Signal System Performance Measures for Prioritizing Resources and Assessing Outcomes

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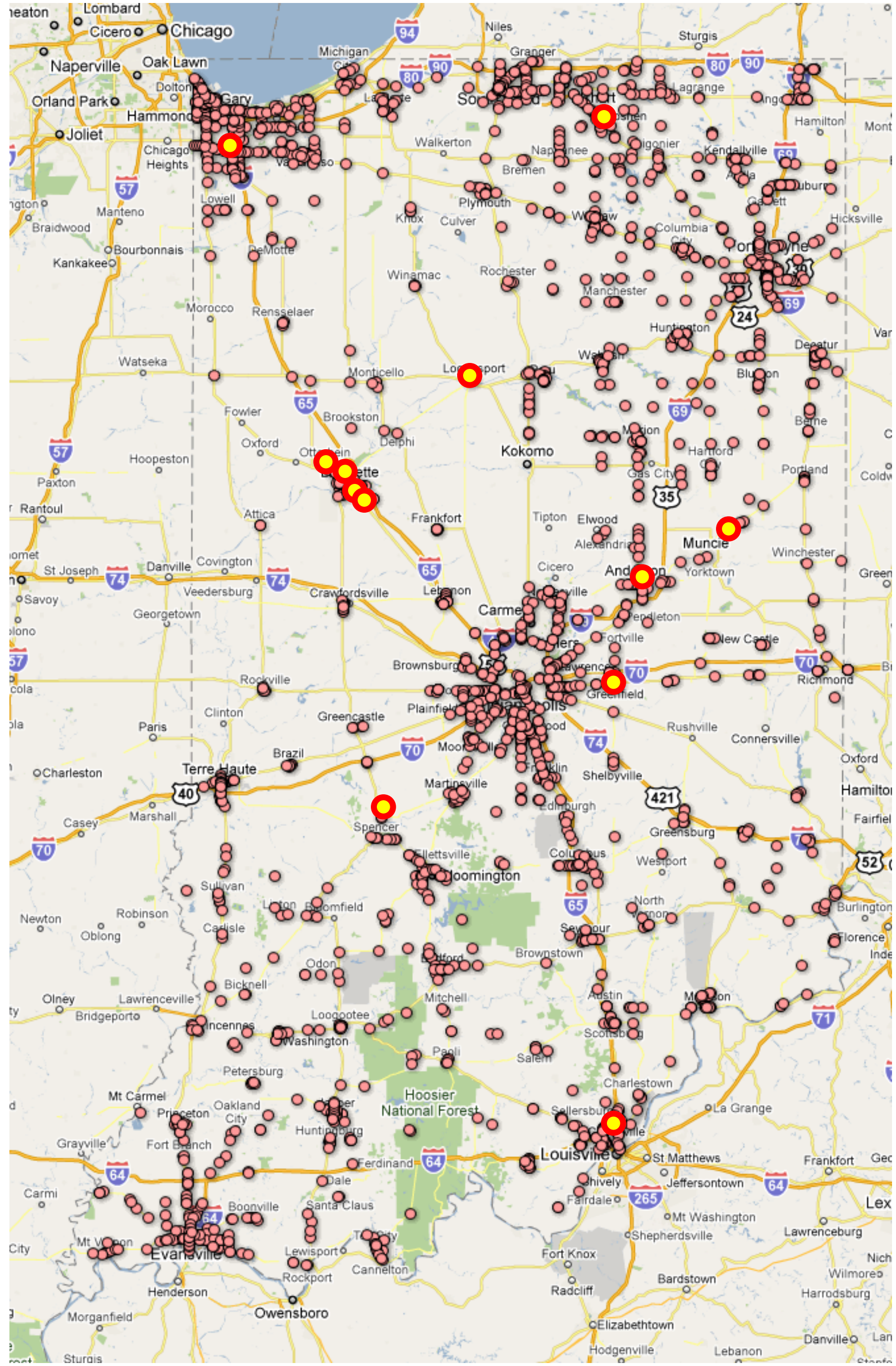
Active Traffic Management Workshop
December 13, 2011
Merrillville, Indiana

Question

- **How should the agency program resources to improve traffic control?**
- *Where current control is providing the least satisfactory performance*
- Impossible to know without performance measures
- Impractical to compile performance measures without automation



Traffic Signal Timing Process

I. Define Objectives, Assess and Prioritize activities by Time of Day and location

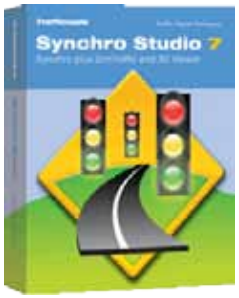
II. Assembly relevant data to support timing and docu-mentation objectives

III. Software Modeling

IV. Timing Design and Docu-mentation

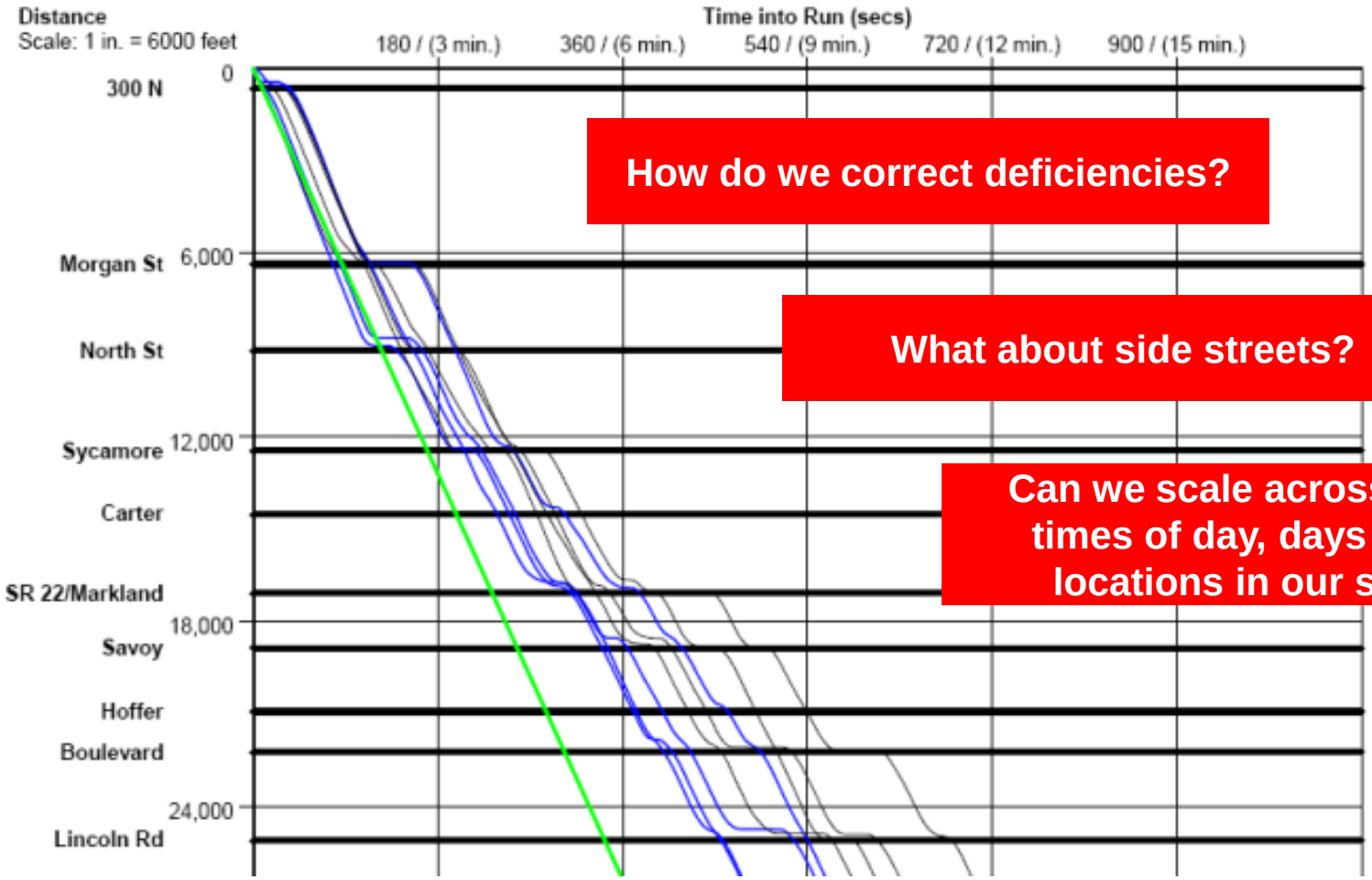
V. Deployment

VI. Assess



Theme of workshop and talk

Floating car (existing method of “statistical analysis”)



How do we correct deficiencies?

What about side streets?

Can we scale across different times of day, days of week, locations in our system?

Aspects of signal operations

$$PF = \frac{(1-P) f_{PA}}{1- g/C}$$

Progression Factor

P = Percent arriving on green

$$d = d_1(PF) + d_2 + d_3$$

$$d_1 = \frac{0.5C\left(1- g_i/C\right)^2}{\left(1- \min(1, X_i)\right) g_i/C}$$

HCM Delay Equation

g = green time (s)
C = cycle length (s)
X = volume to capacity ratio

$$X_i = \frac{v}{s}\frac{C}{g_i}$$

Volume to Capacity Ratio

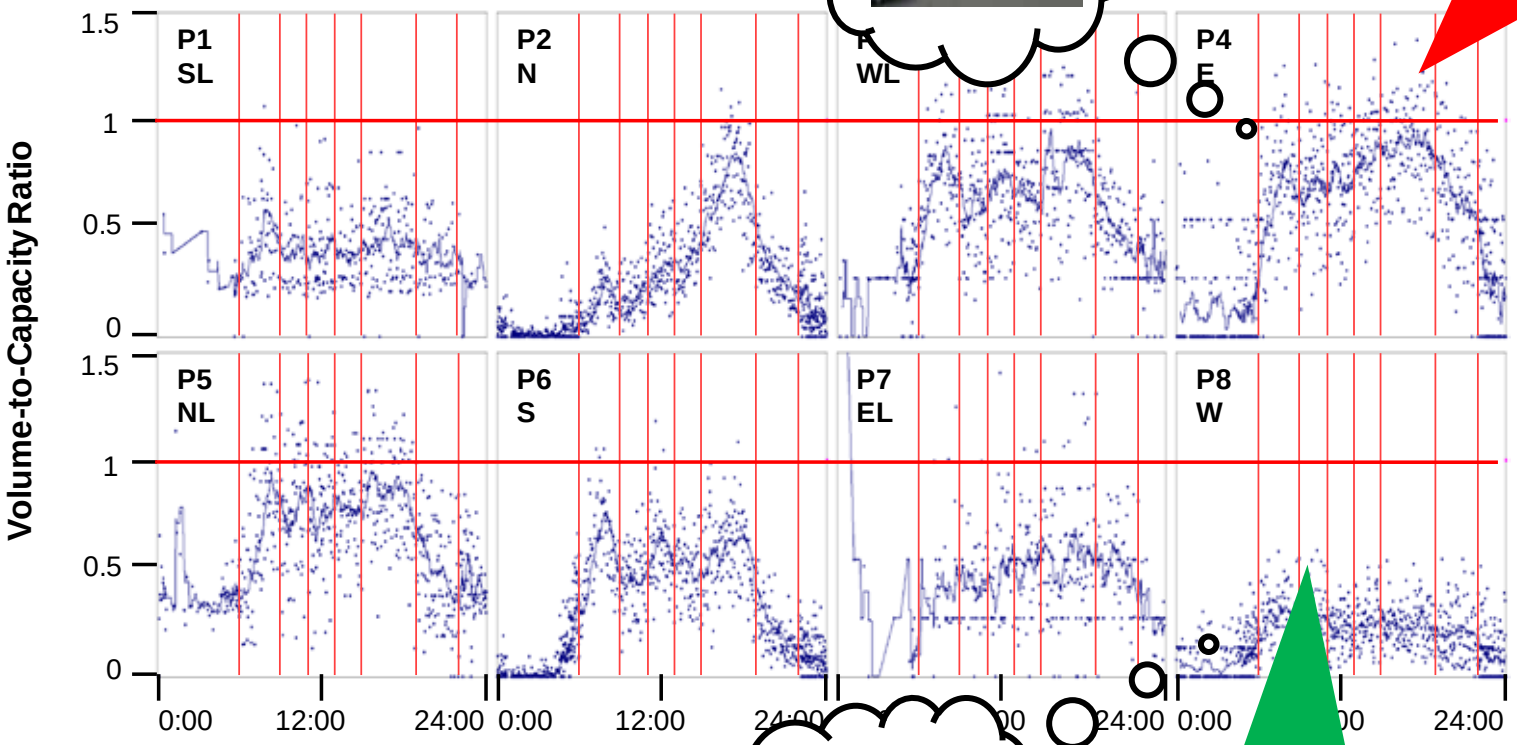
v = flow rate (veh/h)
s = saturation flow rate (veh/h)

