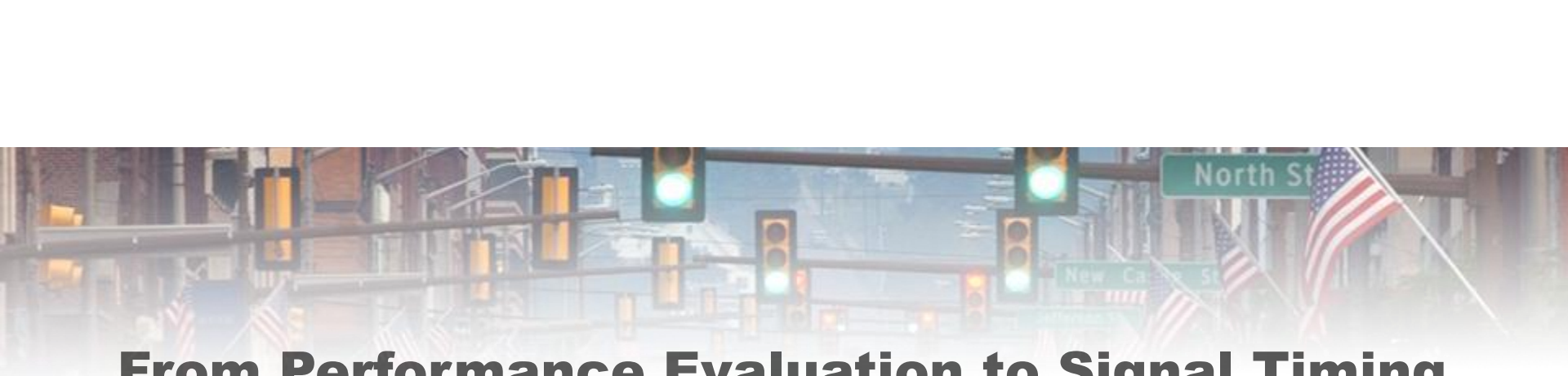




From Performance Evaluation to Signal Timing Optimization: Leveraging Connected Vehicle Data

Zong Tian, PhD, PE
University of Nevada, Reno, NV

June 2026



Outline

- State of the practice on **signal coordination** timing evaluation
- Workflow of using connected vehicle trajectories
- Case demos
- Q&A

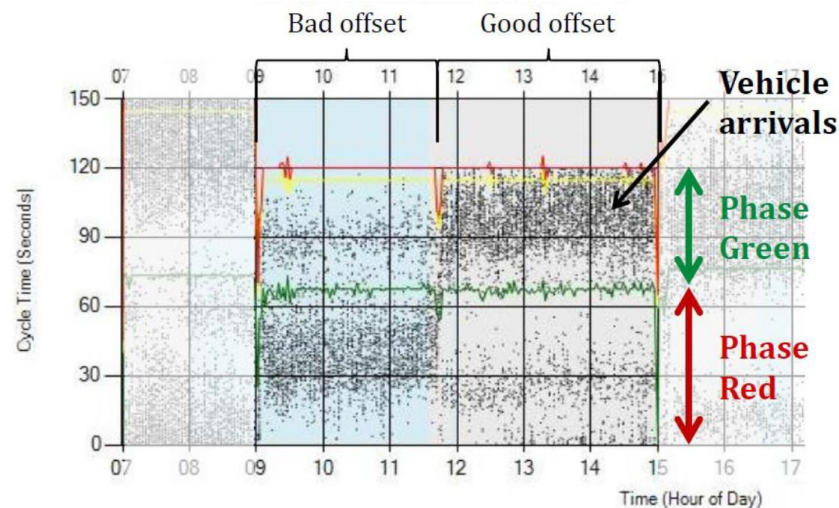


Role of ATSPM

--Select a Metric--

Purdue Phase Termination
 Split Monitor
 Pedestrian Delay
 Preemption Details
 Timing and Actuation
 Purdue Split Failure
 Yellow and Red Actuations
 Turning Movement Counts
 Approach Volume
 Approach Delay
Arrivals on Red
Purdue Coordination Diagram
 Approach Speed
 Left Turn Gap Analysis
 Wait Time
 Split Monitor

- %AoR or %AoG
- Purdue Coordination Diagram



Limitations:

- Link-based measure, not arterial-level performance
- No established criteria for corridor-level performance quality
- Unlikely to produce a timing recommendation



Trajectory-based Performance

- **Manual floating-car travel runs are still the predominant method for before-after studies**
 - What is missing?
 - It does not tell if there is still room to improve.
 - Small sample size and data is not from independent source
- **Automated high-resolution vehicle trajectories from vehicle telematics**



Trajectories and CSPI

South Fort Apache Road

Timing	GPS File Name	Average Speed (mph)	% Speed	Speed Score	No. of Stops	Stand No. of Stops	% Stop	Stop Score	Original Score	Cycle Adj.	Spacing Adj.	Adjusted Score	Quality of Signal Timing
MD1 (E)	Flamingo-West (MD1)-EB-2021-12-30 10-17-29	34.2	76%	86	3	1.7	16%	98	95	95	95	95	A
MD1 (E)	Flamingo-West (MD1)-EB-2021-12-29 09-35-37	26.5	59%	69	5	3.8	35%	70	70	70	70	70	C-

South Tenaya Way

Rainbow Boulevard

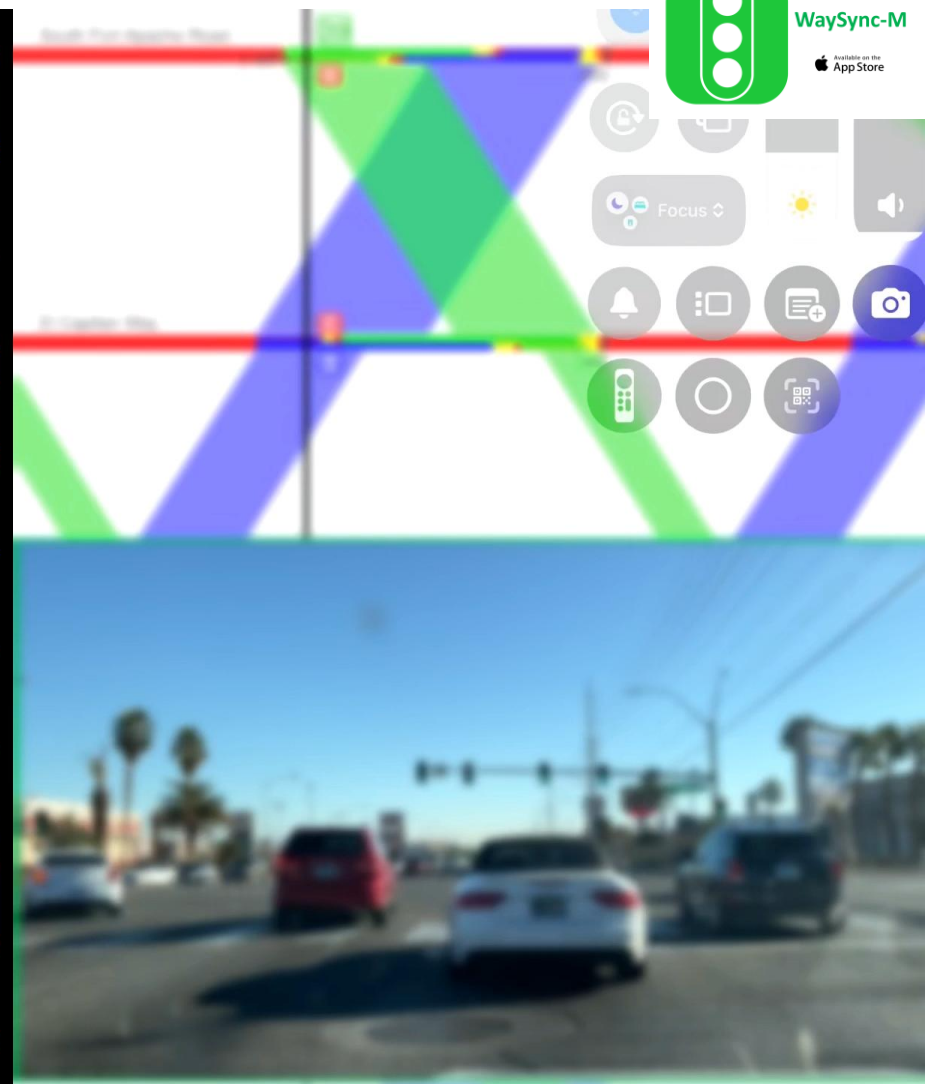
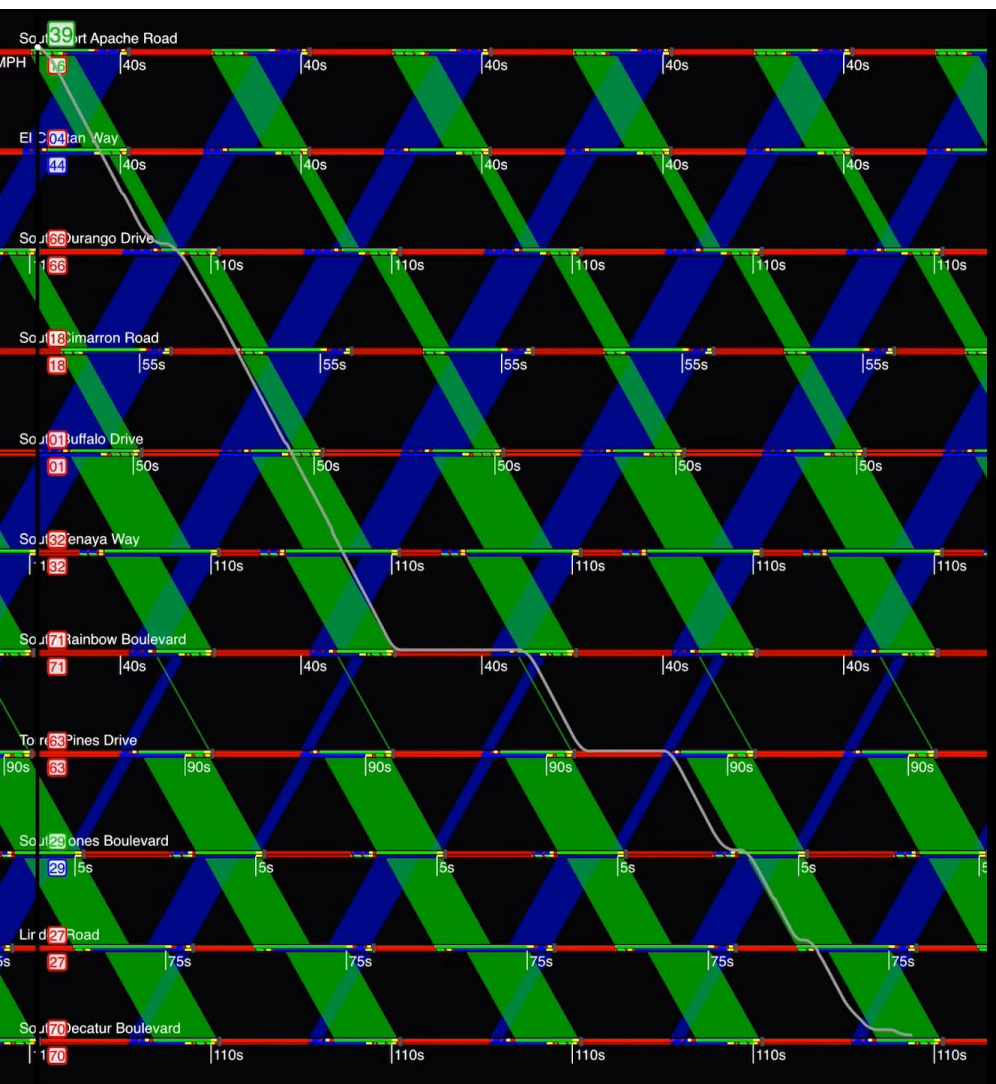
Torrey Pines Drive

