Adaptive Traffic Signal Control

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Presentation Overview

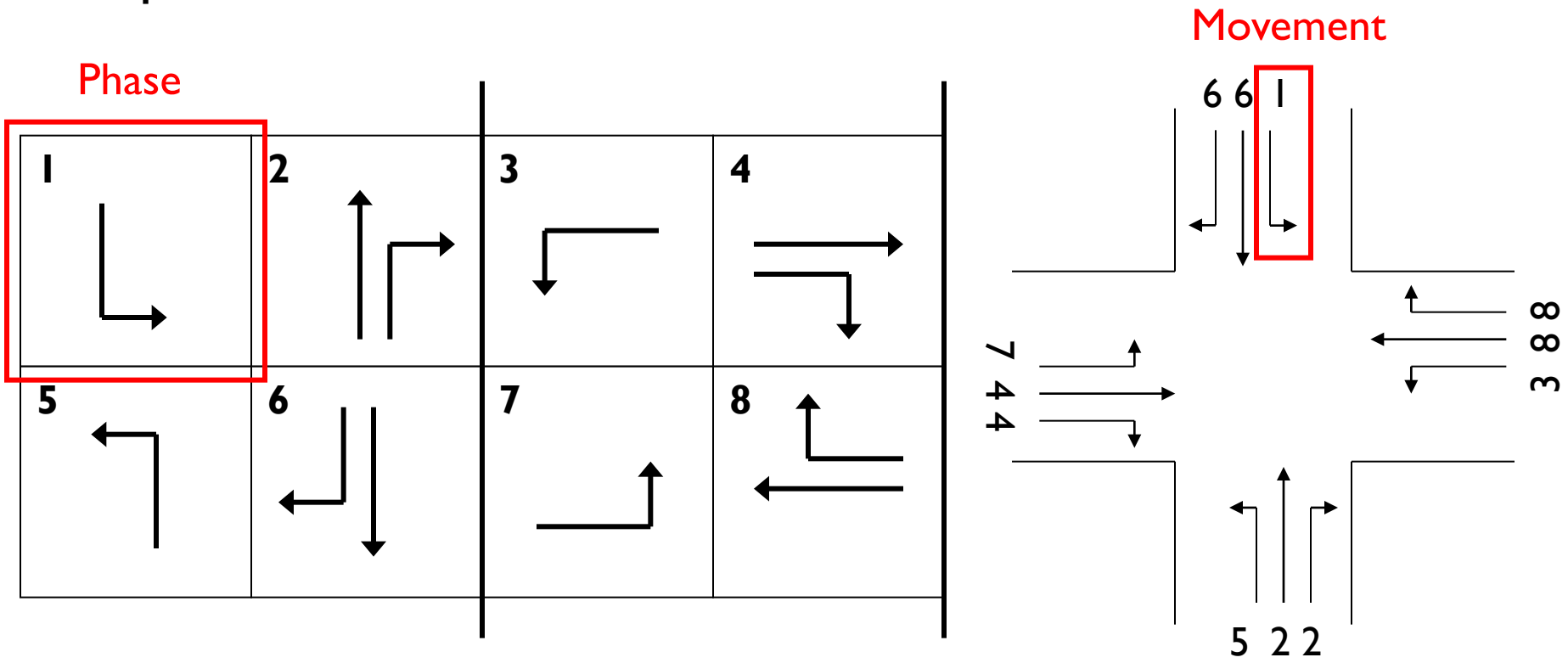
- Traffic Signals 101
  - Types of Traffic Signal Control
  - Terminology Overview
- What is Adaptive Signal Control?
- Adaptive Systems in WV
- Preliminary Evaluation Results
  - Simulation
  - Field Data
- Planning for Traffic Signals

Types of Traffic Signal Control

- Basic (Free) Operation
  - With or without vehicle/pedestrian detection
  - Commonly used for isolated intersections
  - Green times programmed based on anticipated demand
- Coordinated (Time-of-Day) Operation
  - With or without vehicle/pedestrian detection
  - Used in corridor or downtown grid signal systems
  - Cycle, Offset, and Splits are the key parameters that are typically programmed for anticipated demand at different time periods
- Adaptive Operation
  - Requires vehicle detection
  - Most systems dynamically adjust Cycle, Offset, and Splits based on current or historical demand

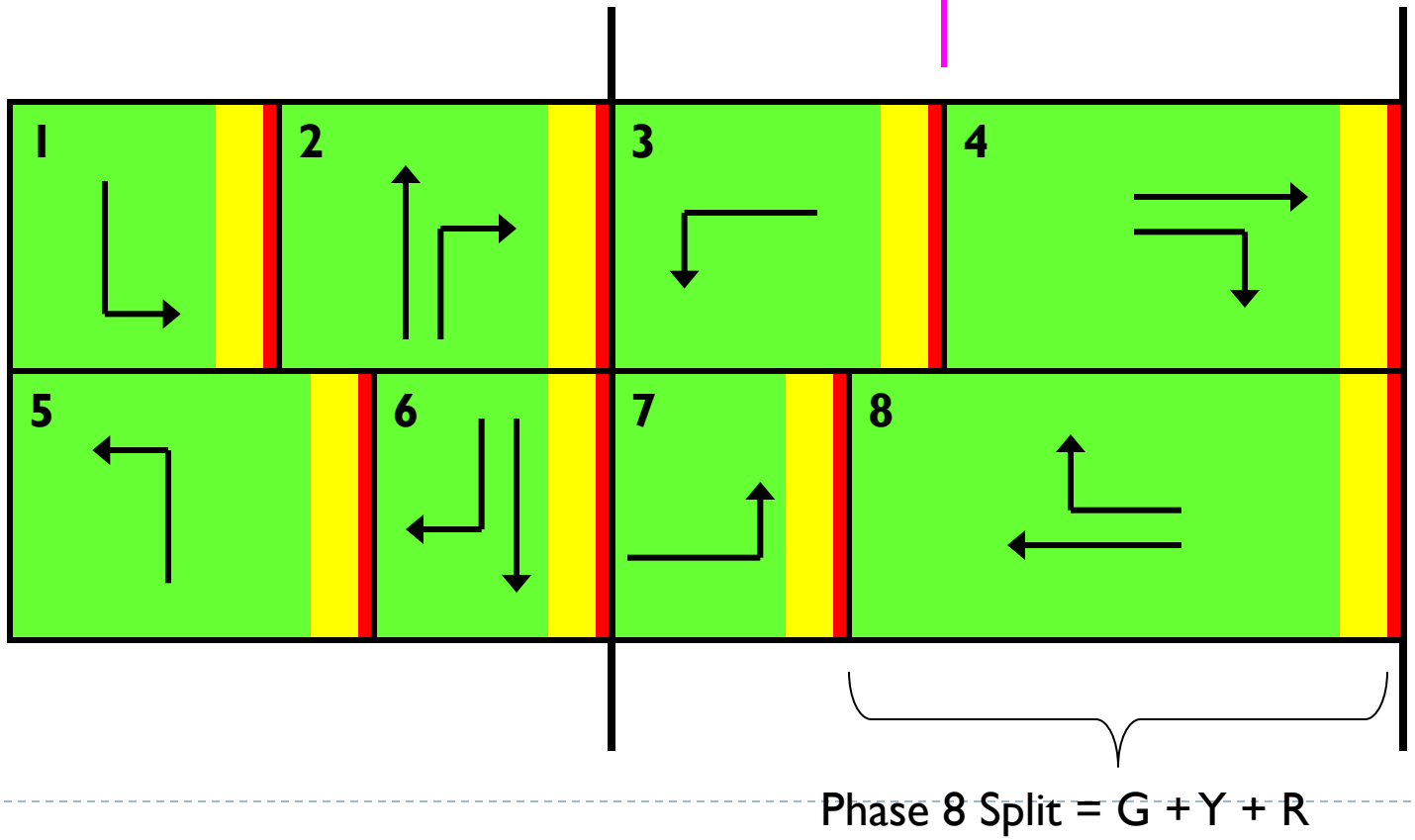
What is a Phase Split?

- Each signalized intersection movement is a phase
- 4-way intersection with left-turn arrows has 8 phases
- Split Time = Green + Yellow + All Red



What is a Phase Split?

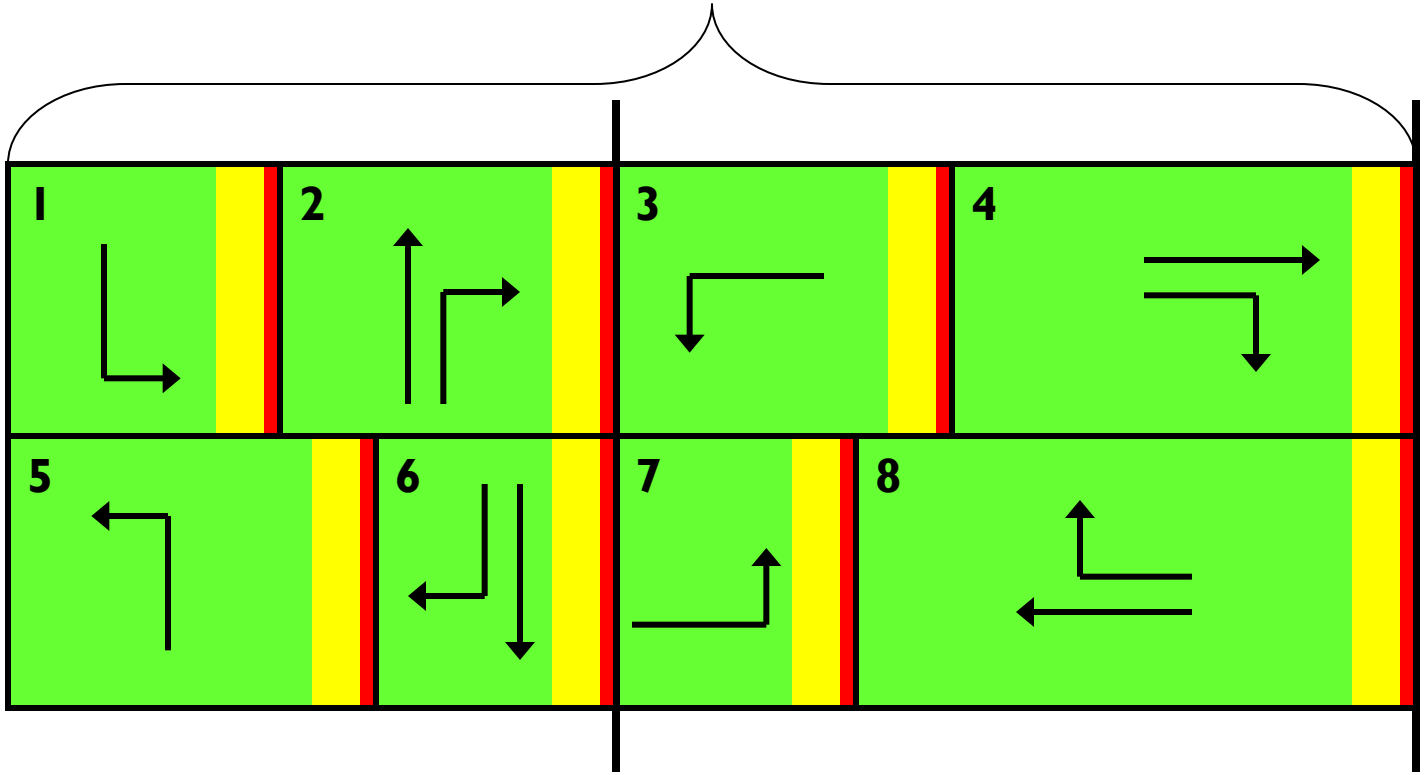
- Phase split times are programmed to account for demand
- Duration can also be shortened with vehicle detection



What is a Cycle?