Capacity Utilization

Low capacity utilization

High capacity utilization (Split Failures)

24-hour Volume-to-Capacity



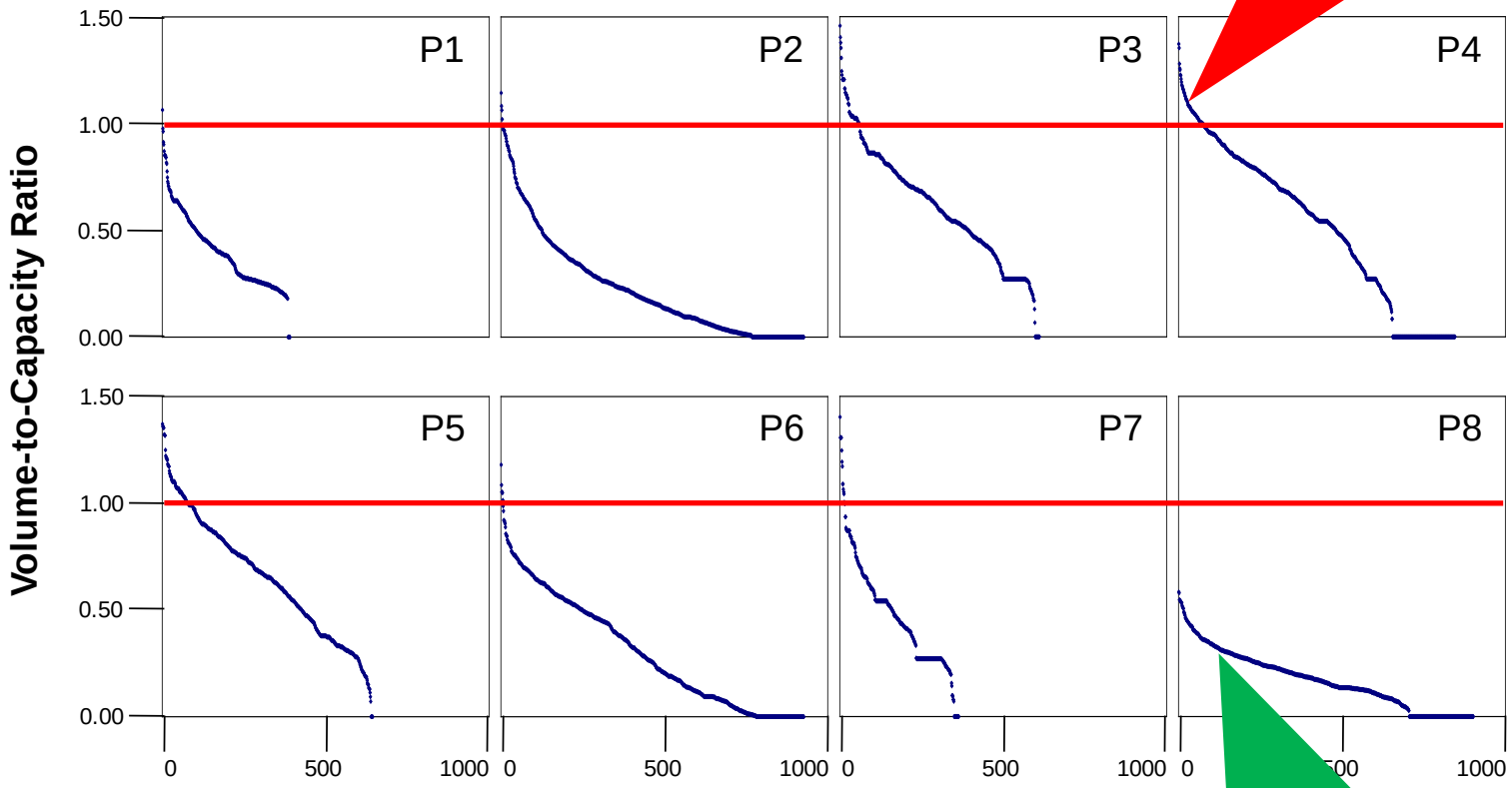
Likely Capacity deficiency

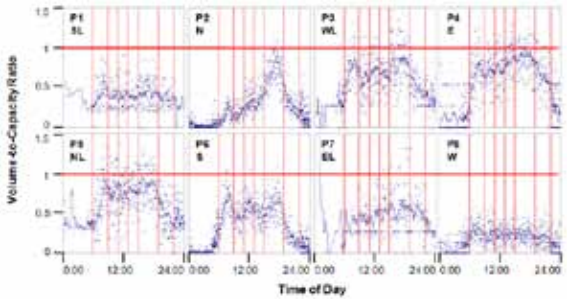
Unlikely capacity deficiency

Day, C.M., E.J. Smaglik, D.M. Bullock, and J.R. Sturdevant, “Quantitative Evaluation of Actuated Coordinated Versus Nonactuated Coordinated Phases,” *Transportation Research Record No. 2080*, TRB, National Research Council, Washington, D.C., pp. 8-21, 2008.

Bullock, D.M., C.M. Day; J.R. Sturdevant, ”Signalized Intersection Performance Measures for Operations Decision Making,” ITE Journal, August 2008.

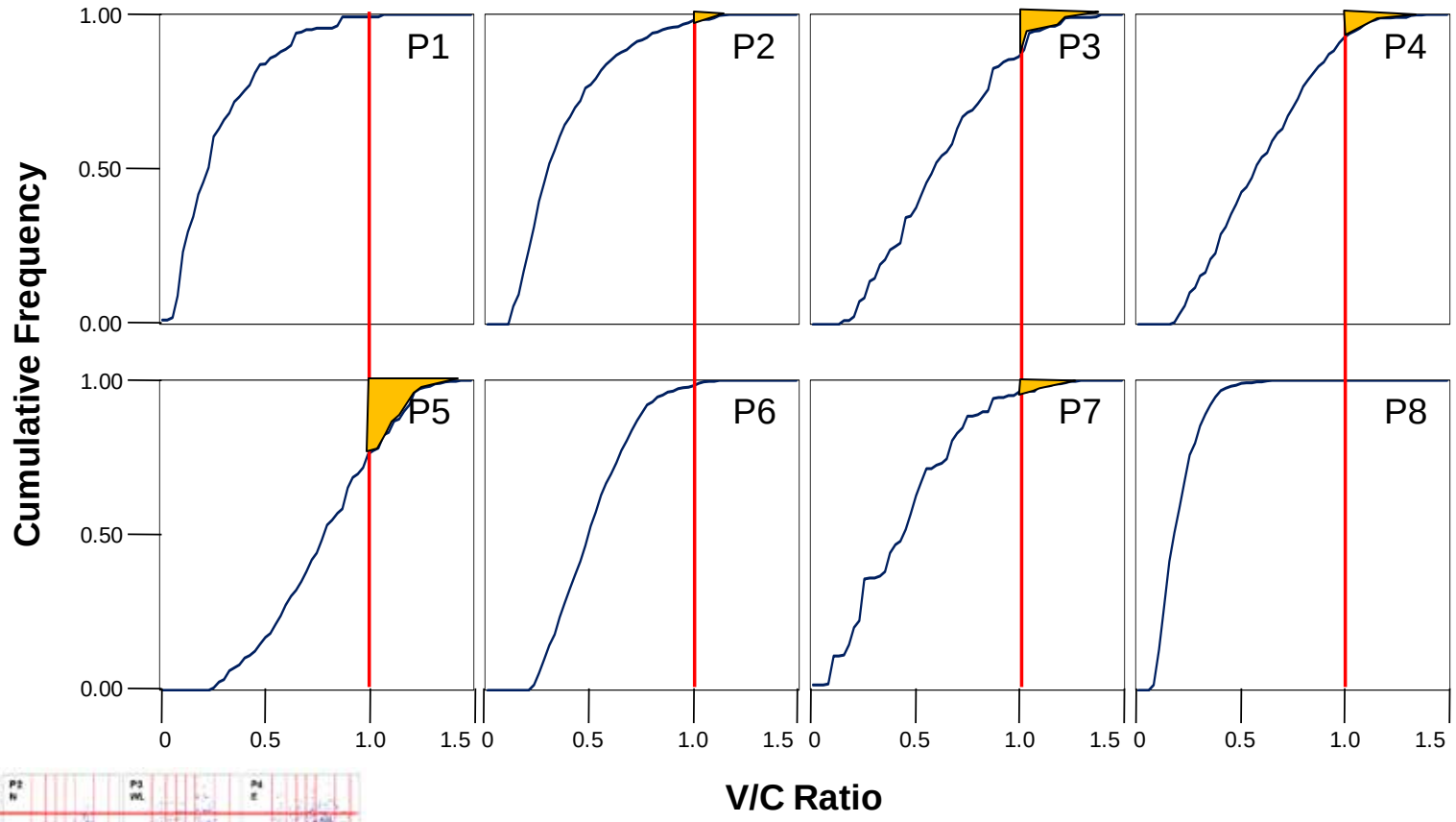
Pareto-Sorted V/C ratio

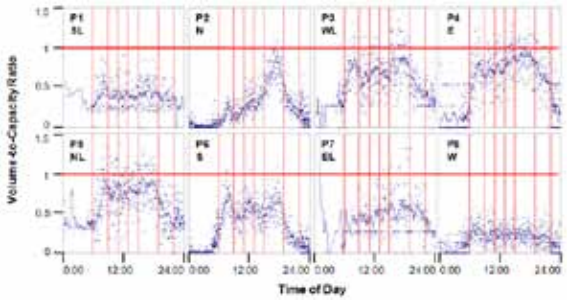




Day, C.M., Sturdevant, J.R., and Bullock, D.M. (2010). Outcome oriented performance measures for management of signalized arterial capacity. *Transportation Research Record No. 2192*, Washington, D.C.: Transportation Research Board, 24-36.

Cumulative Frequency of V/C Ratio





Can we use V/C ratio to predict split failures?