Jones Boulevard

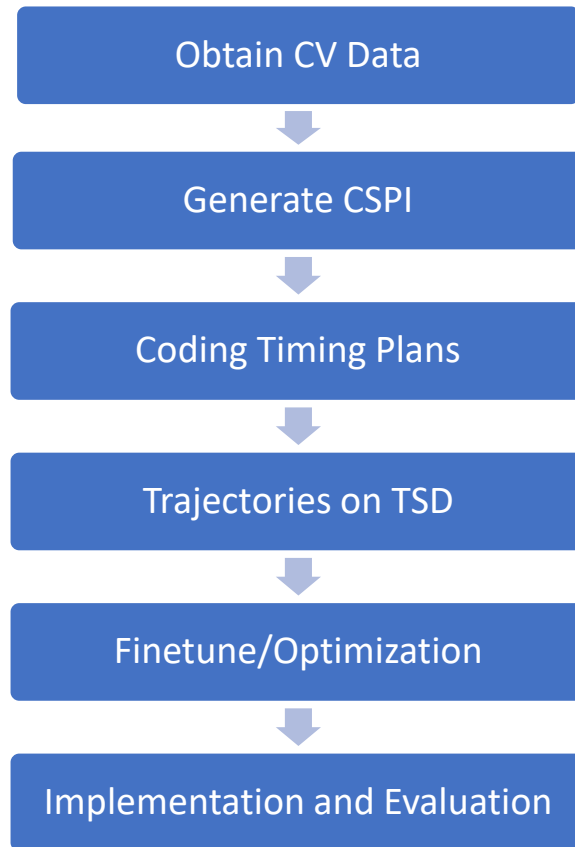
Lindell Road

South Decatur Boulevard





The PM-Optimization Approach



CV - Connected Vehicle (telematics)

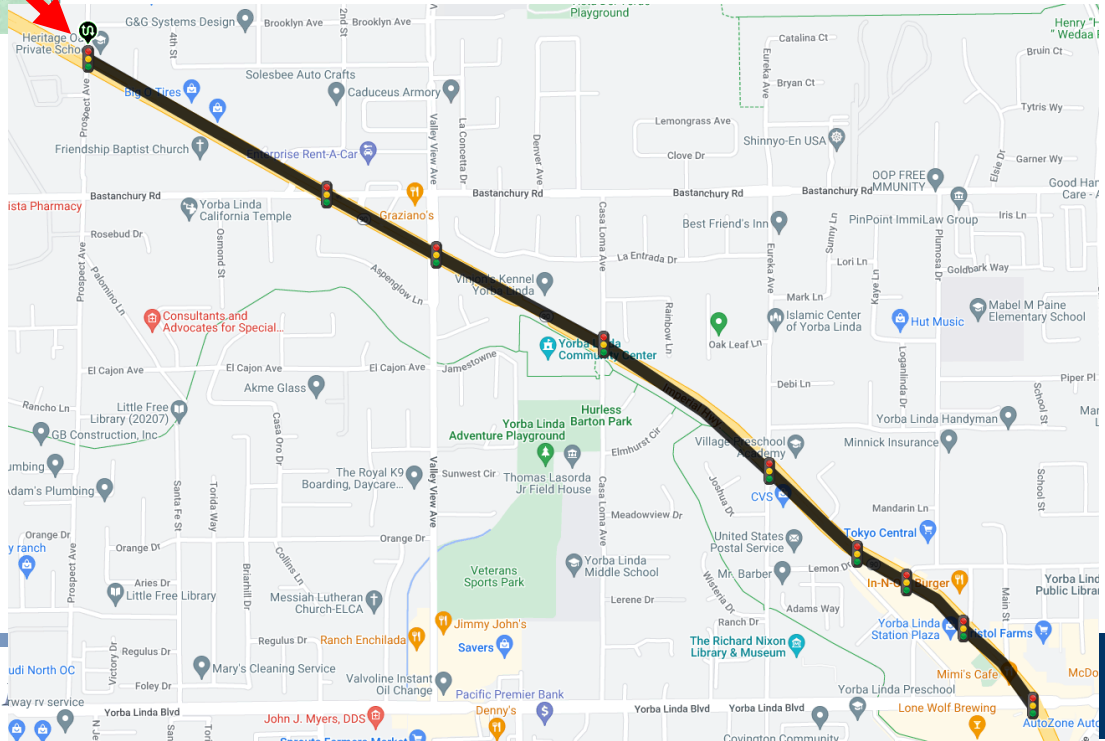
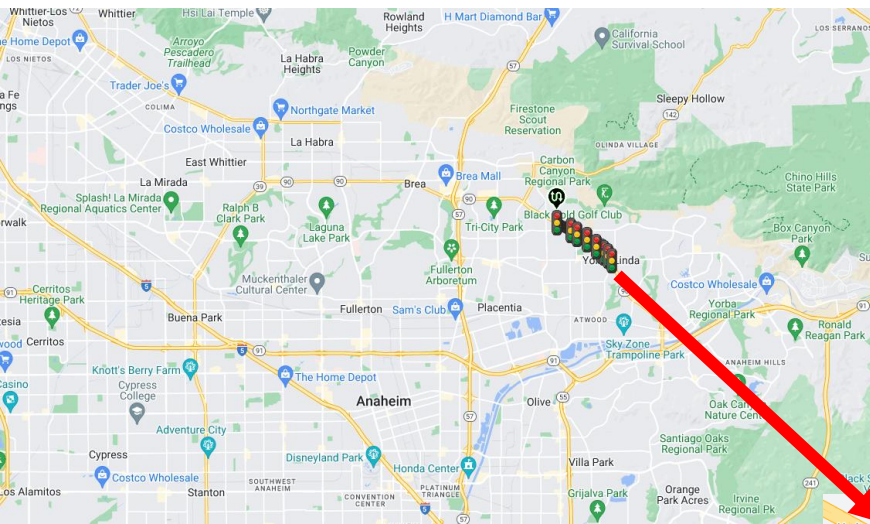
CSPI - Corridor Synchronization Performance Index

TSD - Time-space Diagram



Case 1. Imperial Hwy, Yorba Linda, CA

PM Peak
9 Signals
AADT=35,000



Corridor Synchronization Performance Index

Summary

OCTA

Arterial: Imperial Hwy

Timing	No. of Runs	Average Speed (mph)	Greens per Red (GpR)	Stops per Mile (SpM)	Speed Score	GpR score	SpM score	Total Score	Average Travel Time (s)	Average Delay Time (s)	Average Total Stop Time (s)
PM (Avg)	127	29.3	4.9	1	29	40	30	99	222	99	42
PM (NW)	47	28	4	1.1	27	32	29	88	229	106	49
PM (SE)	80	30.1	5.5	0.9	30	40	31	101	218	95	38

