ARE ADAPTIVE SIGNAL CONTROL SYSTEMS A SOLUTION TO GROWING URBAN CONGESTION?

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COLIN KAEPERNICK

QB #7

HEIGHT:	6-4
WEIGHT:	230
AGE:	25
COLLEGE:	NEVADA
EXPERIENCE:	3

QUICK STATS (2012):

TDS	INT	YDS	RTG
10	3	1,814	98.3

University of Nevada ITE

Outline

- Overview of adaptive signal control systems
- Before-after evaluation studies
- SMRT developed at UNR for signal timing
- Final thoughts

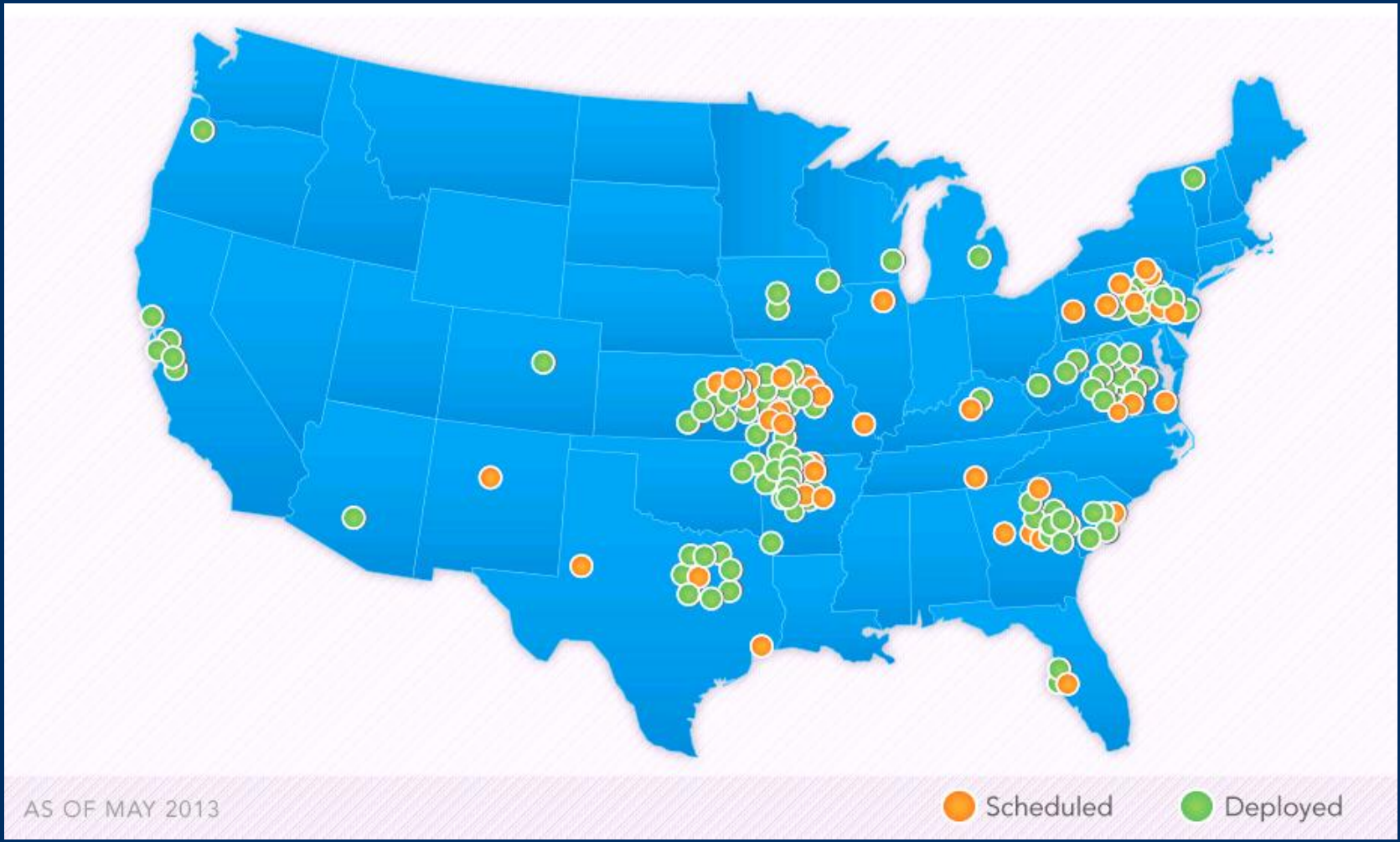
Signal Control Systems in the U.S.

- About 300,000 signals in the U.S.
- Conventional systems (95%+)
  - Centralized
  - Closed-loop

- Adaptive systems
  - Various vendor systems are emerging
  - Not yet widely accepted by agencies

Adaptive Systems in the U.S.

InSync by Rhythm Engineering



Adaptive System Performance

- Before-after studies
- A valid comparison study must posses:
  - ✓ Extensive data: travel time runs, delays, queues
  - ✓ A broad range of flow conditions: normal, directional, special events, preemption
  - ✓ *Truly optimized conventional TOD timing plans
  - ✓ What if a comparison is made against bad TOD timing plans?

What is Considered as a Good Timing Plan

- **Ideal conditions**
  - ✓ **No extensive over-capacity**
  - ✓ **Spacing is adequate (not too short)**
  - ✓ **Protected LTs which allows lead/lag phasing**
- **Rule of thumb**
  - ✓ **No more than 1 stop for every 5 signals**

Adaptive vs. Conventional

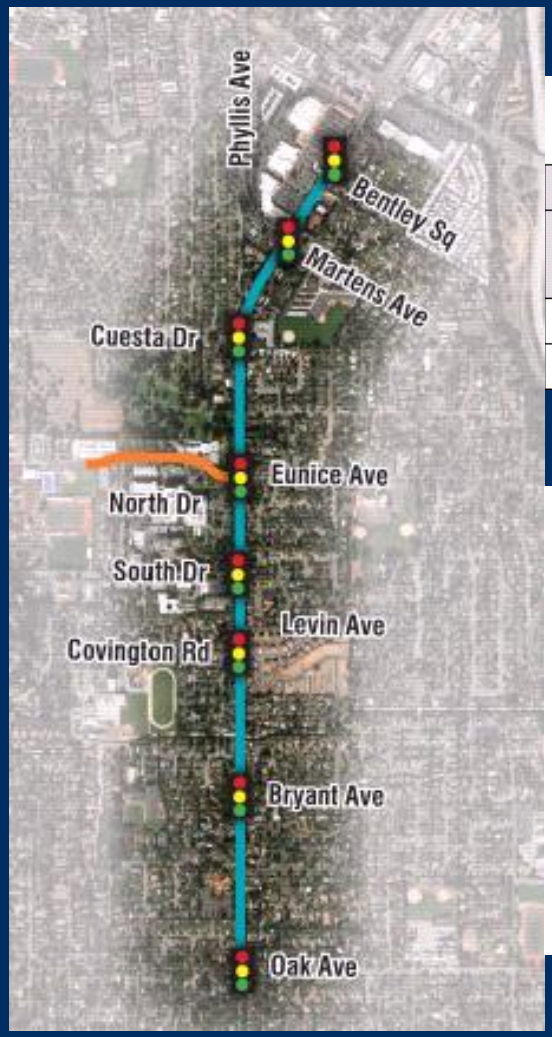


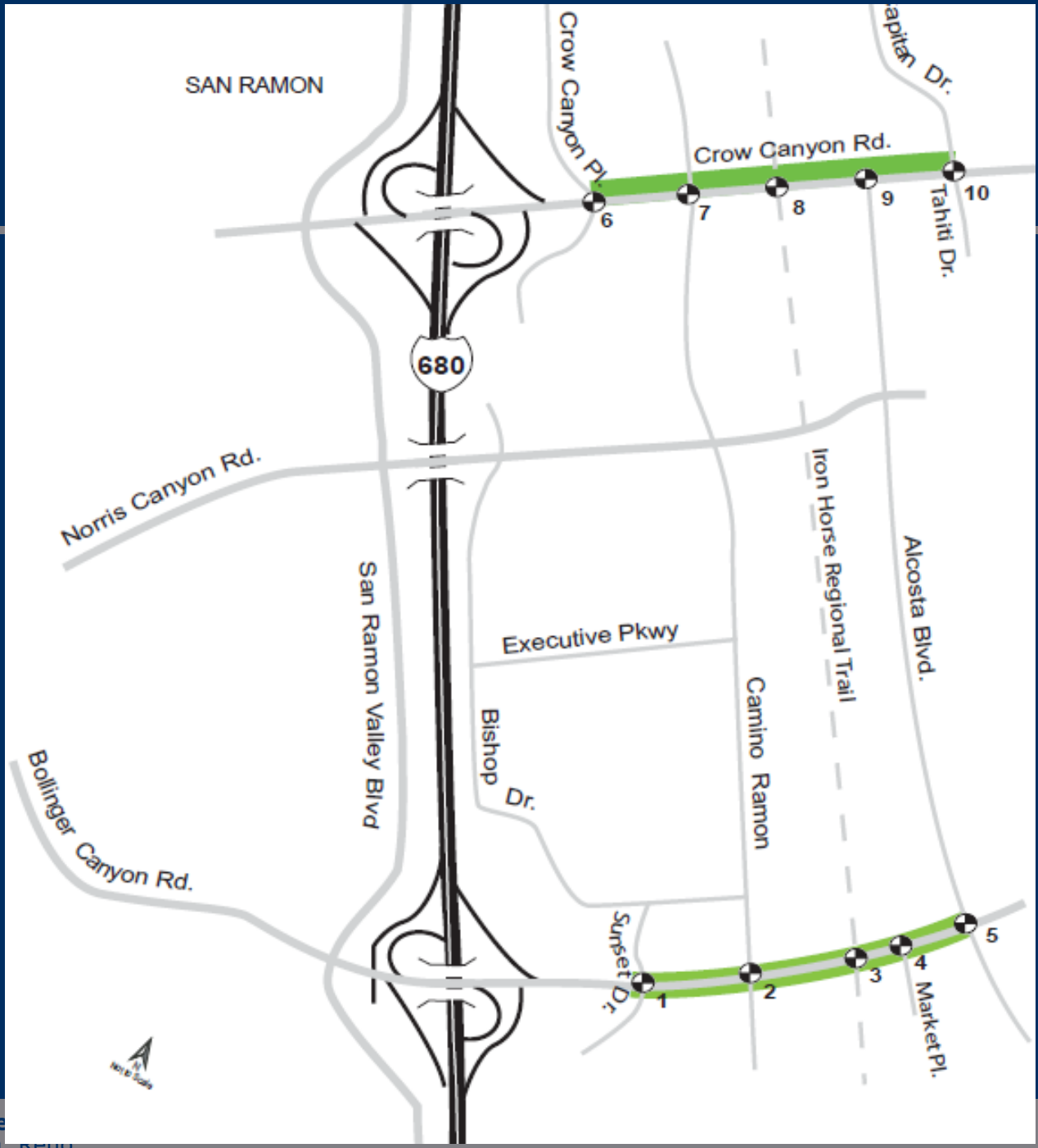
Table 7 – Average Number of Stops for Grant Road Analysis

	SB			NB			Both Directions		
	Before	After	% change	Before	After	% change	Before	After	% change
AM	3.3	1.5	-55%	3.2	2.7	-16%	3.25	2.1	-35%
PM	2.7	2.3	-15%	2.8	2.8	0%	2.75	2.55	-7%

Table 1 – Existing Operations, Cycle Lengths and Time of Day

Intersection	AM Peak[1]	Time of Day	AM Off-Peak	Time of Day	Mid-Day Peak[1]	Time of Day	PM Peak[1]
Bentley Sq	140	7:40-9:30A	Free	9:30-11:30A	120	11:30A-2:30P	130
Phyllis Ave/Martens Dr	140	7:40-9:30A	Free	9:30-11:30A	120	11:30A-2:30P	130
Cuesta Dr	140	7:40-9:30A	Free	9:30-11:30A	120	11:30A-2:30P	130
North Dr/Eunice Ave	120	7:00-9:30A	Free	9:30-11:30A	120	11:30A-2:30P	130
South Dr	120	7:00-9:30A	Free	9:30-11:30A	100	11:30A-2:30P	116
Covington Rd	120	7:00-9:30A	Free	9:30-11:30A	100	11:30A-2:30P	116
Bryant Ave	120	7:00-9:30A	Free	9:30-11:30A	100	11:30A-2:30P	116
Oak Ave	120	7:00-9:30A	Free	9:30-11:30A	100	11:30A-2:30P	116

[1]Period Cycle Length (seconds)


Crow Canyon Rd.
Tahiti Dr.
Alcosta Blvd.
Iron Horse Regional Trail
Camino Ramon
Market Pl.
Sunset Dr.
Executive Pkwy
Bishop Dr.
San Ramon Valley Blvd
Norris Canyon Rd.
680
Bollinger Canyon Rd.
SAN RAMON
1
2
3
4
5
6
7
8
9
10

Bollinger Canyon Road

Eastbound

Time Period	Test Period	Average Travel Time (sec)	Average Number of Stops (No.)
AM Peak (7 - 9AM)	Before	86.7	1.1
	After	64.0	0.2
	% Diff.	-26.2%	-81.8%
AM Off-Peak (9 - 11 AM)	Before	70.6	0.7
	After	64.5	0.6
	% Diff.	-8.6%	-14.3%
Midday Peak (11:30AM - 1:30 PM)	Before	114.1	1.5
	After	71.8	0.7
	% Diff.	-37.1%	-53.3%
PM Peak (4:30 - 6:30PM)	Before	79.5	0.6
	After	83.9	0.6
	% Diff.	5.5%	0.0%

Westbound

Time Period	Test Period	Average Travel Time (sec)	Average Number of Stops (No.)
AM Peak (7 - 9AM)	Before	108.5	2.0
	After	69.9	0.4
	% Diff.	-35.6%	-80.0%
AM Off-Peak (9 - 11 AM)	Before	84.2	1.0
	After	79.5	1.0
	% Diff.	-5.6%	0.0%
Midday Peak (11:30AM - 1:30 PM)	Before	102	1.3
	After	73.7	0.5
	% Diff.	-27.7%	-61.5%
PM Peak (4:30 - 6:30PM)	Before	145.7	2.2
	After	72.5	0.6
	% Diff.	-50.2%	-72.7%

Bollinger Canyon Road

Eastbound

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AM Peak (7 - 9AM)	Before	86.7	1.1
	After	64.0	0.2
	% Diff.	-26.2%	-81.8%
AM Off-Peak (9 - 11 AM)	Before	70.6	0.7
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Westbound