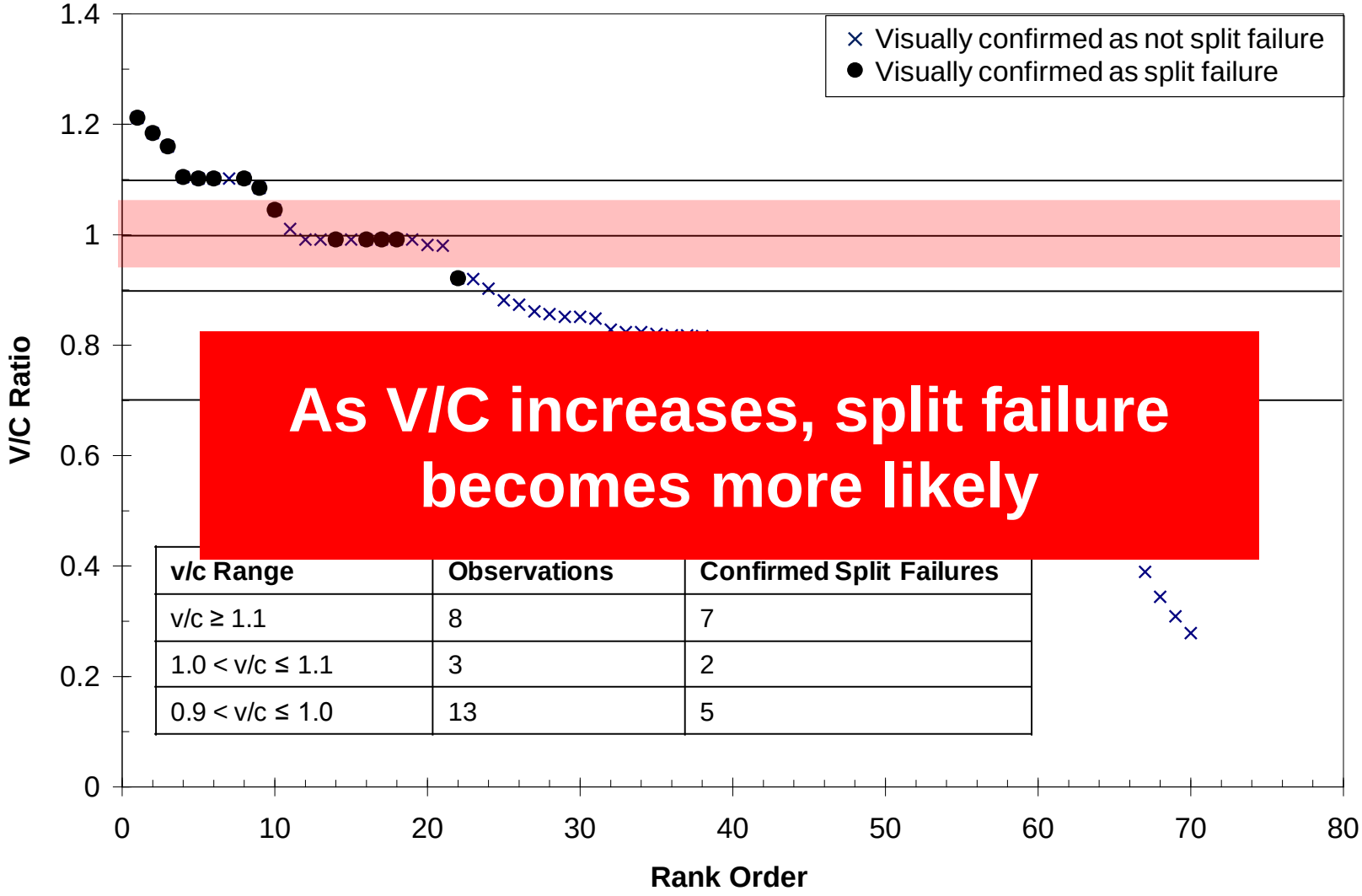
(a) Beginning of green, v/c = 0.55

(b) End of green, v/c = 0.55

(c) Beginning of green, v/c = 1.25

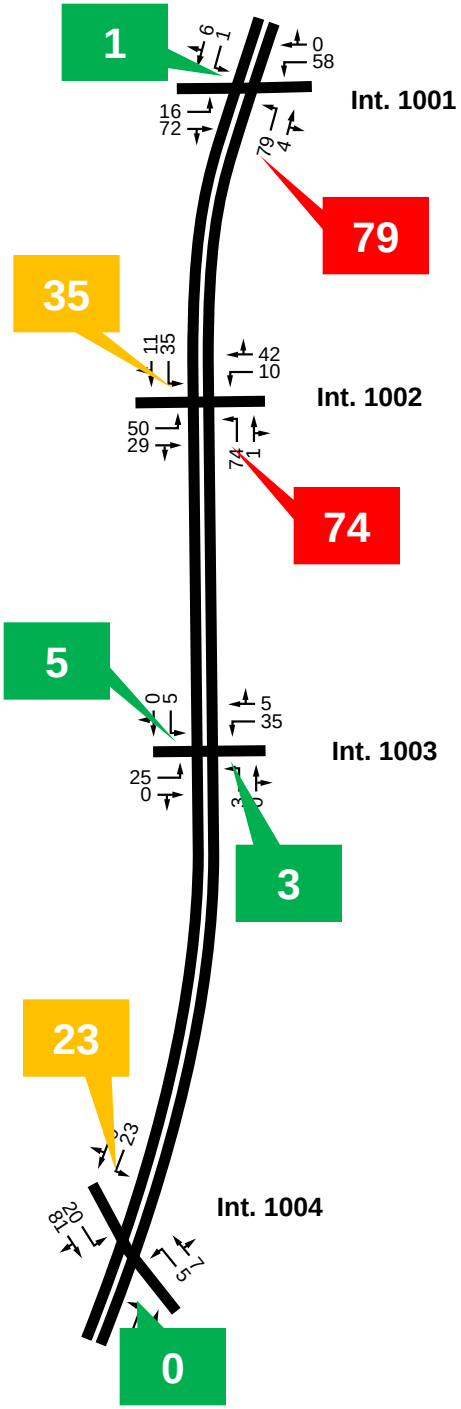
(d) End of green, v/c = 1.25

Can we use V/C ratio to predict split failures?



As V/C increases, split failure becomes more likely

v/c Range	Observations	Confirmed Split Failures
v/c ≥ 1.1	8	7
1.0 < v/c ≤ 1.1	3	2
0.9 < v/c ≤ 1.0	13	5



System Level Count of Split Failures (v/c > 1)

(Northbound & southbound left turns highlighted)

Where should direct resources to target problems in the system?

Degree of Intersection Saturation

$$X_c = \sum_i (v/s)_{ci} \left(\frac{C}{C - L} \right)$$

$(v/s)_c$ ® Critical Ratio of Volume to Saturation

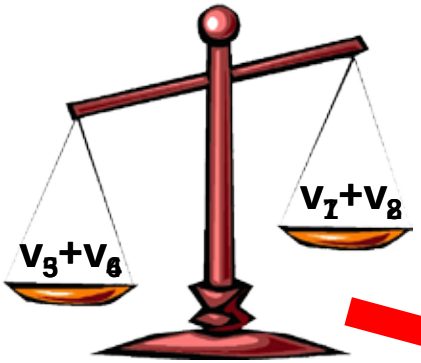
C ® Cycle Length (s)

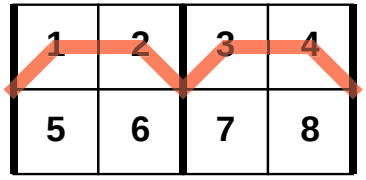
L ® Lost Time (s)

Intersection Saturation

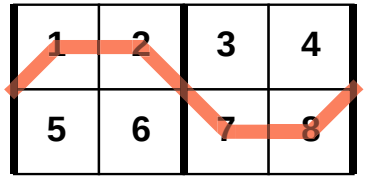
Simplifed equation for Dual-Ring, Eight-Phase Intersection:

$$X_C = \left[\max\left(\frac{v_1}{s_{12}}, \frac{v_2}{s_{56}}\right) + \max\left(\frac{v_3}{s_{34}}, \frac{v_4}{s_{78}}\right)\right]\left(\frac{C}{C - L}\right)$$

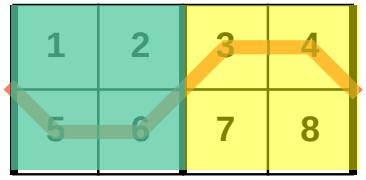




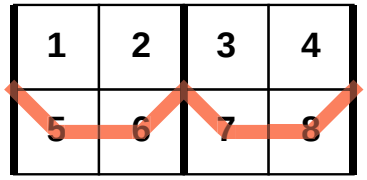
(a) Critical Path 1234



(b) Critical Path 1278

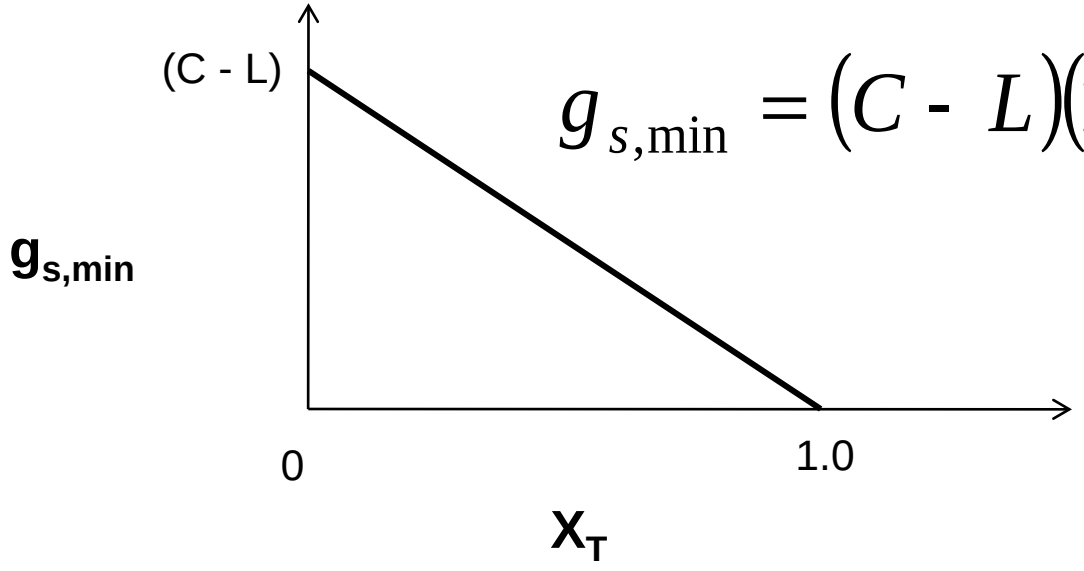


(c) Critical Path 5634



(d) Critical Path 5678

What value of X_C do we consider critical?