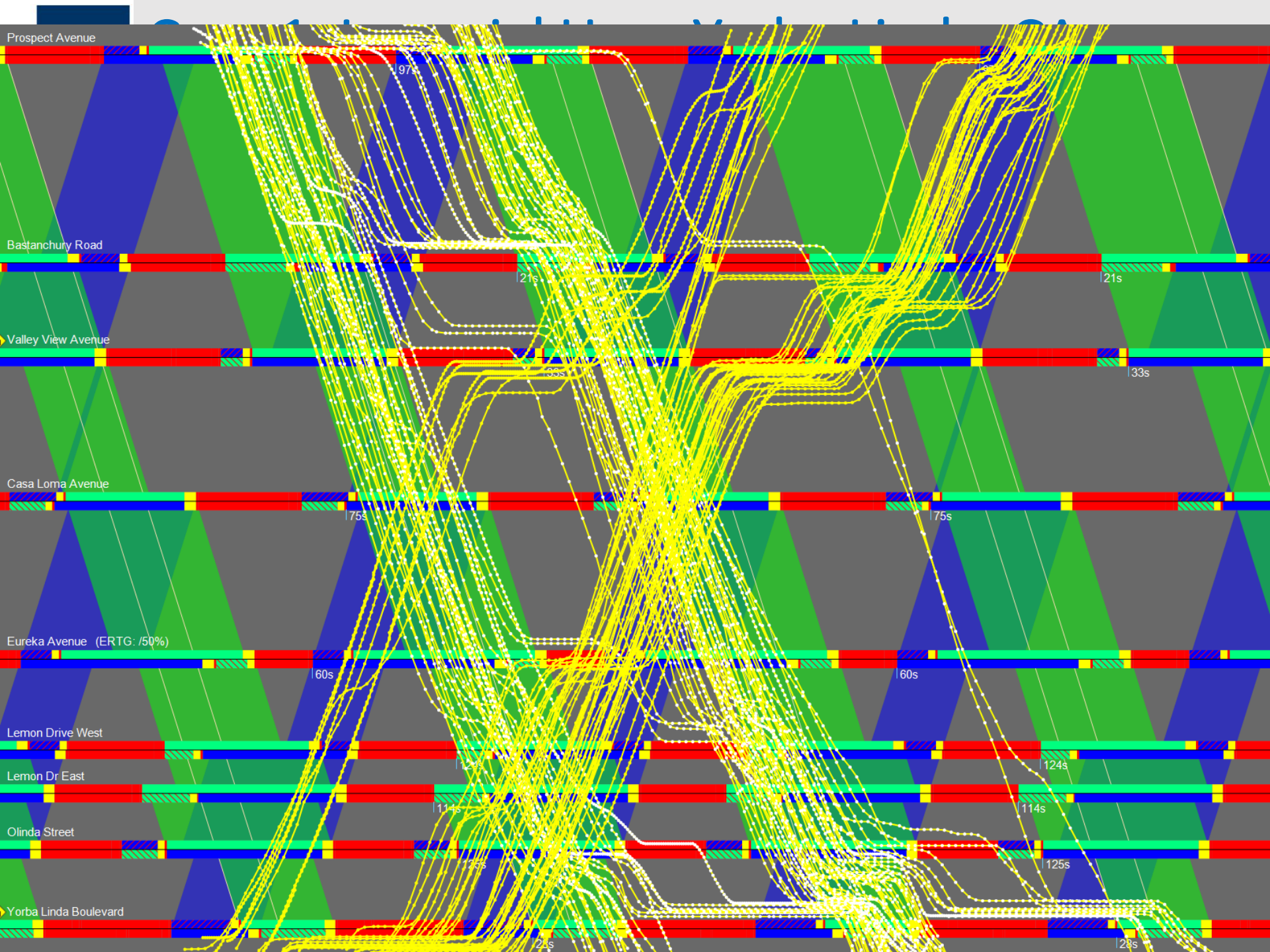
Corridor Synchronization Performance Index

Summary

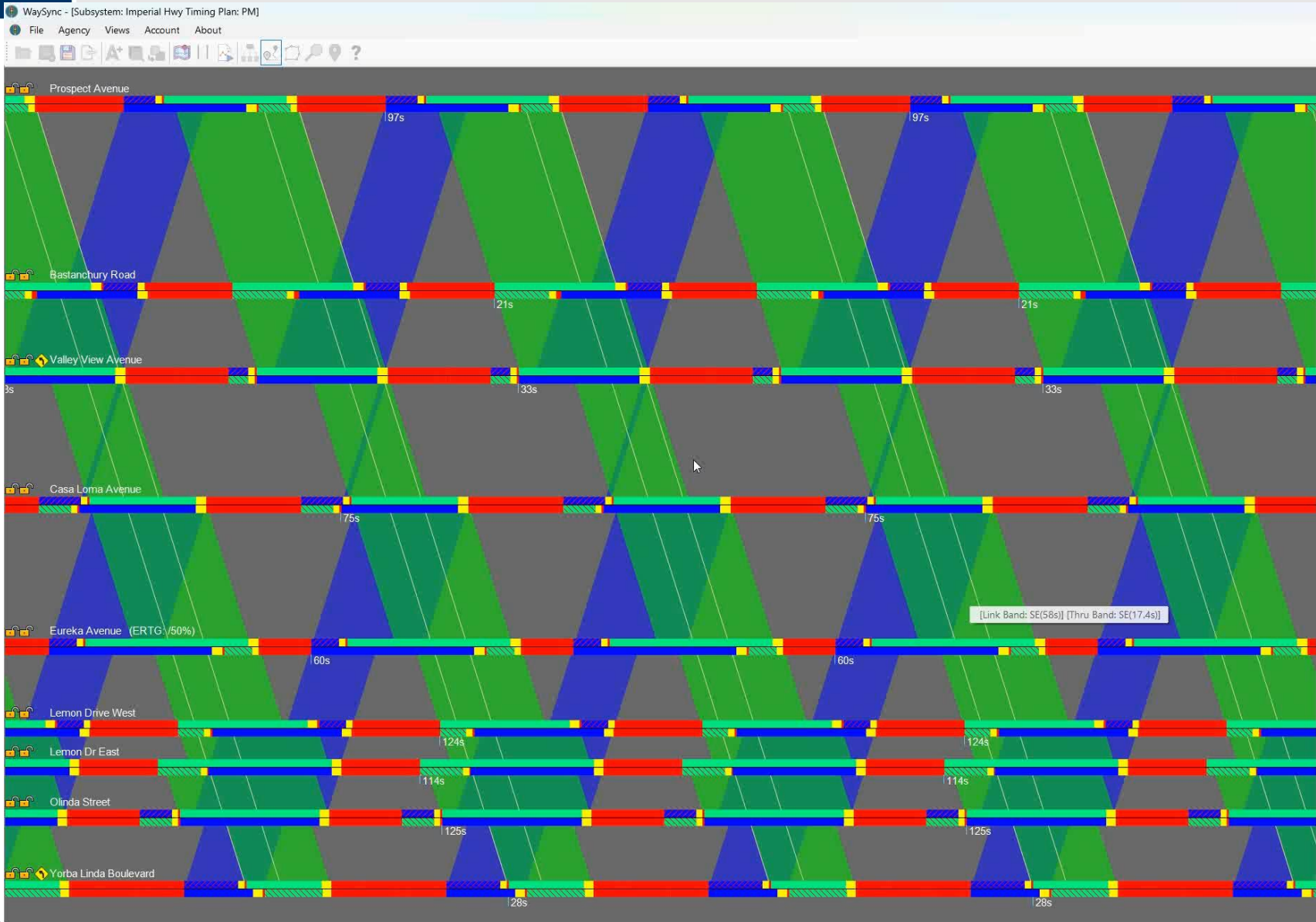
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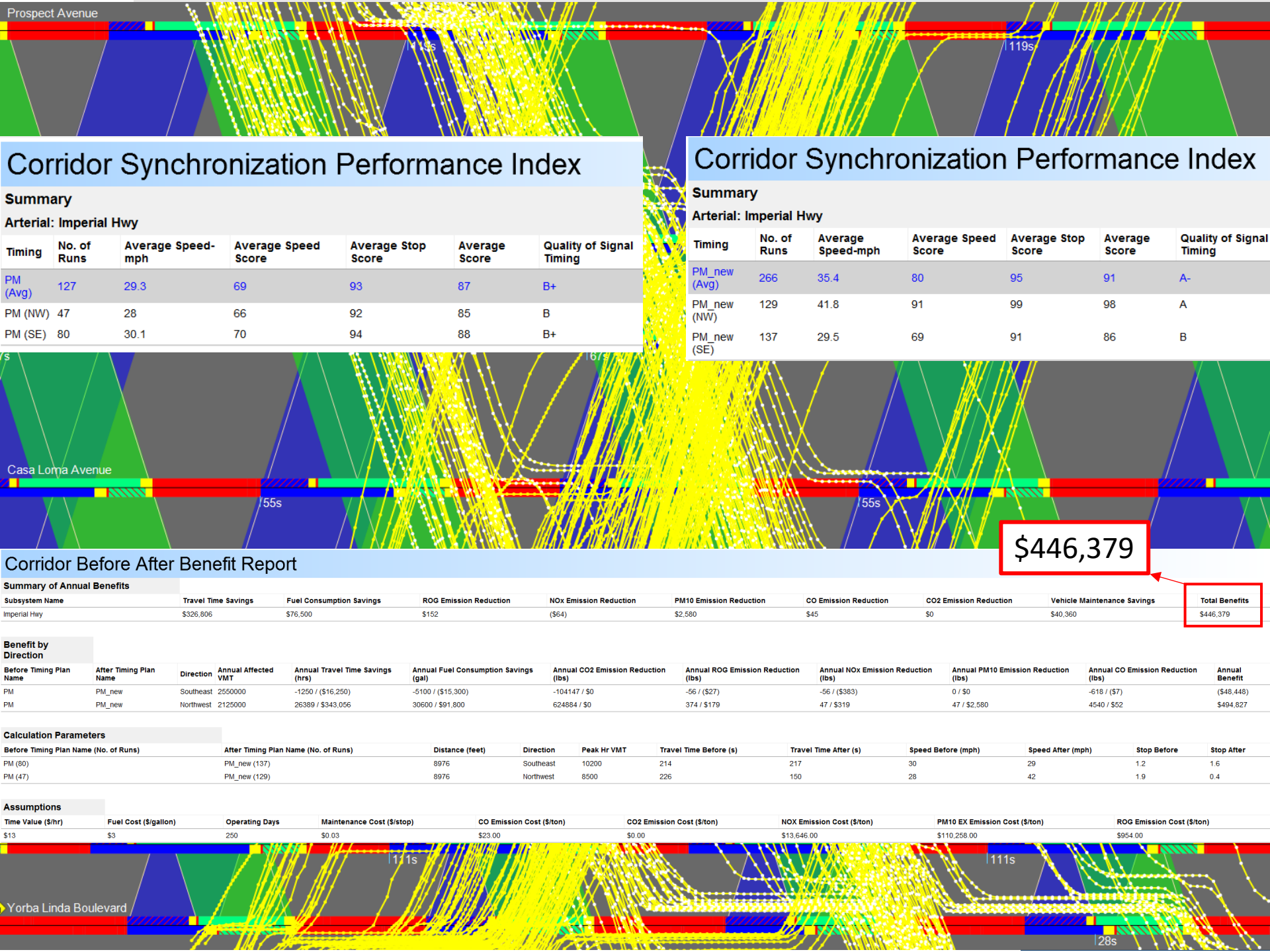
Arterial: Imperial Hwy

