Retime: PTV Vissim – A demo of a novel way to optimize traffic signals in complex urban networks

Aleksandar Stevanovic, Ph.D., P.E.,
Associate Professor, University of Pittsburgh
Senior Technical Advisor, Retime LLC

PTV Talks – A Webinar Series of PTV Group
December 17, 2020

Presentation Overview

- Presentation approach – switching between Retime web platform and PowerPoint presentation
- **>> Start optimization**
- Current practices in traffic signal retiming
- Stochastic simulation as a core of signal optimization
- Brief intro in Genetic Algorithms
- Cloud Computing and its opportunities
- Retime.online - SaaS platform for traffic signal optimization
- Future work

What is a Common State of Practice?

- Collect traffic data once (or couple times) per year
- Feed the data into one of deterministic models (e.g. Synchro, HCS)
- Optimize traffic signals for almost car-exclusive conditions (no transit and bikes, limited pedestrian dynamics)
- Adopt some signal timing parameters and throw away the others (some agencies use deterministic tools only for cycle length, other almost exclusively for coordination and bandwidths)
- Everybody understand – “little in, little out” (to avoid using stronger words)
- Finally, extensive fine-tuning in the field…
- …and bad reputation given to modeling (“Why model when you can measure?”)

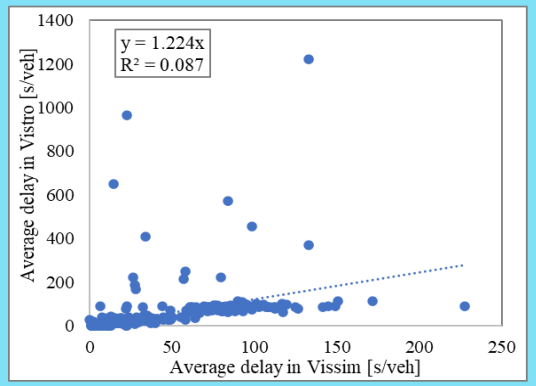
Overall Goal of the Concept

- Take traffic signal optimization to the next level – traffic signal optimization uses analytical modeling not because this is good but because it is quick approach and we have not offered anything better, yet
  - E.g. if HCS software cannot model multimodal operations, why do we use HCS software to optimize signals in areas where we care so much about **multimodal operations**?
- Unlike traffic impact and other evaluation studies, traffic signal optimization never moved away from analytical tools to the use of microsimulation models
- Microsimulation's time is coming – biggest challenge is how to quickly generate, calibrate, and validate models - AI and data analytics tools will help in these activities

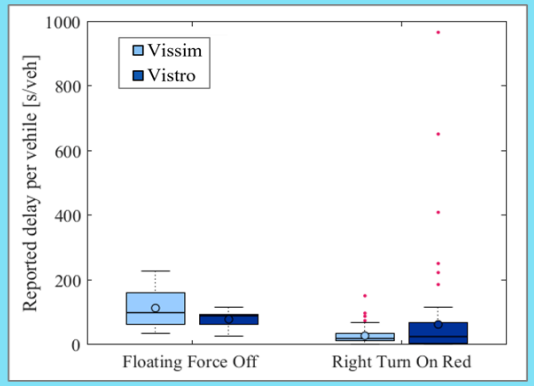
Why use Vissim to Optimize Signals?

- Choose your Objective Function (Optimization Criteria) or Functions
- Field-like traffic controllers
- Model that can be trusted (if properly calibrated & validated)
- Tests with realistic traffic conditions (transit, pedestrian, bicyclists)
- Oversaturation can be modeled
- Queues are real and have the dimension (length, not height )
- Does not spill congestion to a nearby, not-optimized, network (latent demand and delay can be taken in consideration)
- An all-at-once optimization (not sequential)
- Possibility to connect with ATSPM outputs