$$g_{s,\min} = (C - L)(1 - X_T),\ 0 \le X_T \le 1$$

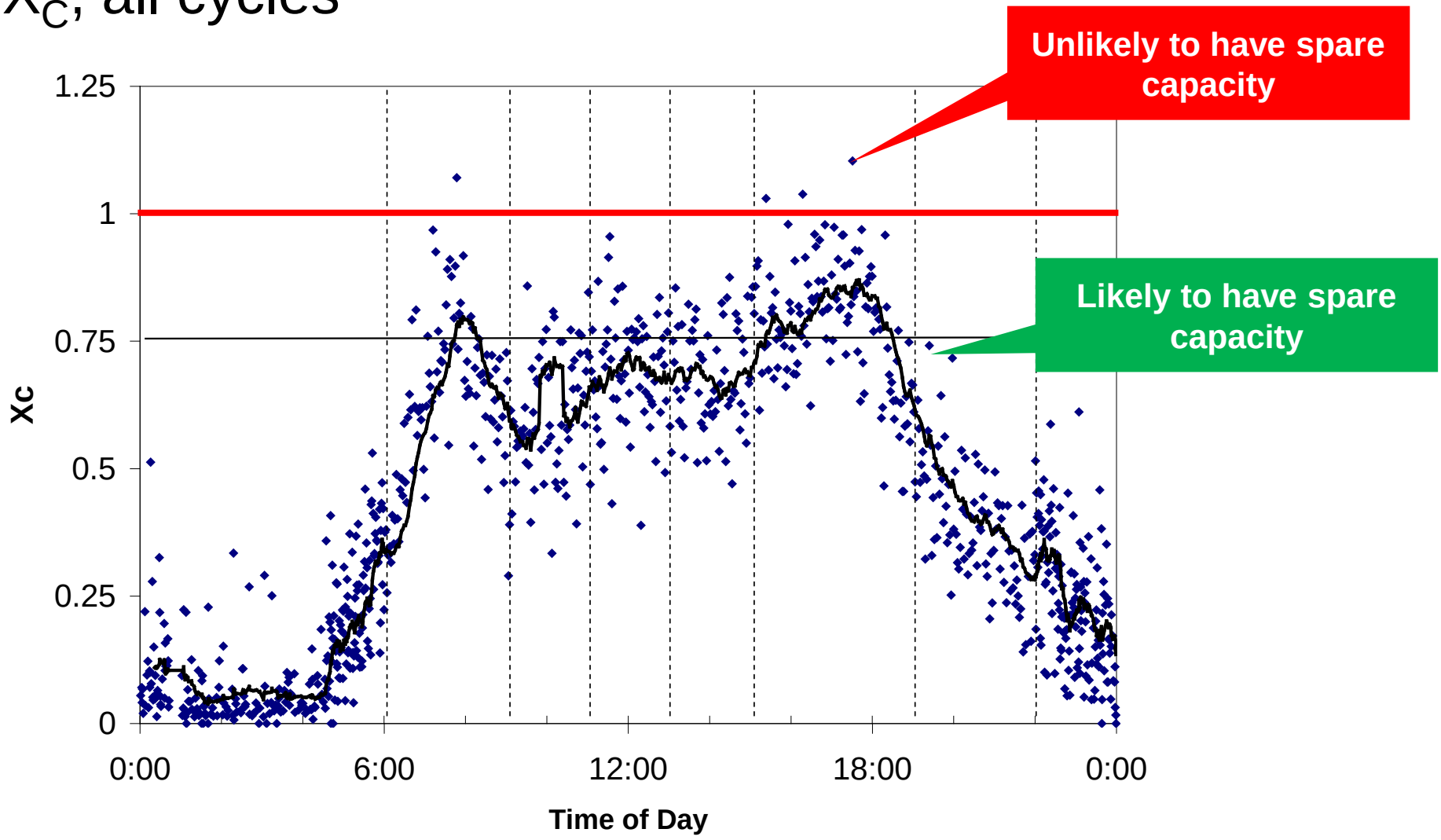
$g_{s,min}$ = minimum slack green time

C = Cycle Length

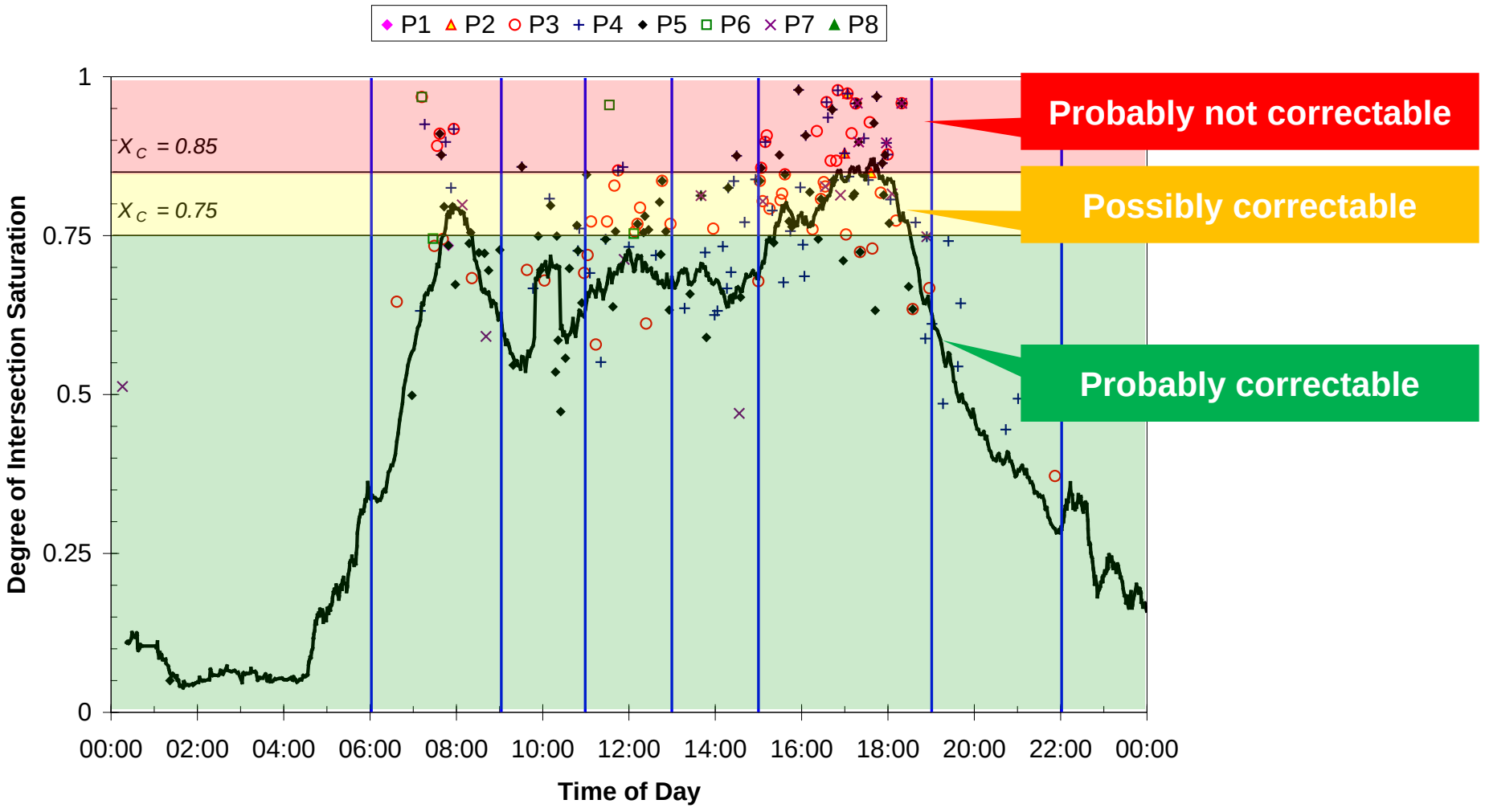
L = Lost Time (clearance intervals)

X_T = Threshold value of X_C where we expect could improve operation by adjusting splits (higher number ~ more optimistic)

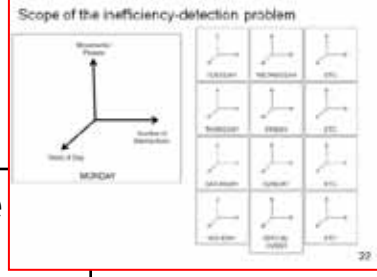
X_C, all cycles



X_C, Only cycles with split failures



Example system report outcomes



Intersection	Phase	Total split failures	Correctable ($X_T \leq 0.75$ criteria)	Correctable ($X_T \leq 0.85$ criteria)
1001	1	1	1	1
	2	4	0	1
			16	38
			27	44
			34	61
			1	2
			5	11
	8	0	9	0
	TOTAL	236	93	158
1002	…	…	…	…
	TOTAL	256	103	209
1003	…	…	…	…
	TOTAL	69	69	69
1004	…	…	…	…
	TOTAL	141	88	124

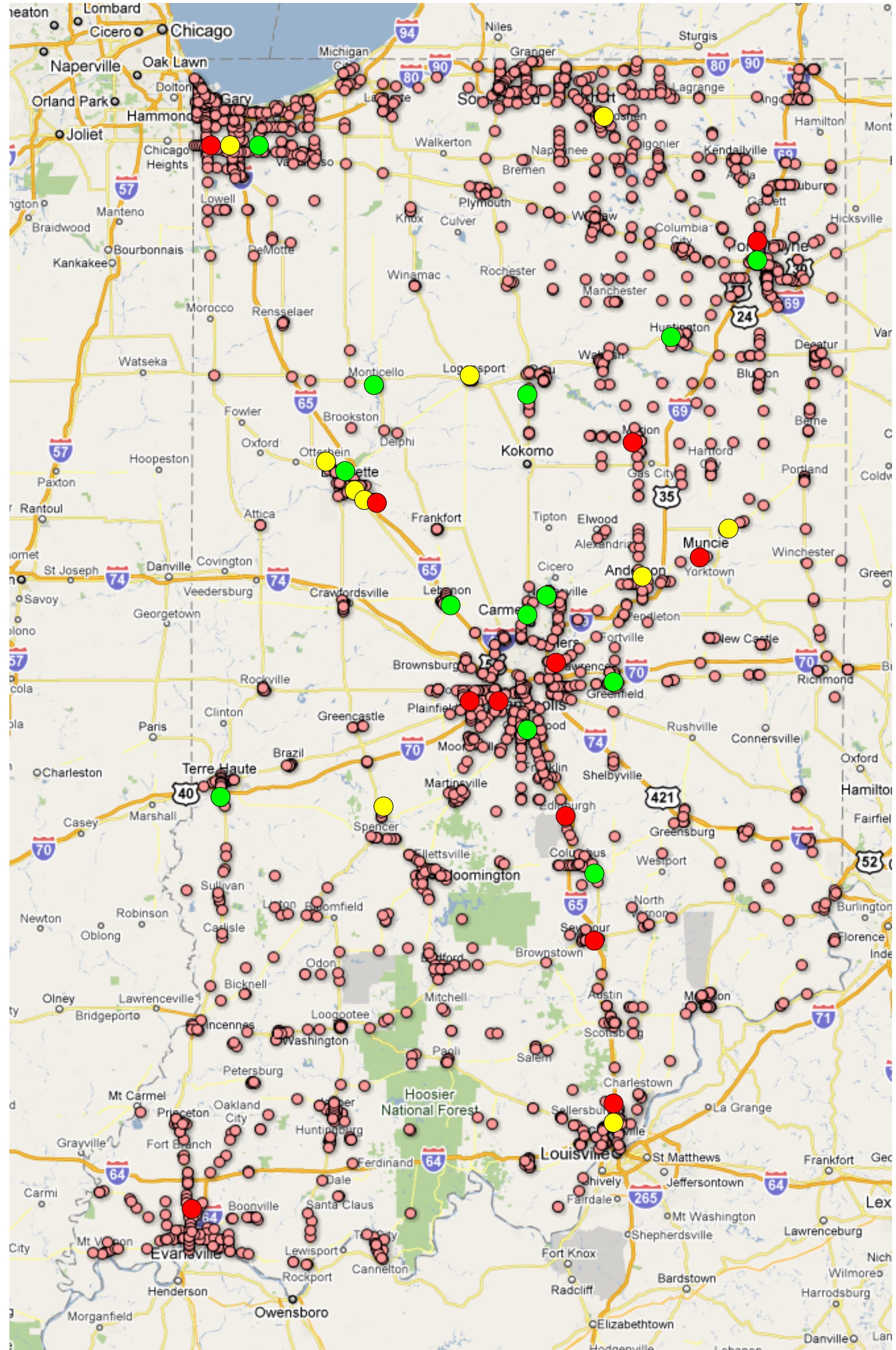
Where is the greatest opportunity to improve operations by rebalancing splits?

System Report: Capacity Utilization

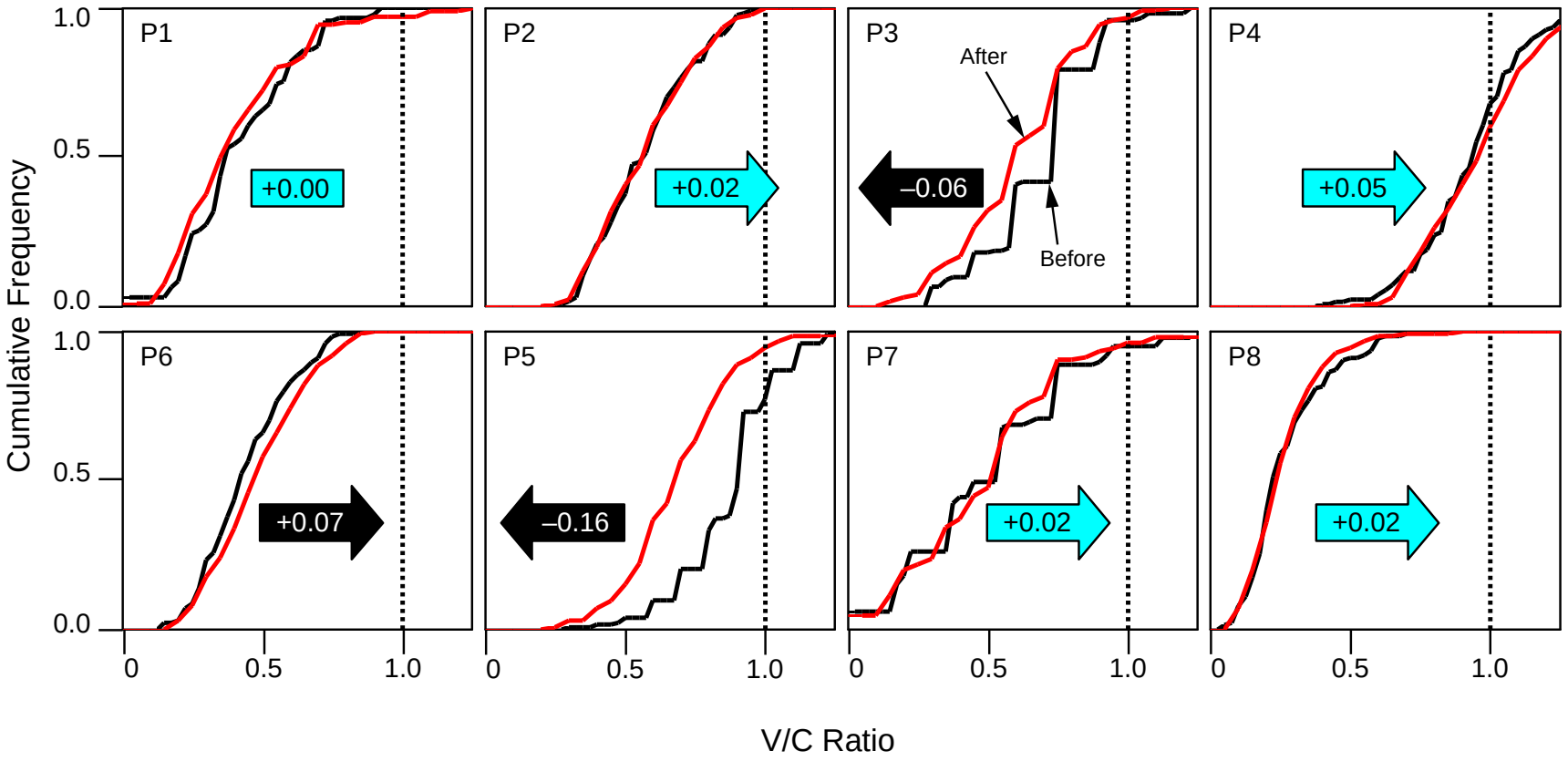
High Split Failures with low opportunity for re-allocating green times