Timing	No. of Runs	Average Speed-mph	Average Speed Score	Average Stop Score	Average Score	Quality of Signal Timing	Average Travel Time (s)	Average Delay Time (s)	Average Total Stop Time (s)
PM (Avg)	127	29.3	69	93	87	B+	222	99	42
PM (NW)	47	28	66	92	85	B	229	106	49
PM (SE)	80	30.1	70	94	88	B+	218	95	38



Case 1. Imperial Hwy, Yorba Linda, CA





Corridor Synchronization Performance Index

Summary

Arterial: Imperial Hwy

Timing	No. of Runs	Average Speed-mph	Average Speed Score	Average Stop Score	Average Score	Quality of Signal Timing
PM (Avg)	127	29.3	69	93	87	B+
PM (NW)	47	28	66	92	85	B
PM (SE)	80	30.1	70	94	88	B+

Corridor Synchronization Performance Index

Summary

Arterial: Imperial Hwy

Timing	No. of Runs	Average Speed-mph	Average Speed Score	Average Stop Score	Average Score	Quality of Signal Timing
PM_new (Avg)	266	35.4	80	95	91	A-
PM_new (NW)	129	41.8	91	99	98	A
PM_new (SE)	137	29.5	69	91	86	B

Corridor Before After Benefit Report

\$446,379

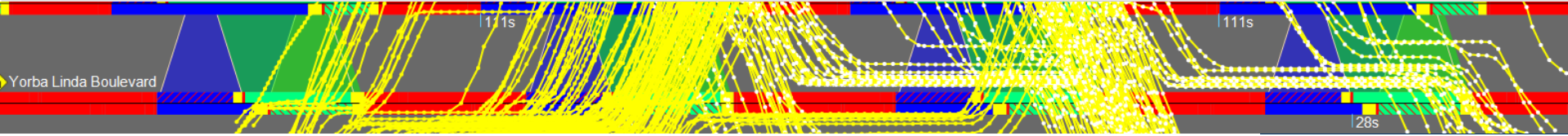
Total Benefits

Summary of Annual Benefits										Total Benefits
Subsystem Name	Travel Time Savings	Fuel Consumption Savings	ROG Emission Reduction	NOx Emission Reduction	PM10 Emission Reduction	CO Emission Reduction	CO2 Emission Reduction	Vehicle Maintenance Savings		
Imperial Hwy	\$326,806	\$76,500	\$152	(\$64)	\$2,580	\$45	\$0	\$40,360		\$446,379

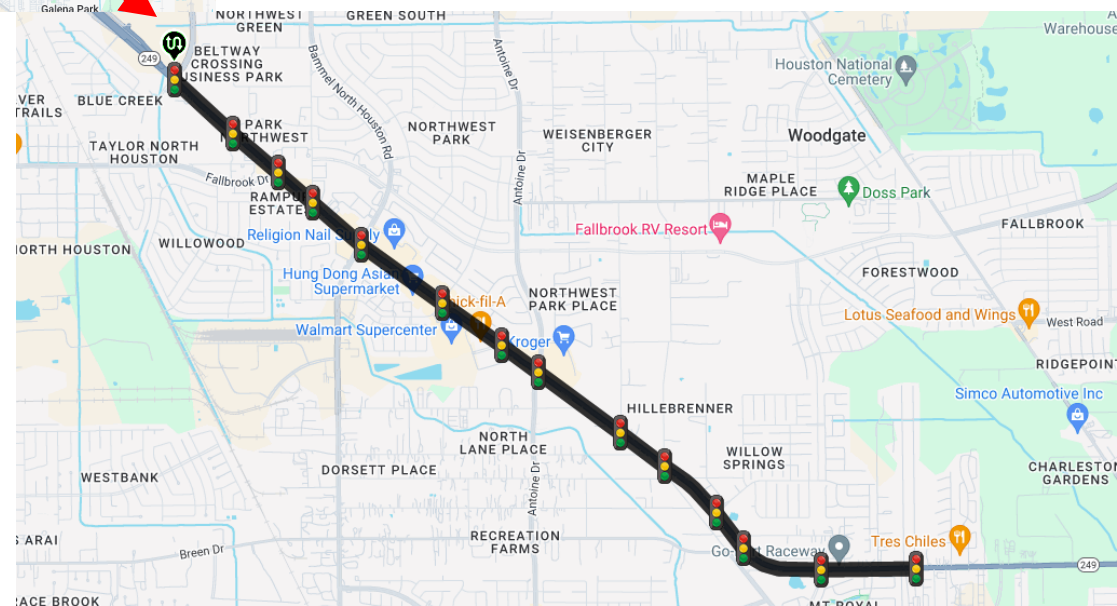
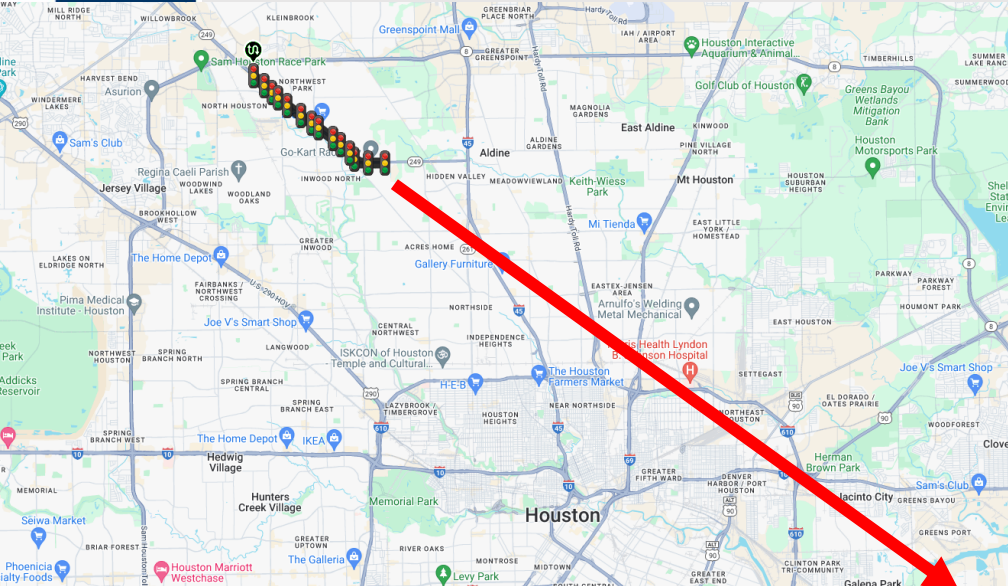
Benefit by Direction											
Before Timing Plan Name	After Timing Plan Name	Direction	Annual Affected VMT	Annual Travel Time Savings (hrs)	Annual Fuel Consumption Savings (gal)	Annual CO2 Emission Reduction (lbs)	Annual ROG Emission Reduction (lbs)	Annual NOx Emission Reduction (lbs)	Annual PM10 Emission Reduction (lbs)	Annual CO Emission Reduction (lbs)	Annual Benefit
PM	PM_new	Southeast	2550000	-1250 / (\$16,250)	-5100 / (\$15,300)	-104147 / \$0	-56 / (\$27)	-56 / (\$383)	0 / \$0	-618 / (\$7)	(\$48,448)
PM	PM_new	Northwest	2125000	26389 / \$343,056	30600 / \$91,800	624884 / \$0	374 / \$179	47 / \$319	47 / \$2,580	4540 / \$52	\$494,827