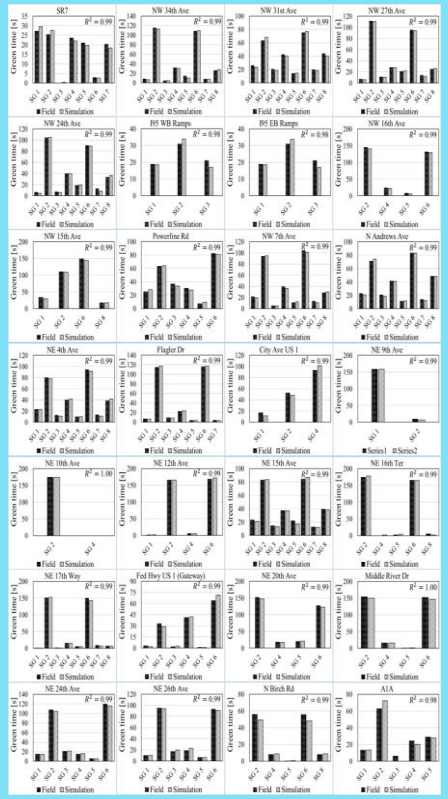
Simulation versus Analytics

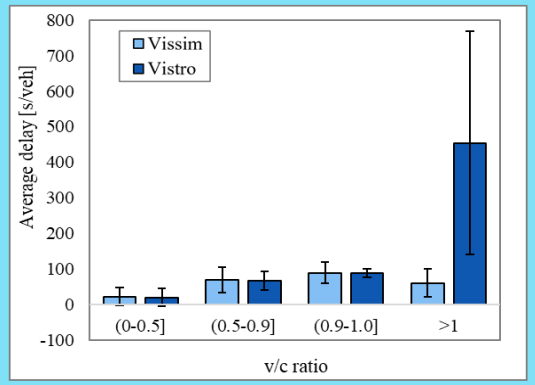


a) Vissim/Vistro delays all movements

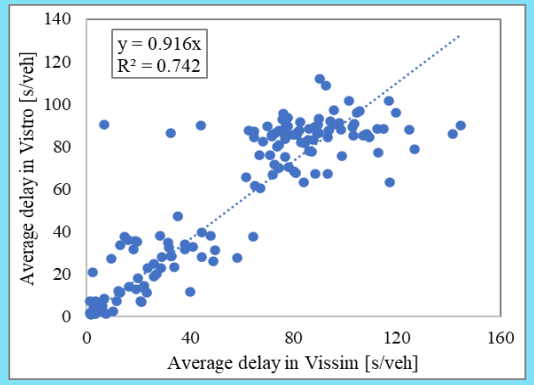


b) Vissim/Vistro delays for specific signal/field operations



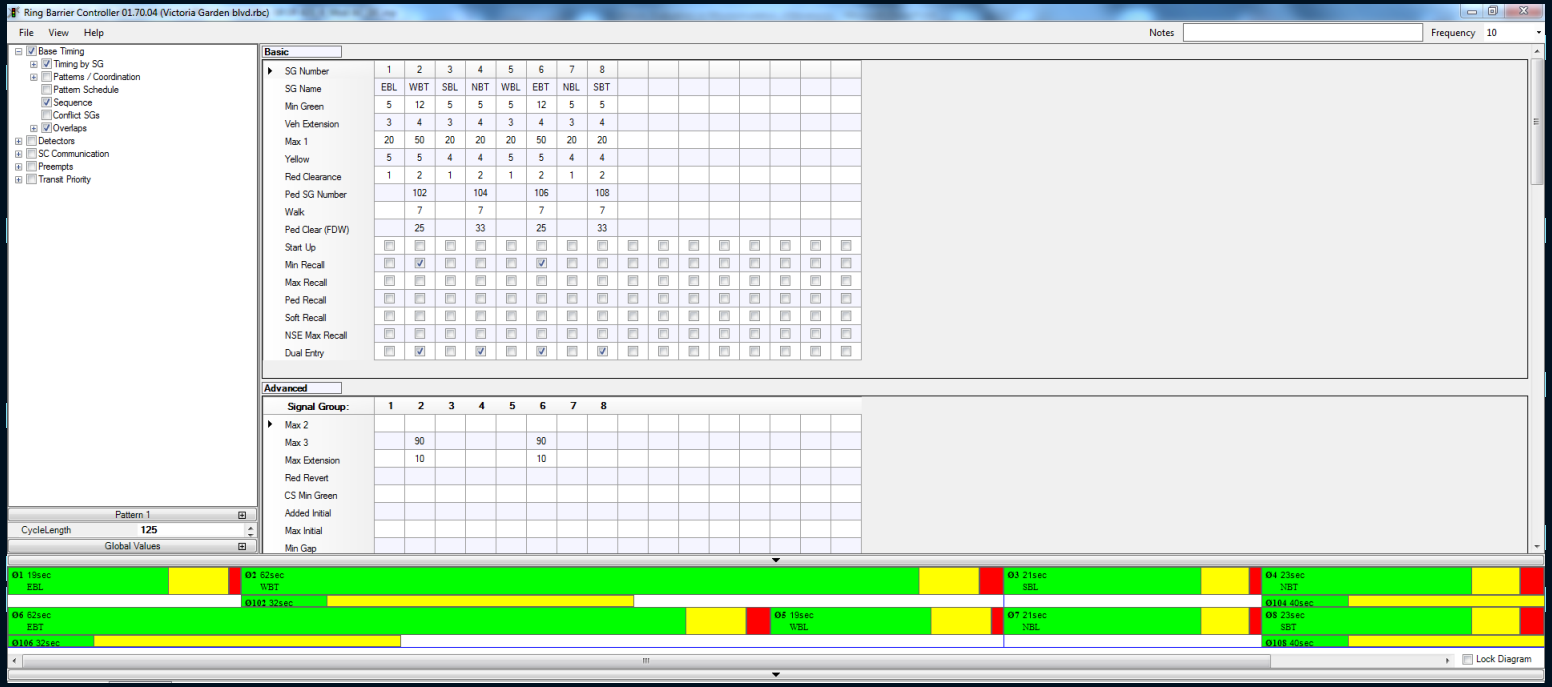


c) Vissim/Vistro delays for different v/c ratios



d) Vissim/Vistro delays without main outliers

Field-like Ring-Barrier Controllers



Shortcomings of Stochastic Optimizations

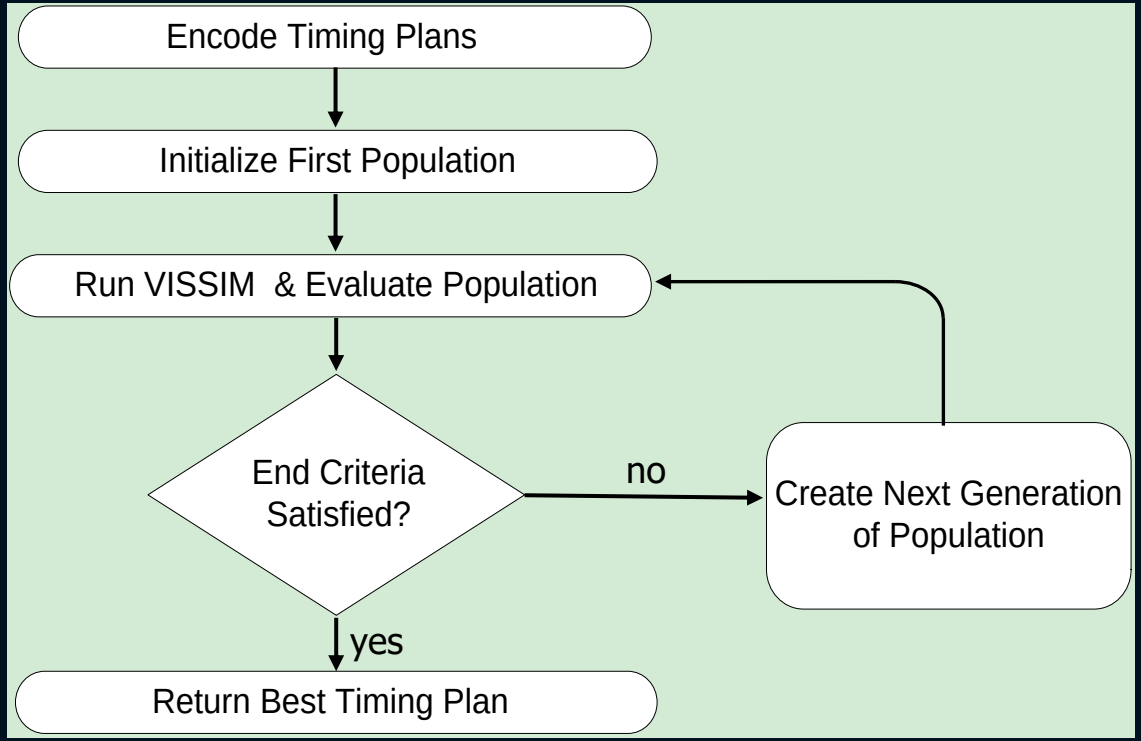
- Long optimization time – with cloud computing can be few hours or over the night
- Objective Function is difficult to choose – users can explore how various signal solutions perform and pick and choose one they like
- Tedious to properly calibrate & validate a model – new data sources and AI algorithms may help us to prepare model inputs quickly
- Curse of multimodal operations – if a transit service works as preemption what is to optimize? – we can optimize signals around to make the best out of operations constrained by transit preemption
- No guarantee that the optimal solution is found – deterministic tools guarantee that the real optimal solution is NOT found

EVOLUTIONARY OPTIMIZATION (CHECK WEB)

