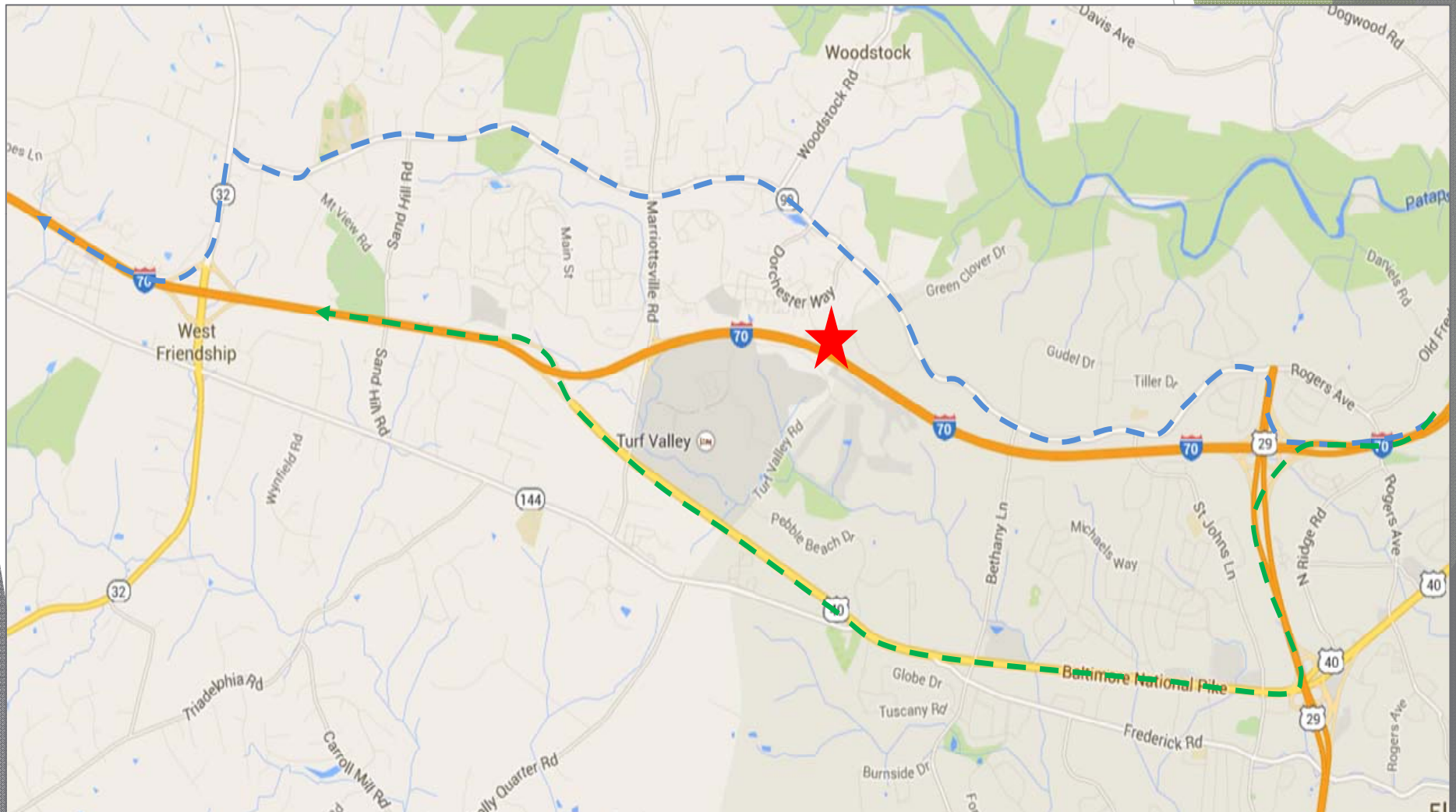




# Challenges / Benefits to Arterial Performance Measures

- ▶ Created a common lexicon/language
  - ▶ Between Traffic, Ops, Planning
  - ▶ Define Performance Levels (Good, Mediocre, and Ugly)
  - ▶ Effective communication with management and public
- ▶ Systematic approach
  - ▶ Link performance to budget/funding
  - ▶ Long term performance tracking
  - ▶ Predictable return on investment
- ▶ Linking to other Priorities
  - ▶ Operations during freeway incidents
  - ▶ Energy efficiency, Global warming (GHG emissions)

# Real-Time Arterial Performance





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# Conclusions – Final Thoughts

- ▶ Arterial Performance Measures
  - ▶ We now have the data
  - ▶ Re-identification and Hi-Res Data enable
- ▶ Key Measures Include
  - ▶ Travel time (Median of CFD)
  - ▶ Travel-time reliability (Slope of CFD)
  - ▶ Quality of progression (% Arrivals on Green)
  - ▶ Degree of capacity saturation (ROR/GOR)
- ▶ These Enable **Performance Management** of Arterials

# And beyond ... Volume Data Everywhere

- ▶ I95 Corridor Coalition in partnership with MCOMP II (FHWA) to accelerate availability of real-time volume estimates from probe data
  - ▶ Concept of operations and data specifications
  - ▶ Requirements for accuracy and common data formats
- ▶ Testbed for Calibration and Validation
  - ▶ Pool of verified volume data contributed by states
  - ▶ Requirements for long-term viability
- ▶ Industry cooperative research project
  - ▶ Minimize risk, create win-win scenario
- ▶ Volume data needed in demanding modeling/simulations of advanced technology, and performance measures.
- ▶ Contact Reuben Juster ([rmjcar@umd.edu](mailto:rmjcar@umd.edu)) or myself

# Thank You!

Stanley E. Young, P.E. Ph.D.

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