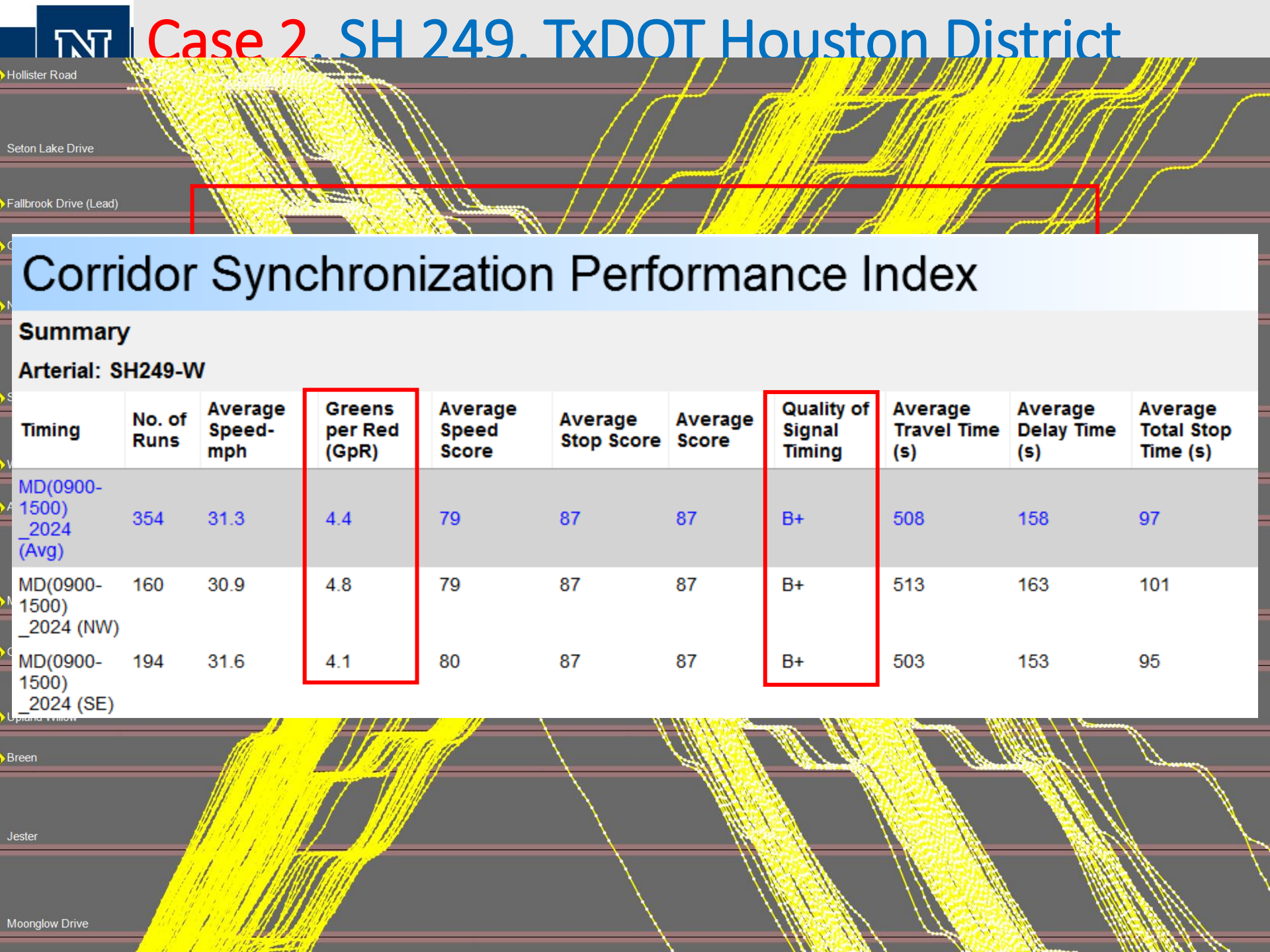
Calculation Parameters											
Before Timing Plan Name (No. of Runs)	After Timing Plan Name (No. of Runs)	Distance (feet)	Direction	Peak Hr VMT	Travel Time Before (s)	Travel Time After (s)	Speed Before (mph)	Speed After (mph)	Stop Before	Stop After	
PM (80)	PM_new (137)	8976	Southeast	10200	214	217	30	29	1.2	1.6	
PM (47)	PM_new (129)	8976	Northwest	8500	226	150	28	42	1.9	0.4	

Assumptions									
Time Value (\$/hr)	Fuel Cost (\$/gallon)	Operating Days	Maintenance Cost (\$/stop)	CO Emission Cost (\$/ton)	CO2 Emission Cost (\$/ton)	NOX Emission Cost (\$/ton)	PM10 EX Emission Cost (\$/ton)	ROG Emission Cost (\$/ton)	
\$13	\$3	250	\$0.03	\$23.00	\$0.00	\$13,646.00	\$110,258.00	\$954.00	