- The total time it takes to serve all phase splits

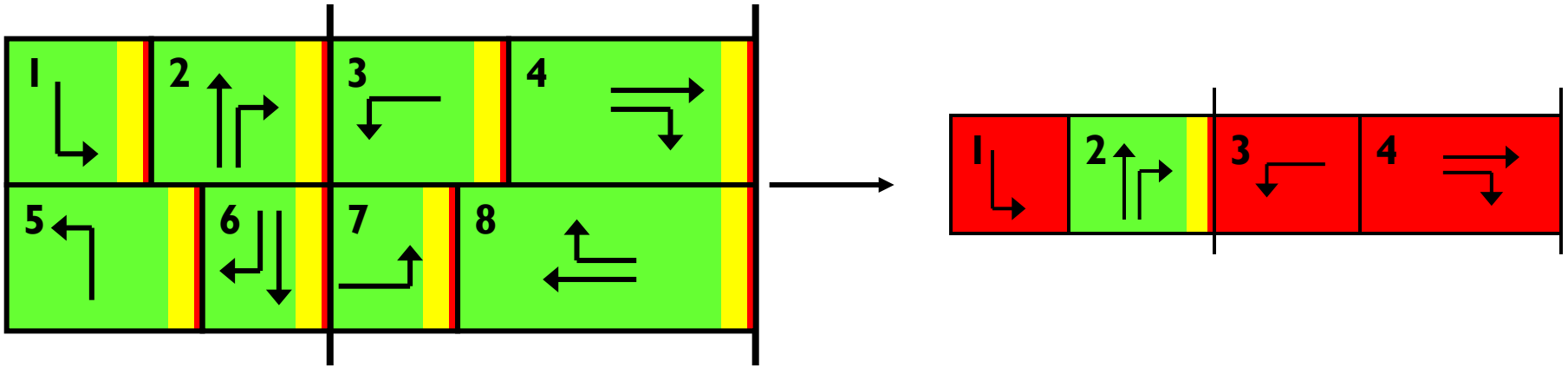
Cycle = Split 1 + Split 2 + Split 3 + Split 4
Cycle = Split 5 + Split 6 + Split 7 + Split 8



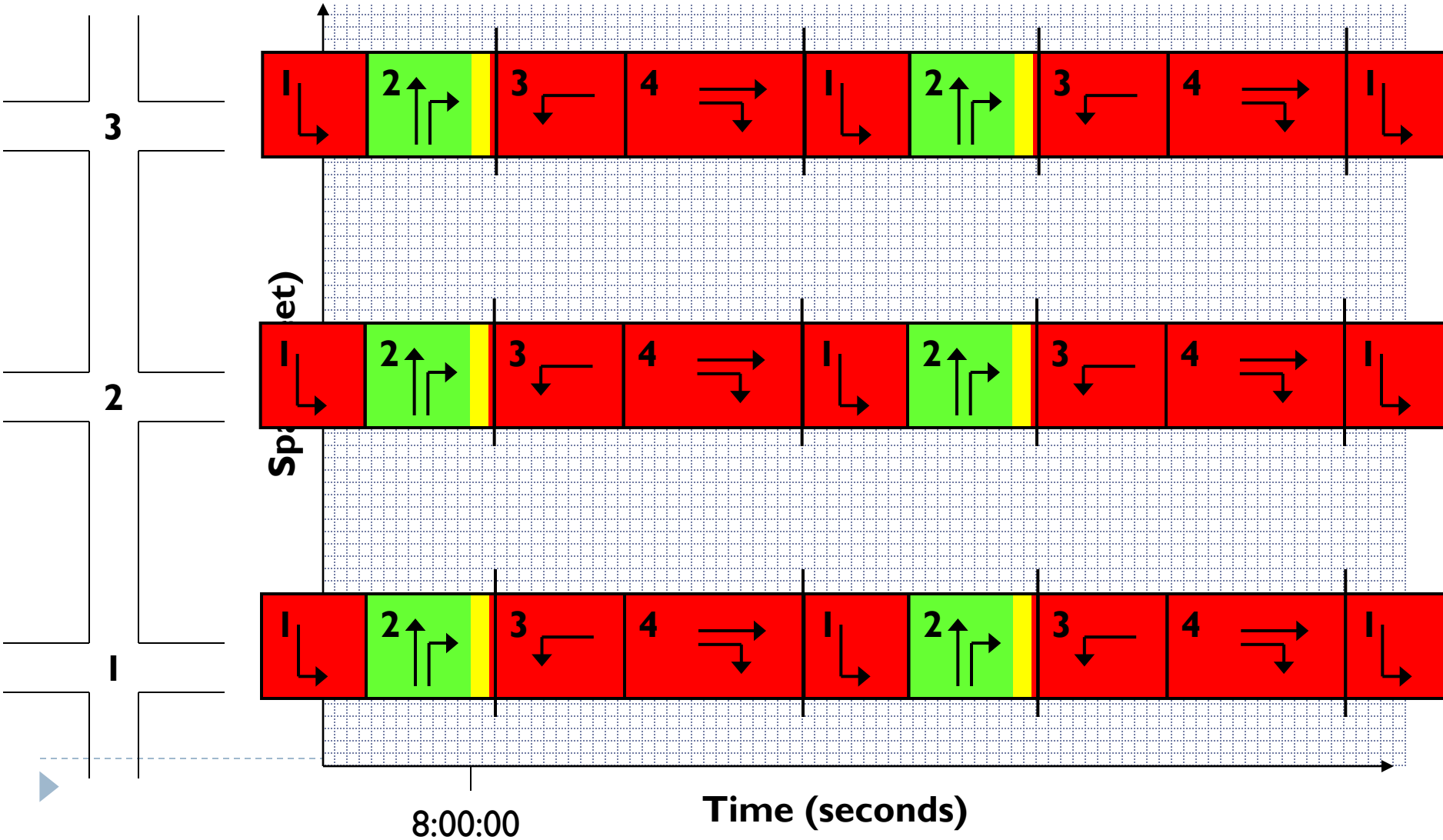
What is an Offset?

- Programmed for the "mainline" movement at each intersection to provide progression through the system
  - i.e., Offsetting the start of green

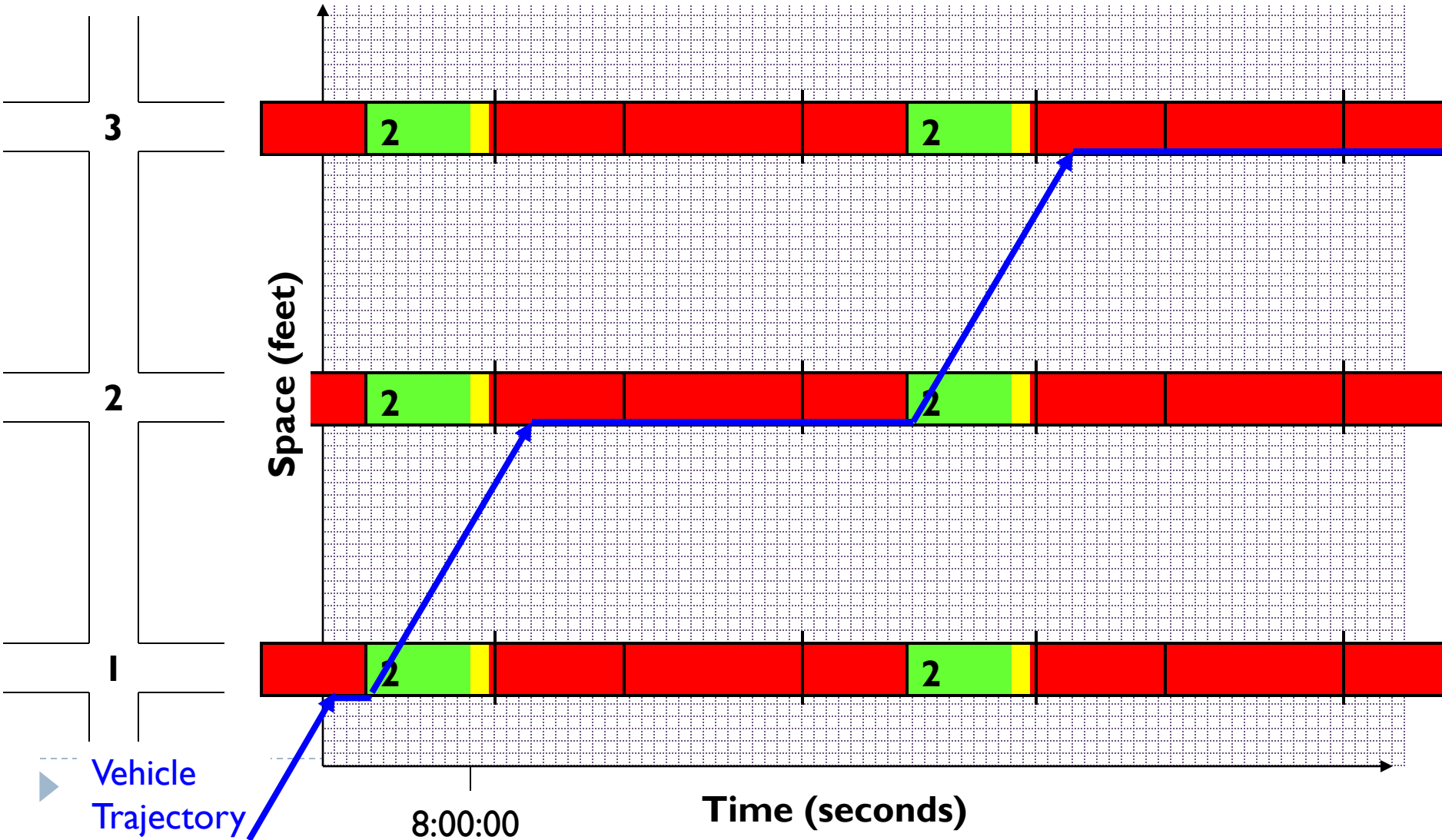
- Consider a Northbound Phase 2 movement only:



Time-Space Diagram (NB)