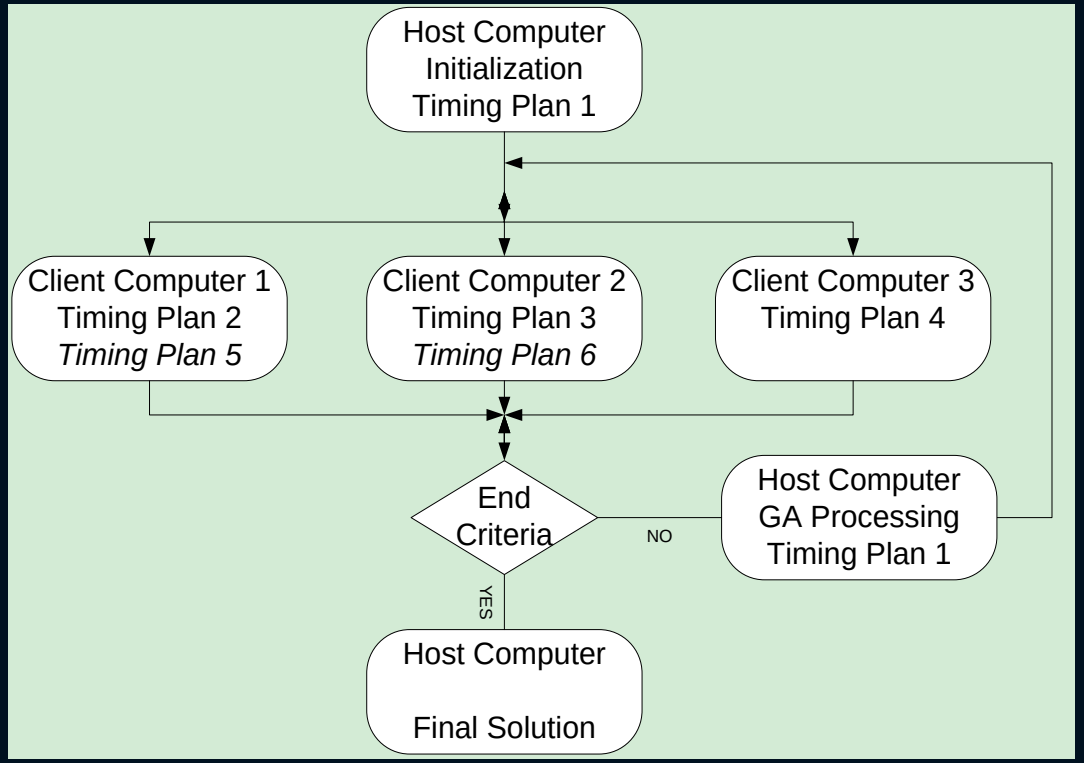
A Brief Intro to Genetic Algorithms

- A technique for solving search and optimization problems
- Solutions are evolved through several generations
- A stochastic search process based on survival of the fittest
- Mimics natural evolution
- The best solutions are preserved through generations
- GAs are in general independent from the specific problem