MD Peak
14 Signals
AADT=45,000





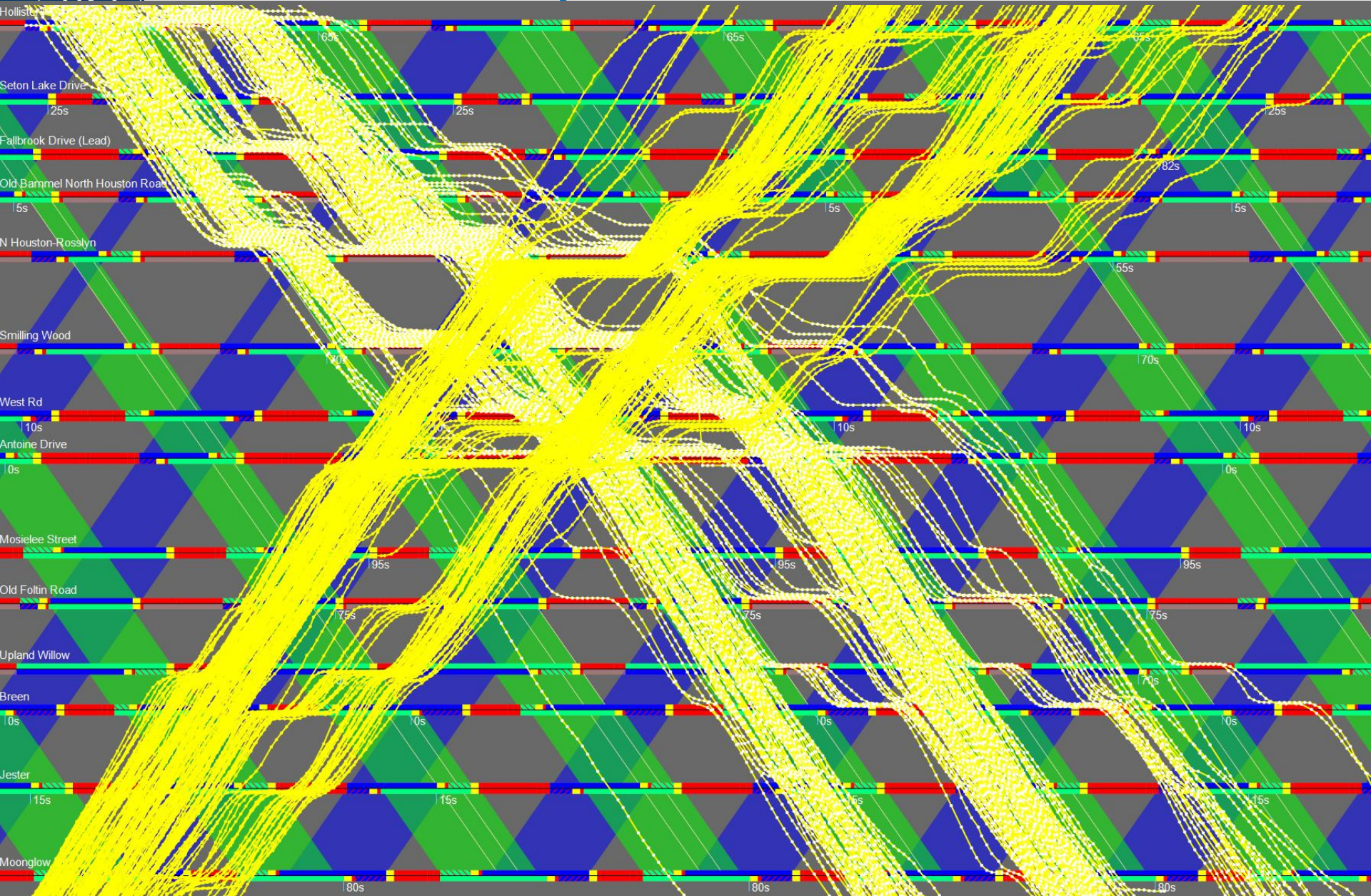
Case 2. SH 249. TxDOT Houston District

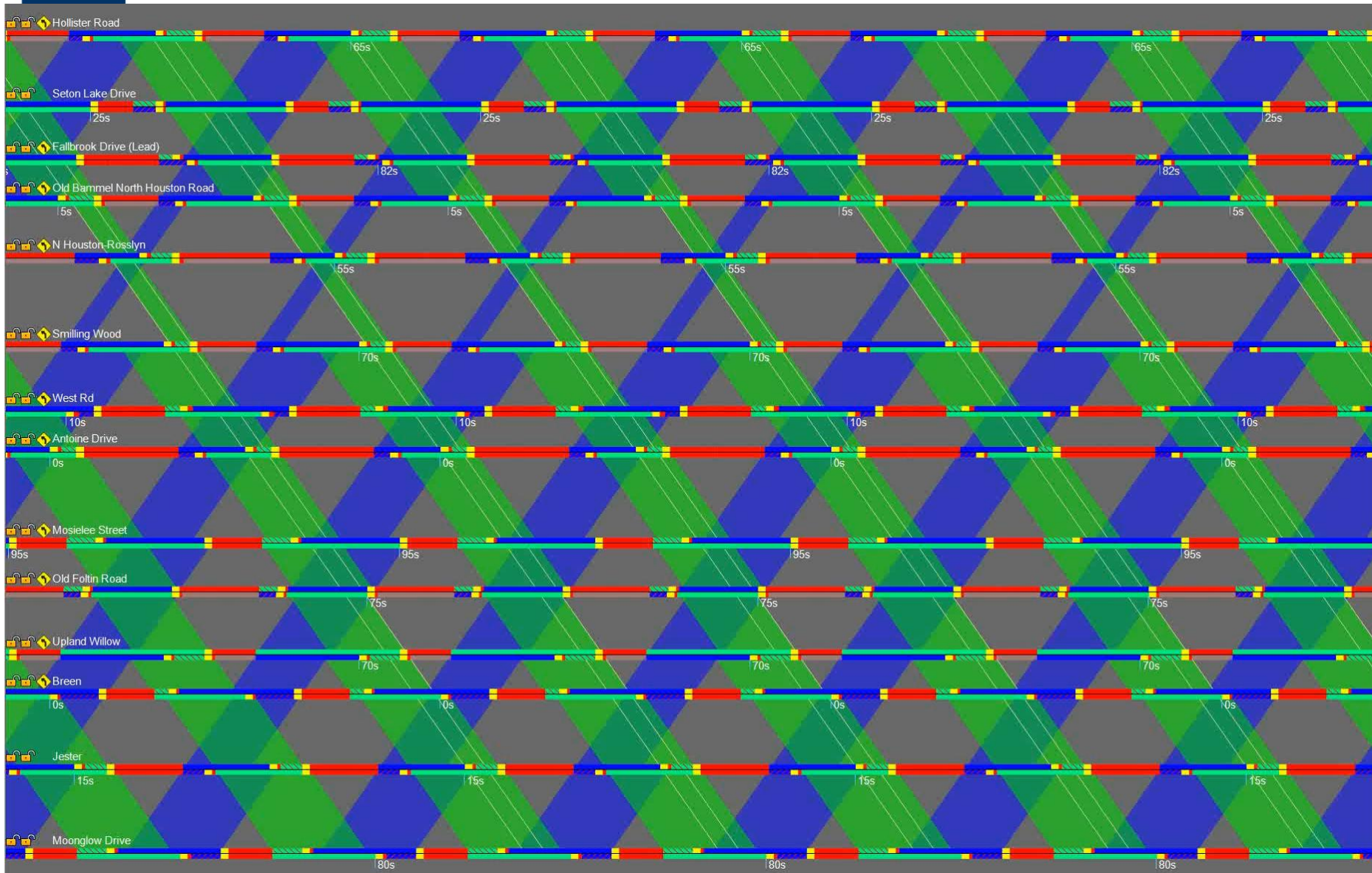
Corridor Synchronization Performance Index

Summary

Arterial: SH249-W

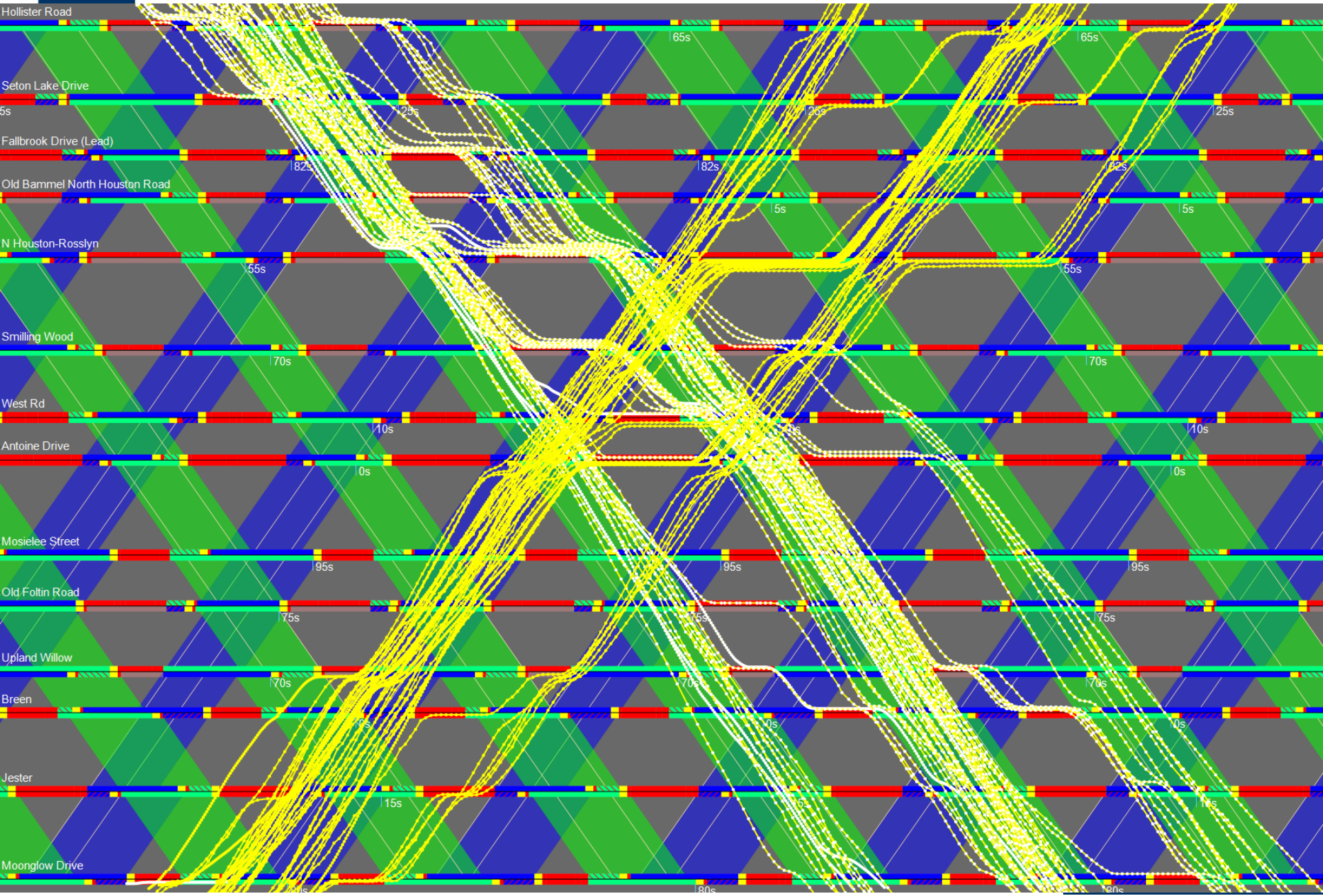
Timing	No. of Runs	Average Speed-mph	Greens per Red (GpR)	Average Speed Score	Average Stop Score	Average Score	Quality of Signal Timing	Average Travel Time (s)	Average Delay Time (s)	Average Total Stop Time (s)
MD(0900-1500)_2024 (Avg)	354	31.3	4.4	79	87	87	B+	508	158	97
MD(0900-1500)_2024 (NW)	160	30.9	4.8	79	87	87	B+	513	163	101
MD(0900-1500)_2024 (SE)	194	31.6	4.1	80	87	87	B+	503	153	95