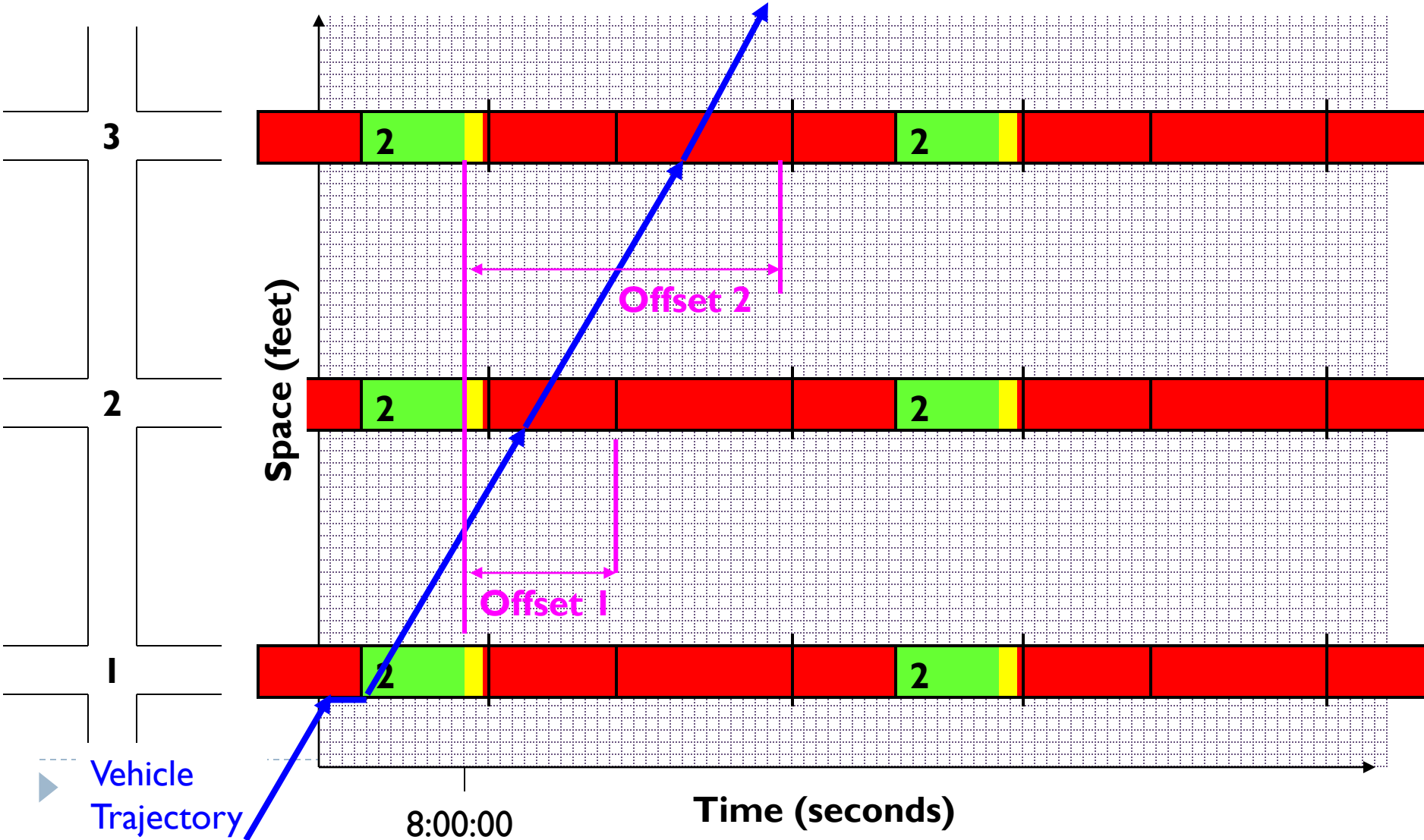


Time-Space Diagram (Zero Offset)



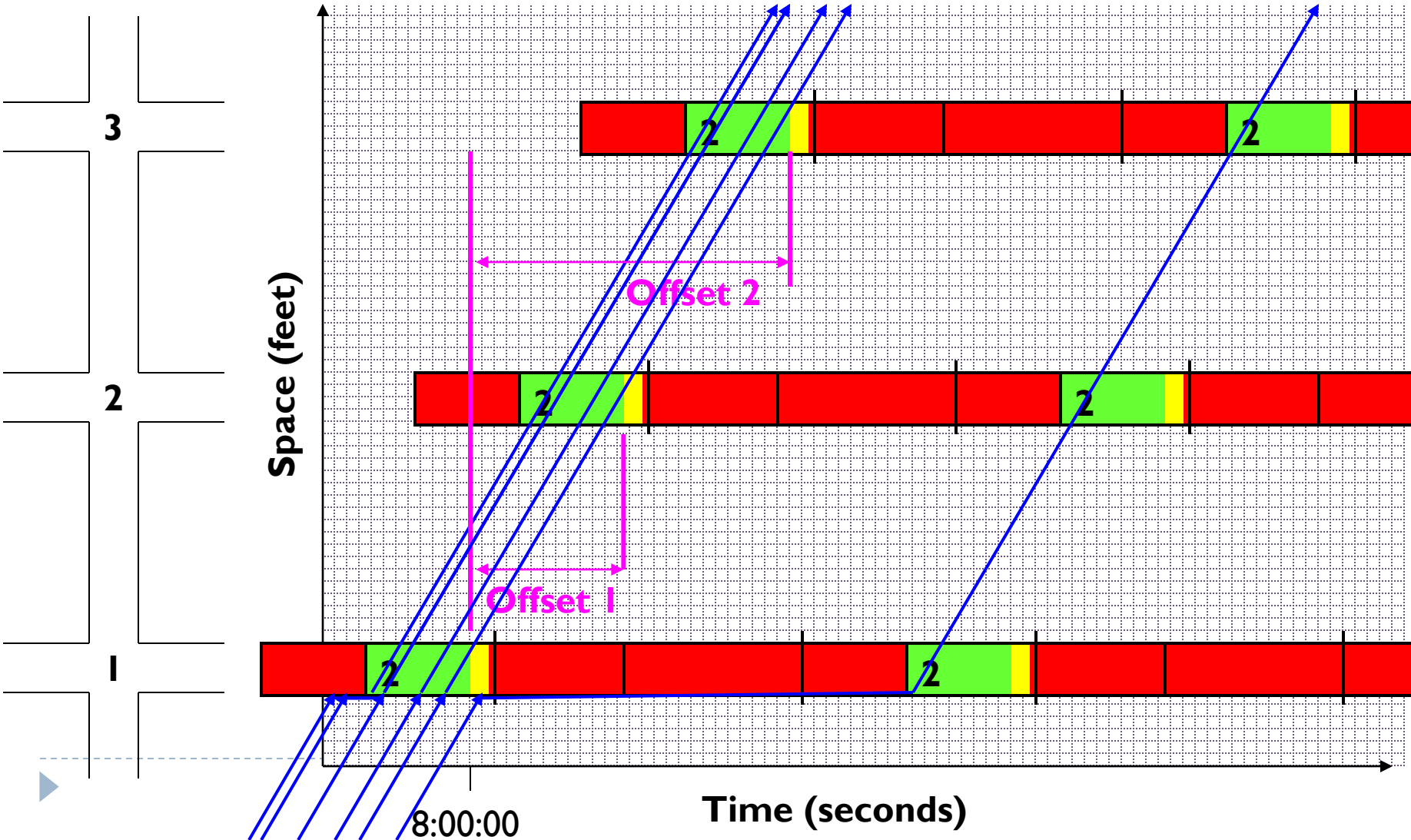
- Vehicle Trajectory

Time-Space Diagram (w/ offsets)



- Vehicle Trajectory

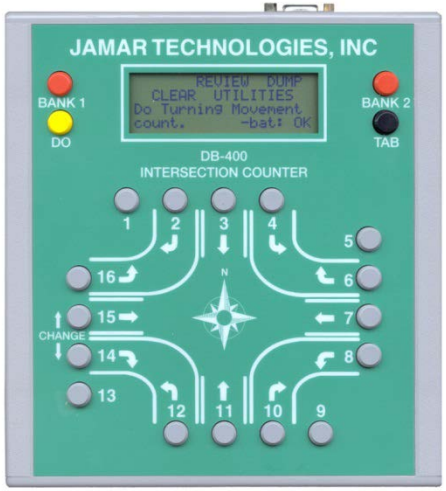
Time-Space Diagram (w/ offsets)



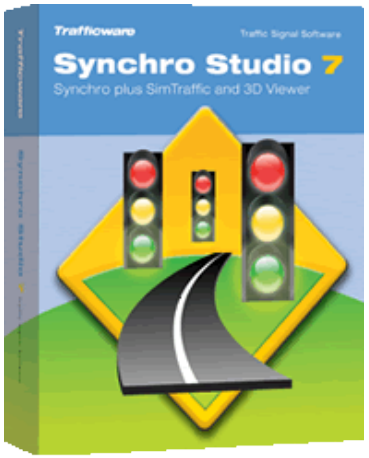
Coordination Plans

- Traffic engineers can deploy multiple coordination plans to accommodate different traffic patterns
- How are these plans derived?