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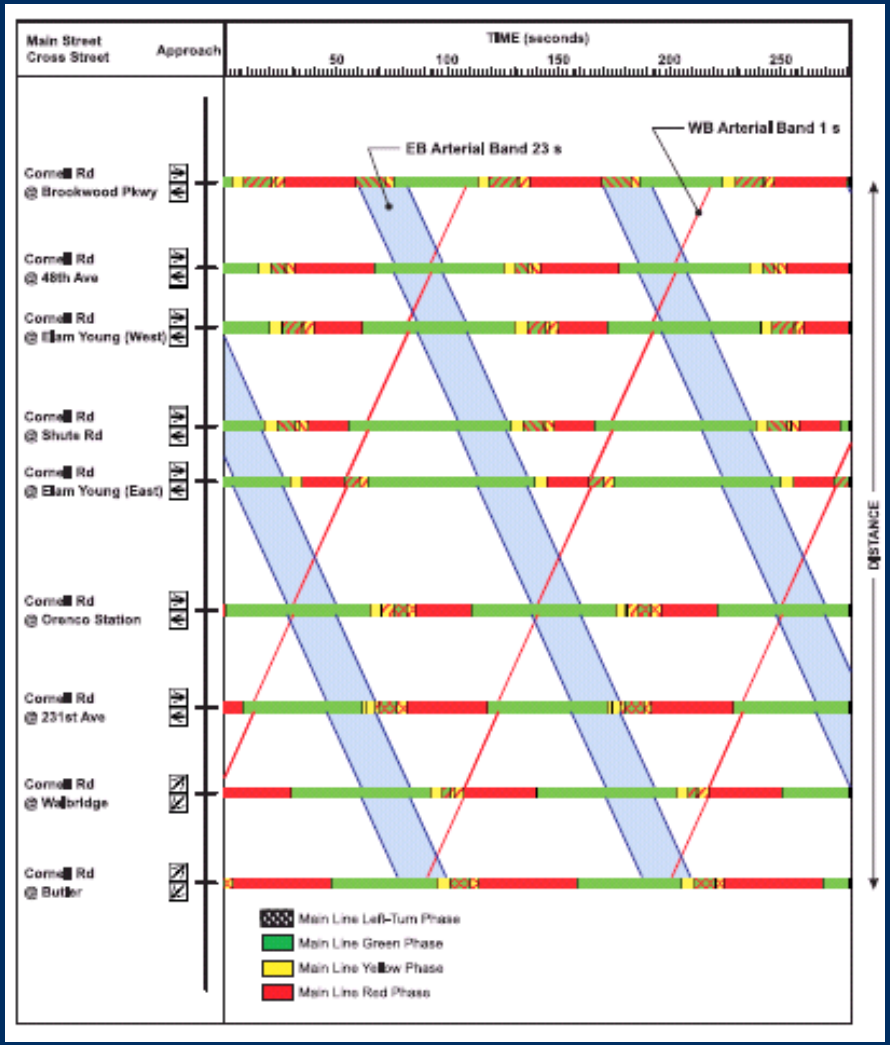
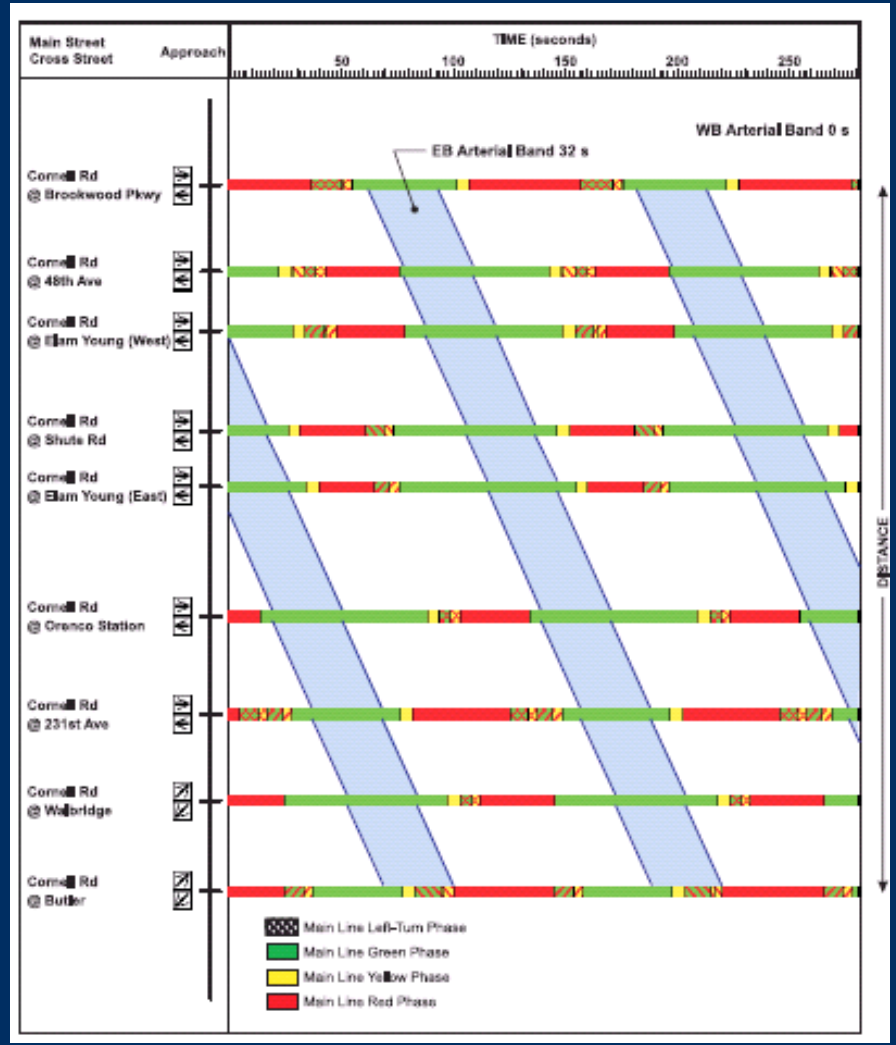
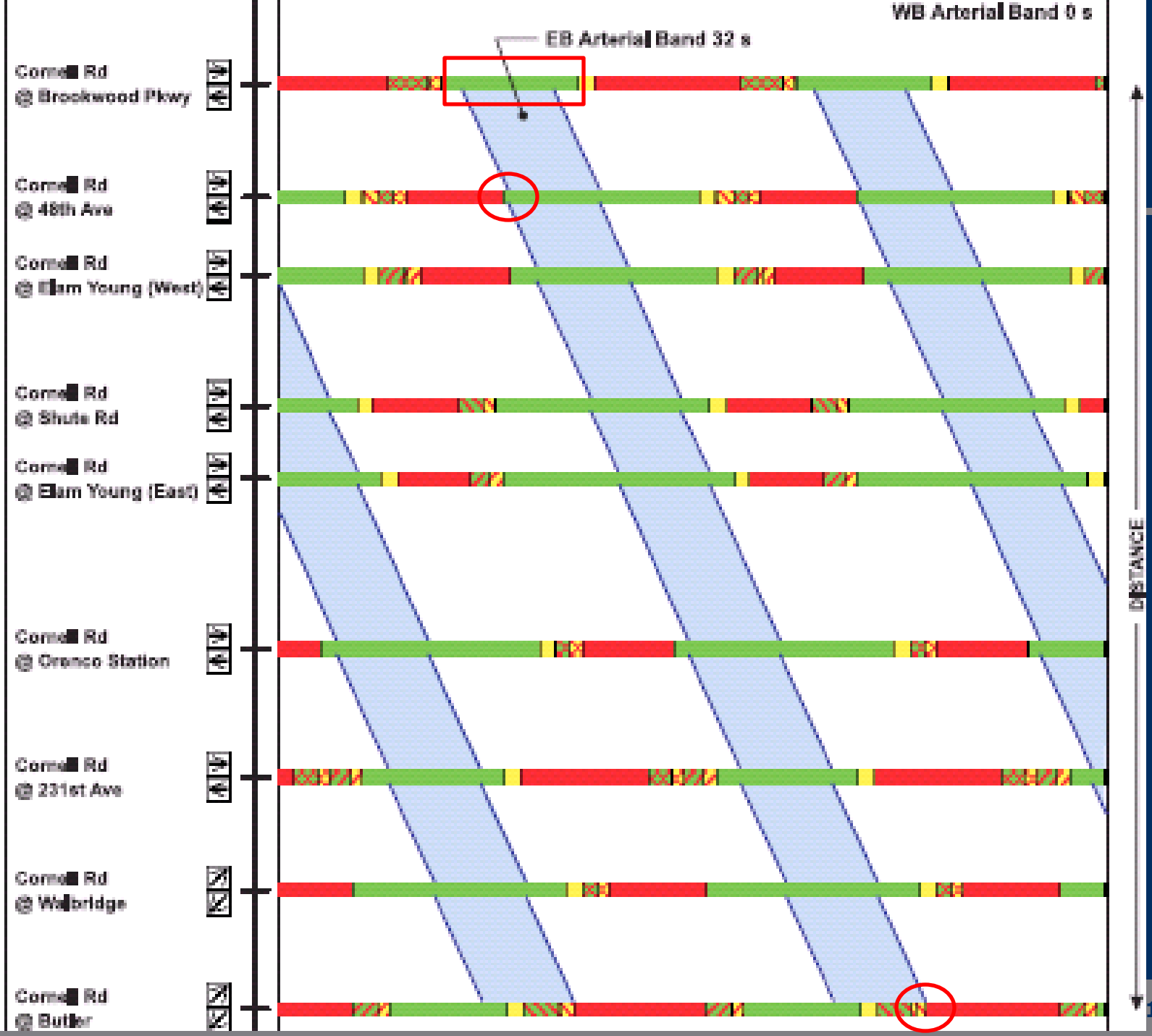
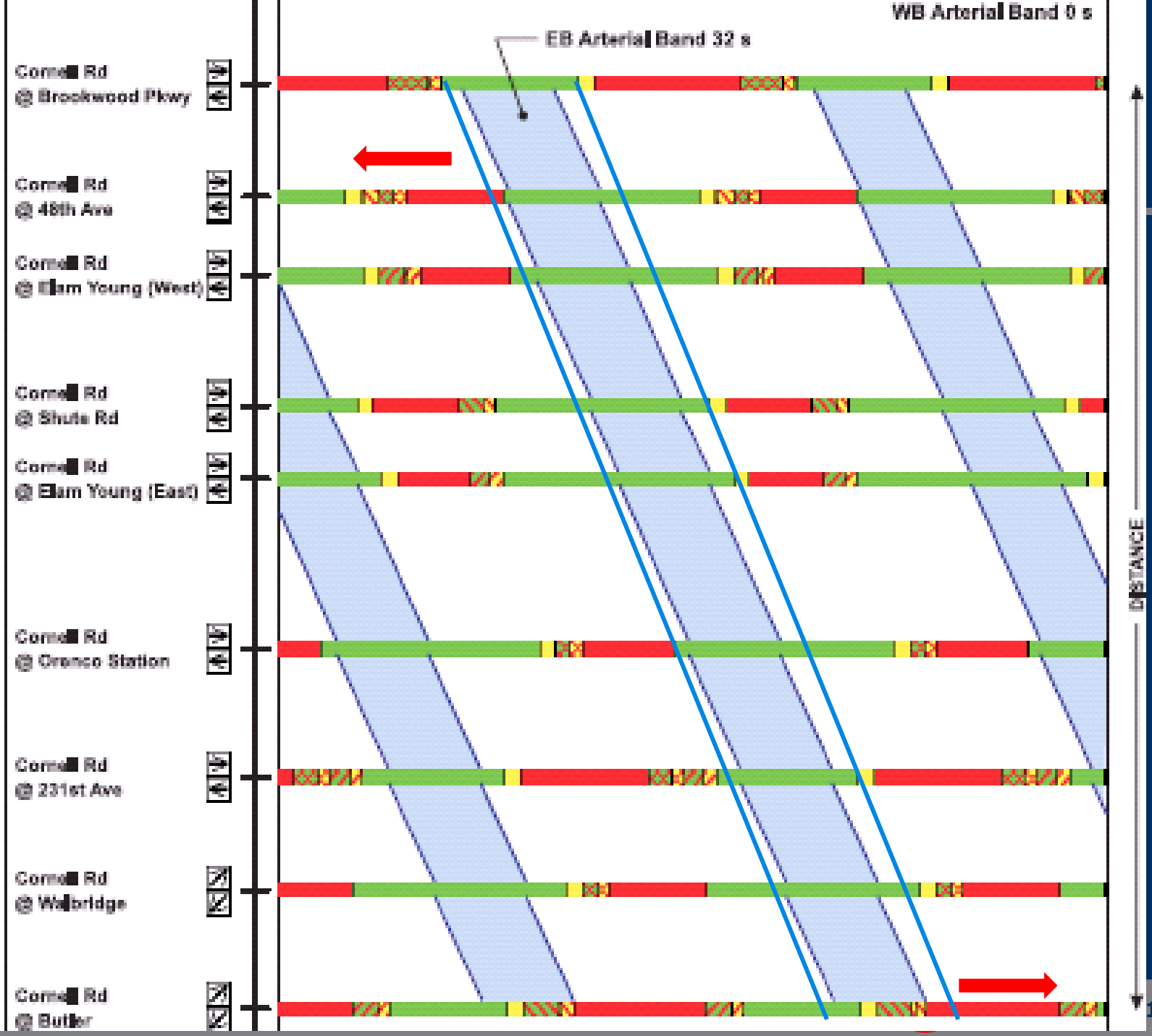
PM Peak (4:30 - 6:30PM)	Before	145.7	2.2
	After	72.5	0.6
	% Diff.	-50.2%	-72.7%