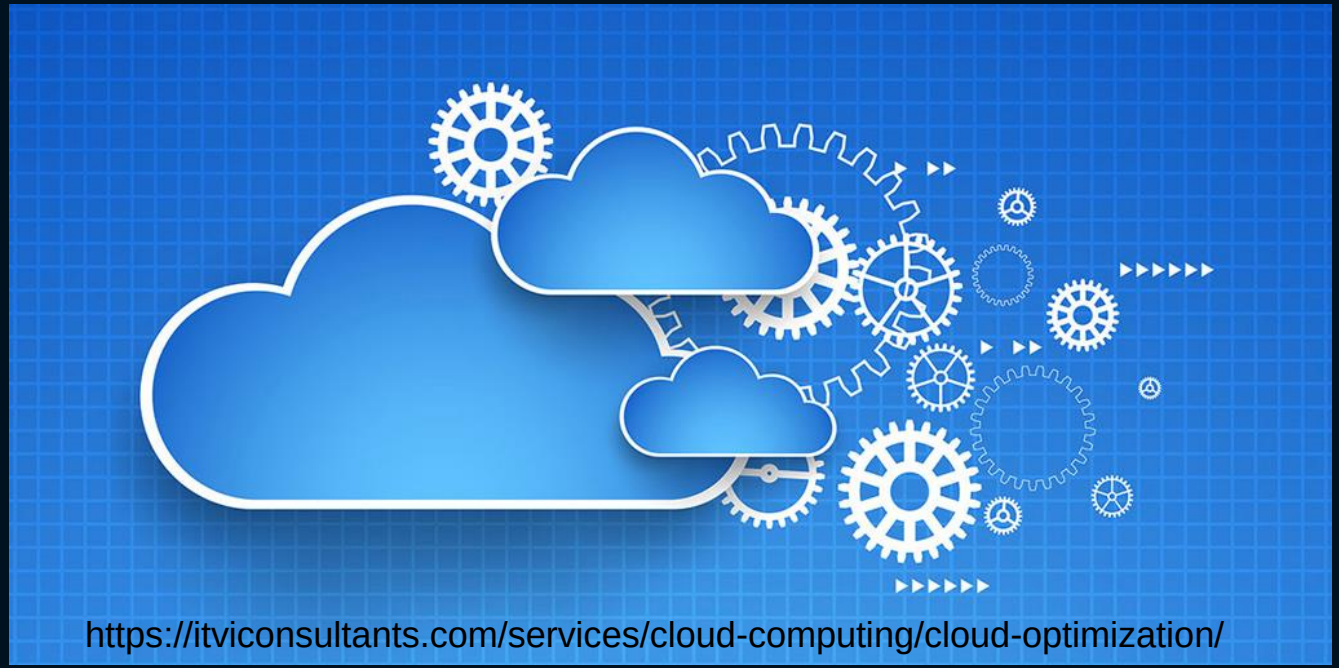
VISSIM-based GA Optimization of Signals



Distributed GA Processing

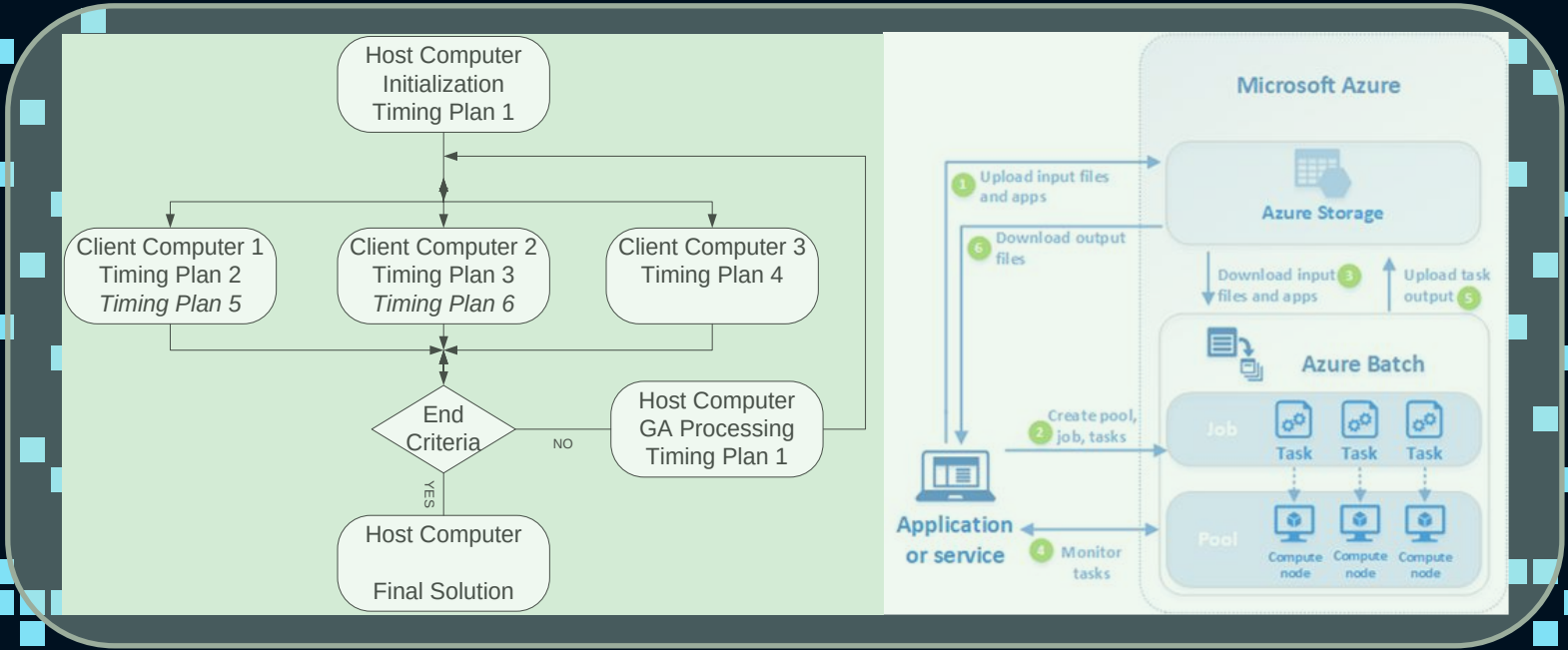


Enables Tremendous Computation Resources



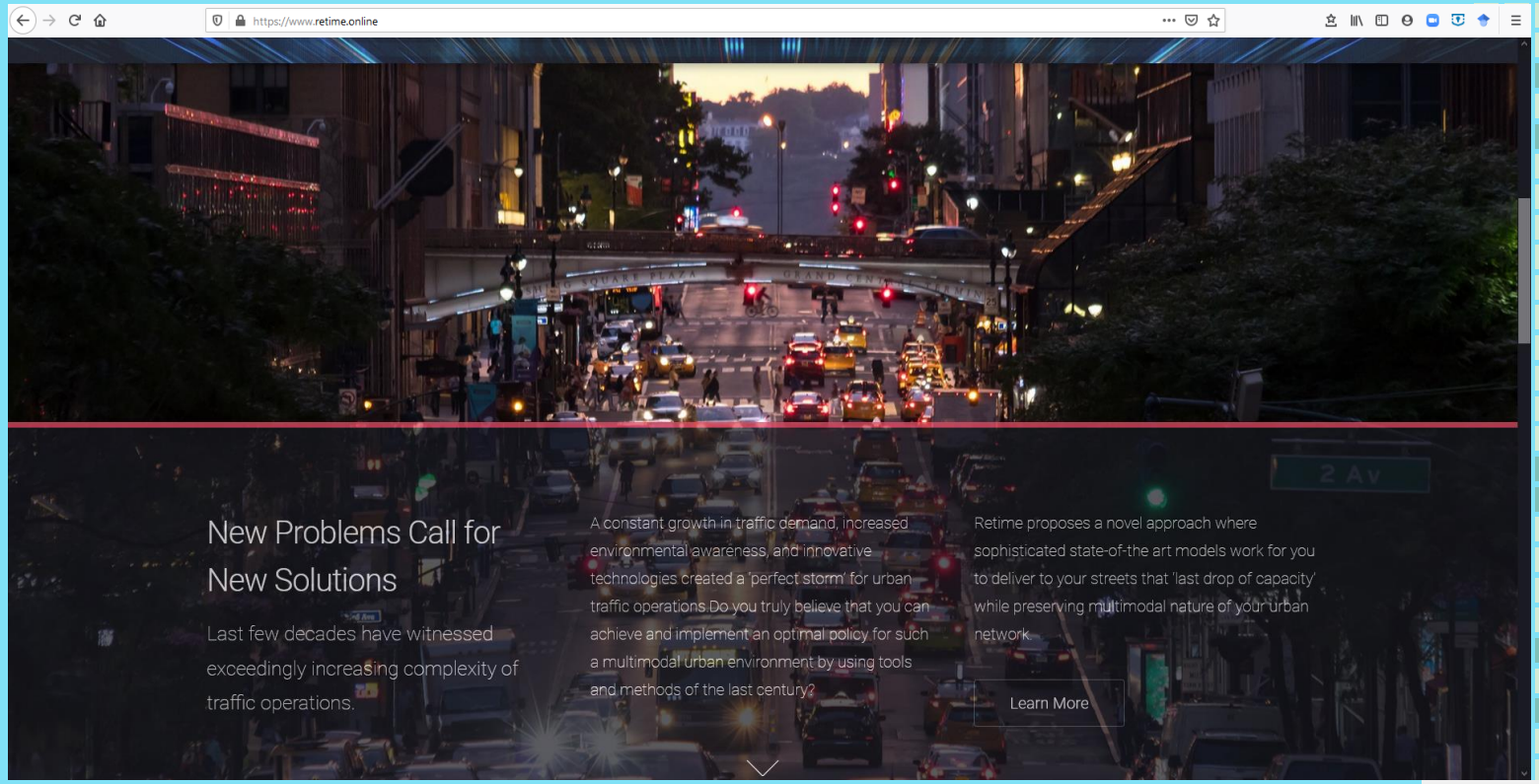
https://itviconsultants.com/services/cloud-computing/cloud-optimization/