High Split Failures with moderate opportunity for re-allocating green times

High Split Failures with substantial opportunity for re-allocating green times



Impact of Changes to Control Parameters



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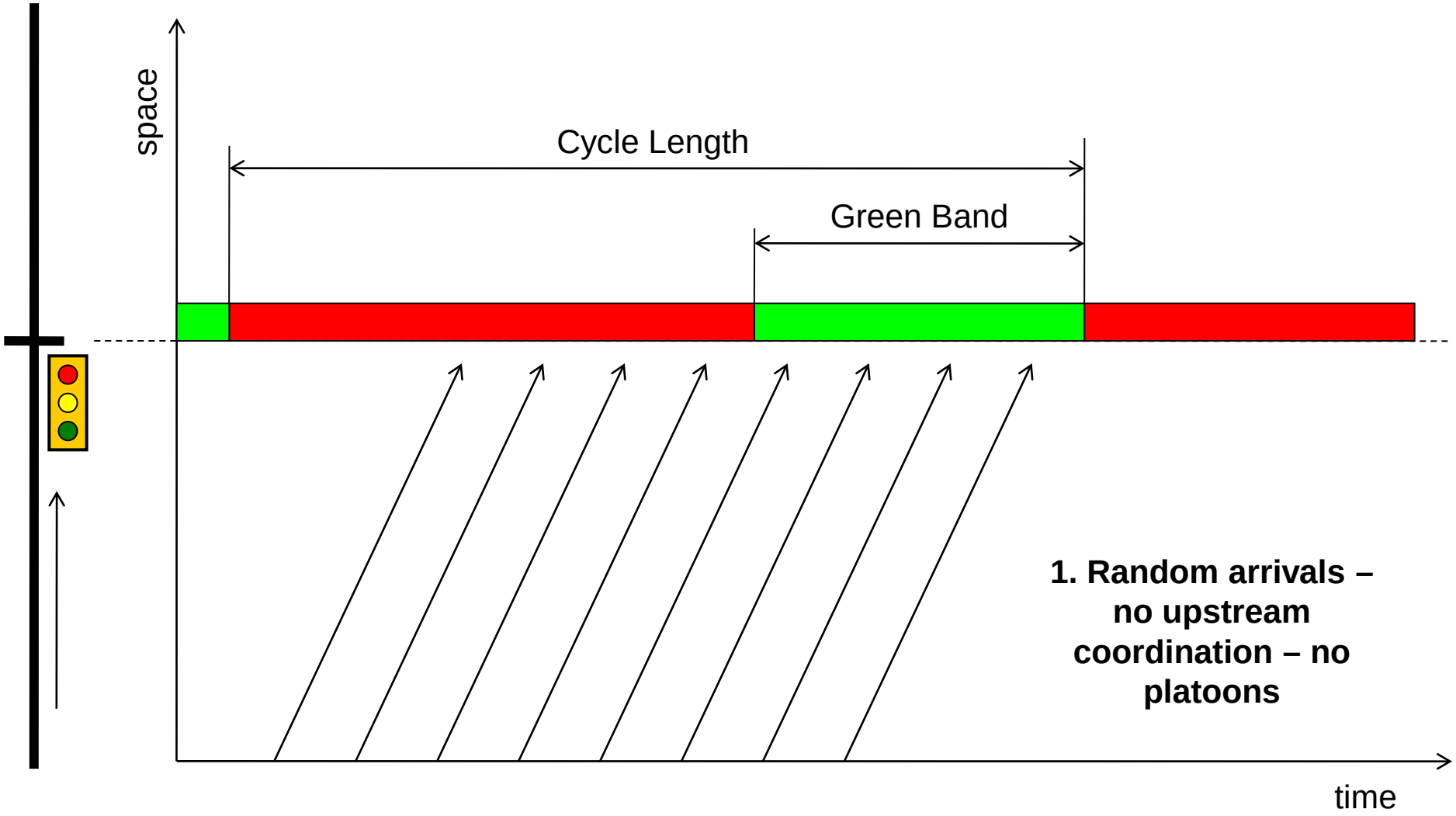
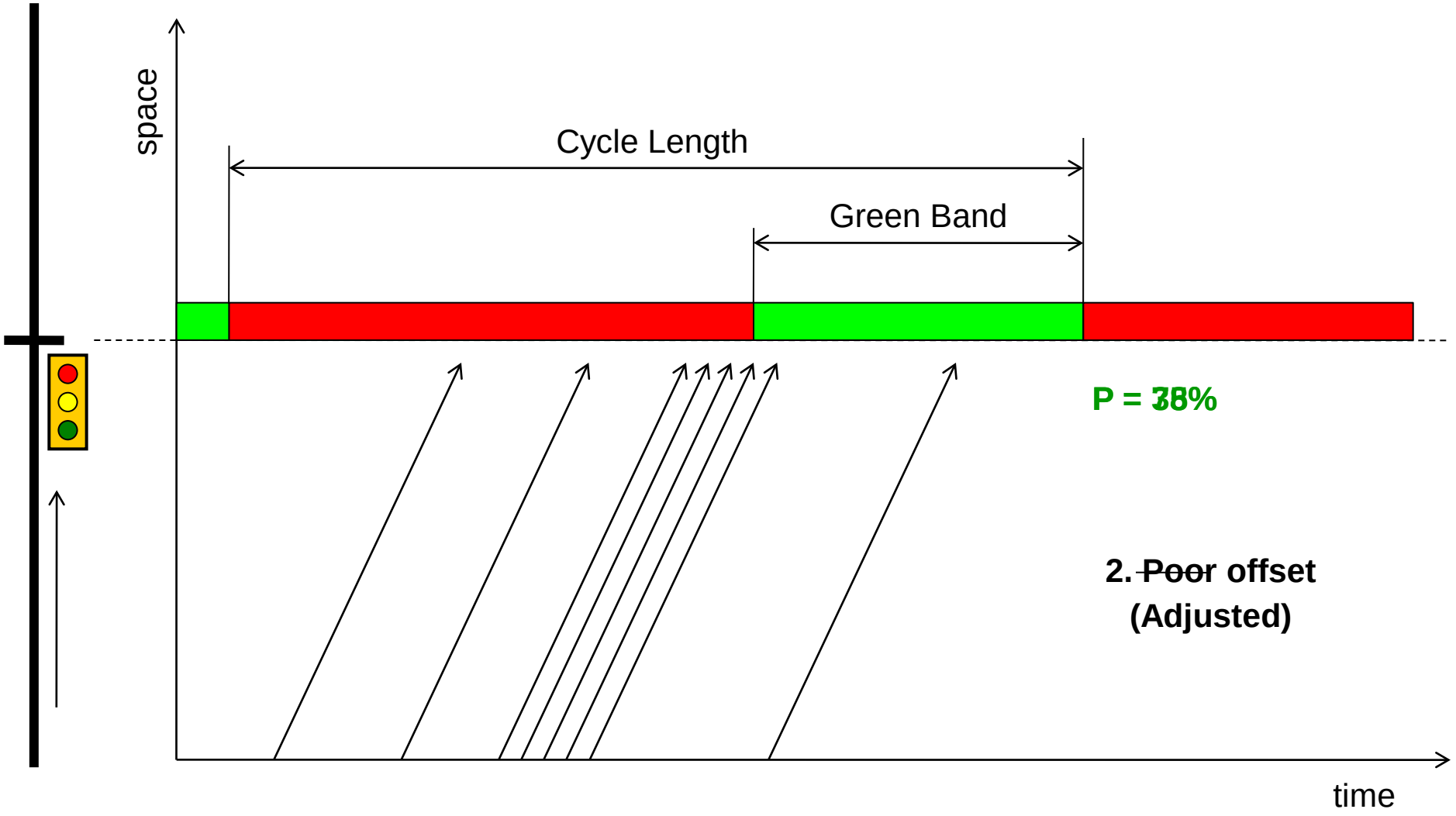
Quality of Progression

Why poor progression?

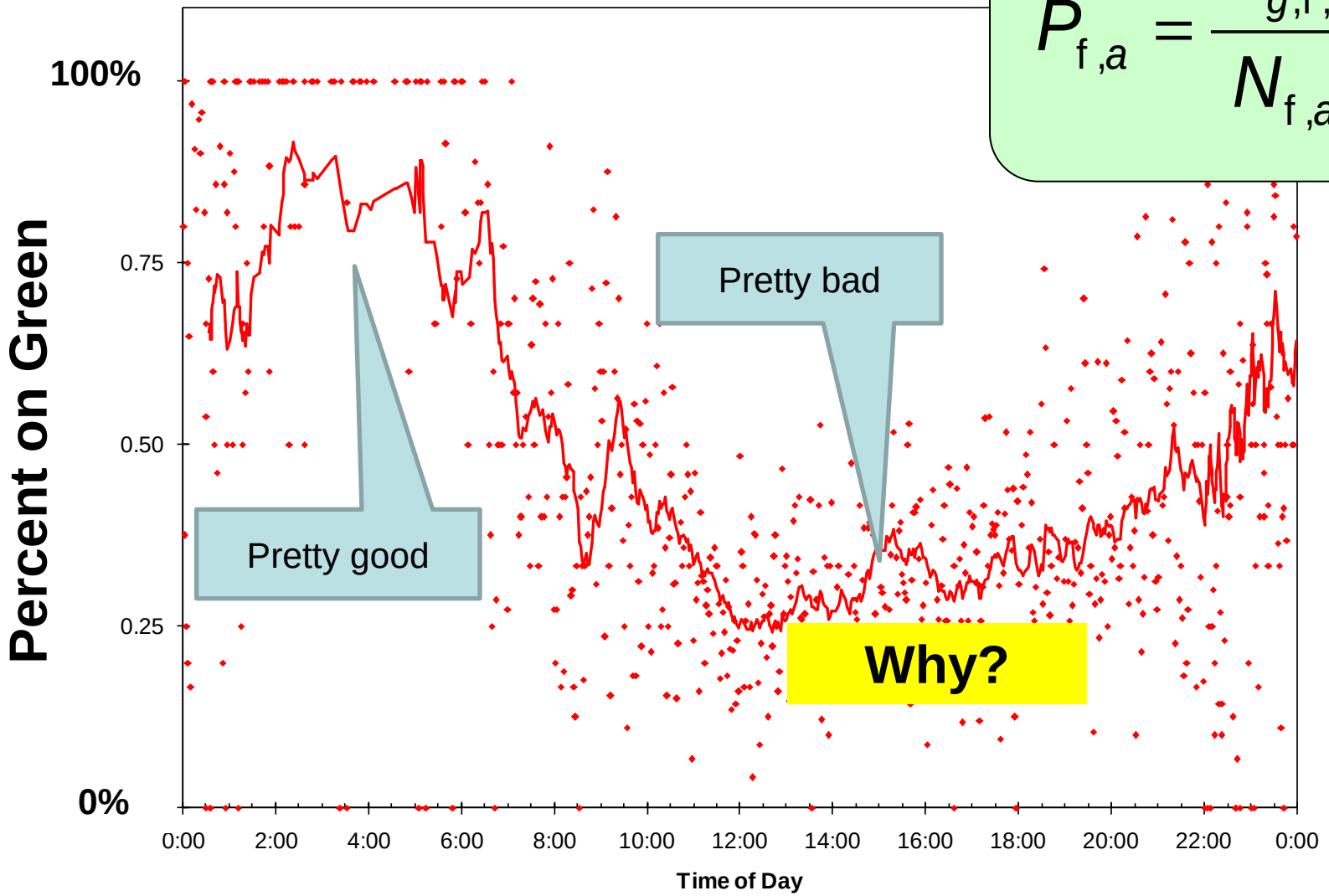


Why poor progression?