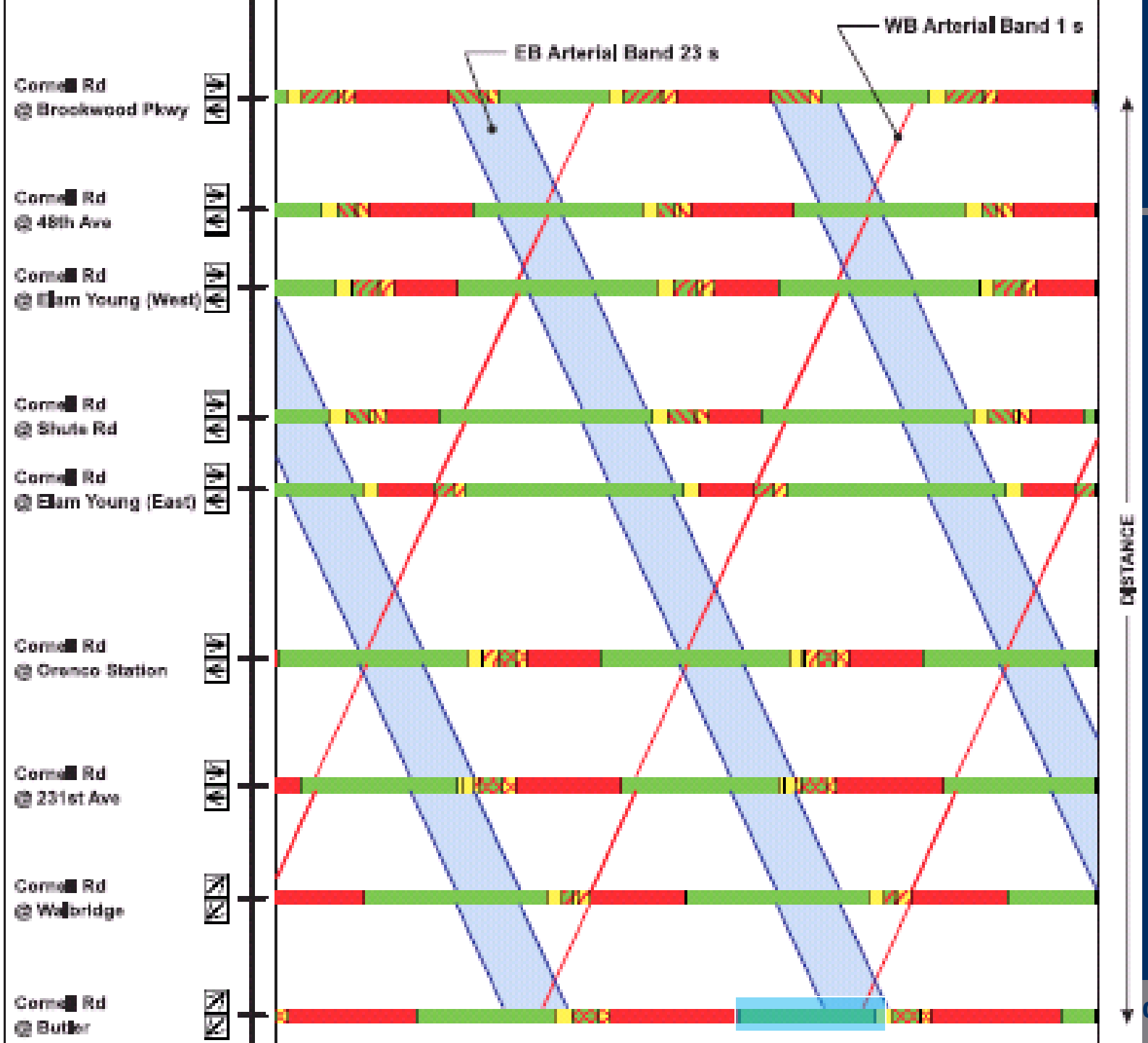
Adaptive vs. Conventional






WB Arterial Band 0 s
EB Arterial Band 32 s
Cornell Rd
@ Brookwood Pkwy
Cornell Rd
@ 48th Ave
Cornell Rd
@ Elam Young (West)
Cornell Rd
@ Shute Rd
Cornell Rd
@ Elam Young (East)
Cornell Rd
@ Cranco Station
Cornell Rd
@ 231st Ave
Cornell Rd
@ Walbridge
Cornell Rd
@ Butler
DISTANCE


WB Arterial Band 0 s
EB Arterial Band 32 s
Cornell Rd
@ Brookwood Pkwy
Cornell Rd
@ 48th Ave
Cornell Rd
@ Elam Young (West)
Cornell Rd
@ Shute Rd
Cornell Rd
@ Elam Young (East)
Cornell Rd
@ Cranco Station
Cornell Rd
@ 231st Ave
Cornell Rd
@ Walbridge
Cornell Rd
@ Butler
DISTANCE


EB Arterial Band 23 s
WB Arterial Band 1 s
Cornell Rd
@ Brookwood Pkwy
Cornell Rd
@ 48th Ave
Cornell Rd
@ Elam Young (West)
Cornell Rd
@ Shute Rd
Cornell Rd
@ Elam Young (East)
Cornell Rd
@ Cronco Station
Cornell Rd
@ 231st Ave
Cornell Rd
@ Walbridge
Cornell Rd
@ Butler
DISTANCE

Adaptive vs. Conventional

Adaptive vs. Conventional

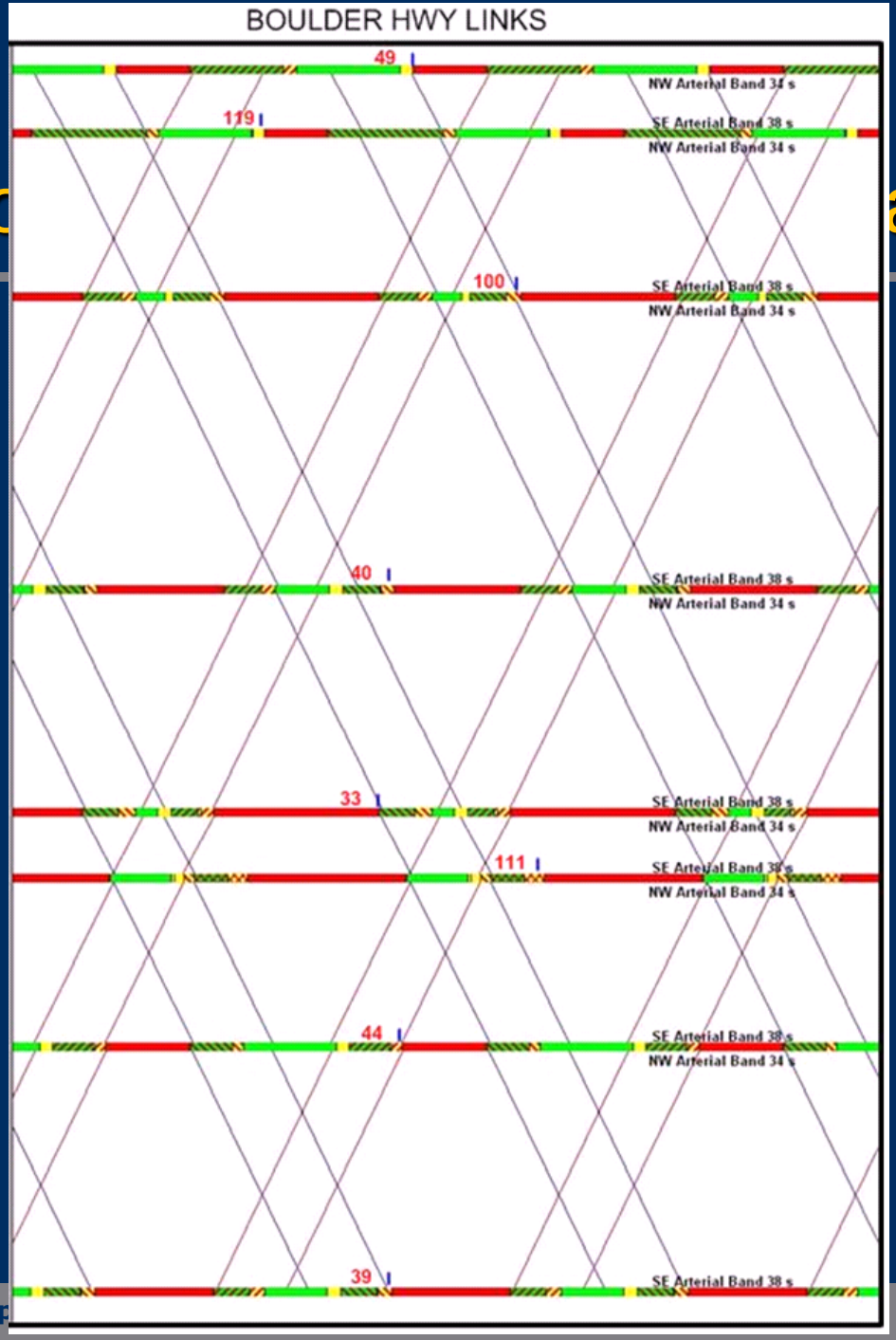
Number of Stops

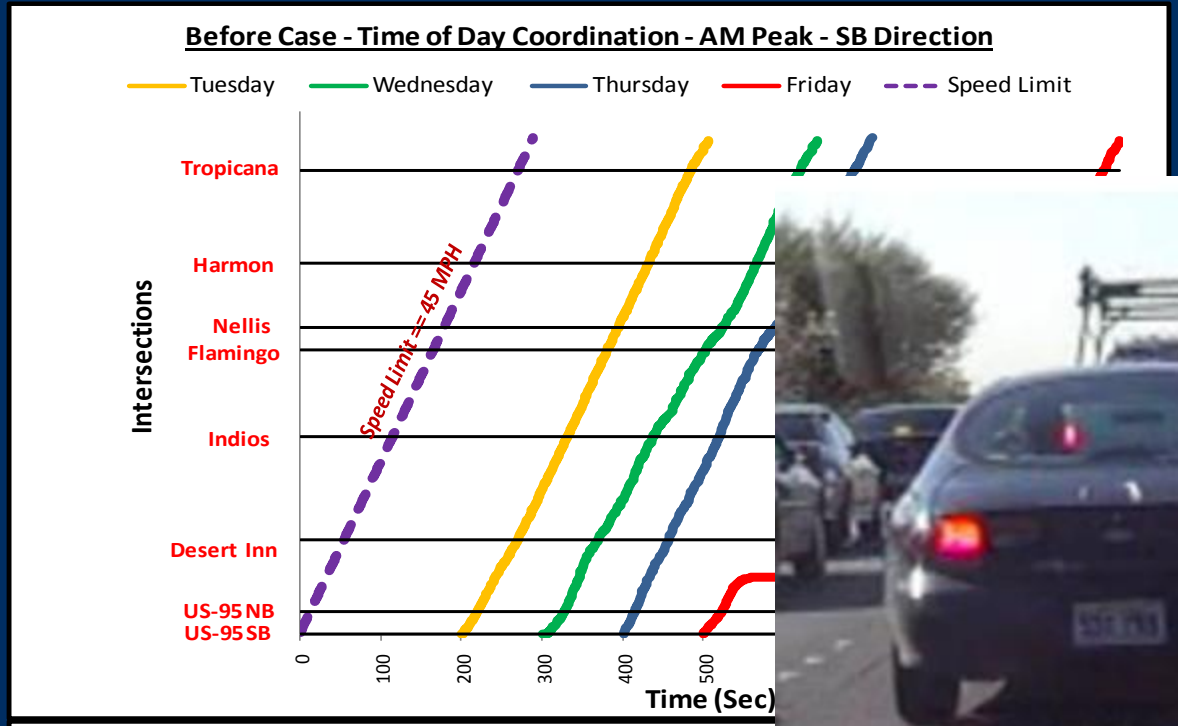
Corridor – Direction	Period	Average # Stops **Before**	Average # Stops **After**
College EB	6:00-7:20	3	3.5
	7:20-9:10	3.5	3
	9:10-11:45	4.5	2.5
	11:45-14:45	4.5	2
	14:45-18:00	4	3
	18:00-19:00	5.5	2
	19:00-20:30	5	2
College WB	6:00-7:20	3.5	4
	7:20-9:10	4	4
	9:10-11:45	4	2.5
	11:45-14:45	11	3.5
	14:45-18:00	12	2.5
	18:00-19:00	2	3
	19:00-20:30	5.5	1.5