Merging Parallel GAs with MS Azure



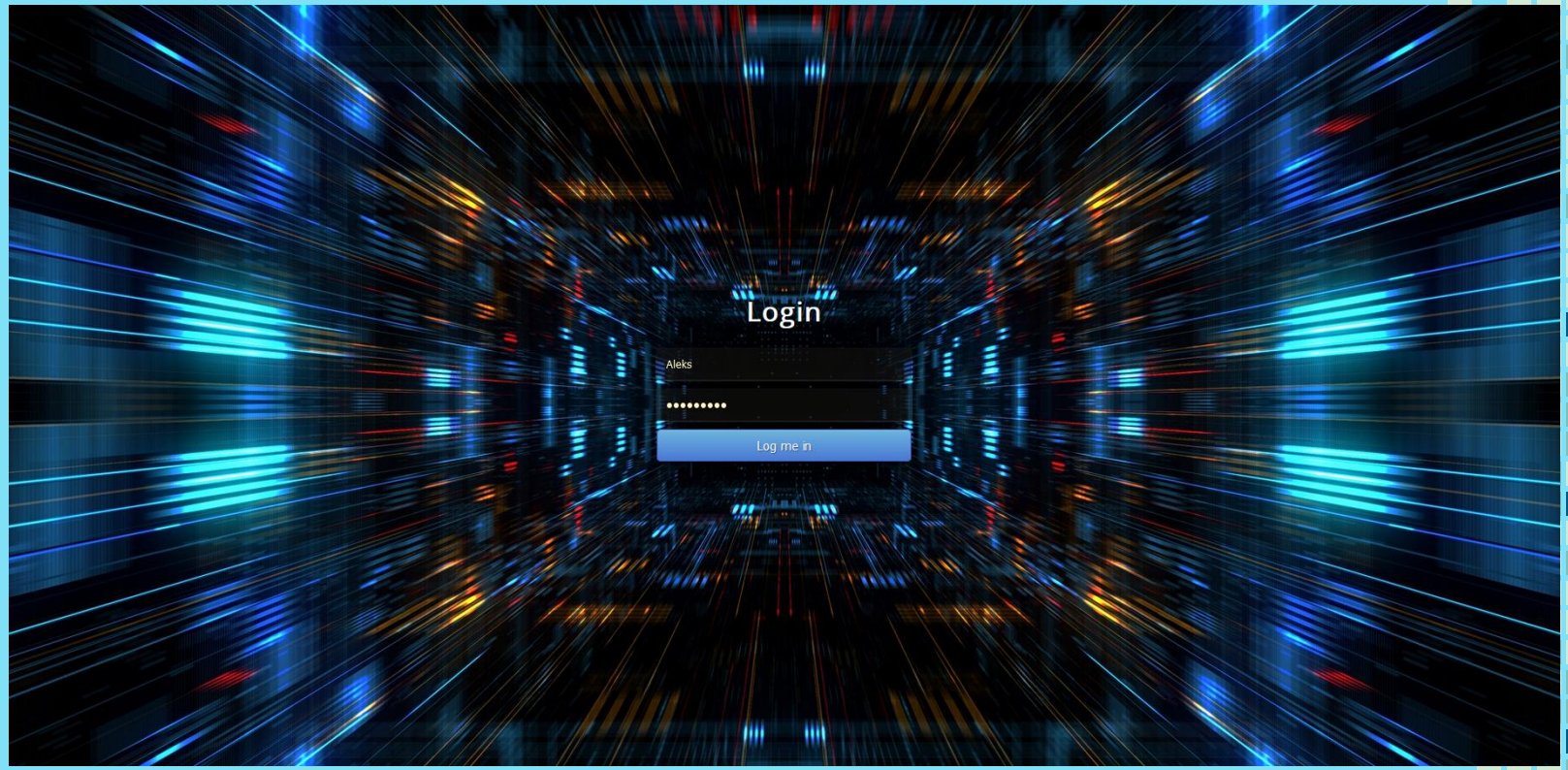
OPTIMIZATION PROCESS (CHECK WEB)