Traffic Data Collection



Optimization Software

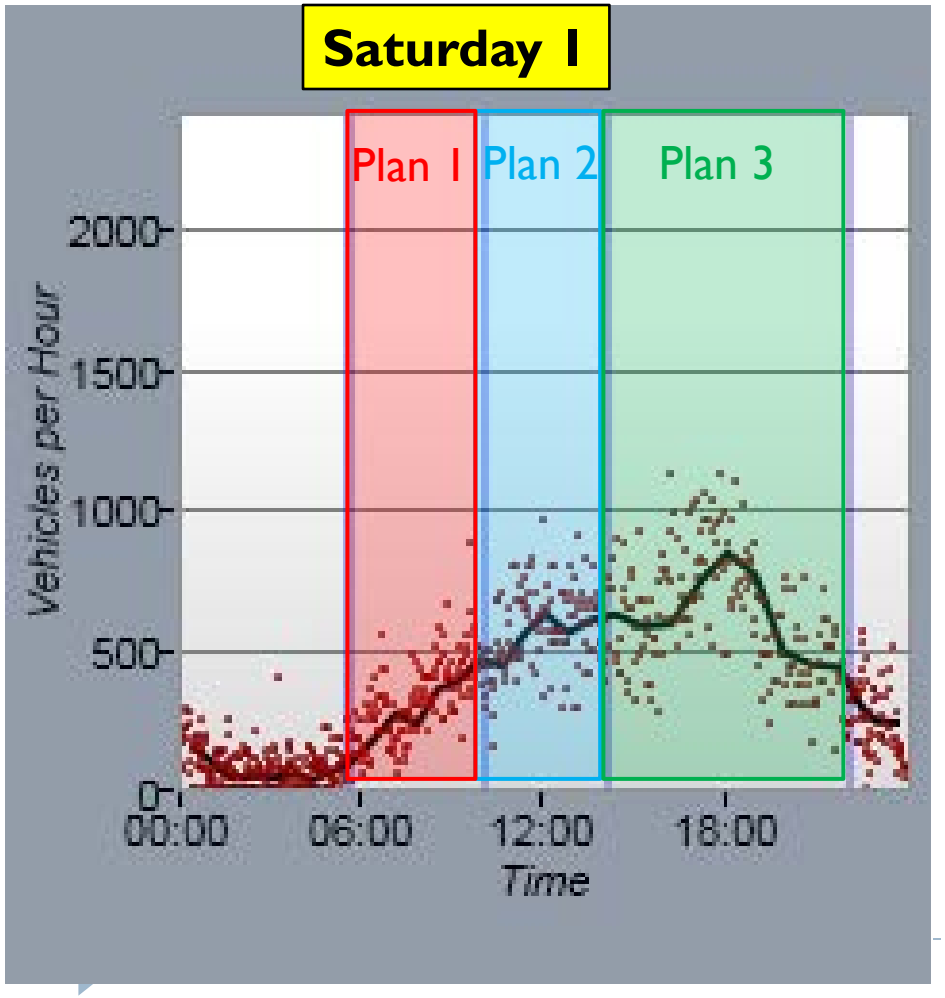


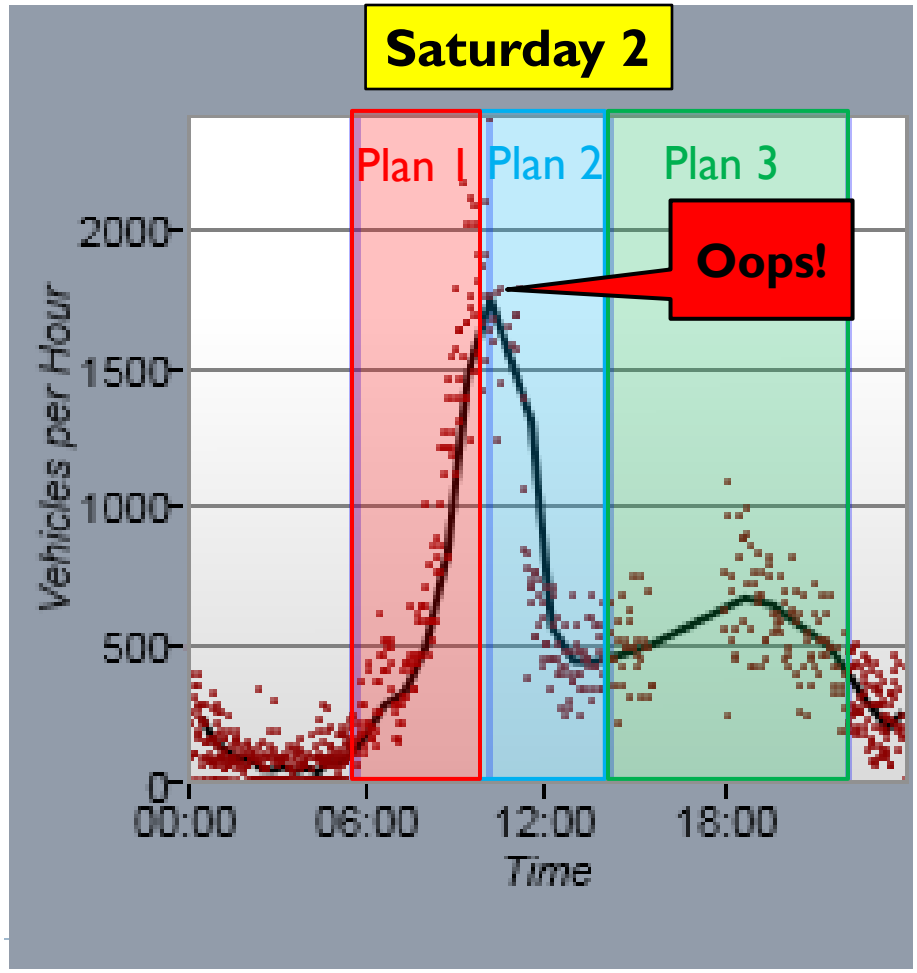
Field Tuning

- This process cannot account for all traffic patterns!

Star City Bridge, Morgantown
Inbound Traffic on Saturday

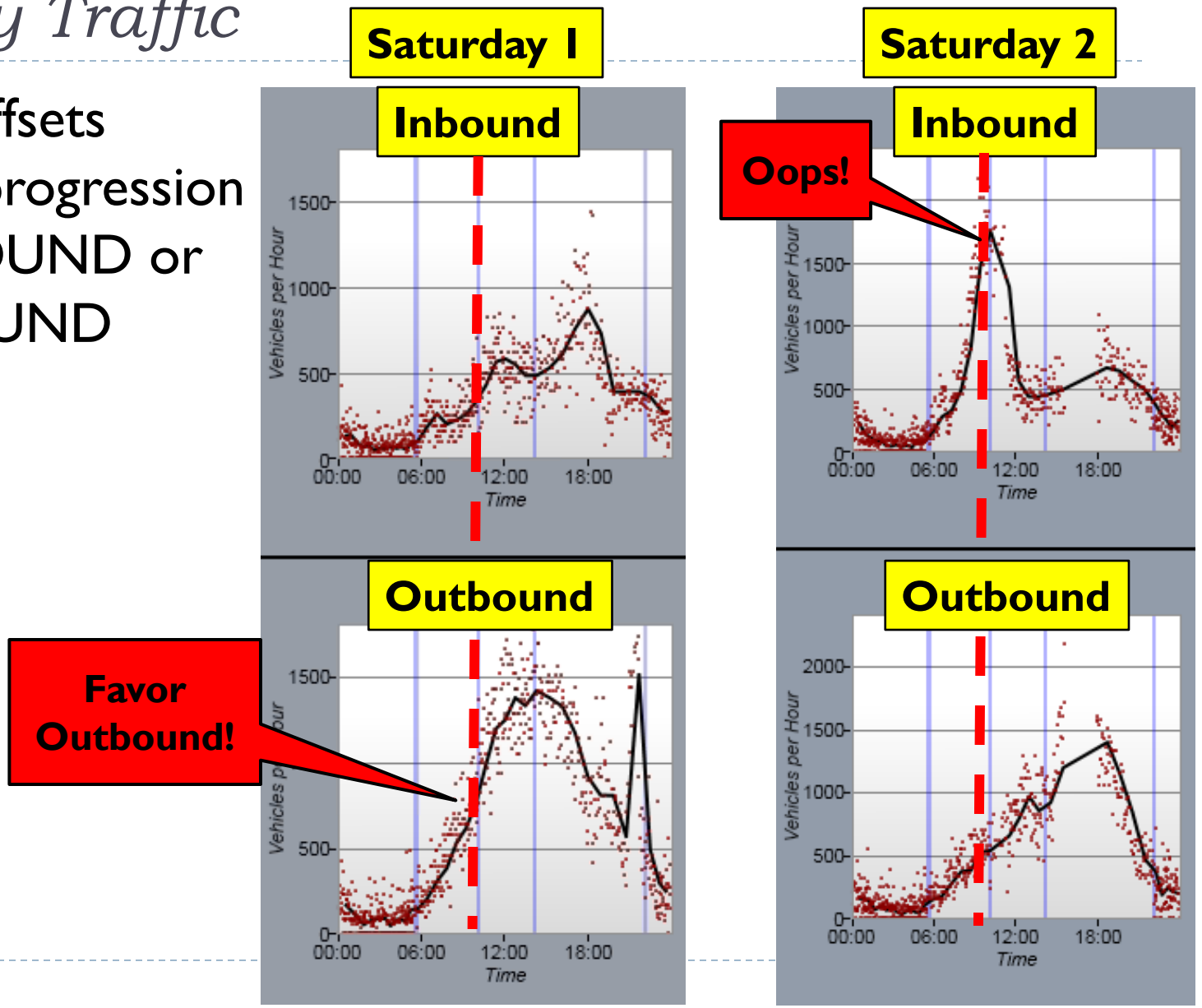
- When to start each Coordination Plan?





Star City Bridge, Morgantown
Saturday Traffic

- Should offsets provide progression for INBOUND or OUTBOUND traffic?



What is Adaptive Signal Control?

- Respond more intelligently to fluctuations in traffic patterns (beyond shortening phase times with vehicle detection)
- All adaptive systems require vehicle detection
- Adjust phase split times
  - More/less time for a left-turn movements or side streets
- Adjust cycle length
  - Longer for congested periods, shorter for off-peak
- Adjust offsets
  - Accommodate inbound vs. outbound traffic
  - Account for change in traffic speeds due to severe weather

Adaptive Signal Control

- 20+ adaptive control systems on the market
- <1% of signals nationwide use adaptive technology
- NONE of the systems are "plug and play"
- Each system is unique

- FHWA Every Day Counts Initiative
  - Identified ASC as being significantly underutilized
  - Providing some guidance on how to select a system
  - Developing guidelines on how to evaluate performance