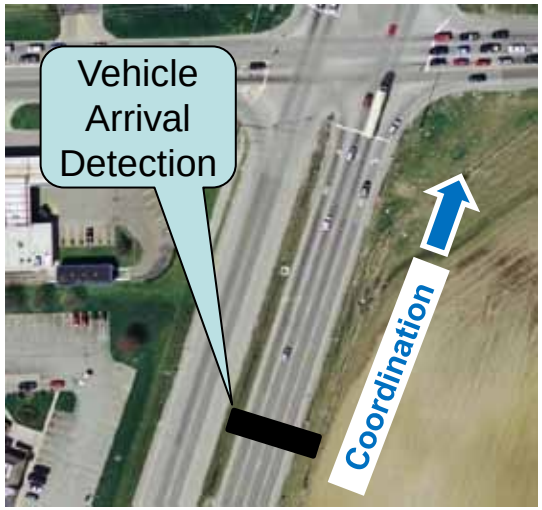


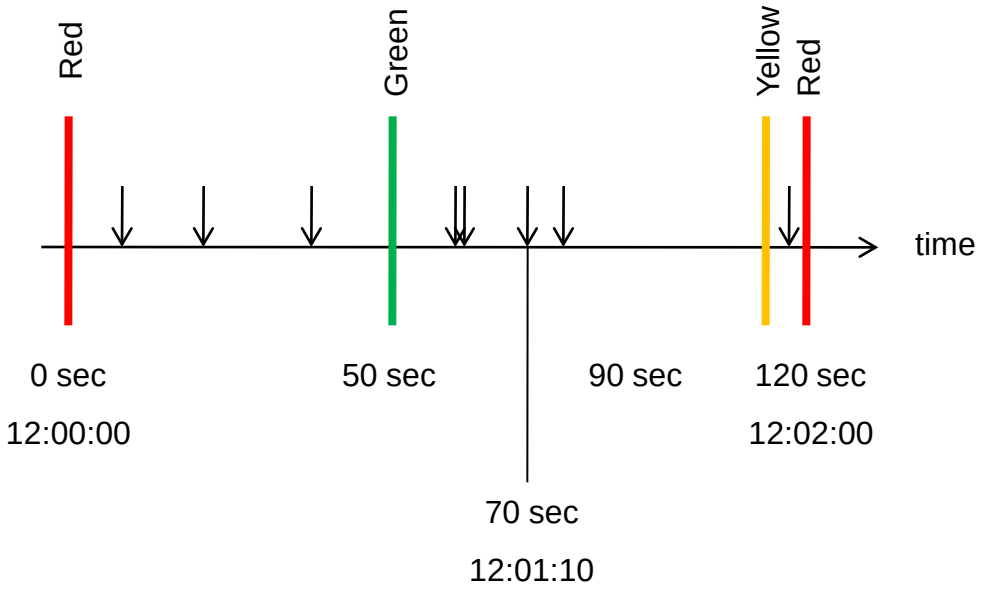
Poor offsets or random arrivals?

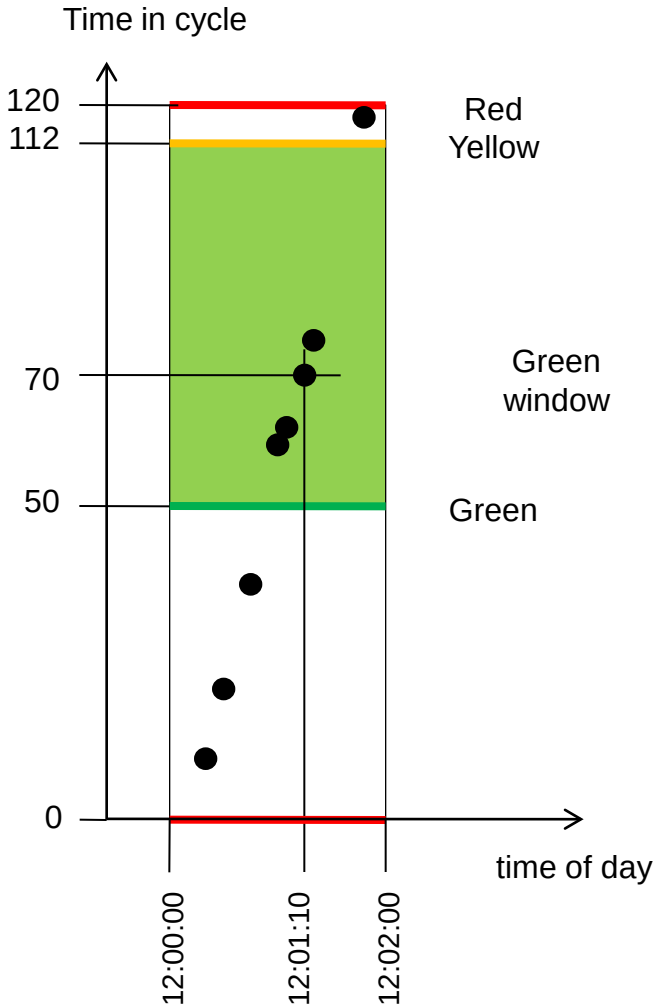
$$P_{f,a} = \frac{N_{g,f,a}}{N_{f,a}}$$



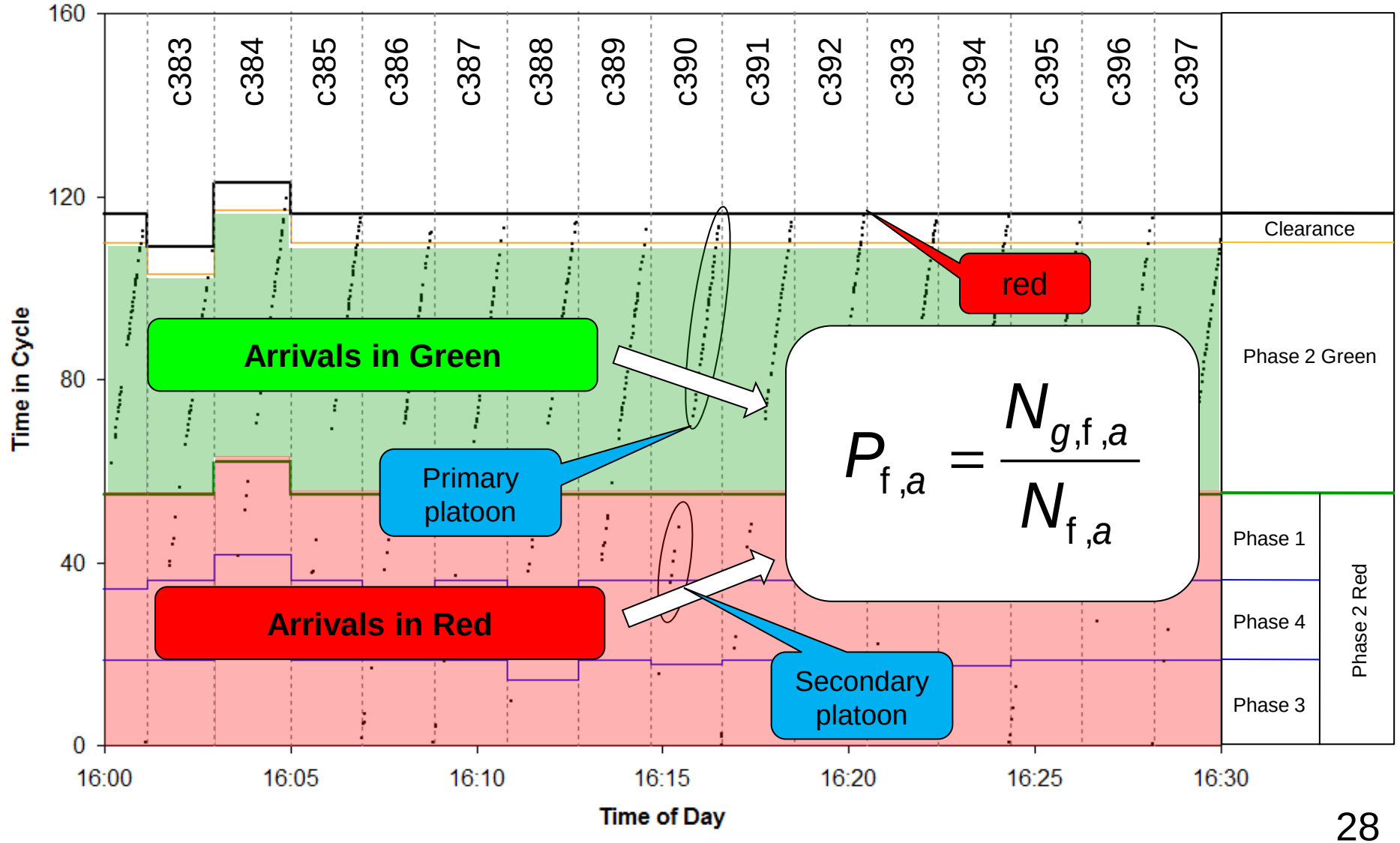
Quality of Progression



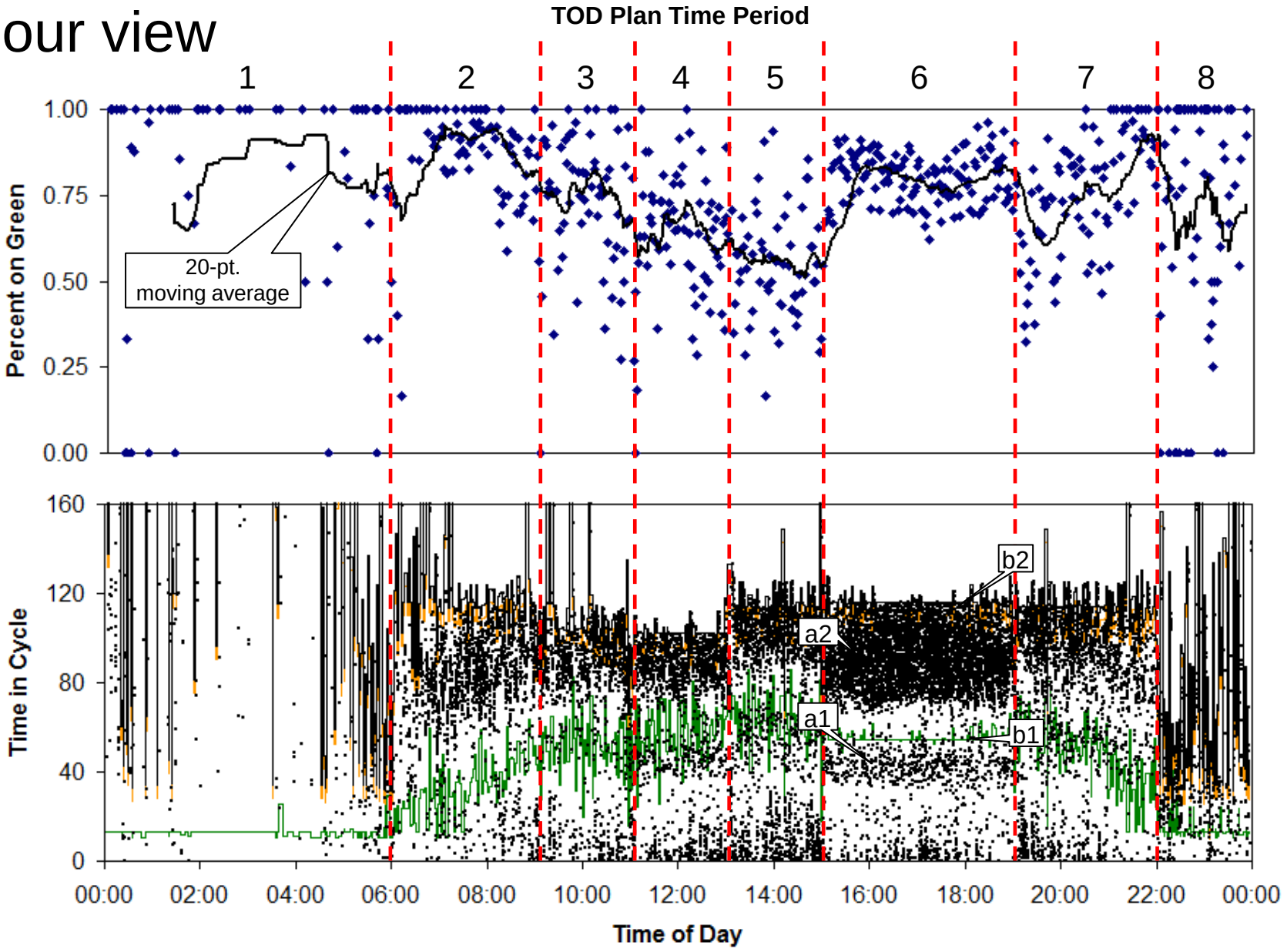




“Purdue Coordination Diagram”