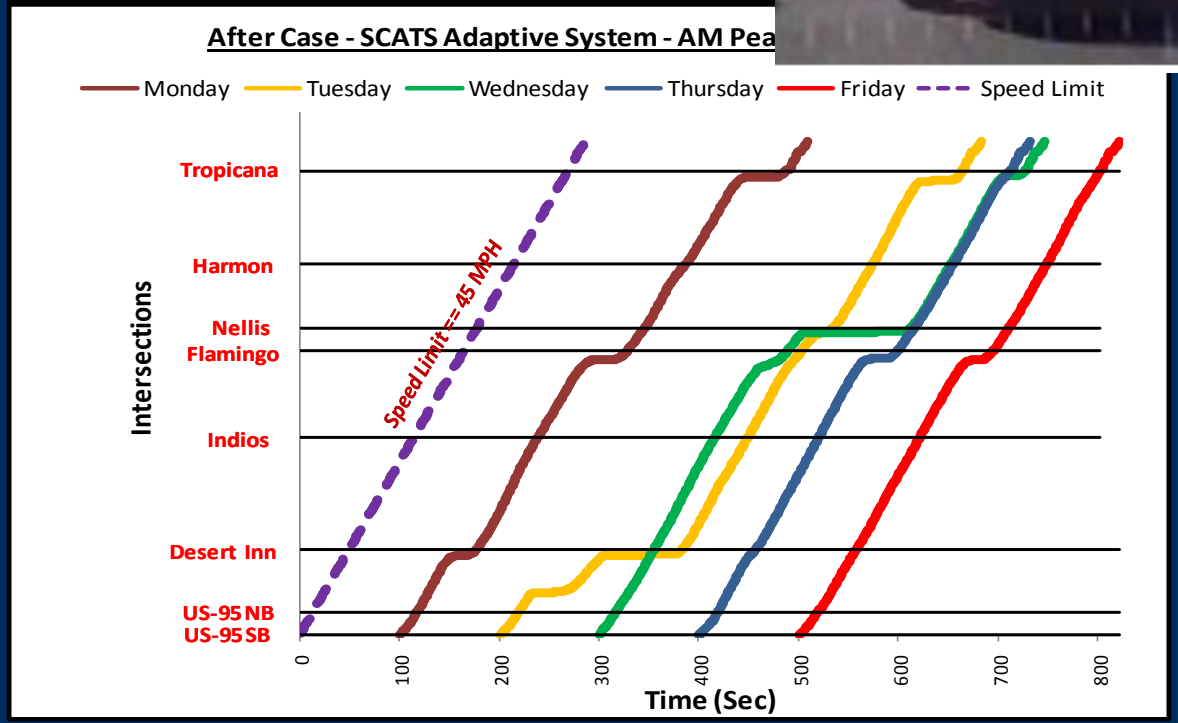
Case Study

Boulder Highway, Las Vegas

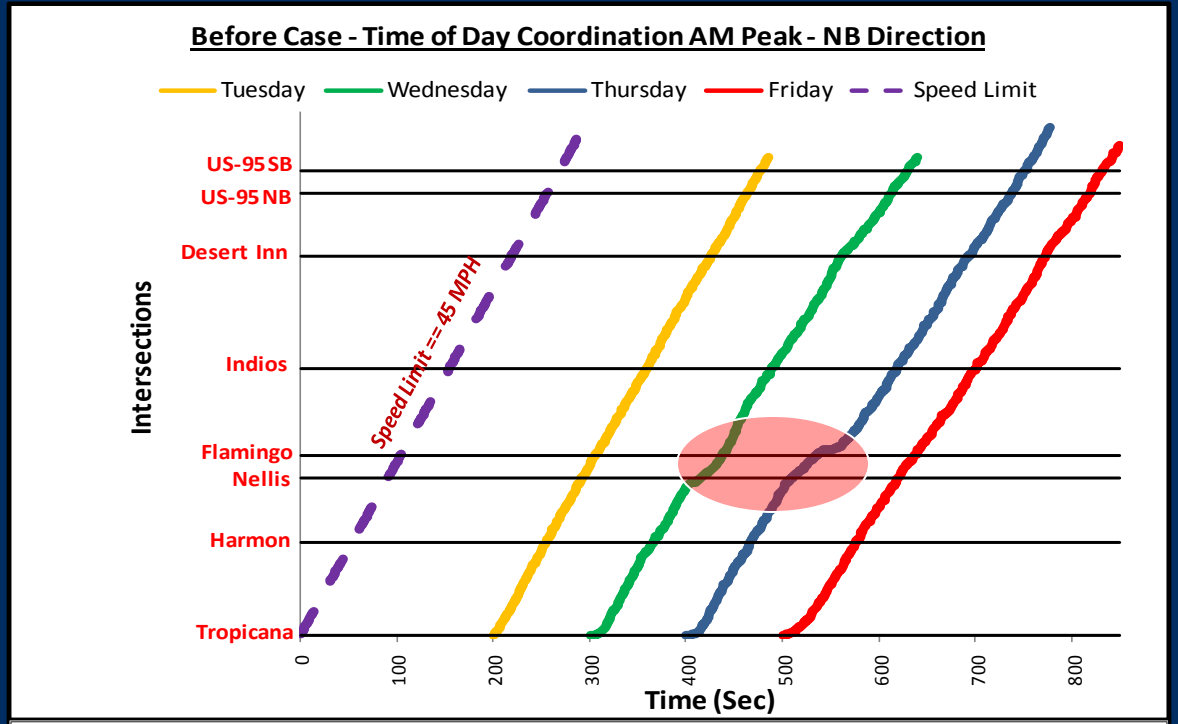
Bo as


BOULDER HWY LINKS
49
NW Arterial Band 34 s
119
SE Arterial Band 38 s
NW Arterial Band 34 s
100
SE Arterial Band 38 s
NW Arterial Band 34 s
40
SE Arterial Band 38 s
NW Arterial Band 34 s
33
SE Arterial Band 38 s
NW Arterial Band 34 s
111
SE Arterial Band 38 s
NW Arterial Band 34 s
44
SE Arterial Band 38 s
NW Arterial Band 34 s
39
SE Arterial Band 38 s