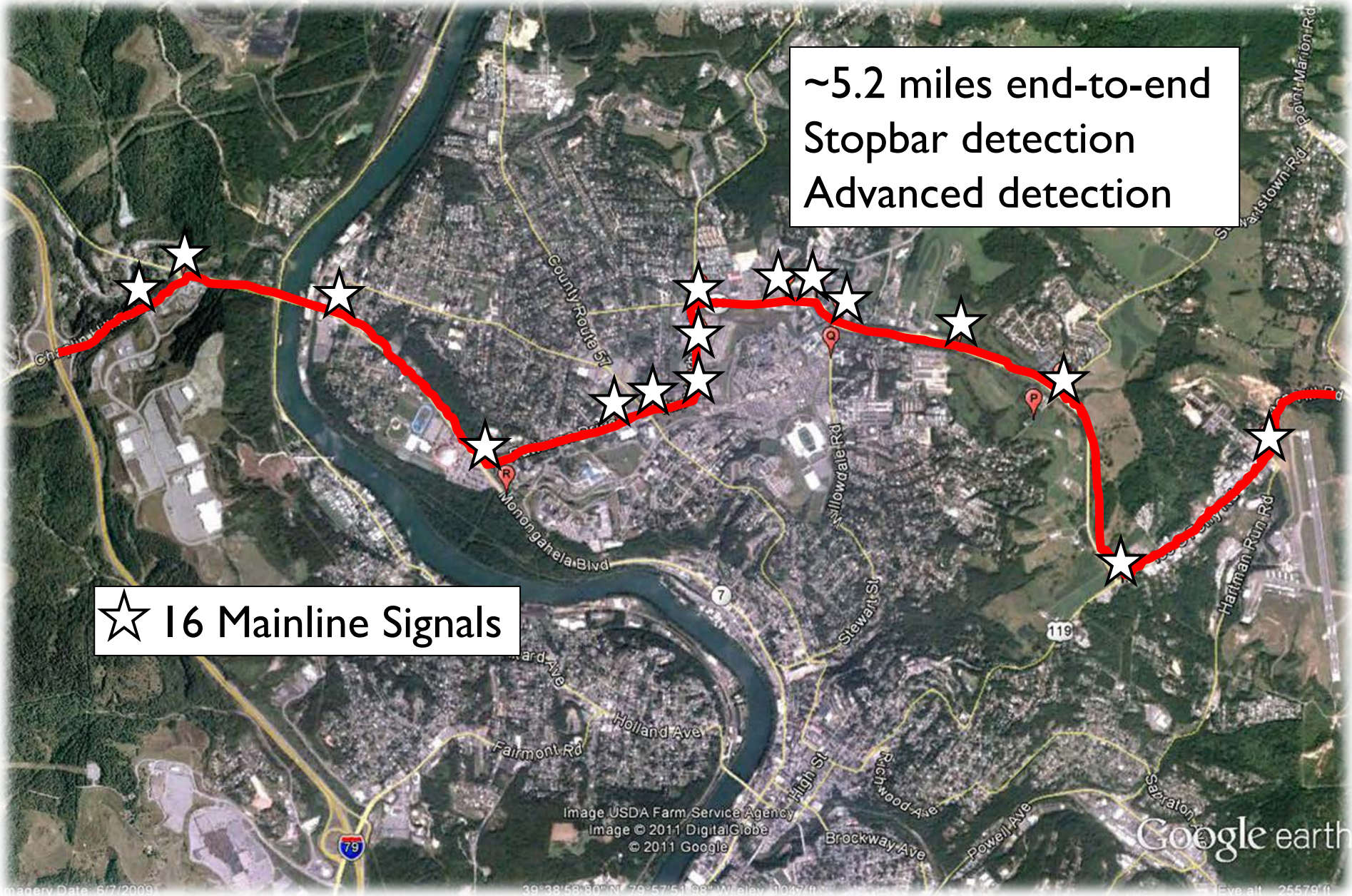
Adaptive Systems in WV

- WVDOH operates traffic signals statewide
  - ~1,900 traffic signals
  - ~107 closed loop signal systems (running coordinated timings)
- Adaptive Signal Control Deployments
  - (16) Morgantown WV-705 Corridor (In Progress)
  - (5) Teays Valley SR-34 Corridor (Summer 2012)
  - (3) Elkins US-219 Corridor (In Progress)
  - (5) St. Albans US-60 Corridor (In Progress)
  - (8) Morgantown Beechurst/University Corridor (Spring 2013)
- Rahall Transportation Institute is managing and evaluating the performance of these systems

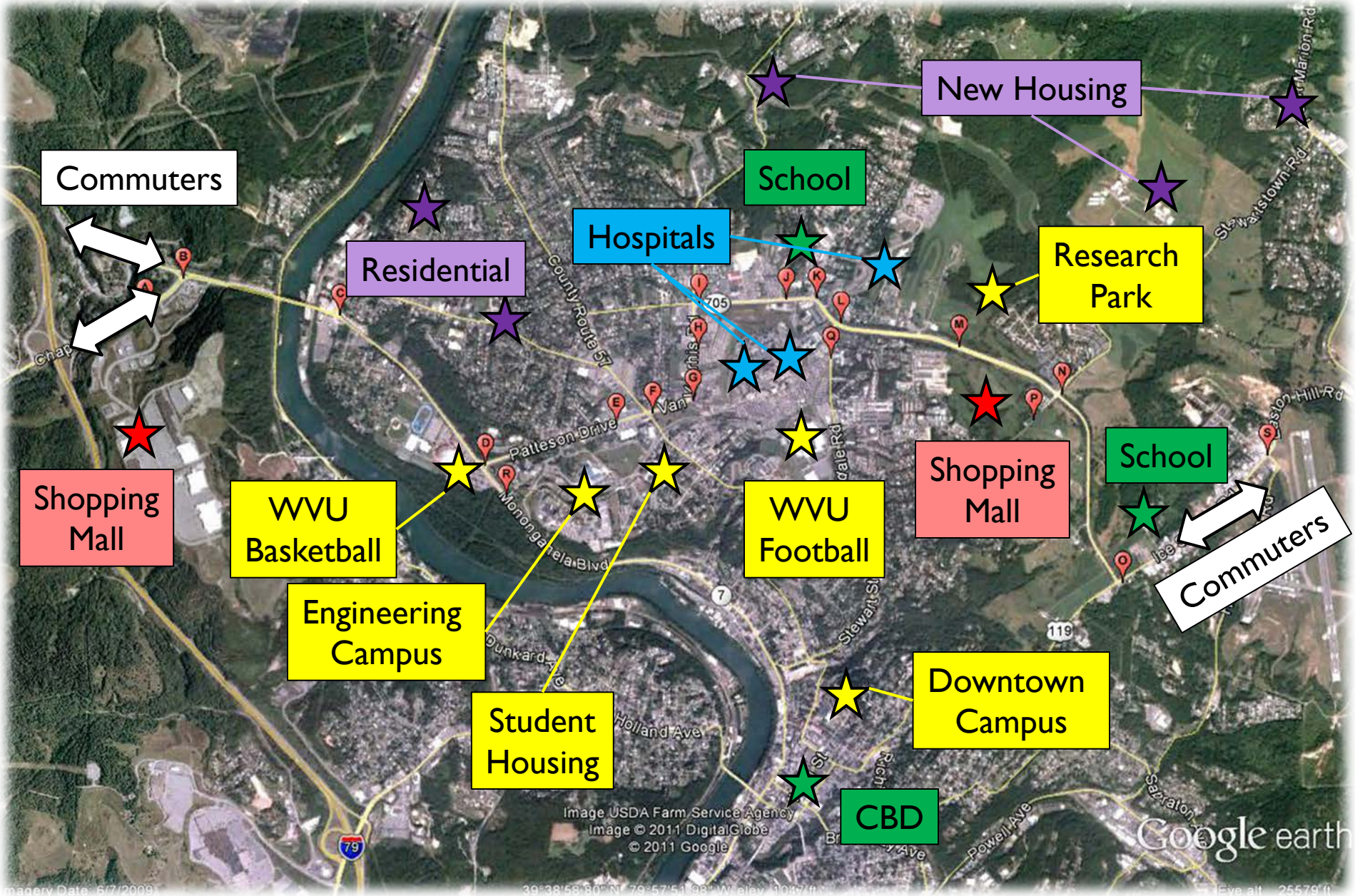
Adaptive Signal Control Evaluation

- Morgantown WV-705 Corridor
  - Adaptive System: ACS-Lite & Traffic Responsive Hybrid
  - Evaluation Mechanism
    - Intersection Delay & Progression – Simulation using VISSIM
    - Travel Time – Bluetooth & GPS
    - Safety – Eventually crash records
- Teays Valley SR-34 Corridor
  - Adaptive System: InSync
  - Evaluation Mechanism
    - Travel Time – GPS

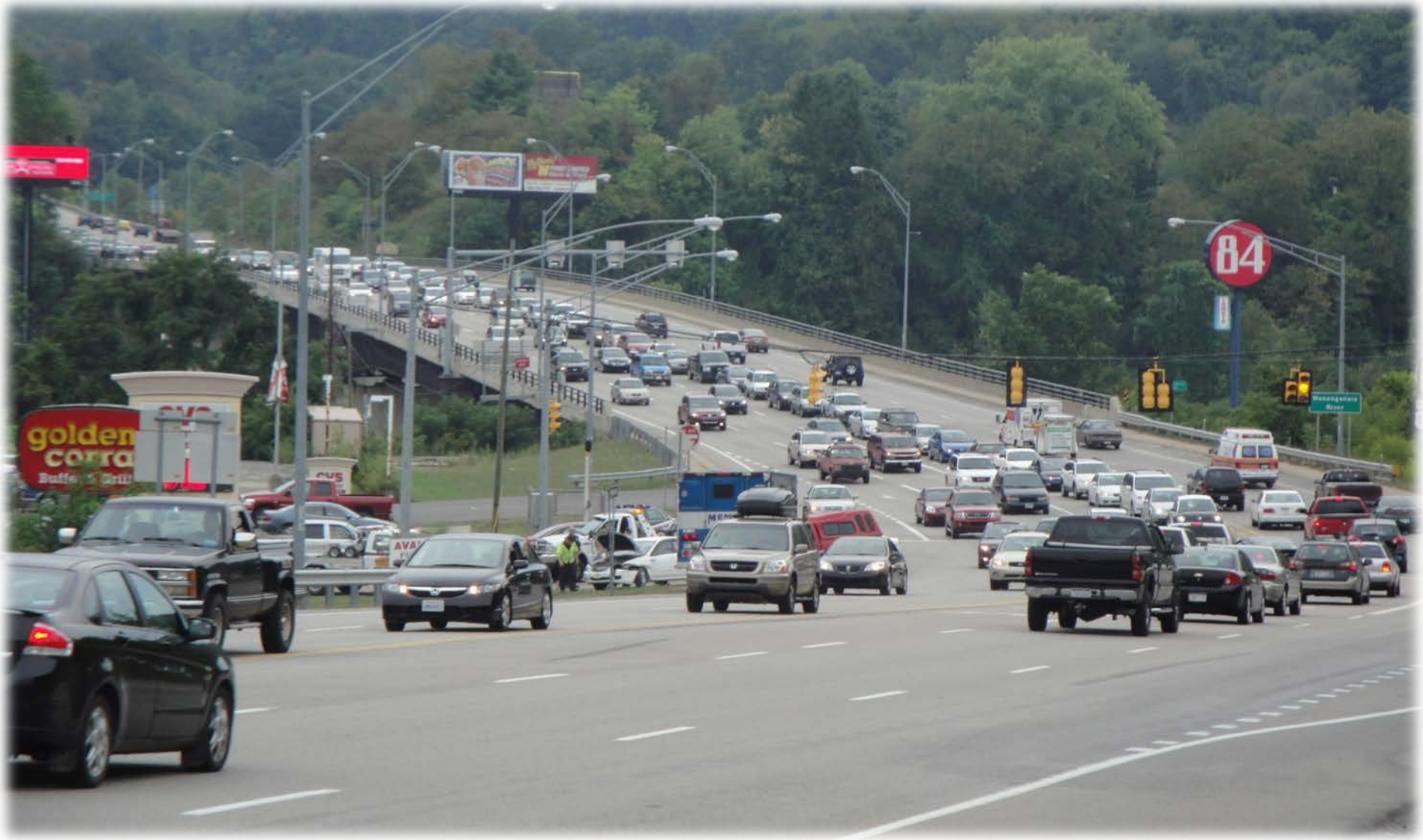
WV 705 Signalized Intersections



WV 705 Traffic Generators



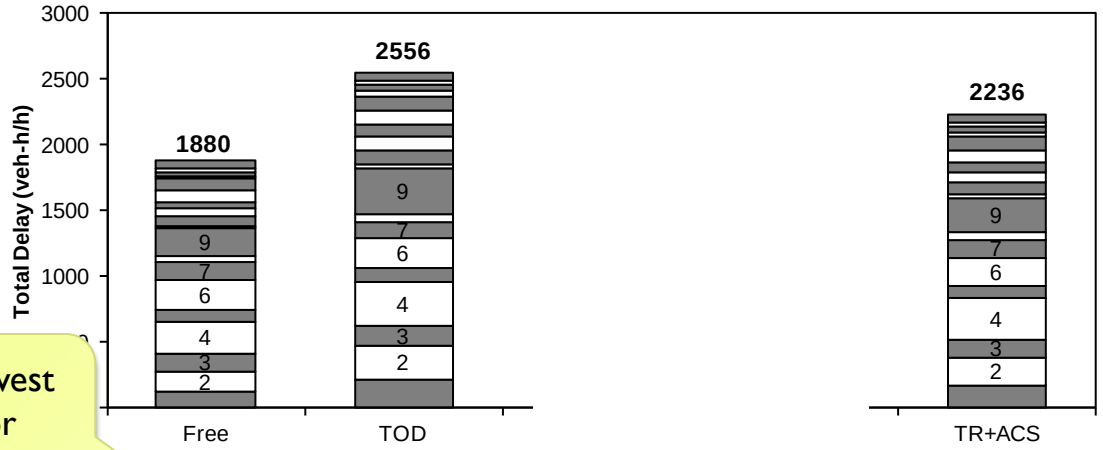
WV 705 Corridor



WV 705 System Evaluation with Simulation

- WV 705 corridor was modeled in VISSIM with traffic signal controller simulators to evaluate:
  - Free operation (no coordination)
  - Basic Coordination Plans (TOD)
  - TOD + Traffic Responsive (TR)
  - TOD + ACS-Lite (ACS)
  - TOD + TR + ACS (Adaptive)
- Total Delay and Hourly Delay Summarized
  - By System (All intersection movements)
  - By Mainline Movement (705 thru movements)
  - By Minor Movement (Left-turns and side-streets)