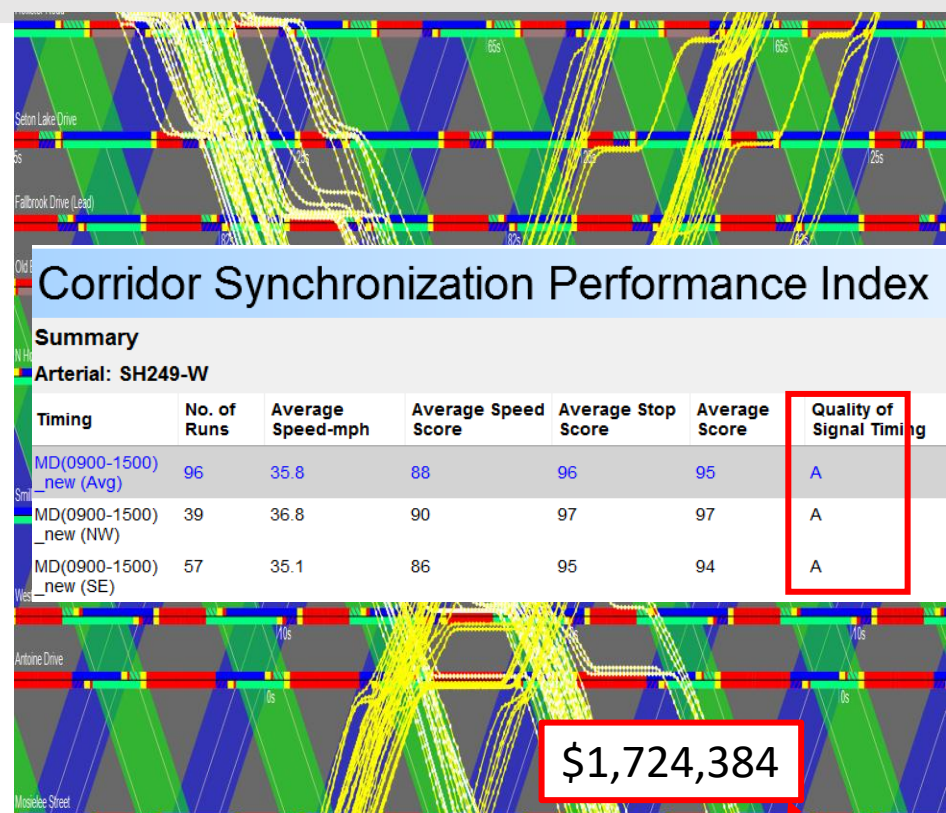
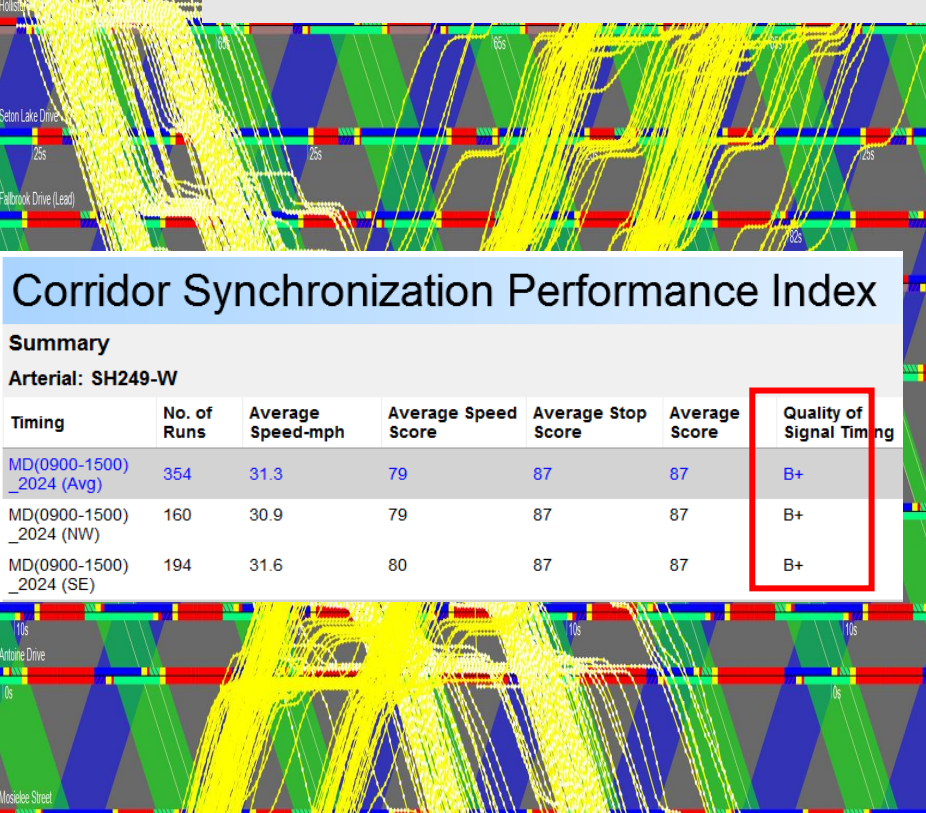


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Case 2. SH 249, TxDOT Houston District



Case 2. SH 249, TxDOT Houston District



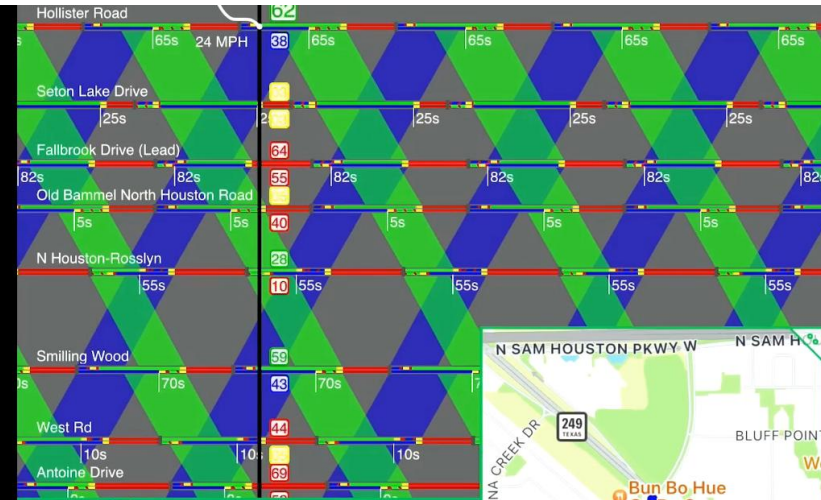
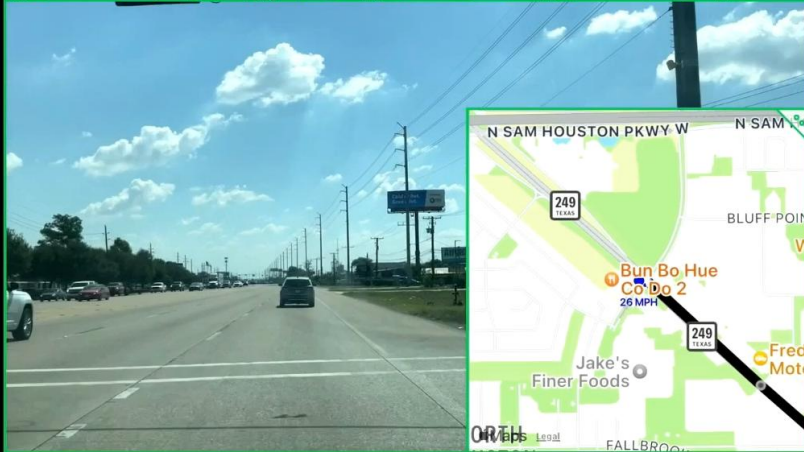
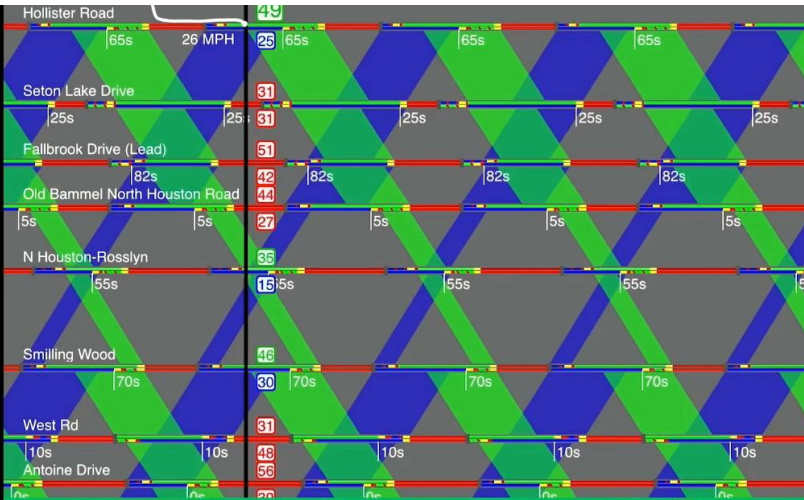
Corridor Before After Benefit Report

Summary of Annual Benefits										
Subsystem Name	Travel Time Savings	Fuel Consumption Savings	ROG Emission Reduction	NOx Emission Reduction	PM10 Emission Reduction	CO Emission Reduction	CO2 Emission Reduction	Vehicle Maintenance Savings	Total Benefits	
SH249-W	\$1,128,472	\$361,047	\$690	\$3,289	\$13,285	\$492	\$28,263	\$188,847	\$1,724,384	