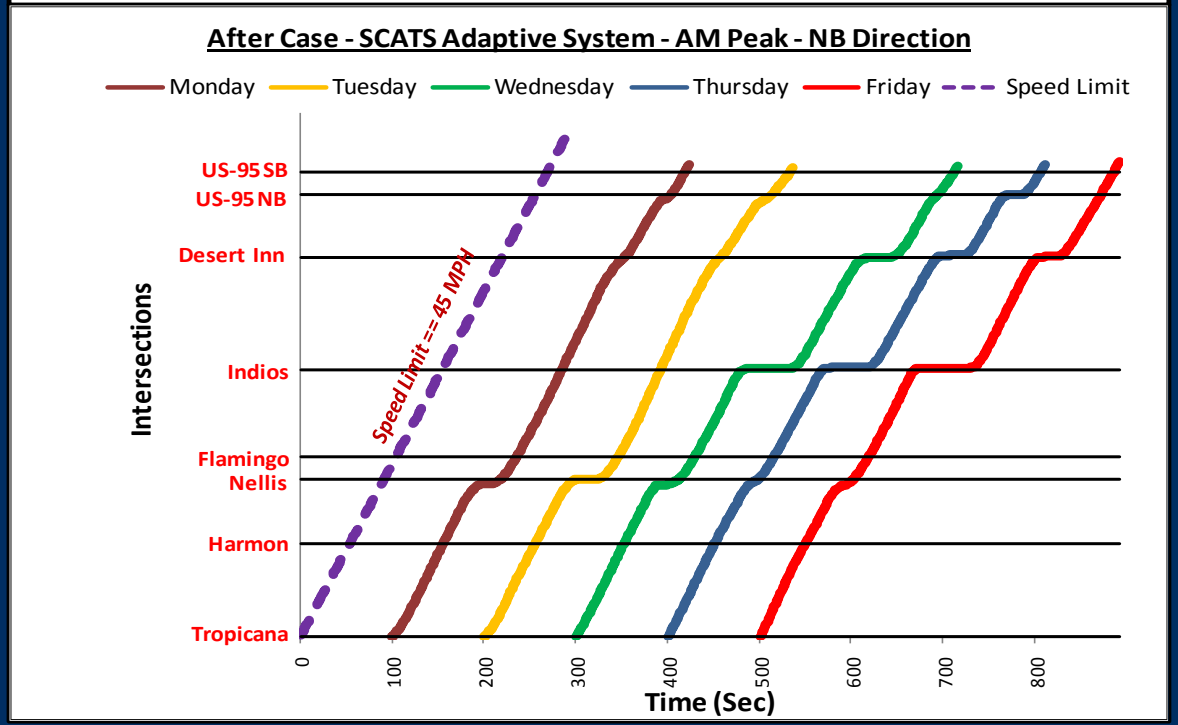




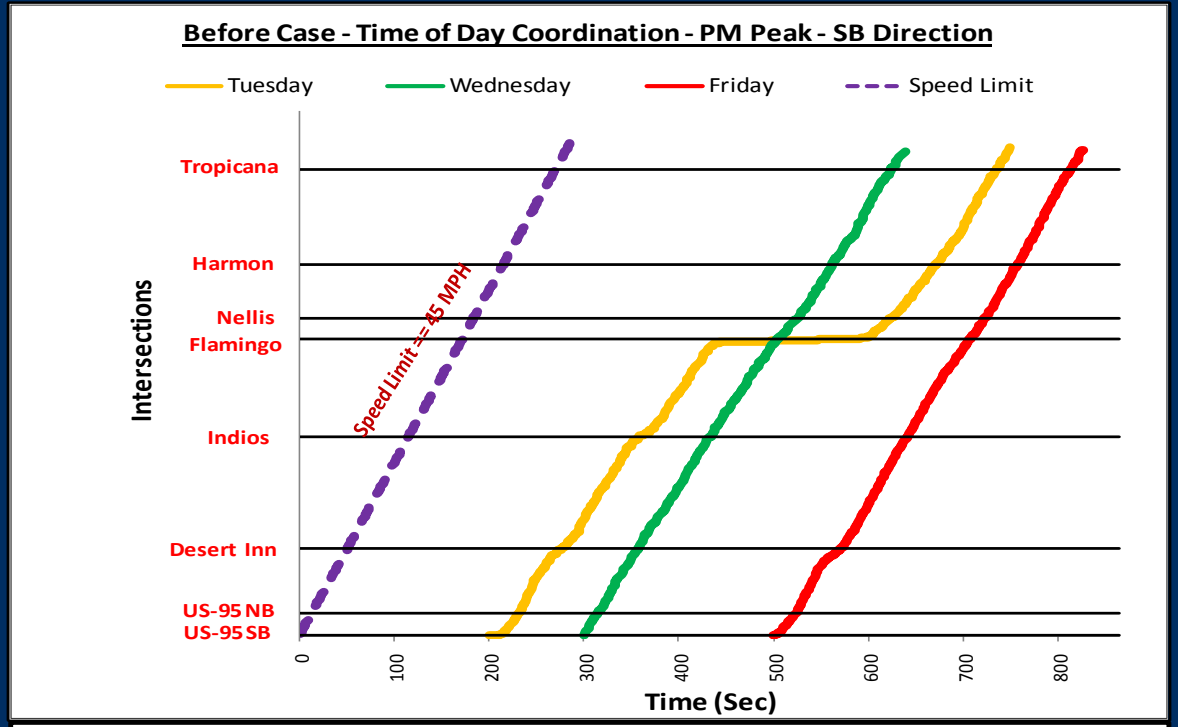
After – Adaptive
At least 1 stop



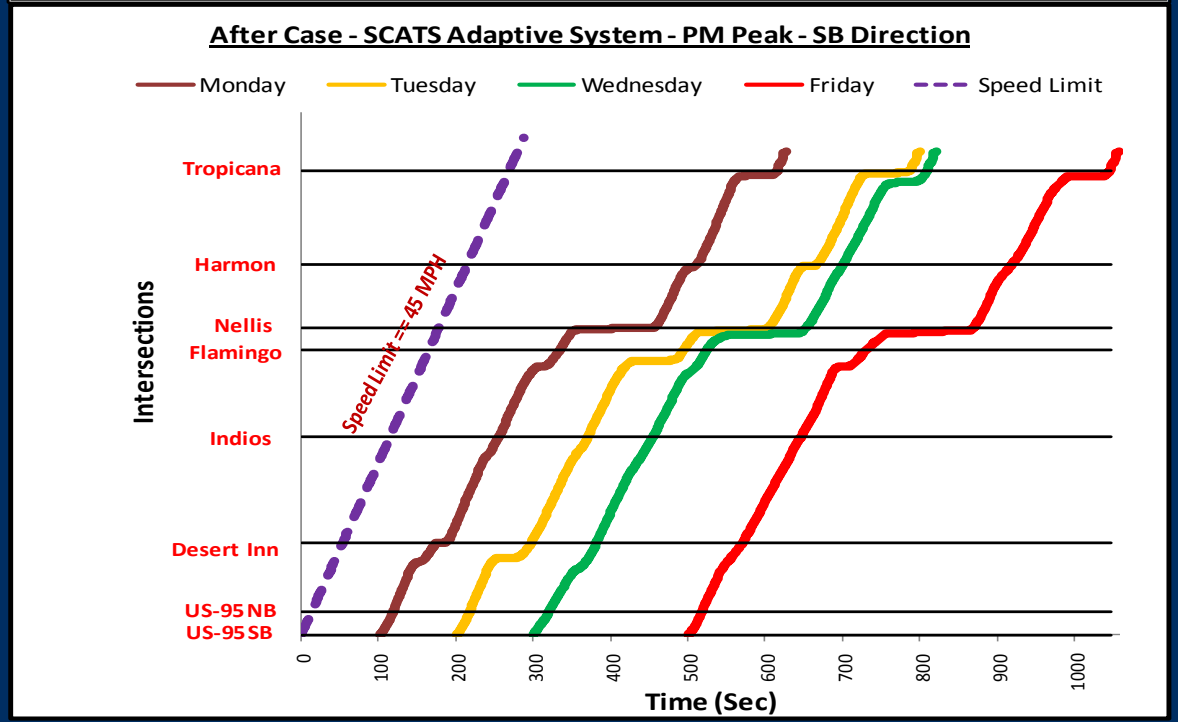
Before – Time of Day
1 short stop



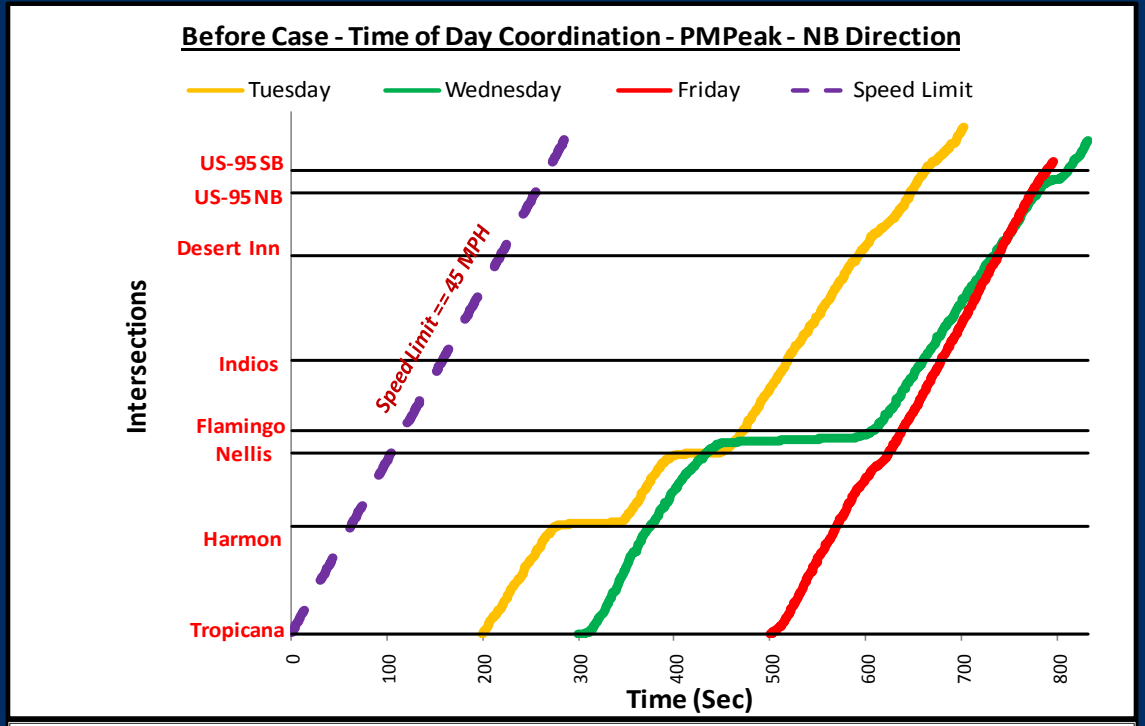
After – Adaptive
At least 1 stop



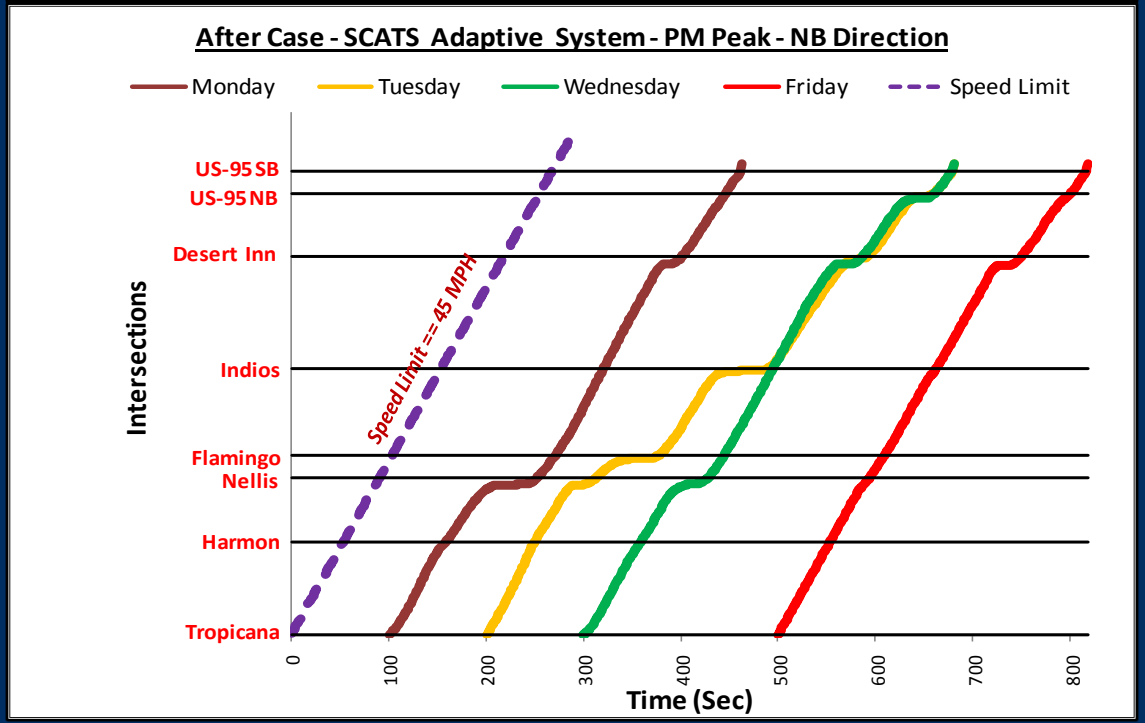
Before – Time of Day



After – Adaptive

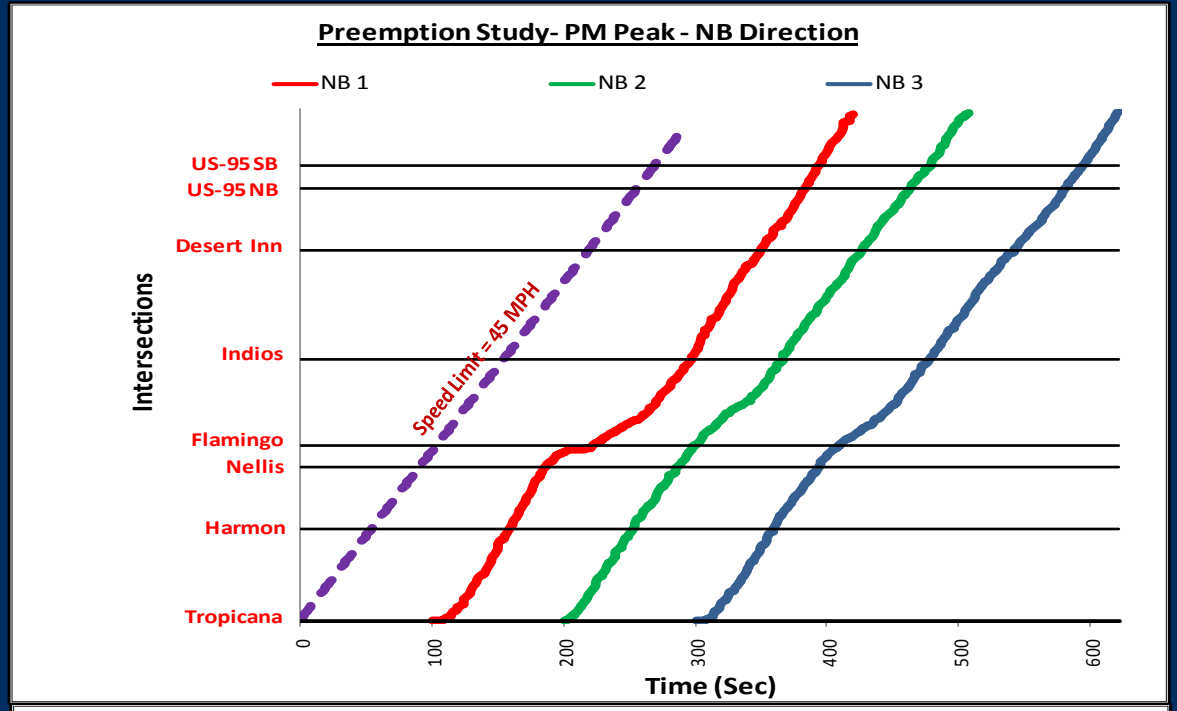


Before – Time of Day

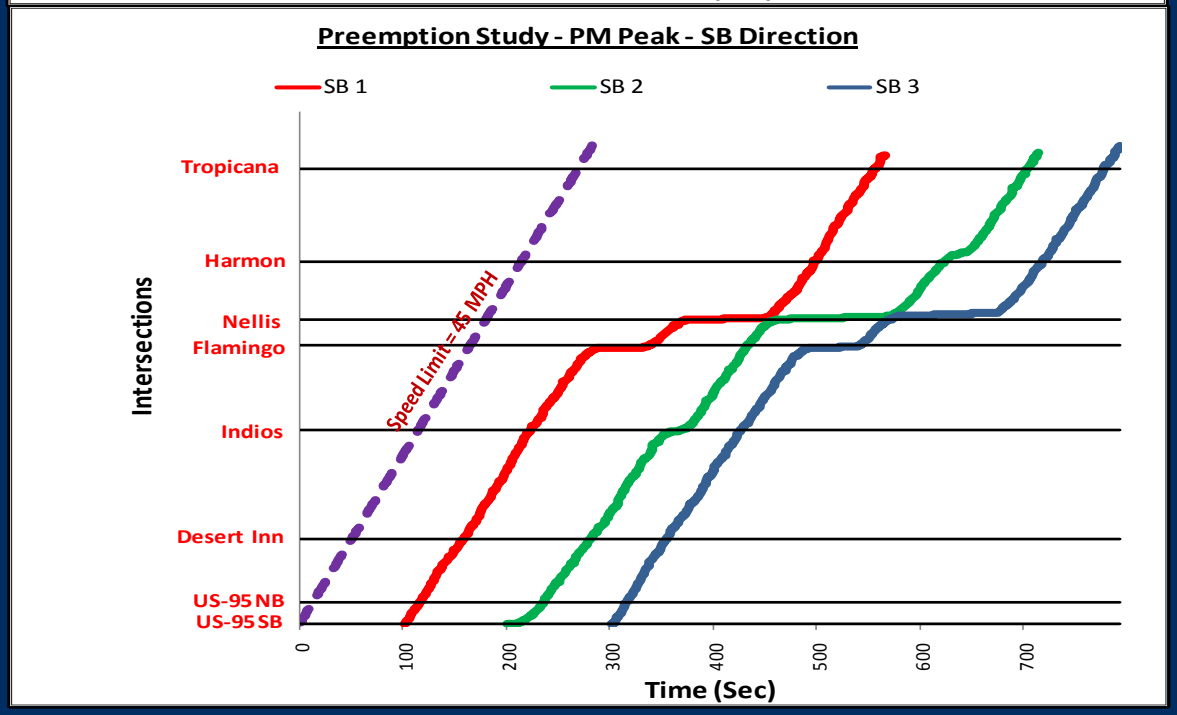


After – Adaptive

Preemption

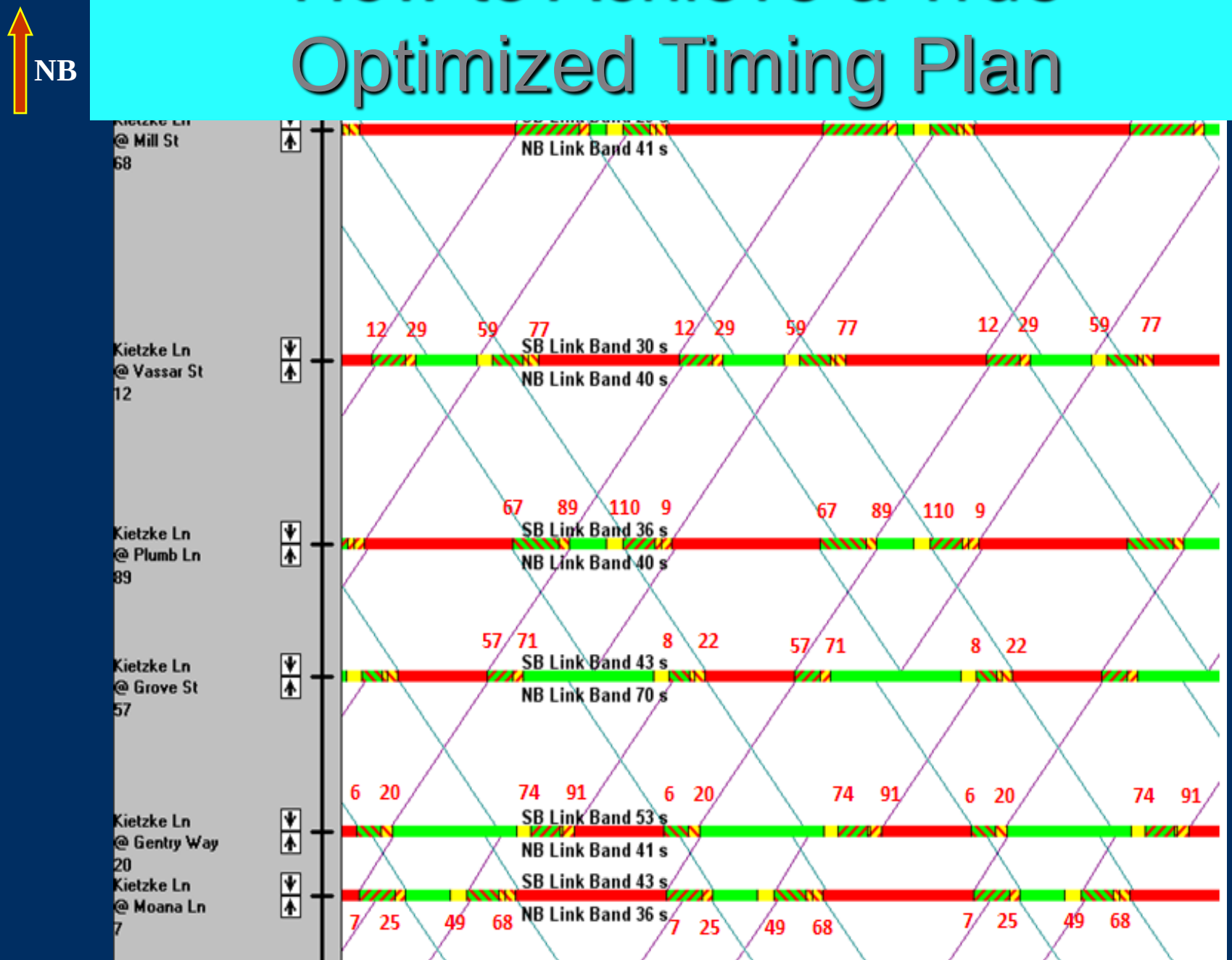


Before – Time of Day

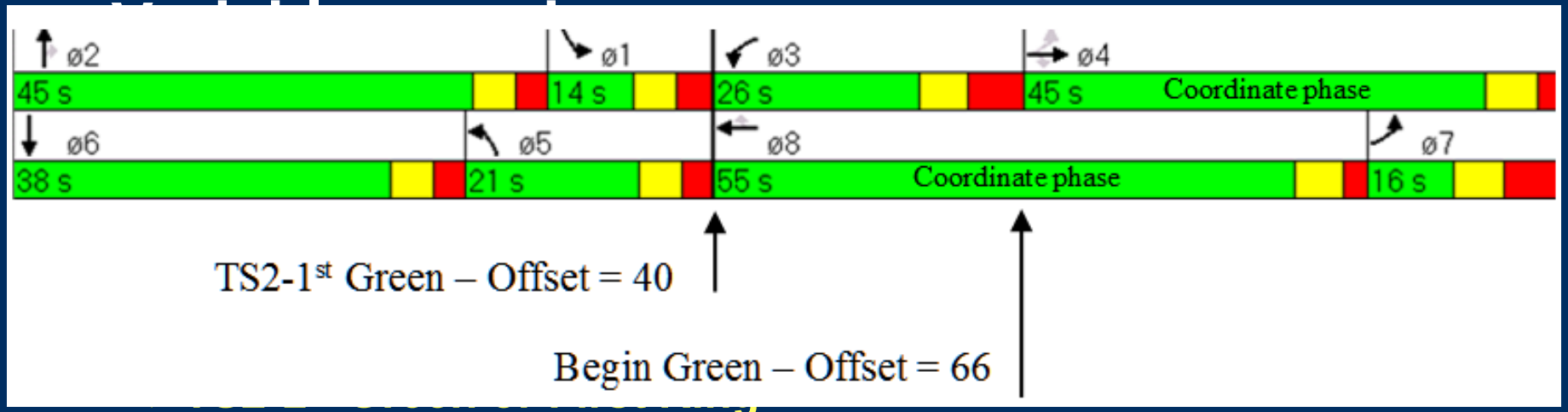


After – Adaptive