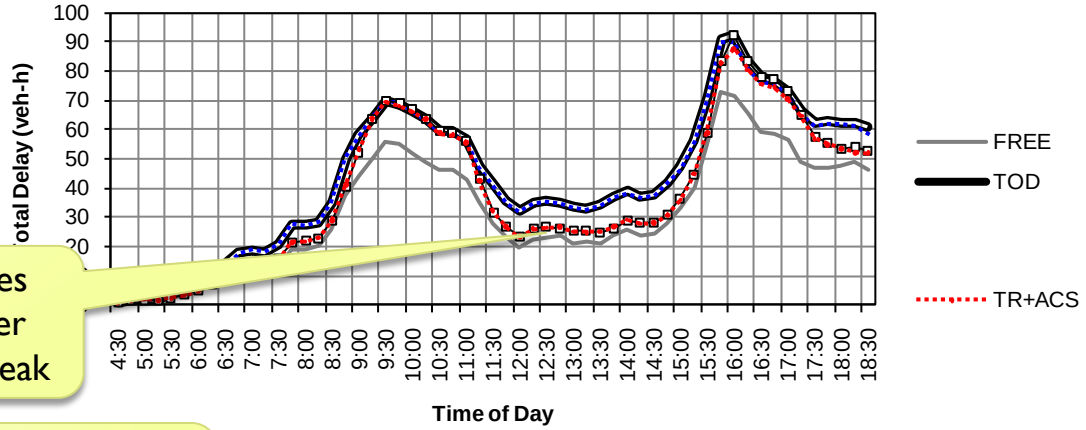
All Movements



System Delay is lowest in Free, but major

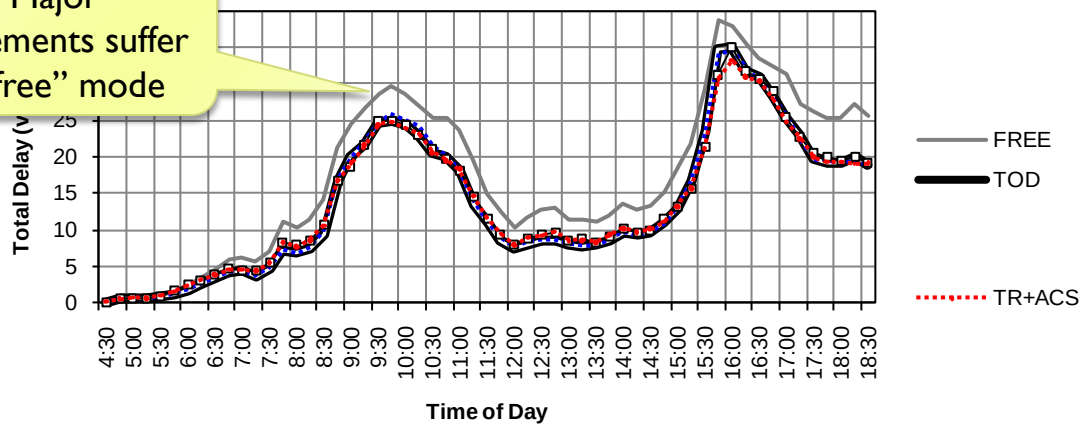
All Movements

Adaptive provides most benefit over TOD during off-peak

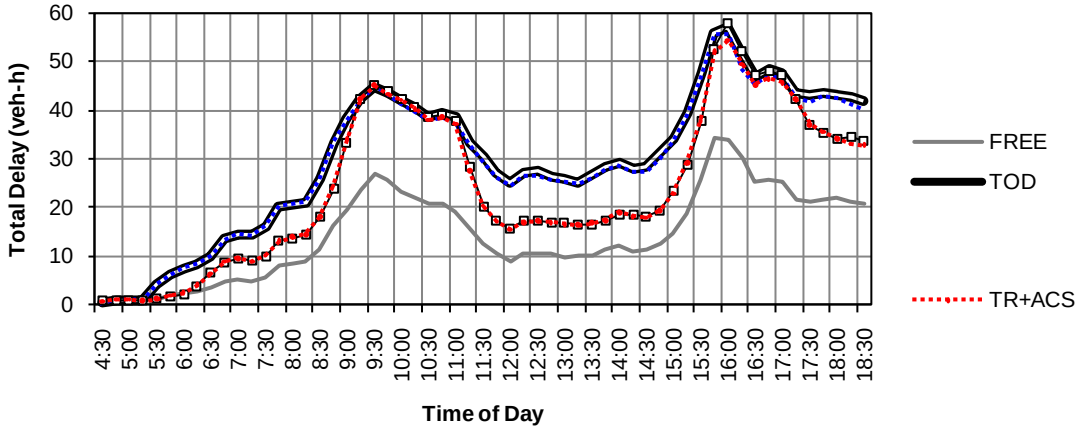


Major Movements

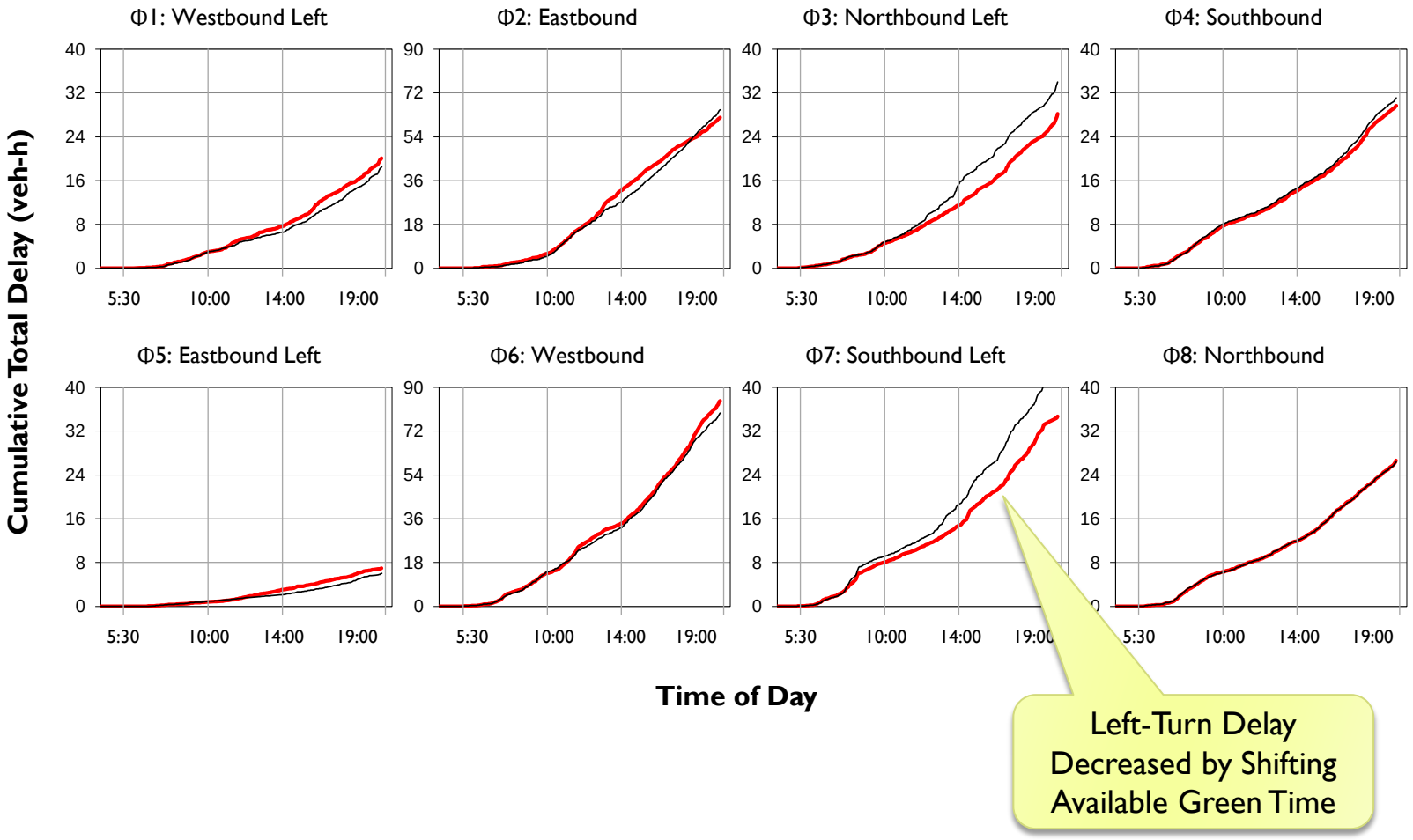
Major Movements suffer in "free" mode



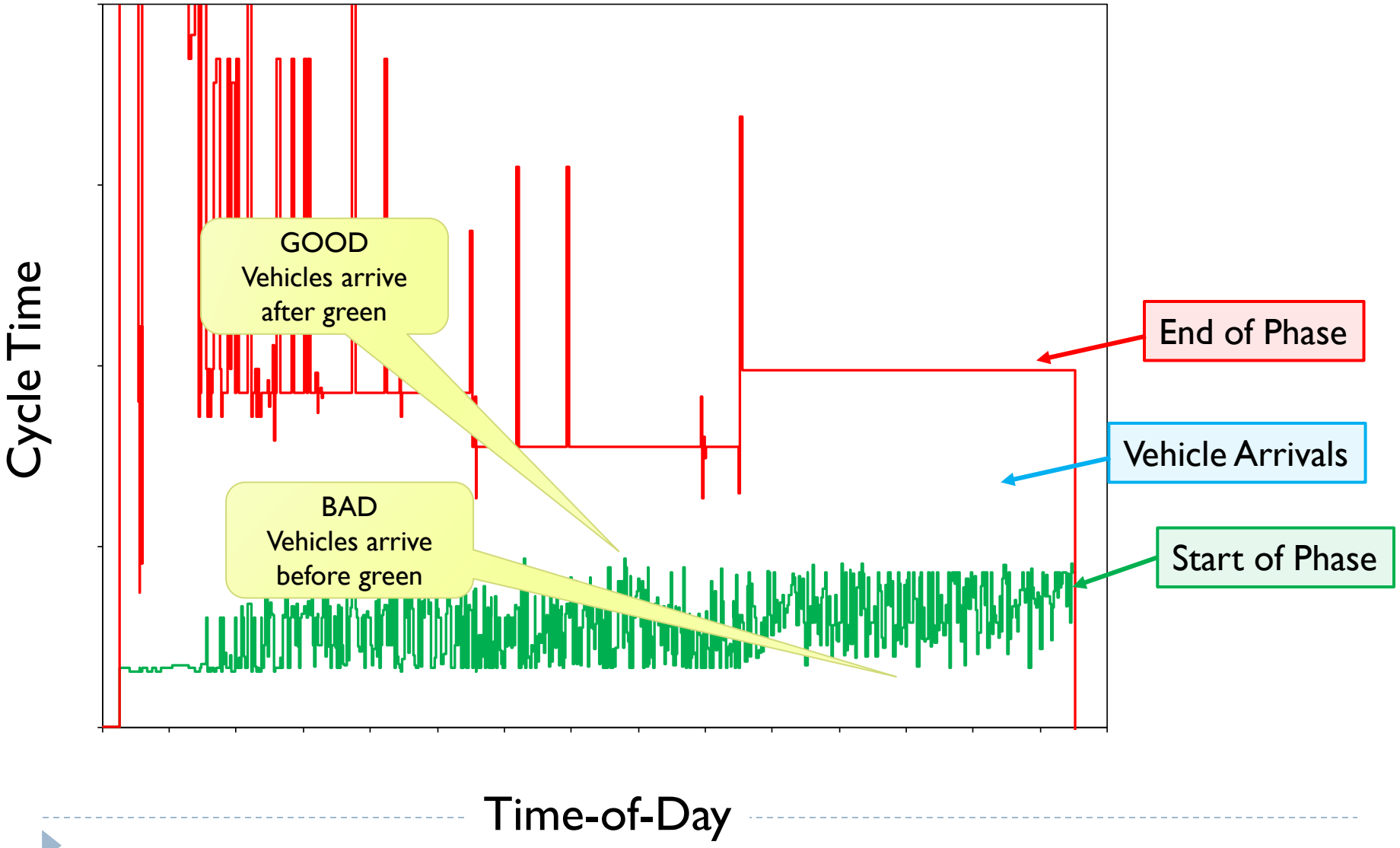
Minor Movements



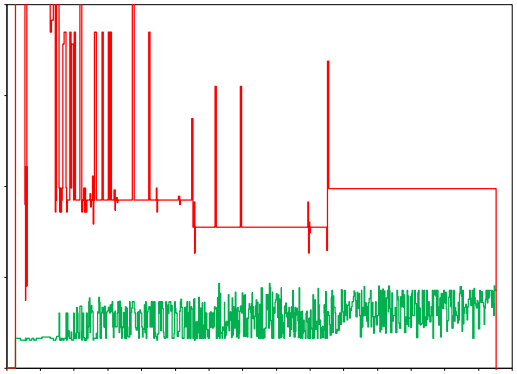
Cumulative Total Delay – University & Patteson

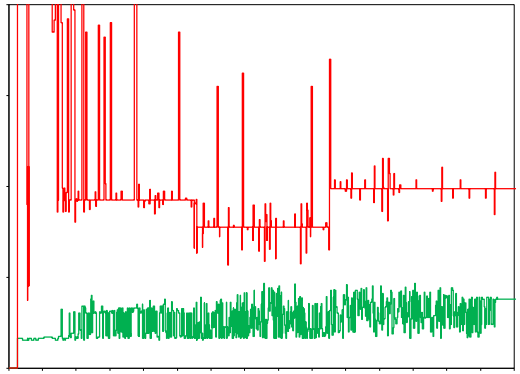


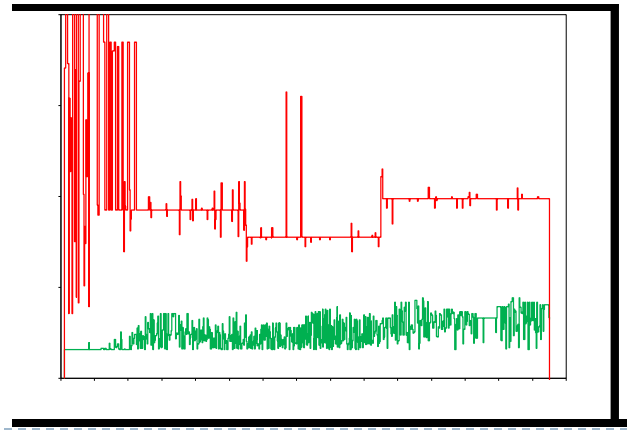
Coordination Diagram to Evaluate Offsets