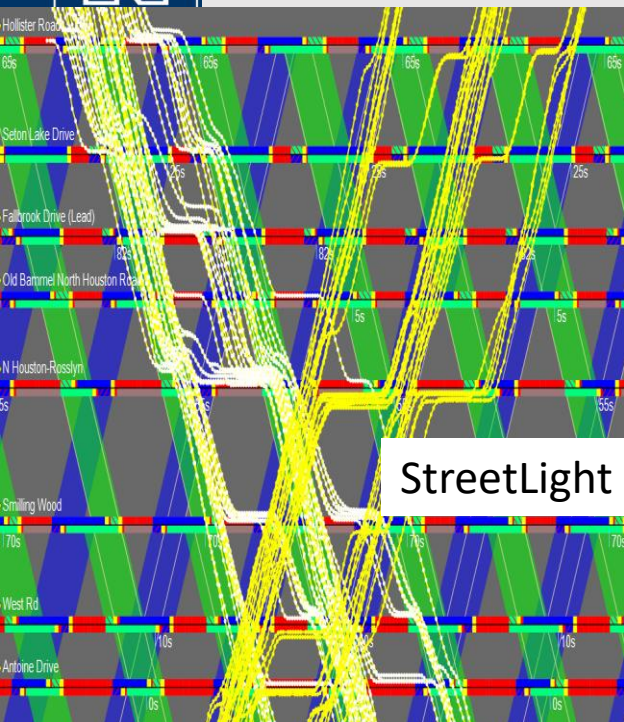
Benefit by Direction											
Before Timing Plan Name	After Timing Plan Name	Direction	Annual Affected VMT	Annual Travel Time Savings (hrs)	Annual Fuel Consumption Savings (gal)	Annual CO2 Emission Reduction (lbs)	Annual ROG Emission Reduction (lbs)	Annual NOx Emission Reduction (lbs)	Annual PM10 Emission Reduction (lbs)	Annual CO Emission Reduction (lbs)	Annual Benefit
MD(0900-1500)_2024	MD(0900-1500)_new	Southeast	10940814	31944 / \$415,278	45951 / \$137,854	938376 / \$10,791	482 / \$230	241 / \$1,644	0 / \$0	5784 / \$174	\$642,667
MD(0900-1500)_2024	MD(0900-1500)_new	Northwest	10940814	54861 / \$713,194	74398 / \$223,193	1519276 / \$17,472	964 / \$460	241 / \$1,644	241 / \$13,285	10603 / \$318	\$1,081,718

Calculation Parameters											
Before Timing Plan Name (No. of Runs)	After Timing Plan Name (No. of Runs)	Distance (feet)	Direction	Peak Hr VMT	Travel Time Before (s)	Travel Time After (s)	Speed Before (mph)	Speed After (mph)	Stop Before	Stop After	
MD(0900-1500)_2024 (194)	MD(0900-1500)_new (57)	23107	Southeast	43763	504	458	32	35	3.1	2.1	
MD(0900-1500)_2024 (160)	MD(0900-1500)_new (39)	23107	Northwest	43763	514	435	31	37	2.9	1.4	

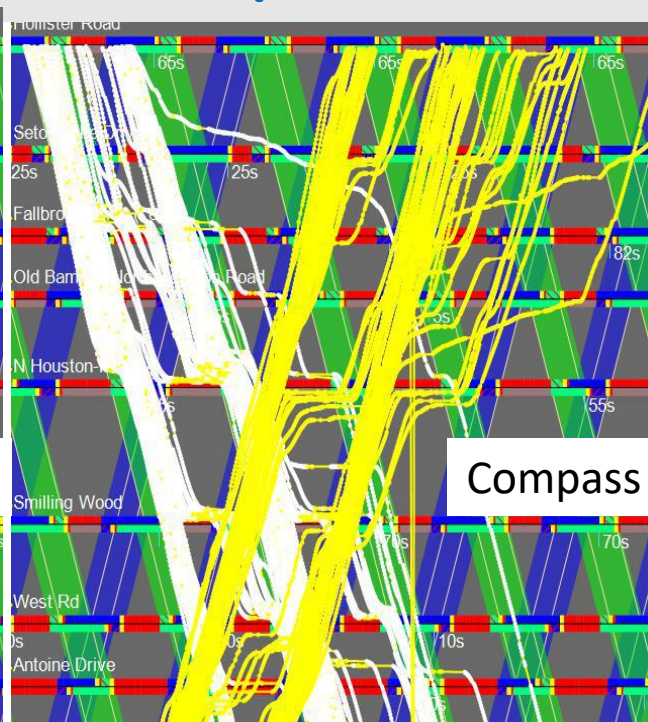
Assumptions										
Time Value (\$/hr)	Fuel Cost (\$/gallon)	Operating Days	Maintenance Cost (\$/stop)	CO Emission Cost (\$/ton)	CO2 Emission Cost (\$/ton)	NOx Emission Cost (\$/ton)	PM10 EX Emission Cost (\$/ton)	ROG Emission Cost (\$/ton)		
\$13	\$3	250	\$0.03	\$60.00	\$23.00	\$13,646.00	\$110,258.00	\$954.00		



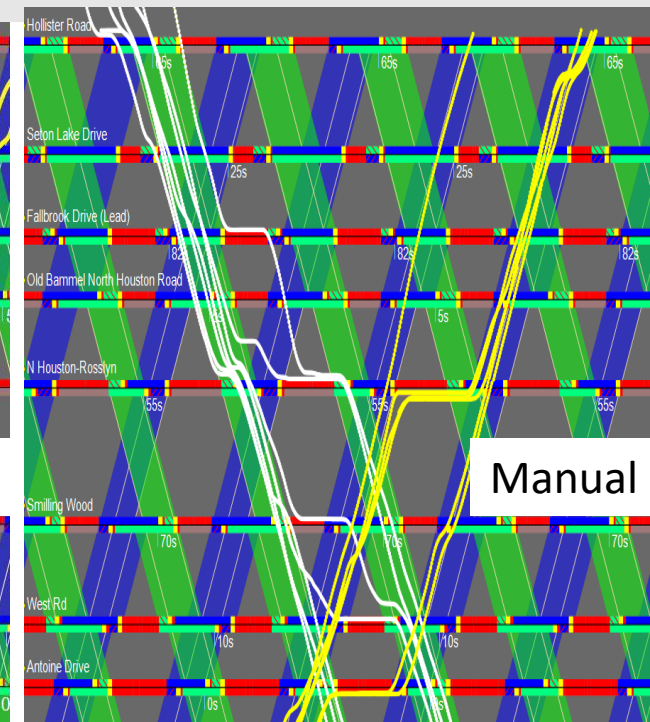
N Data Source Comparison: SH 249, TxDOT



StreetLight



Compass



Manual

Corridor Synchronization Performance Index

Summary
Arterial: SH249-W

Timing	No. of Runs	Average Speed-mph	Average Speed Score	Average Stop Score	Average Score	Quality of Signal Timing	Average Travel Time (s)	Average Delay Time (s)	Average Total Stop Time (s)
MD(0900-1500)_new (Avg)	83	35.8	88	95	95	A	448	99	56
MD(0900-1500)_new (NW)	33	37.2	90	97	97	A	429	79	49
MD(0900-1500)_new (SE)	50	34.9	86	94	94	A	460	111	61

Corridor Synchronization Performance Index

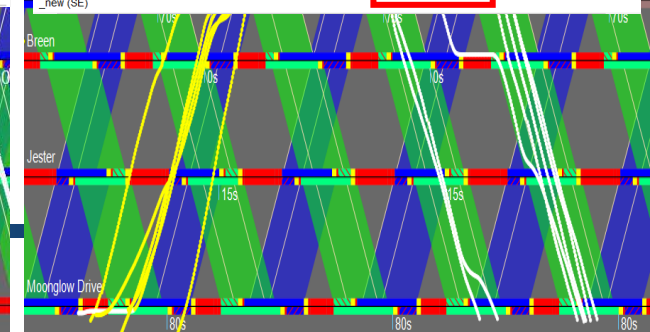
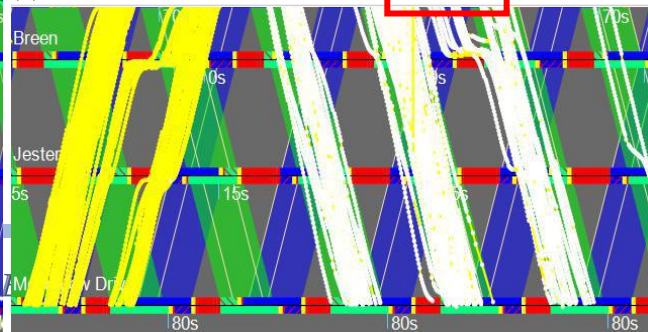
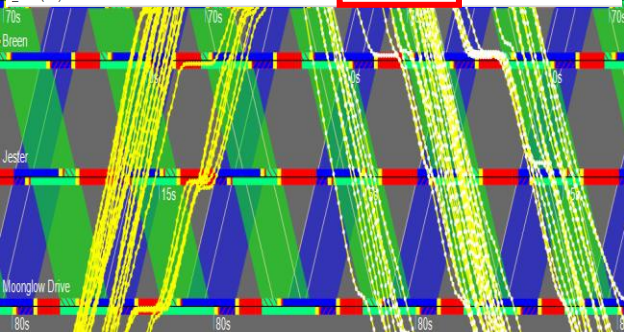
Summary
Arterial: SH249-W

Timing	No. of Runs	Average Speed-mph	Average Speed Score	Average Stop Score	Average Score	Quality of Signal Timing	Average Travel Time (s)	Average Delay Time (s)	Average Total Stop Time (s)
MD(0900-1500)_new_Compass (Avg)	198	38.3	91	97	97	A	420	72	36
MD(0900-1500)_new_Compass (NW)	75	38.7	92	97	97	A	417	70	33
MD(0900-1500)_new_Compass (SE)	123	38	91	97	97	A	422	74	39

Corridor Synchronization Performance Index

Summary
Arterial: SH249-W

Timing	No. of Runs	Average Speed-mph	Average Speed Score	Average Stop Score	Average Score	Quality of Signal Timing	Average Travel Time (s)	Average Delay Time (s)	Average Total Stop Time (s)
MD(0900-1500)_new (Avg)	13	35.6	88	97	97	A	449	99	56
MD(0900-1500)_new (NW)	6	34.6	85	98	96	A	463	113	62
MD(0900-1500)_new (SE)	7	36.4	90	97	97	A	437	86	51



Questions?