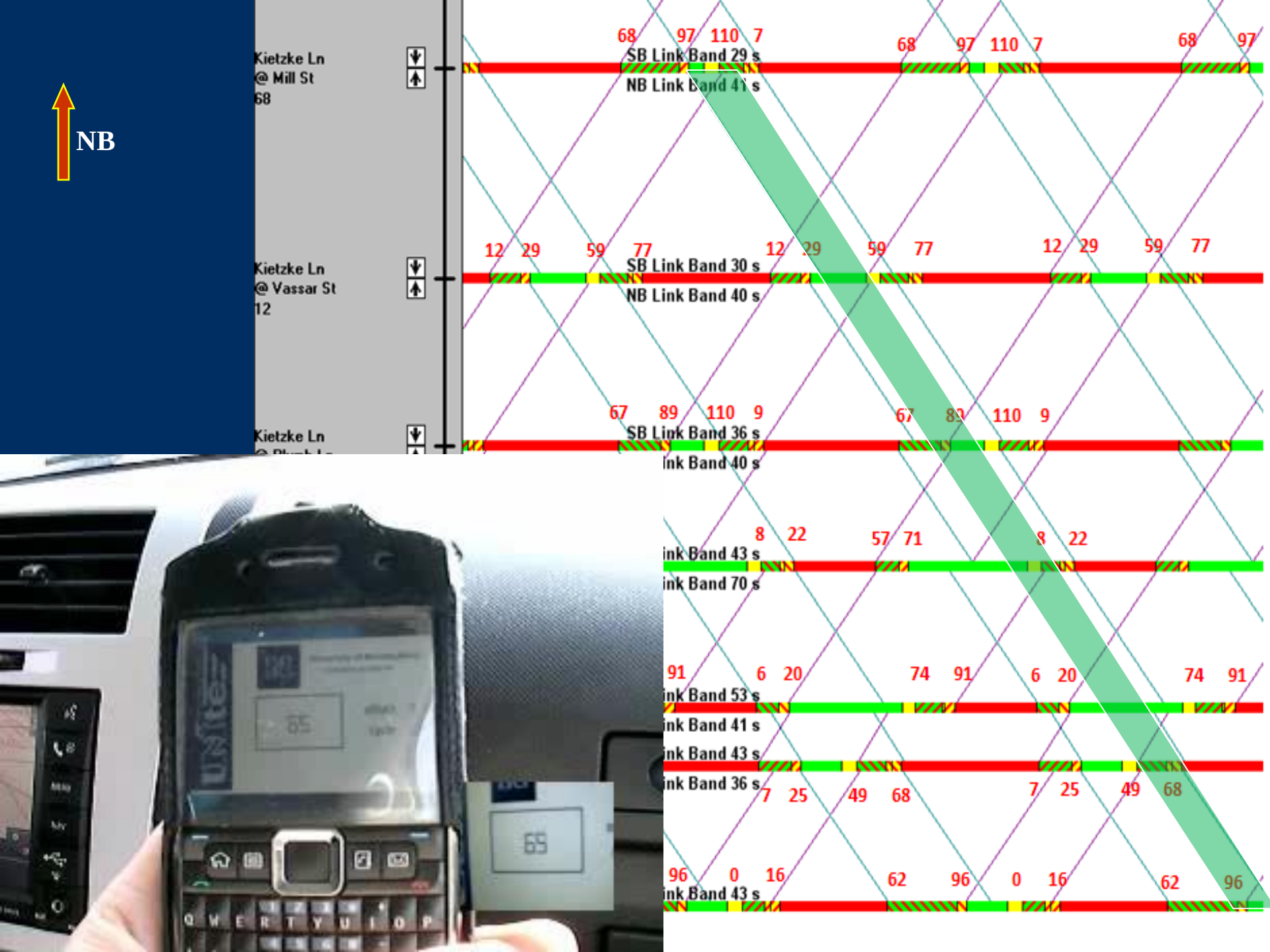
How to Achieve a True Optimized Timing Plan



Real-world Issues



- Signal out of coordination
  - Preemption
  - Pedestrian
  - Loss communication
- Clock time


NB
Kietzke Ln
@ Mill St
68
68 97 110 7
SB Link Band 29 s
NB Link Band 41 s
68 97 110 7
68 97
Kietzke Ln
@ Vassar St
12
12 29 59 77
SB Link Band 30 s
NB Link Band 40 s
12 29 59 77
12 29 59 77
Kietzke Ln
67 89 110 9
SB Link Band 36 s
ink Band 40 s
67 89 110 9
ink Band 43 s
ink Band 70 s
8 22 57 71
8 22
91 6 20 74 91
ink Band 53 s
ink Band 41 s
ink Band 43 s
ink Band 36 s
7 25 49 68
7 25 49 68
96 0 16 62 96
ink Band 43 s
96 0 16 62 96