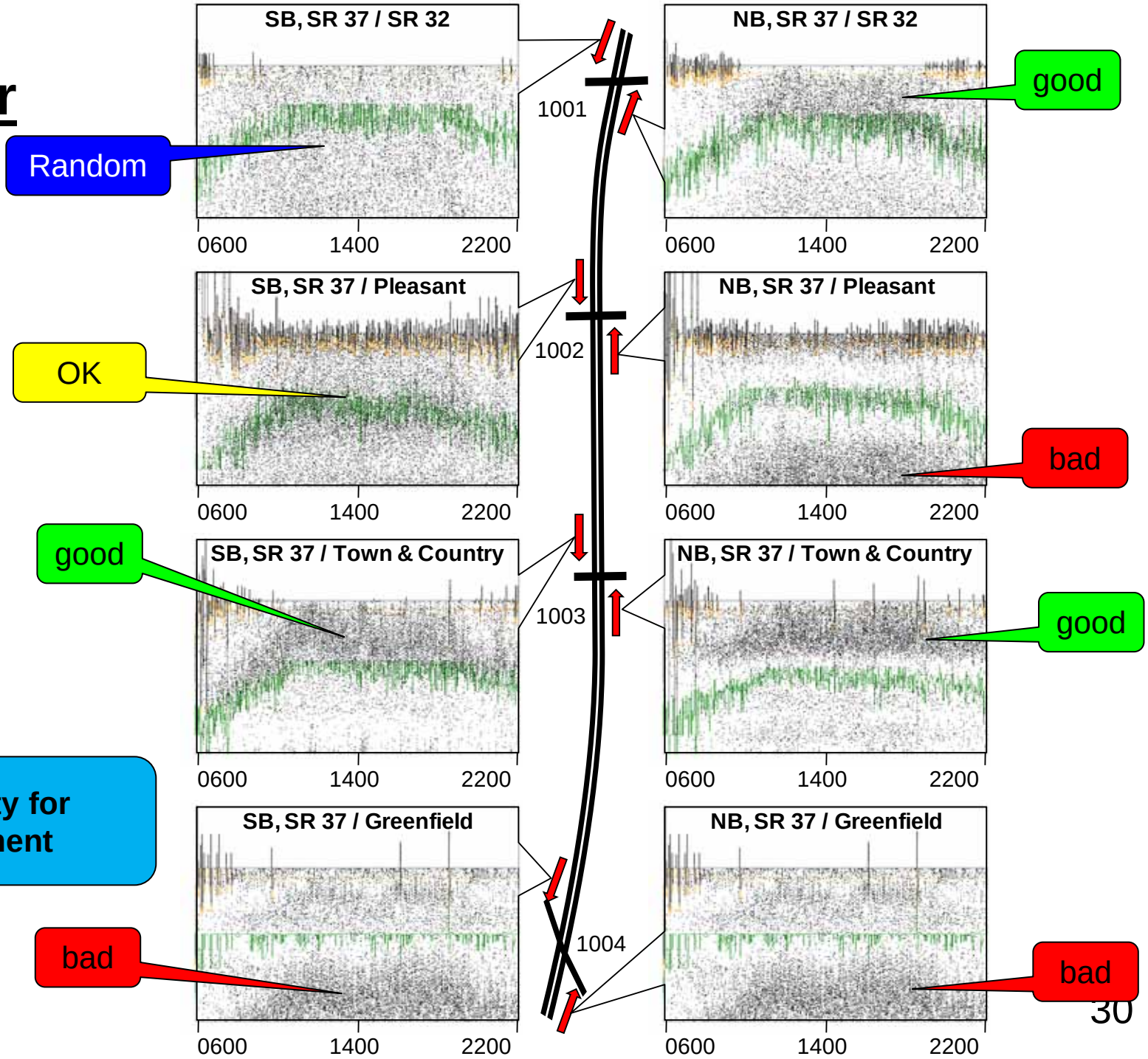


24-hour view



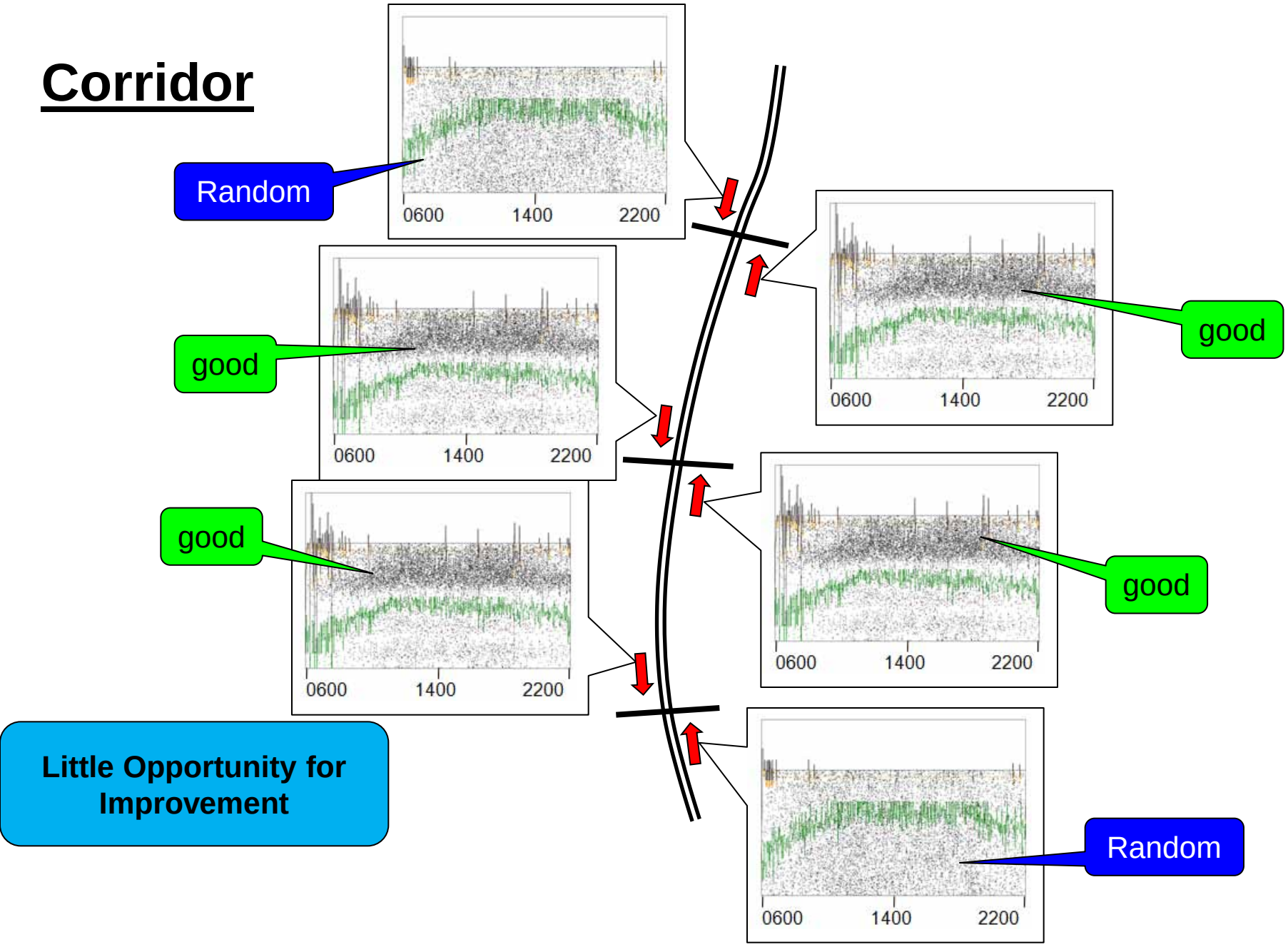
Day, C.M., Haseman, R., Premachandra, H., Brennan, T.M., Wasson, J.S., Sturdevant, J.R., and Bullock, D.M. (2010). Evaluation of arterial signal coordination: methodologies for visualizing high-resolution event data and measuring travel time." *Transportation Research Record No. 2192,* Washington, D.C.: Transportation Research Board, 37-49.

Corridor



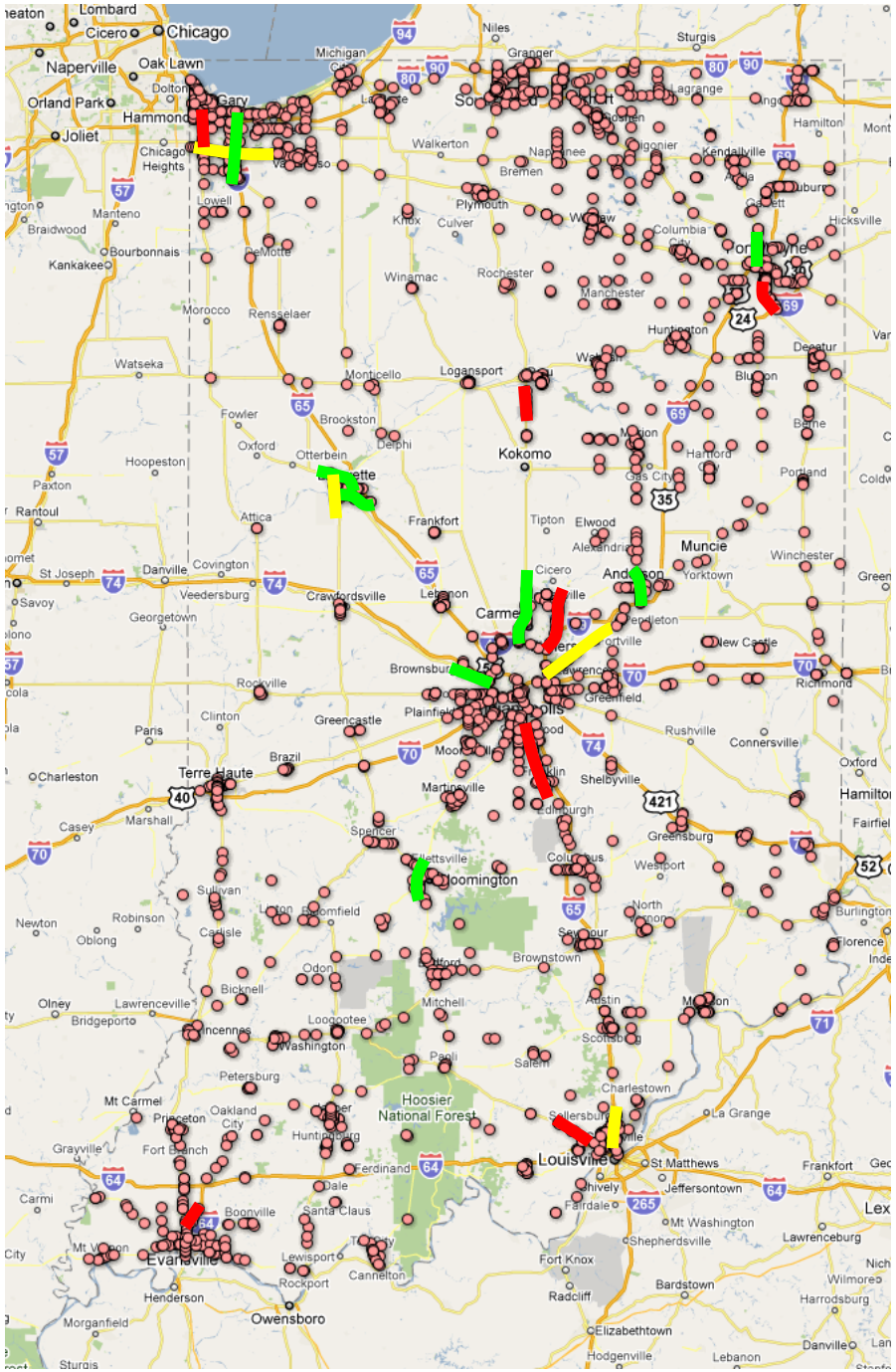
Opportunity for Improvement

Corridor

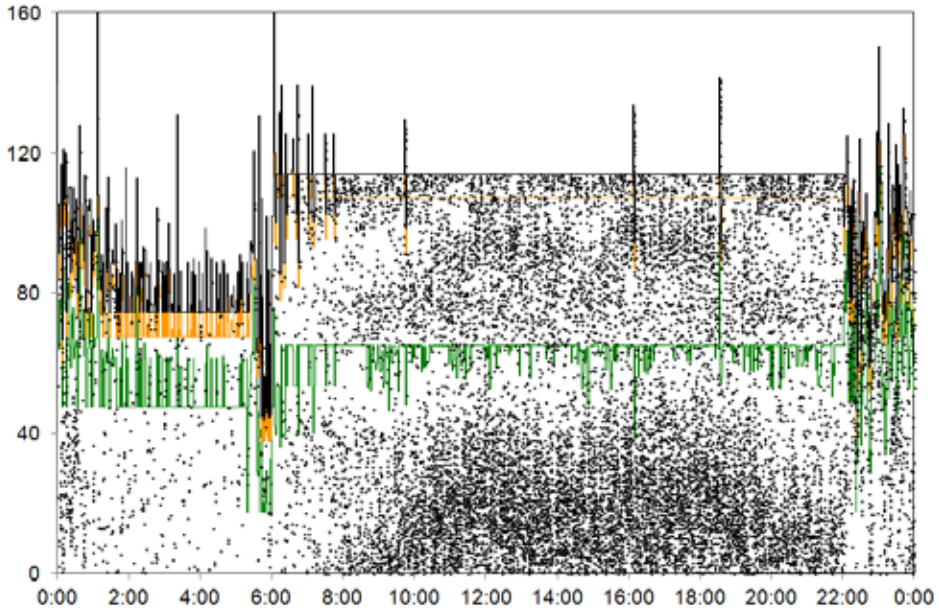

Random
0600
1400
2200
good
0600
1400
2200
good
0600
1400
2200
good
0600
1400
2200
good
0600
1400
2200
Random
0600
1400
2200
Little Opportunity for Improvement