Retime.online Website

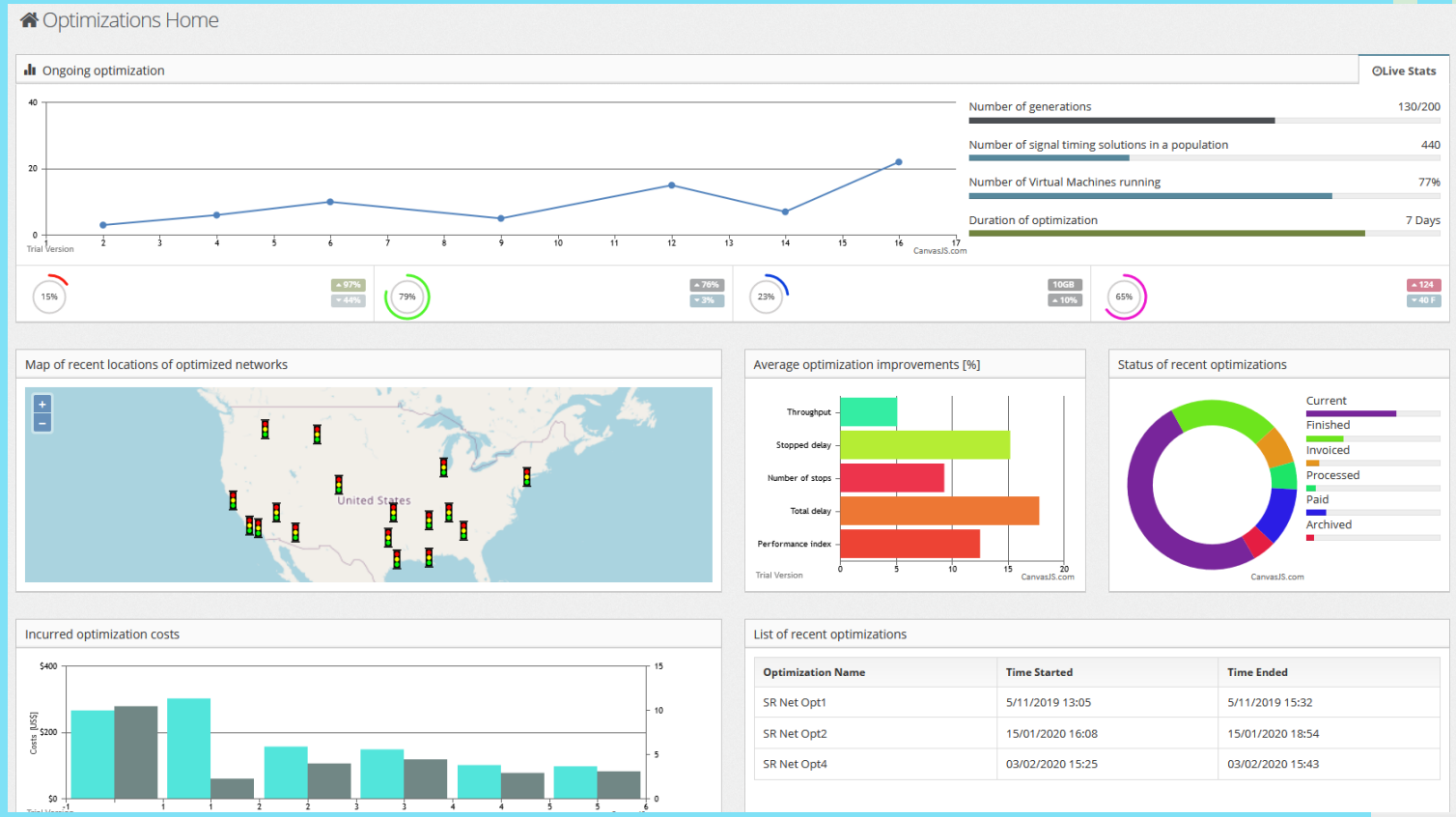


https://www.retime.online/

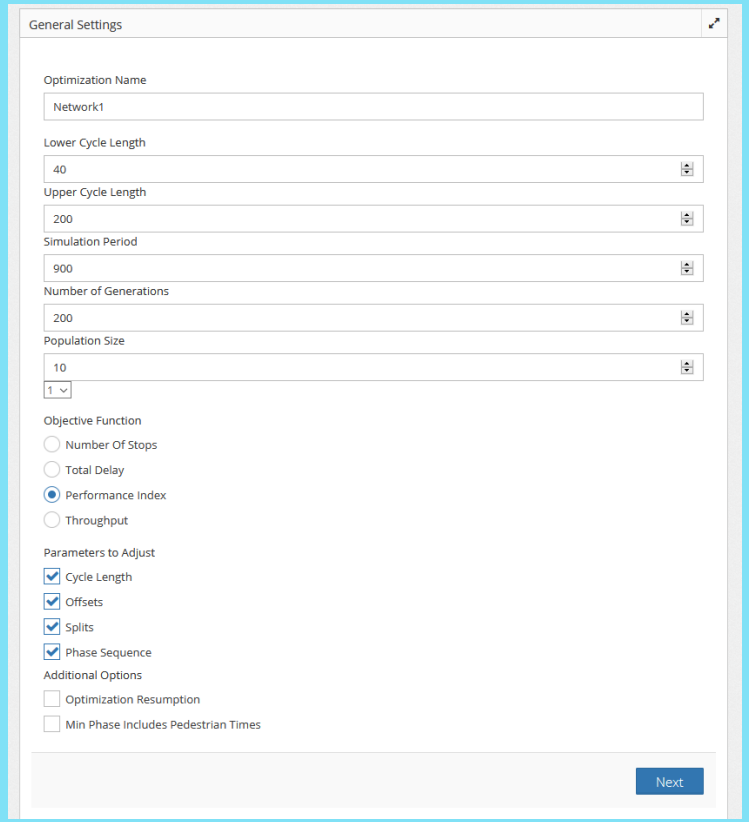
Login with your User Credentials



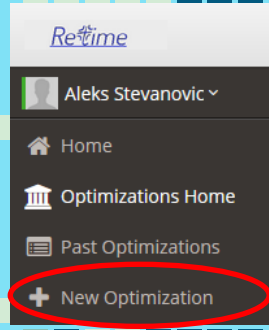
Homepage for Logged Users



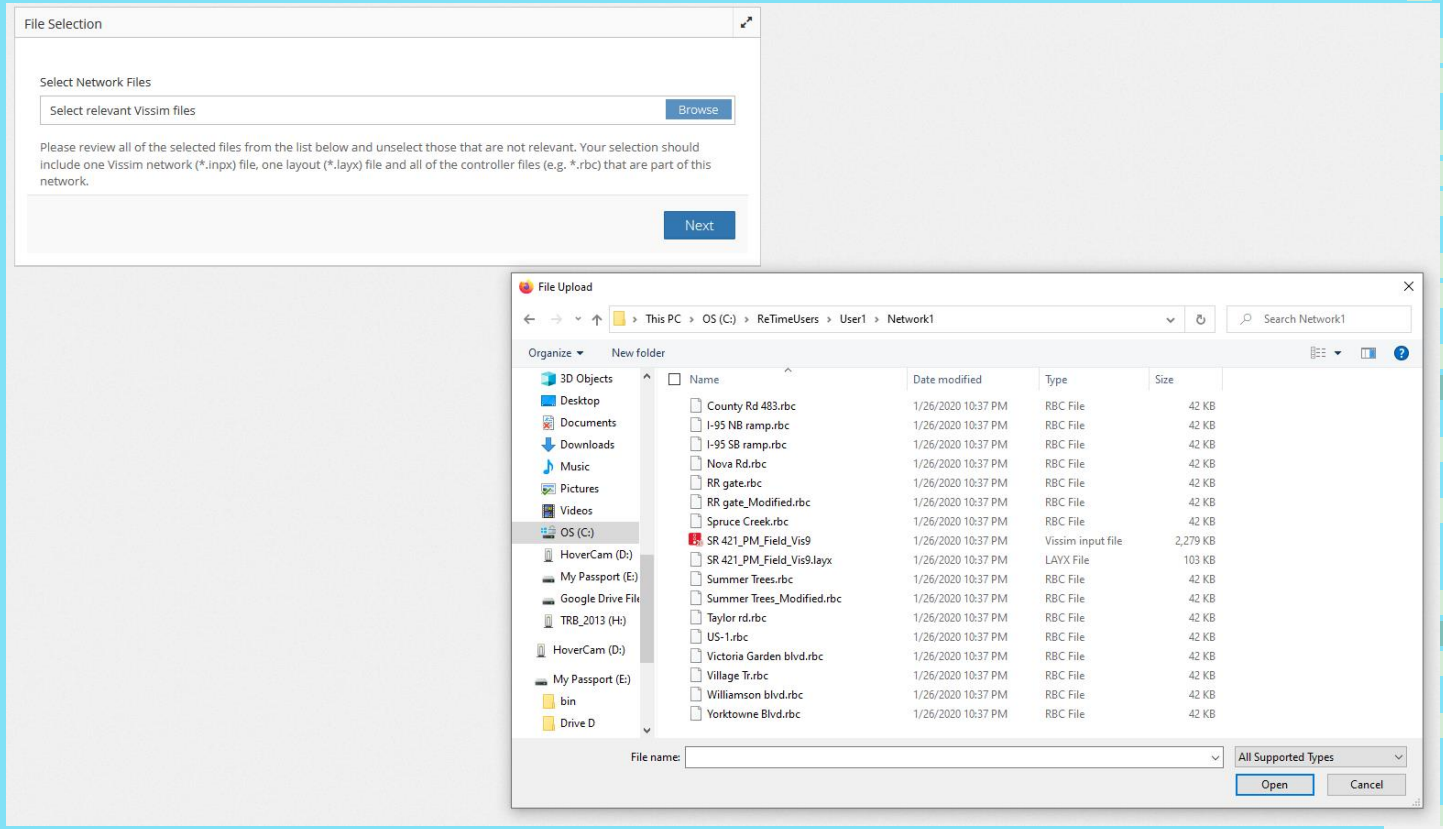
Enter General Optimization Settings



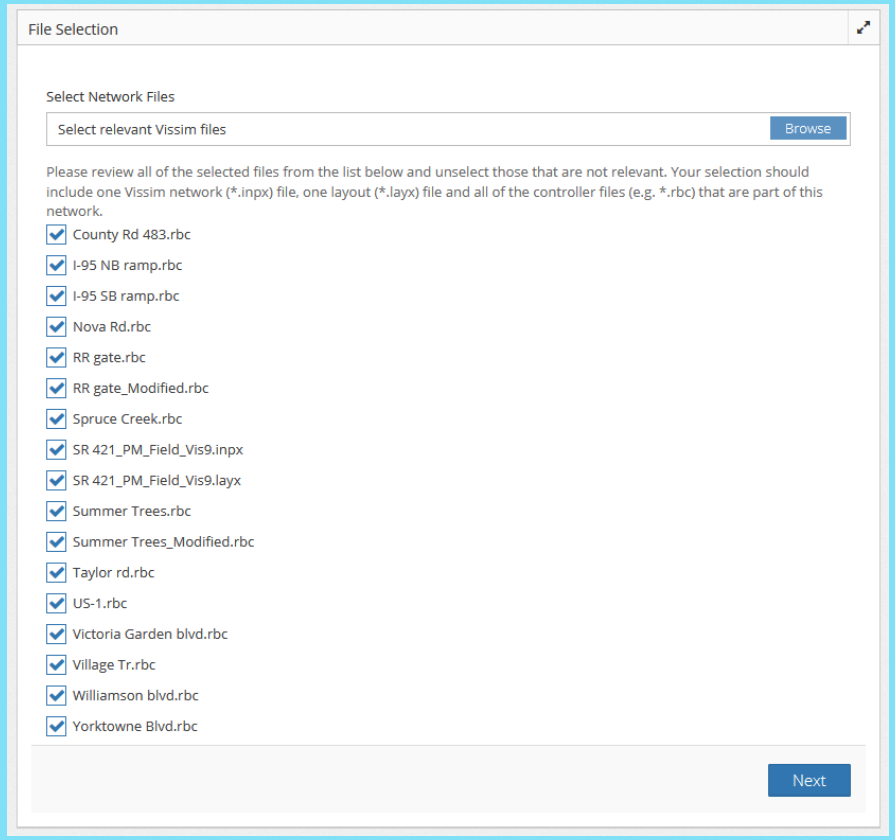
- Name your optimization
- Define range for cycle length
- Define duration of simulation
- Define population & generation numbers for GA optimization
- Select performance measure as an objective function (to be minimized or maximized)
- Select types of signal timings that you want to modify
- Define how you want to treat pedestrian operations