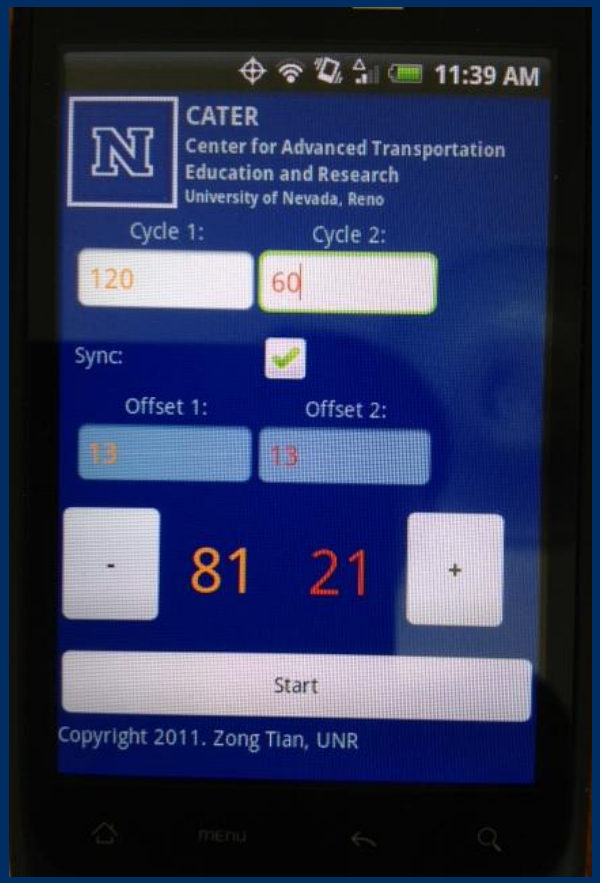
Before-After

After Total = 4’04”
Stop = 1

Before Total = 6’15”
Stop = 4

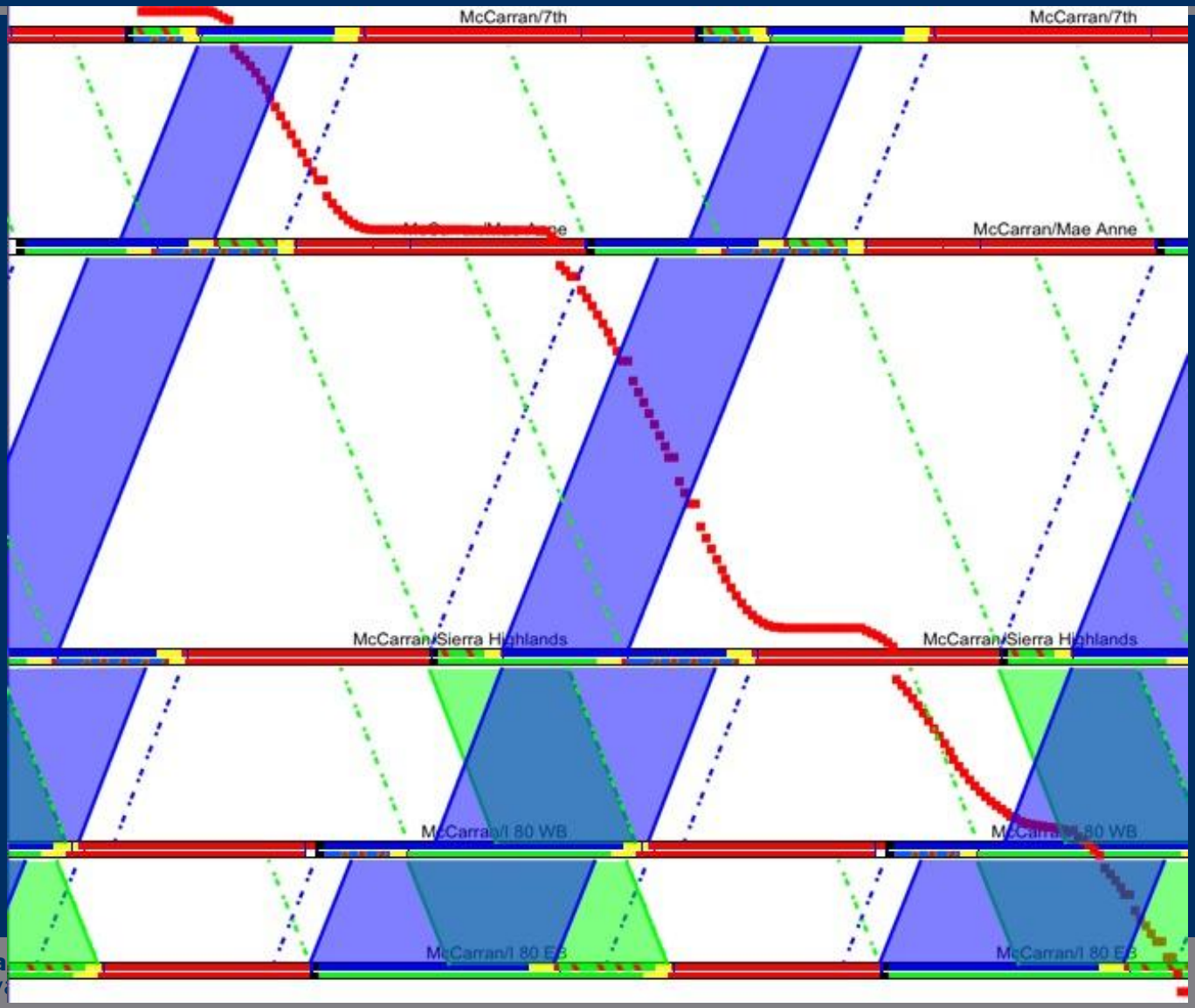
SMRT

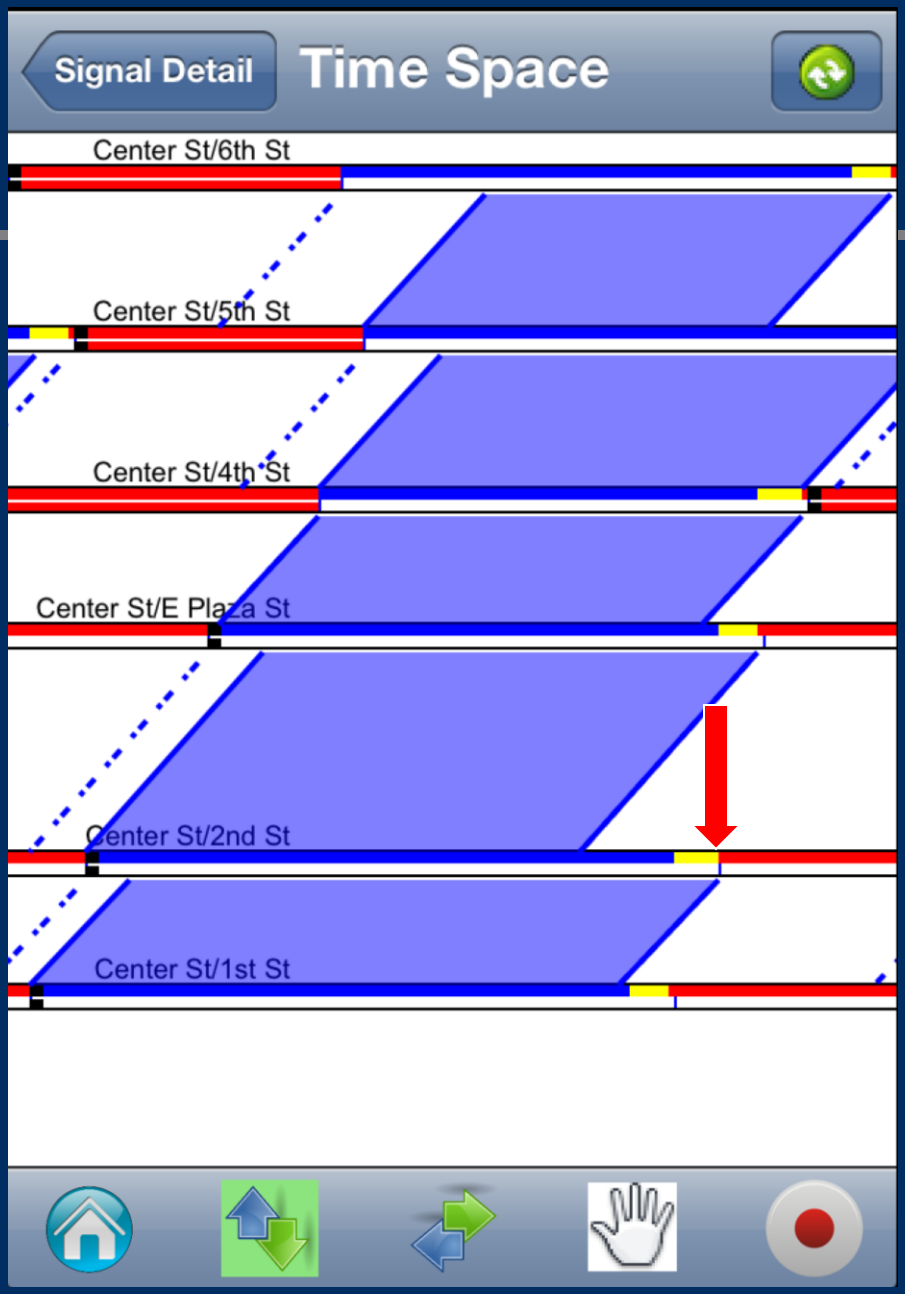
Signal Management and Re-timing Tool

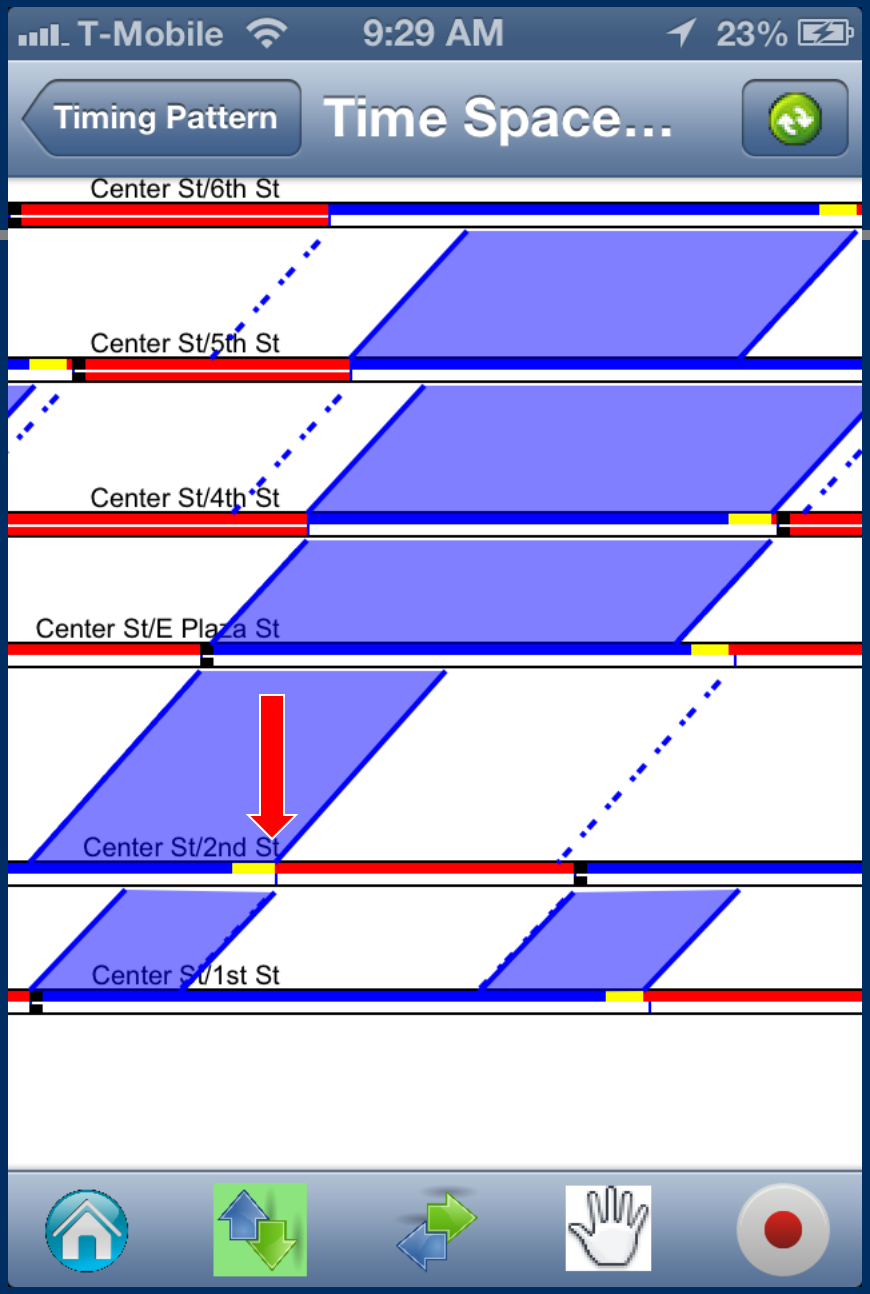


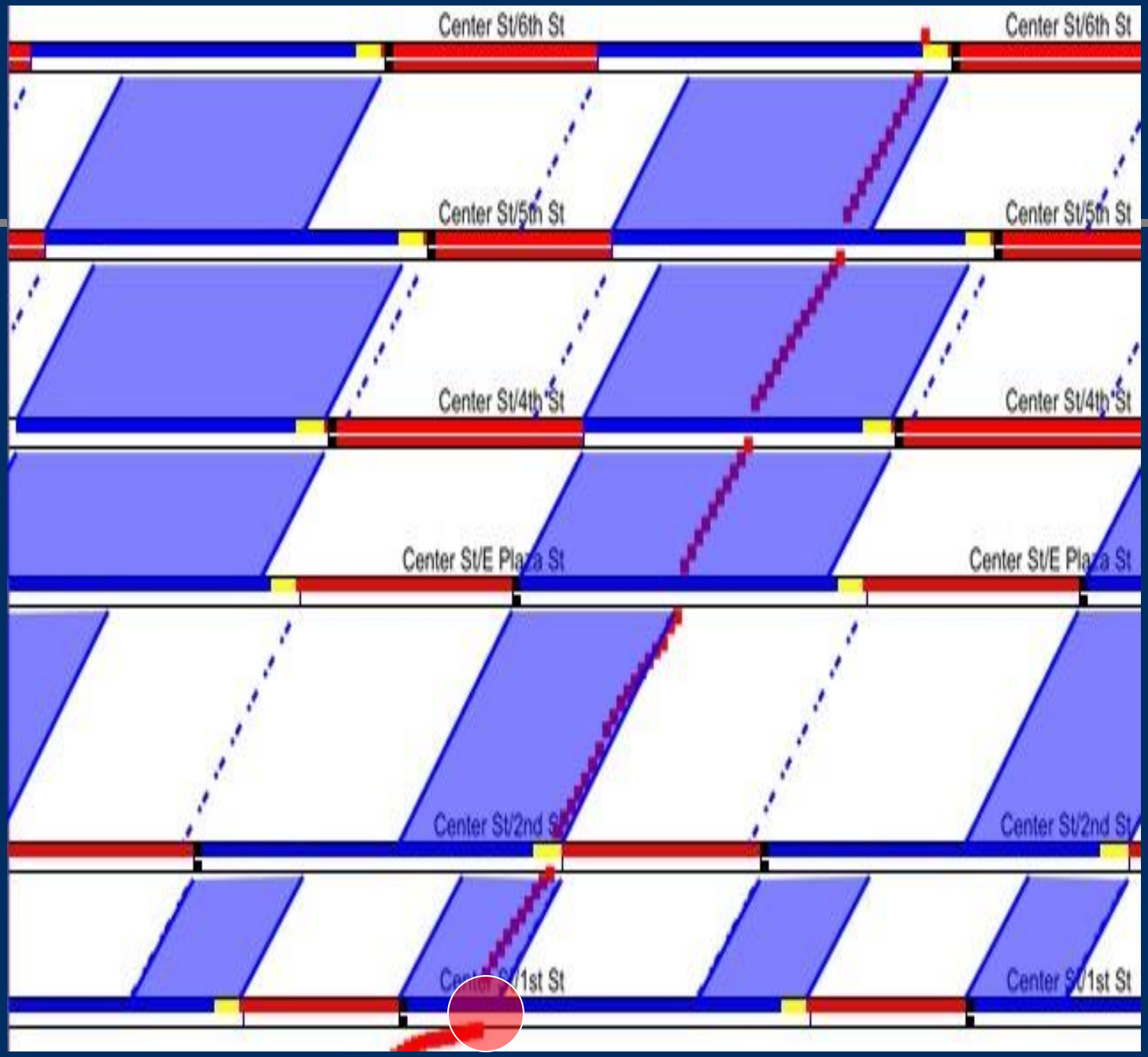
SMRT- Demo

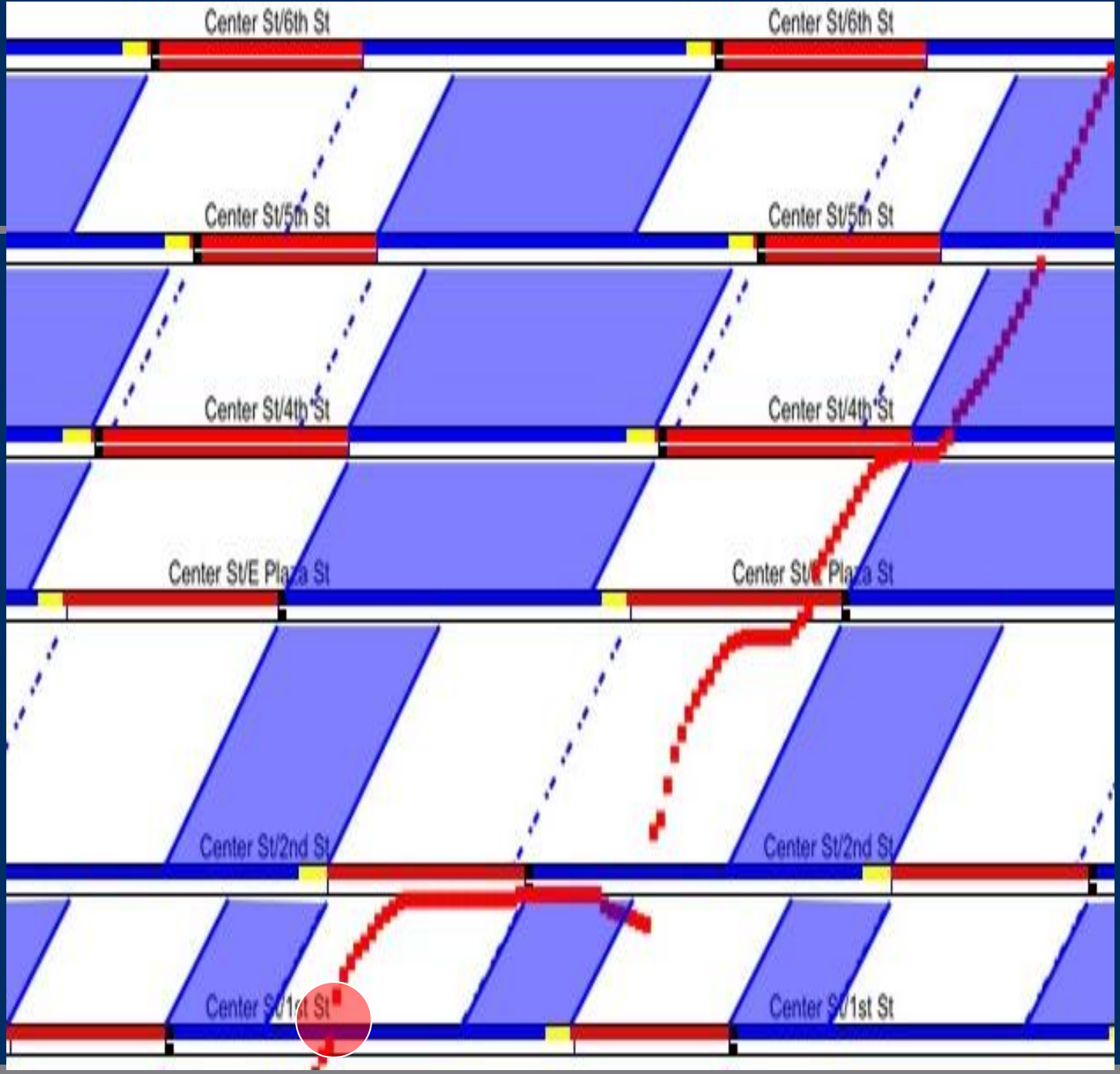
Before Timing

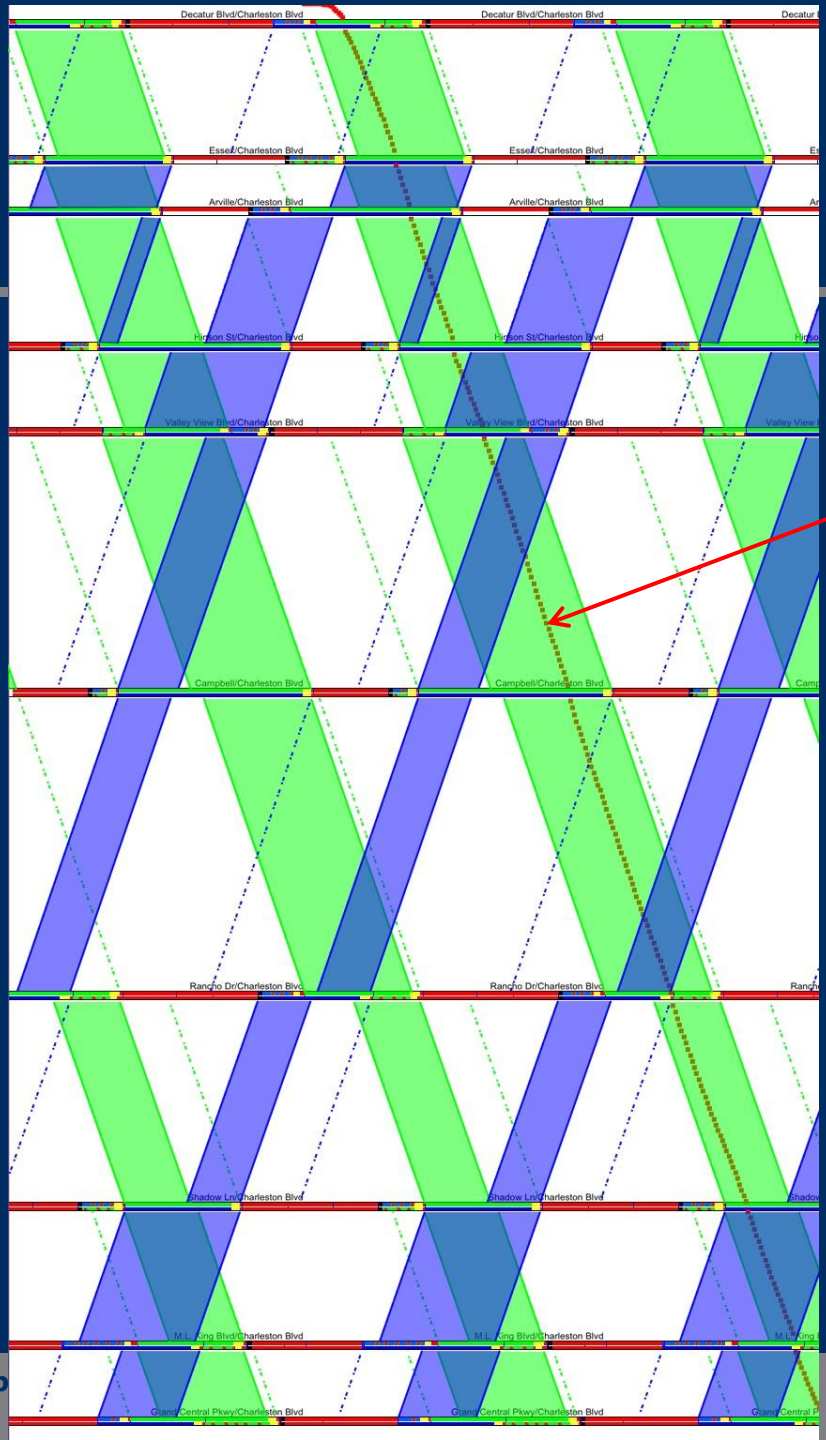



Signal Detail
Time Space
Center St/6th St
Center St/5th St
Center St/4th St
Center St/E Plaza St
Center St/2nd St
Center St/1st St