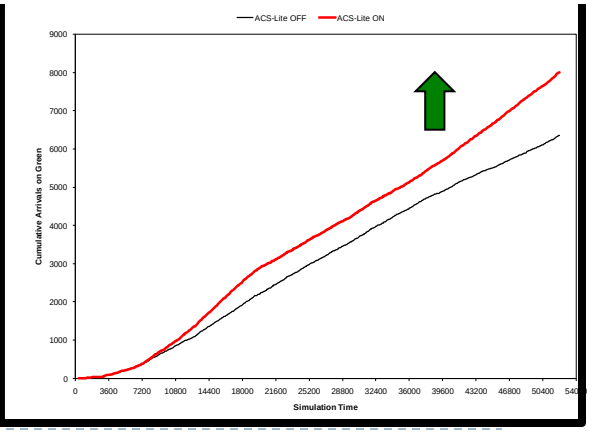


Offset Adjustment
Willowdale – Suncrest Town Center

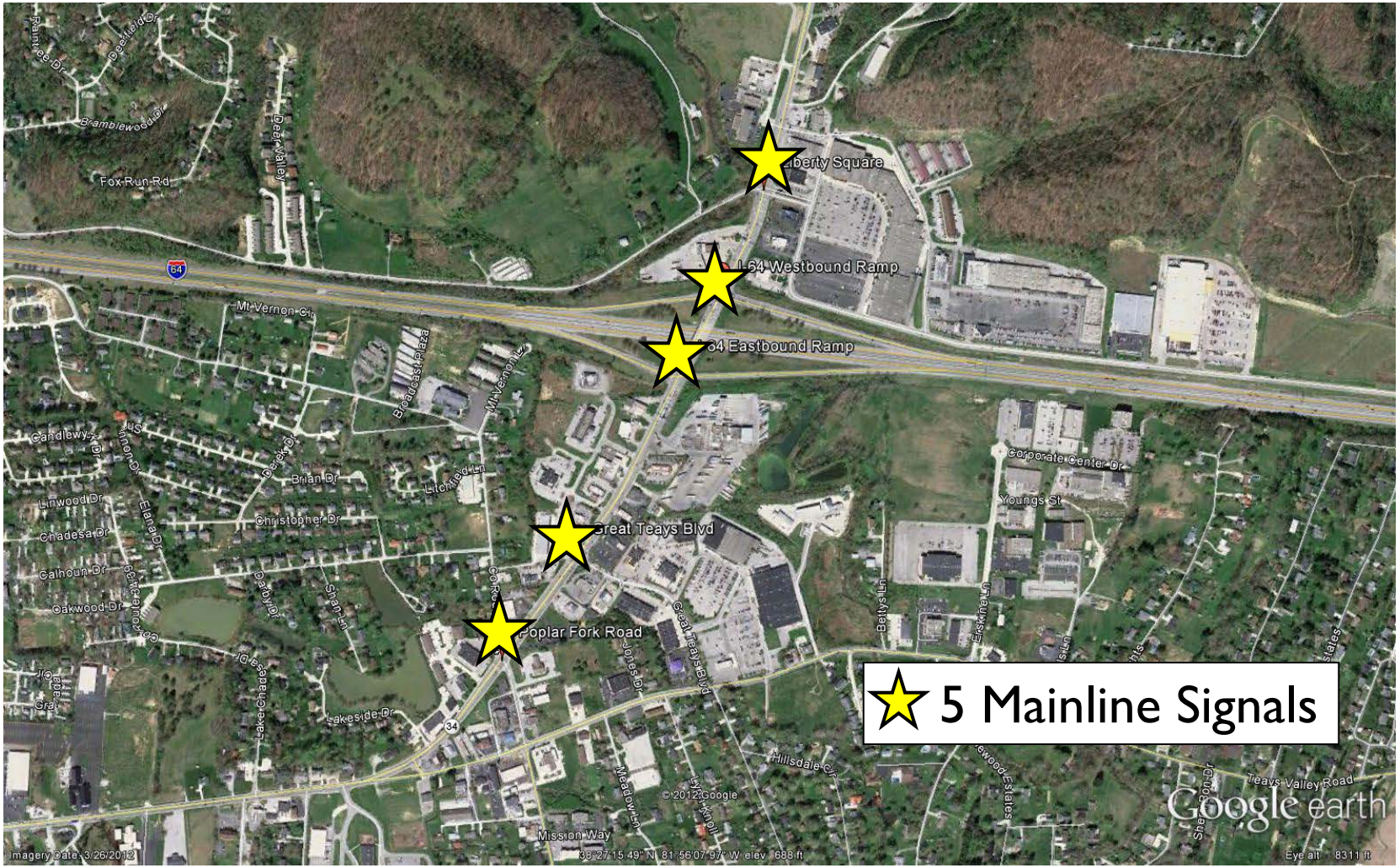






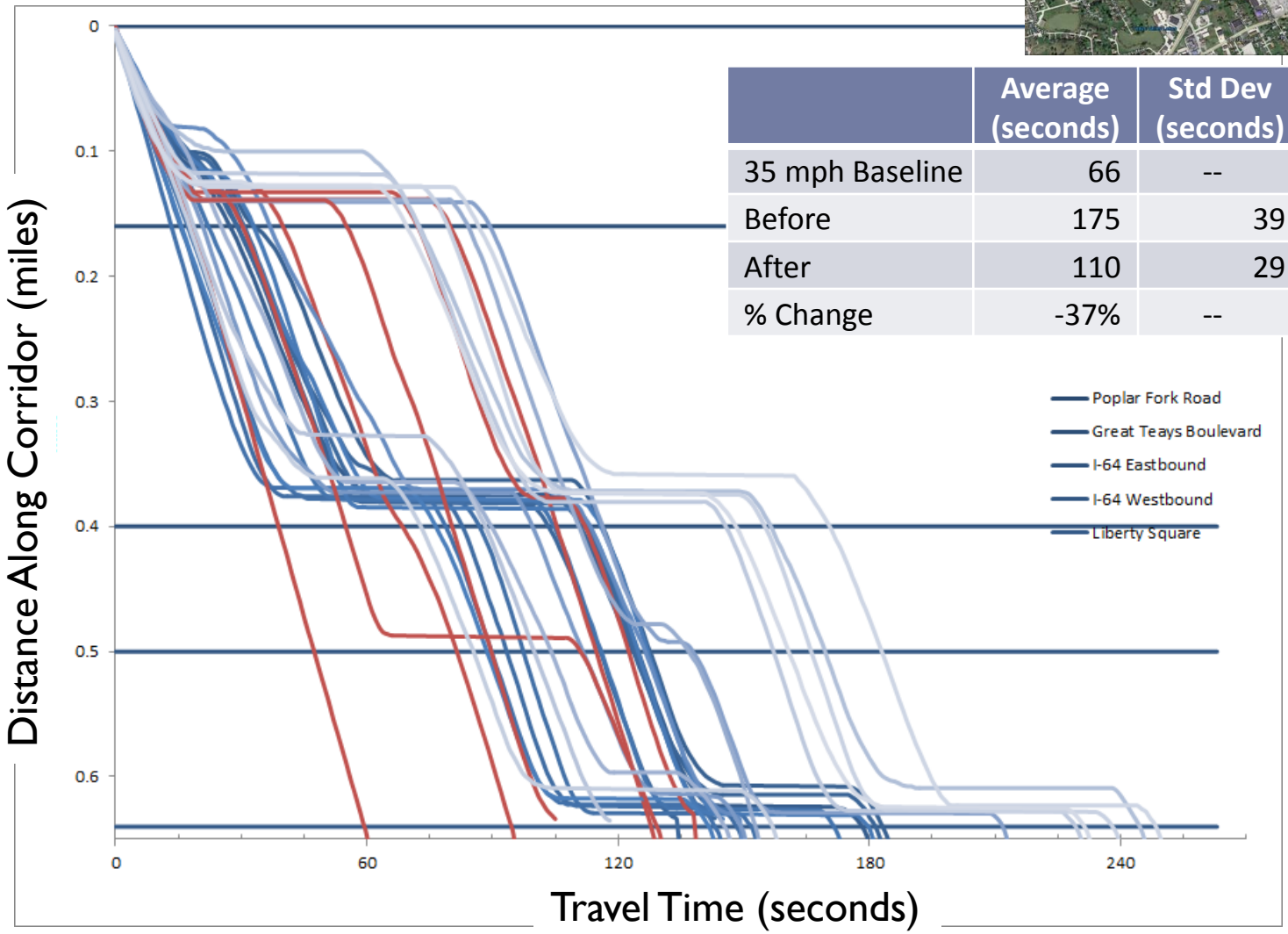


Teays Valley WV-34 System Overview



Northbound - GPS Travel Time Weekday 7AM–11AM

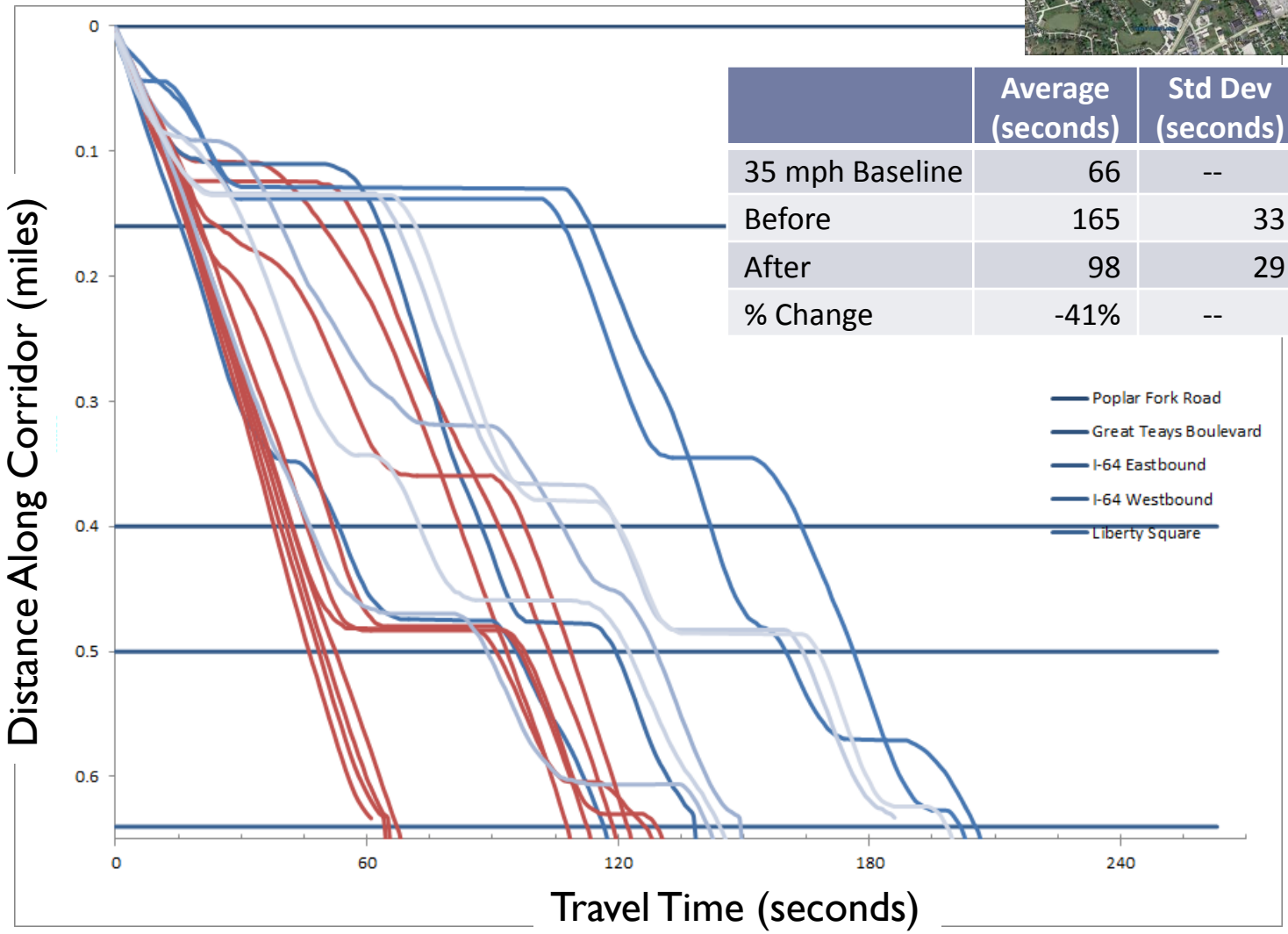
	Average (seconds)	Std Dev (seconds)
35 mph Baseline	66	--
Before	175	39
After	110	29
% Change	-37%	--



Before After

Northbound - GPS Travel Time Weekday 11AM–2PM

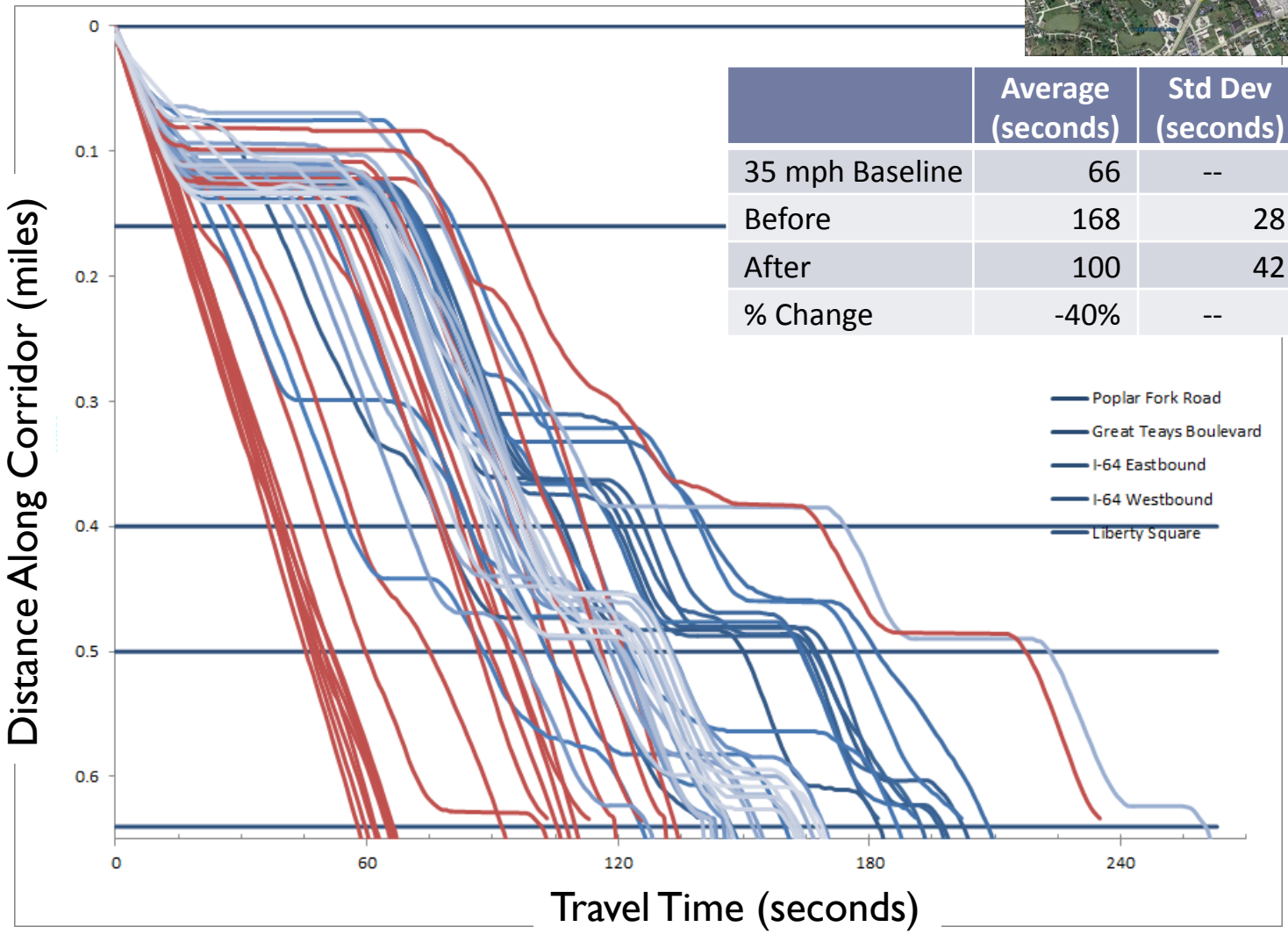
	Average (seconds)	Std Dev (seconds)
35 mph Baseline	66	--
Before	165	33
After	98	29
% Change	-41%	--



Before After

Northbound - GPS Travel Time Weekday 2PM–6PM

	Average (seconds)	Std Dev (seconds)
35 mph Baseline	66	--
Before	168	28
After	100	42
% Change	-40%	--



Before After

Planning for Traffic Signals

- Most of the common planning software packages do not account for basic traffic signal operations, much less adaptive control
- Difficult to evaluate/predict the performance of an adaptive system to quantify the benefits
- If there are fluctuating traffic patterns, adaptive might be a good solution
- If a signal system is being upgraded, often the incremental cost for adaptive is insignificant

Contact Information

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