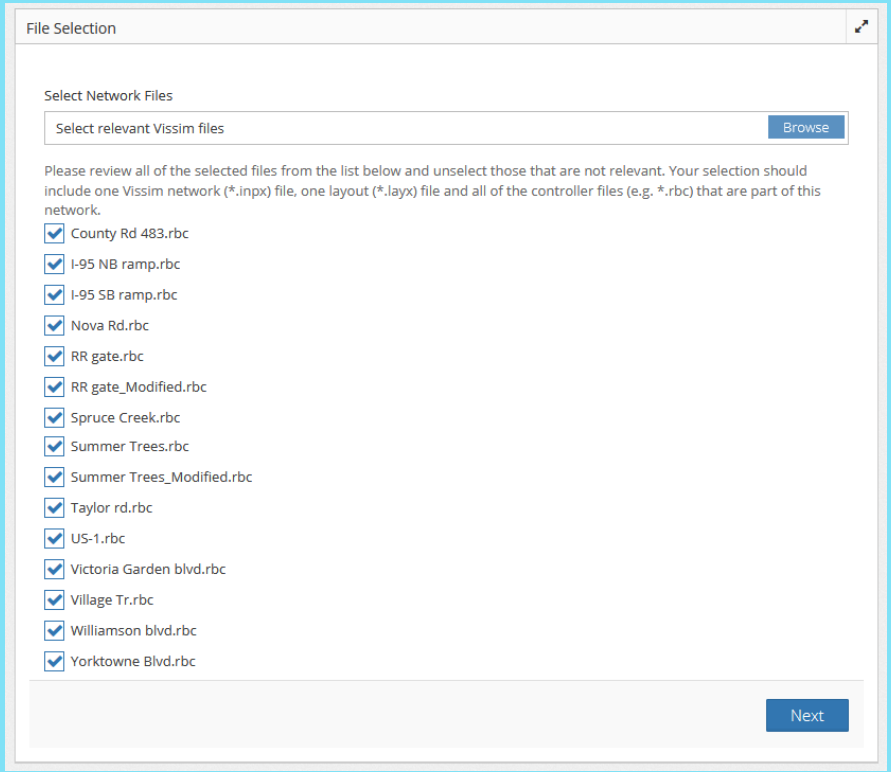
Select Relevant Vissim Files



Confirm Vissim File Selection



Select Controllers to be Optimized



Optimization Starts – Status Page

Current Optimization Task

Current Optimization Status

Population 3 (out of 3) is generated and a new set of 20 solutions is being transferred to the cloud for simulation.

Stop optimization

Vissim Simulations

Sim

Simulations

- **Running** - 20
- **Completed** - 0

- **Total** - 80
- **Completed** - 60
- **Failed** - 0

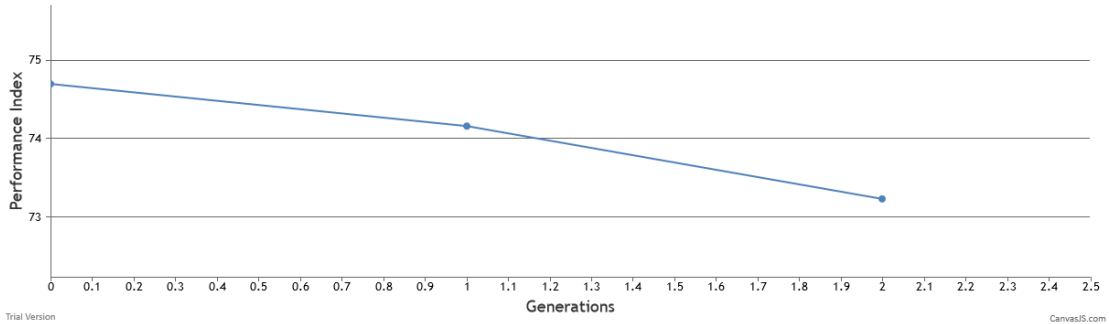
Virtual Machines

VM

Virtual Machines

- **Total** - 50
- **Active** - 20
- **Idle** - 30
- **Stopped** - 0

Current Objective Function



Optimization Facts

Basic Information	
Agency	
User	
Optimization	
Number of signals	
Number of coordinated groups	
Performance Measures	
Total delay [h]	56.52
Total stopped delay [h]	37.81
Delay latent [h]	282.5
Delay per vehicle [s]	61.36
Stopped delay per vehicle [s]	61.36
Performance Index	73.23
Number of stops	5,989
Stops per vehicle	1.81