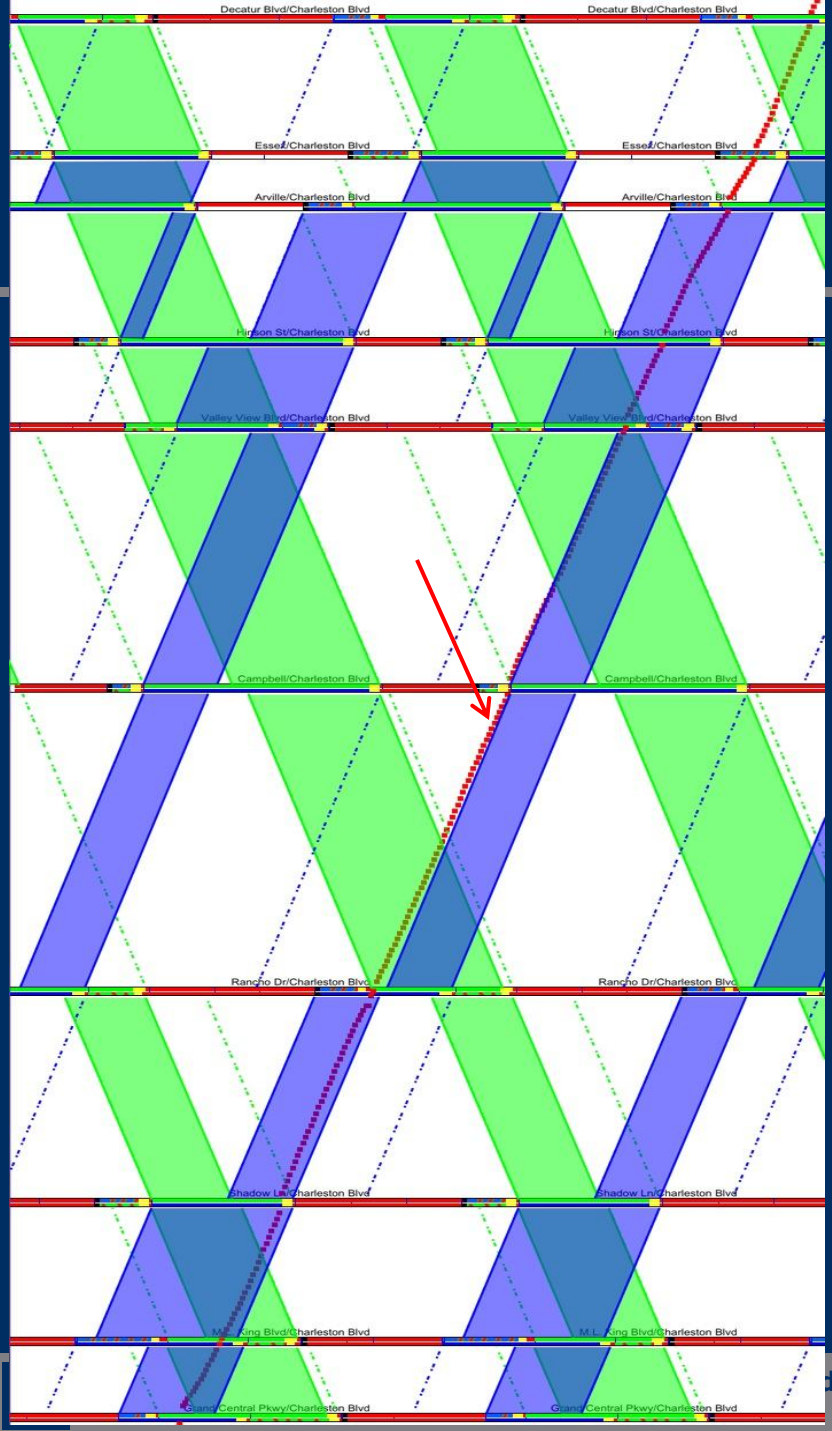

T-Mobile
9:29 AM
23%
Timing Pattern
Time Space...
Center St/6th St
Center St/5th St
Center St/4th St
Center St/E Plaza St
Center St/2nd St
Center St/1st St


Center St/6th St
Center St/6th St
Center St/5th St
Center St/5th St
Center St/4th St
Center St/4th St
Center St/E Plaza St
Center St/E Plaza St
Center St/2nd St
Center St/2nd St
Center St/1st St
Center St/1st St


Center St/6th St
Center St/6th St
Center St/5th St
Center St/5th St
Center St/4th St
Center St/4th St
Center St/E Plaza St
Center St/E Plaza St
Center St/2nd St
Center St/2nd St
Center St/1st St
Center St/1st St


Decatur Blvd/Charleston Blvd
Decatur Blvd/Charleston Blvd
Essex/Charleston Blvd
Essex/Charleston Blvd
Arville/Charleston Blvd
Arville/Charleston Blvd
Hinson St/Charleston Blvd
Hinson St/Charleston Blvd
Valley View Blvd/Charleston Blvd
Valley View Blvd/Charleston Blvd
Campbell/Charleston Blvd
Campbell/Charleston Blvd
Rancho Dr/Charleston Blvd
Rancho Dr/Charleston Blvd
Shadow Ln/Charleston Blvd
Shadow Ln/Charleston Blvd
M.L. King Blvd/Charleston Blvd
M.L. King Blvd/Charleston Blvd
Grand Central Pkwy/Charleston Blvd
Grand Central Pkwy/Charleston Blvd

No stop


Decatur Blvd/Charleston Blvd
Decatur Blvd/Charleston Blvd
Essex/Charleston Blvd
Essex/Charleston Blvd
Arville/Charleston Blvd
Arville/Charleston Blvd
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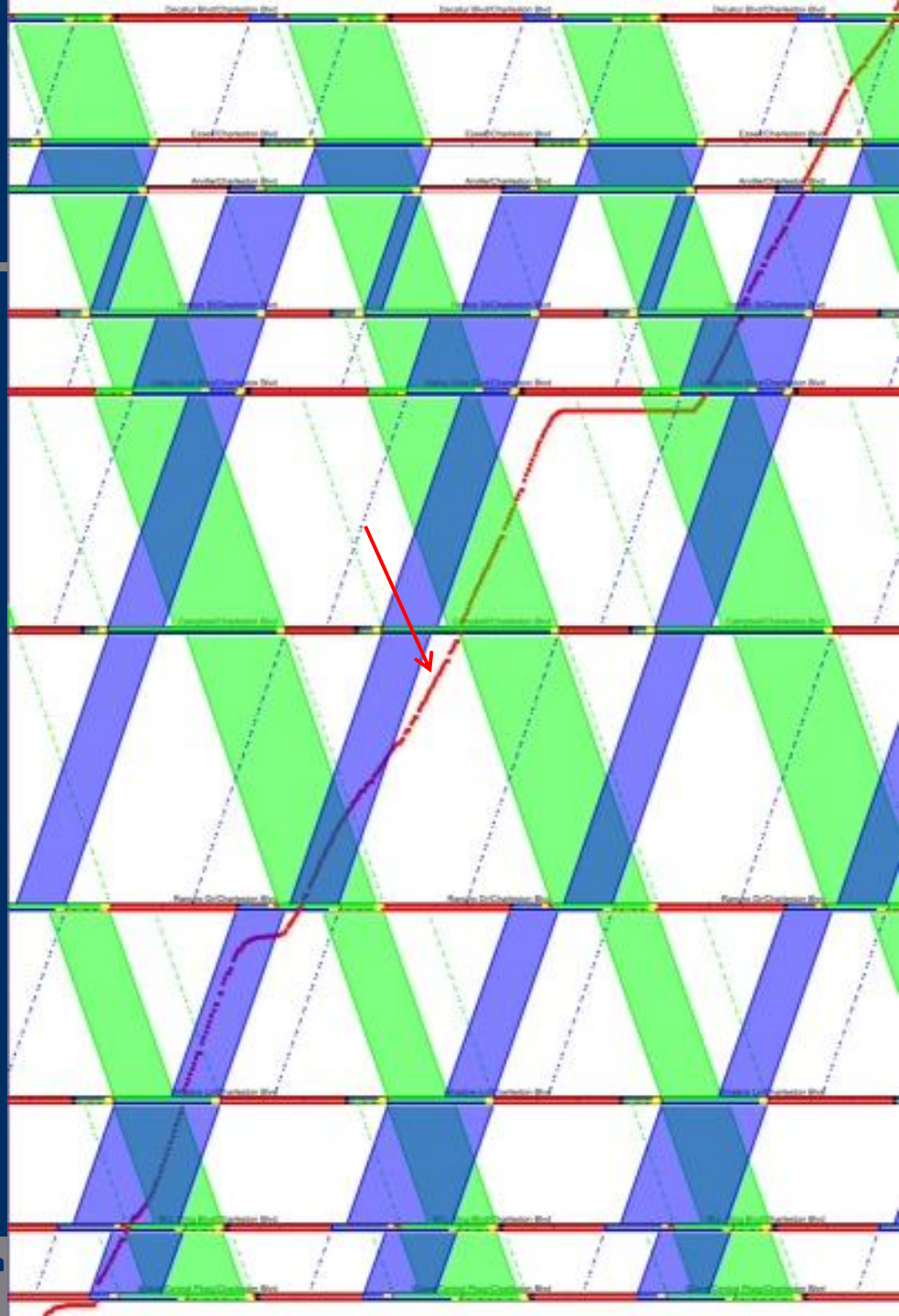
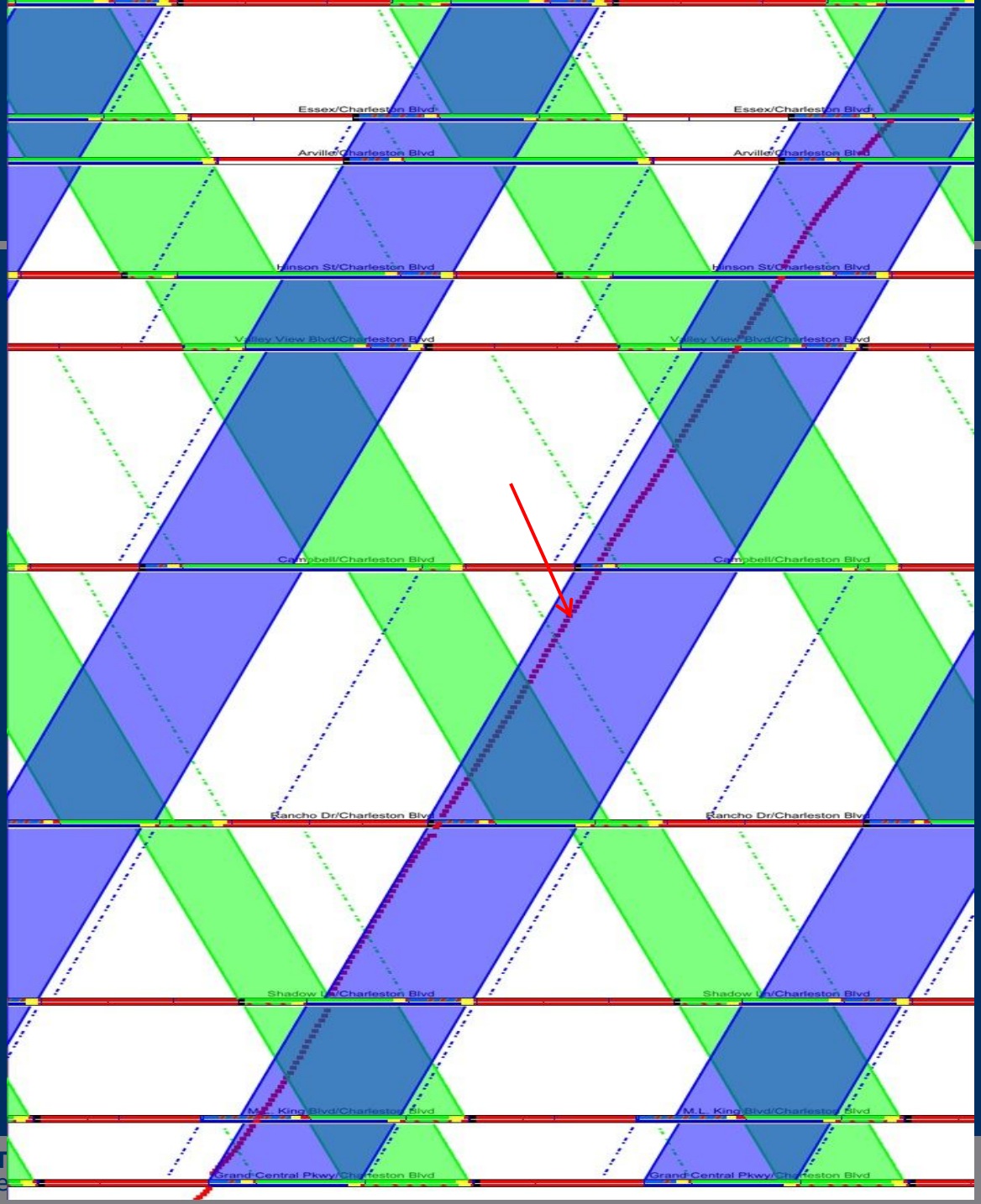
Hinson St/Charleston Blvd
Valley View Blvd/Charleston Blvd
Valley View Blvd/Charleston Blvd
Campbell/Charleston Blvd
Campbell/Charleston Blvd
Rancho Dr/Charleston Blvd
Rancho Dr/Charleston Blvd
Shadow Ln/Charleston Blvd
Shadow Ln/Charleston Blvd
M.L.King Blvd/Charleston Blvd
M.L.King Blvd/Charleston Blvd
Grand Central Pkwy/Charleston Blvd
Grand Central Pkwy/Charleston Blvd




Essex/Charleston Blvd
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Arville/Charleston Blvd
Arville/Charleston Blvd
Hinson St/Charleston Blvd
Hinson St/Charleston Blvd
Valley View Blvd/Charleston Blvd
Valley View Blvd/Charleston Blvd
Campbell/Charleston Blvd
Campbell/Charleston Blvd
Rancho Dr/Charleston Blvd
Rancho Dr/Charleston Blvd
Shadow Ln/Charleston Blvd
Shadow Ln/Charleston Blvd
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Final Thoughts

- Adaptive is good in concept, but the technology/algorithm is still evolving
- Misconceptions
  - Low maintenance, no re-timing effort
  - Better for oversaturated conditions
  - Retiming vs. fine-tuning
- Limitations
  - Unconventional intersections, phasing sequence optimization, Link-based

My Words

Signal timing is more of an art than engineering or science. Therefore, artists (engineers) can never be replaced by machines (adaptive).

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