System Report: Progression Quality

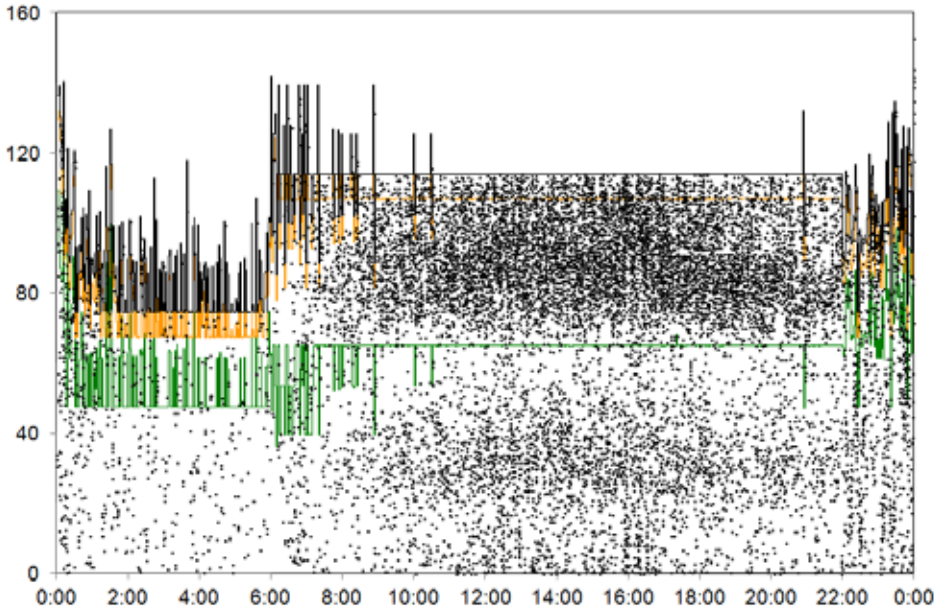
- Low opportunity for improvement
- Moderate opportunity for improvement
- High opportunity for improvement



Impact of Optimization

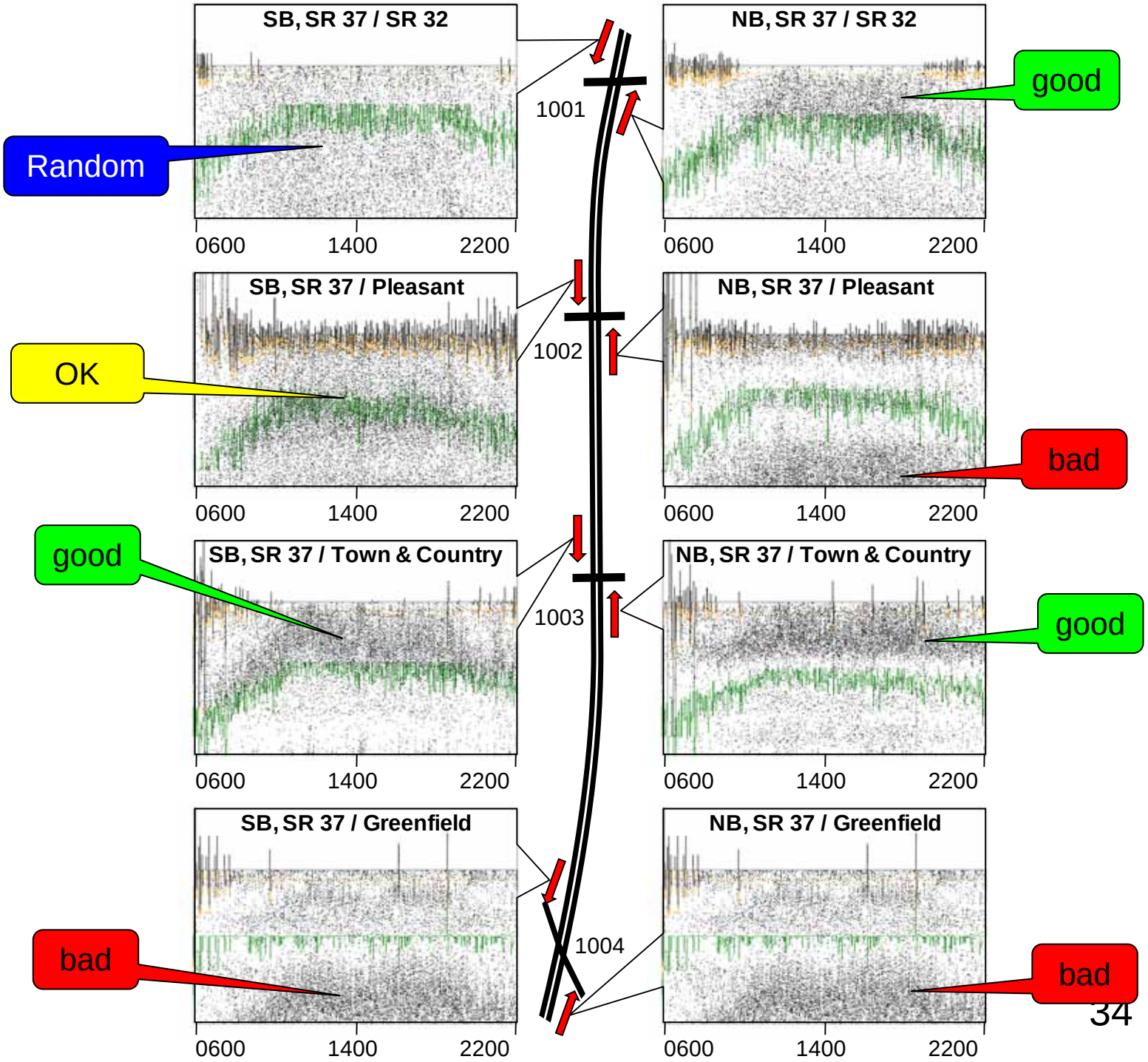


Before Offset Optimization

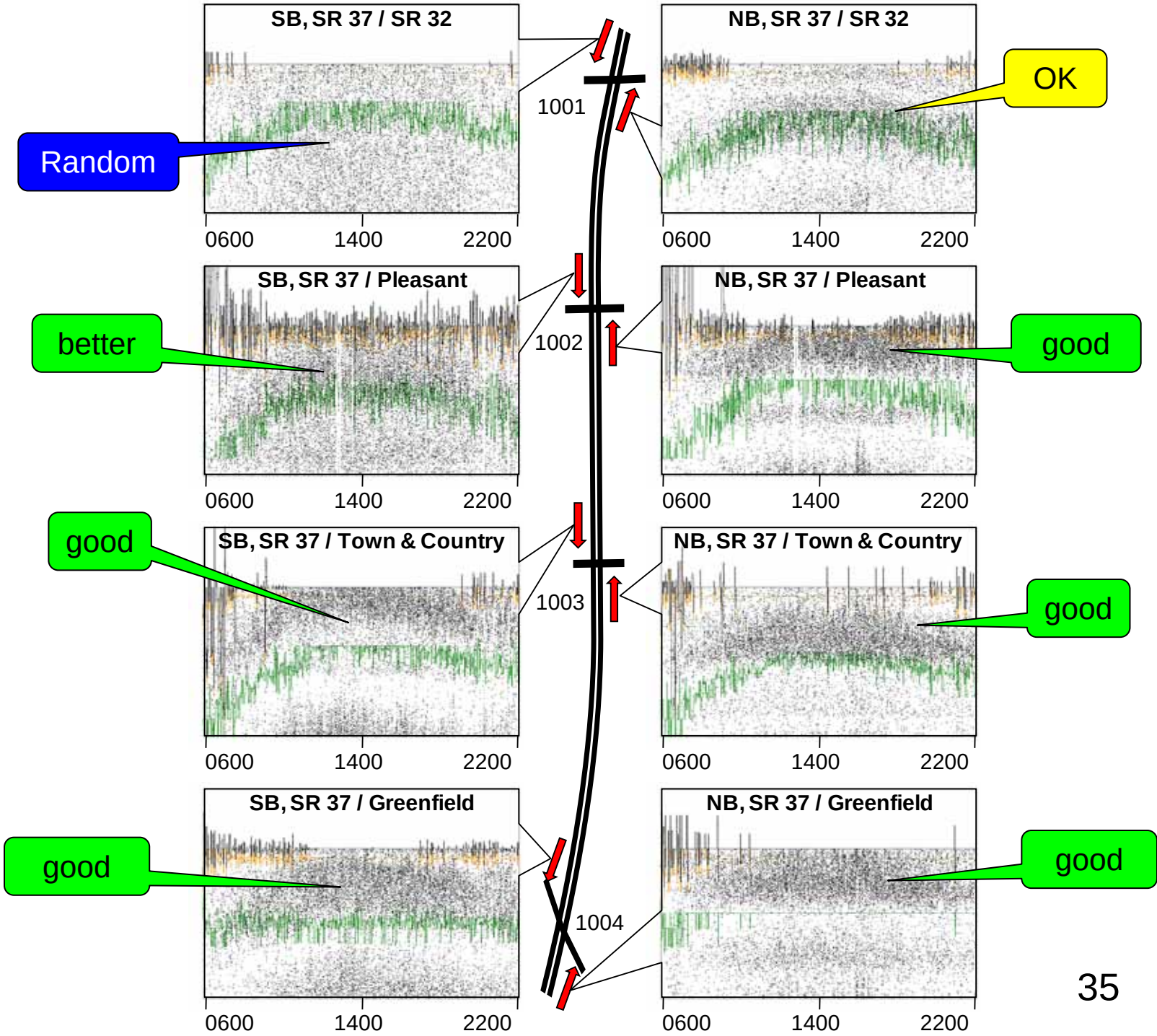


After Offset Optimization

Before


SB, SR 37 / SR 32
NB, SR 37 / SR 32
1001
Random
good
0600
1400
2200
SB, SR 37 / Pleasant
NB, SR 37 / Pleasant
1002
OK
bad
SB, SR 37 / Town & Country
NB, SR 37 / Town & Country
1003
good
good
SB, SR 37 / Greenfield
NB, SR 37 / Greenfield
1004
bad
bad

After


SB, SR 37 / SR 32
NB, SR 37 / SR 32
1001
Random
OK
0600
1400
2200
SB, SR 37 / Pleasant
NB, SR 37 / Pleasant
1002
better
good
SB, SR 37 / Town & Country
NB, SR 37 / Town & Country
1003
good
good
SB, SR 37 / Greenfield
NB, SR 37 / Greenfield
1004
good
good

Measured Impact : Change in Percent on Green

Intersection	Movement	MOE	June 06, Actual	June 06, Predicted After Offset Adjustment	July 25, Actual	July 18, Actual*
SR 37 & SR 32	Northbound	N_g	1755	1425	1472	1810
		POG	59.6%	48.4%	54.9%	56.8%
	Southbound	N_g	1702	1702	1544	1659
		POG	41.2%	41.2%	42.4%	39.0%
SR 37 & Pleasant St.	Northbound	N_g	1628	2655	2741	2995*
		POG	40.1%	65.5%	76.0%	76.6%*
	Southbound	N_g	3180	3674	3371	3471*
		POG	52.9%	61.2%	62.7%	63.0%*
SR 37 & Town and Country Blvd.	Northbound	N_g	3114	2961	2974	3507
		POG	79.5%	75.9%	81.0%	78.7%
	Southbound	N_g	3441	3056	2875	3007
		POG	80.2%	71.1%	72.6%	73.0%
SR 37 & Greenfield Ave.	Northbound	N_g	1678	2917	2827	3438
		POG	37.9%	65.6%	68.6%	69.8%
	Southbound	N_g	2979	3215	3045	3221
		POG	58.9%	63.3%	67.5%	68.2%
Arterial Network		$\sum N_g$	19477	21605	20849	23108
		N	34856	34856	31569	35072
		Overall POG	55.9%	62.0%	66.0%	65.9%

Summary and Closing Message

- Uses of Performance Measures
  - System Observation
  - Locating Inefficiencies
  - Validating Control Policies
  - Before/After Studies and Statistical Analysis

- Aspects of Operations
  - Capacity Utilization
  - Progression Quality

- Continuing Research Objectives
  - Make performance measures a tool for traffic engineers' day-to-day use
    - INDOT example to follow
  - Integration into the control process
    - Optimization
    - Real-Time Control