Best Current Signal Timings

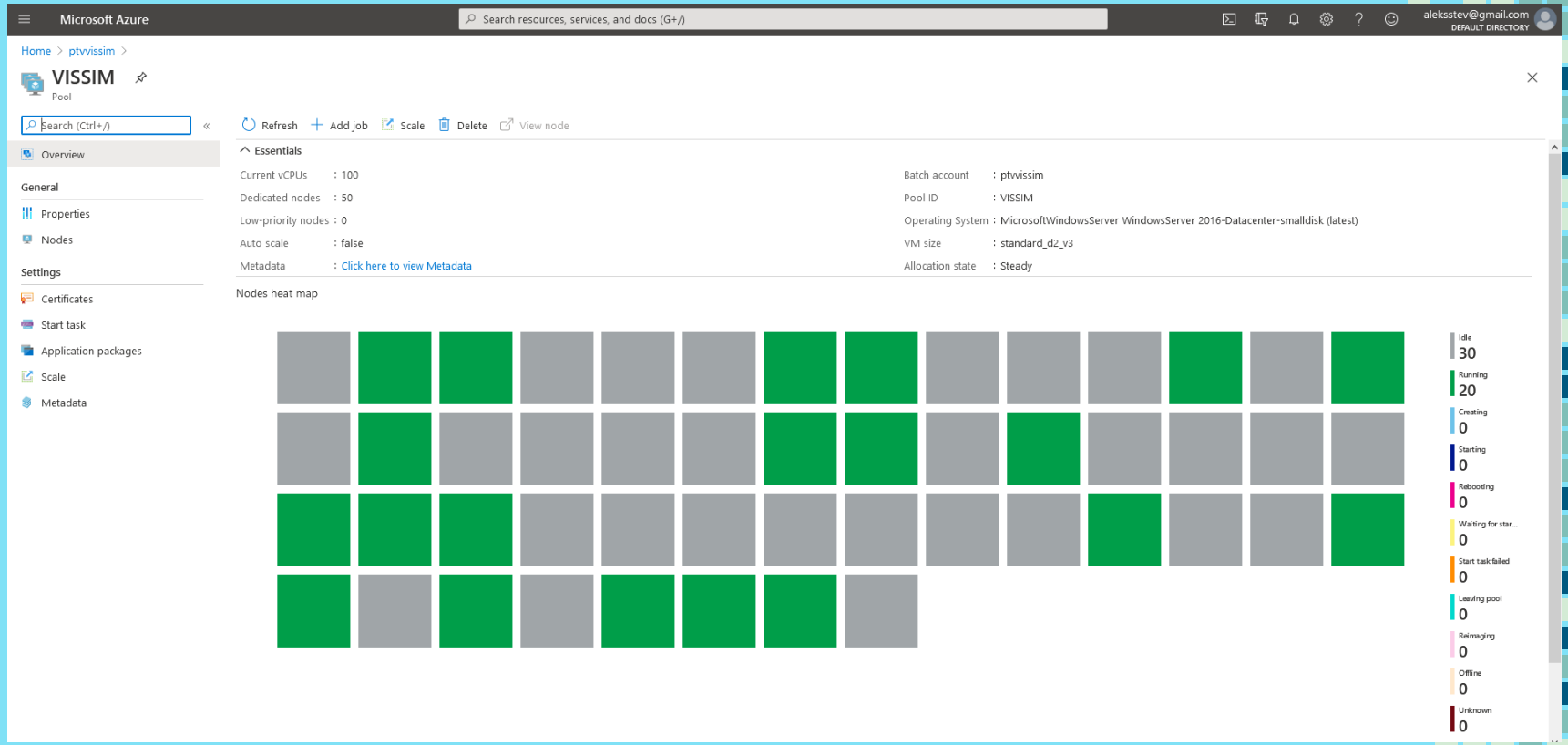
Signal Id	Signal name	Cycle	Offset	Split 1	Split 2	Split 3	Split 4	Split 5	Split 6	Split 7	Split 8	R1.B1	R1.B2	R1.B3	R1.B4	R2.B1	R2.B2	R2.B3	R2.B4
1	SR421_Williamson	98	42	16	39	23	20	30	25	14	29	2	1	4	3	5	6	7	8

Retime

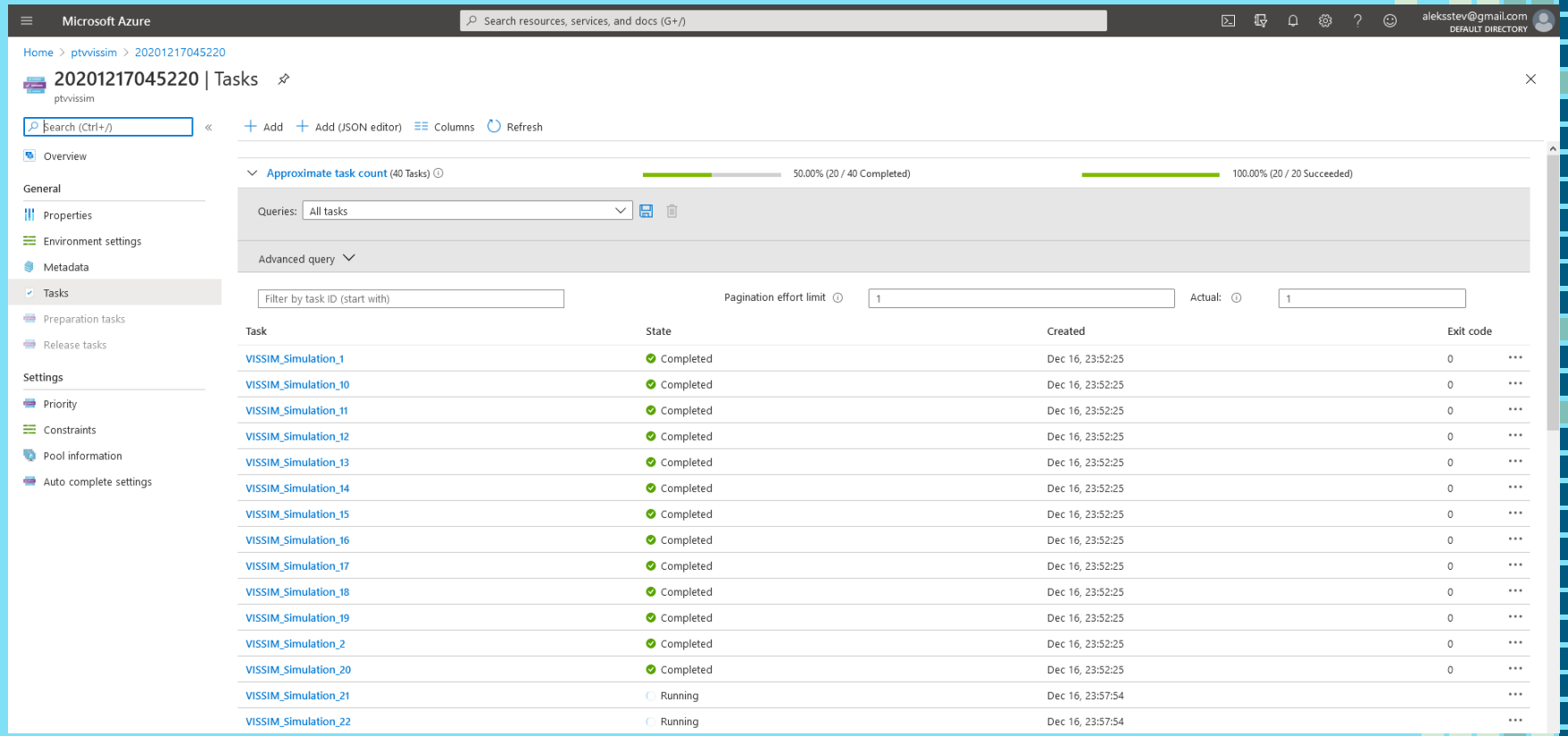
Optimization Process on MS Azure Cloud

- It takes a few minutes to start all of the Virtual Machines on the cloud
  - User defines how many +
  - More VMs – faster optimization but more expensive
- Vissim network is loaded
- Current signal timing plans from Vissim network are used as a seed to create others (defined by Population size)
- The first GA generation runs – a simulation is run on a VM for each solution in the population
- The best solution in each generation is preserved while the others are recombined
- The process continues until the Number of Generations is reached

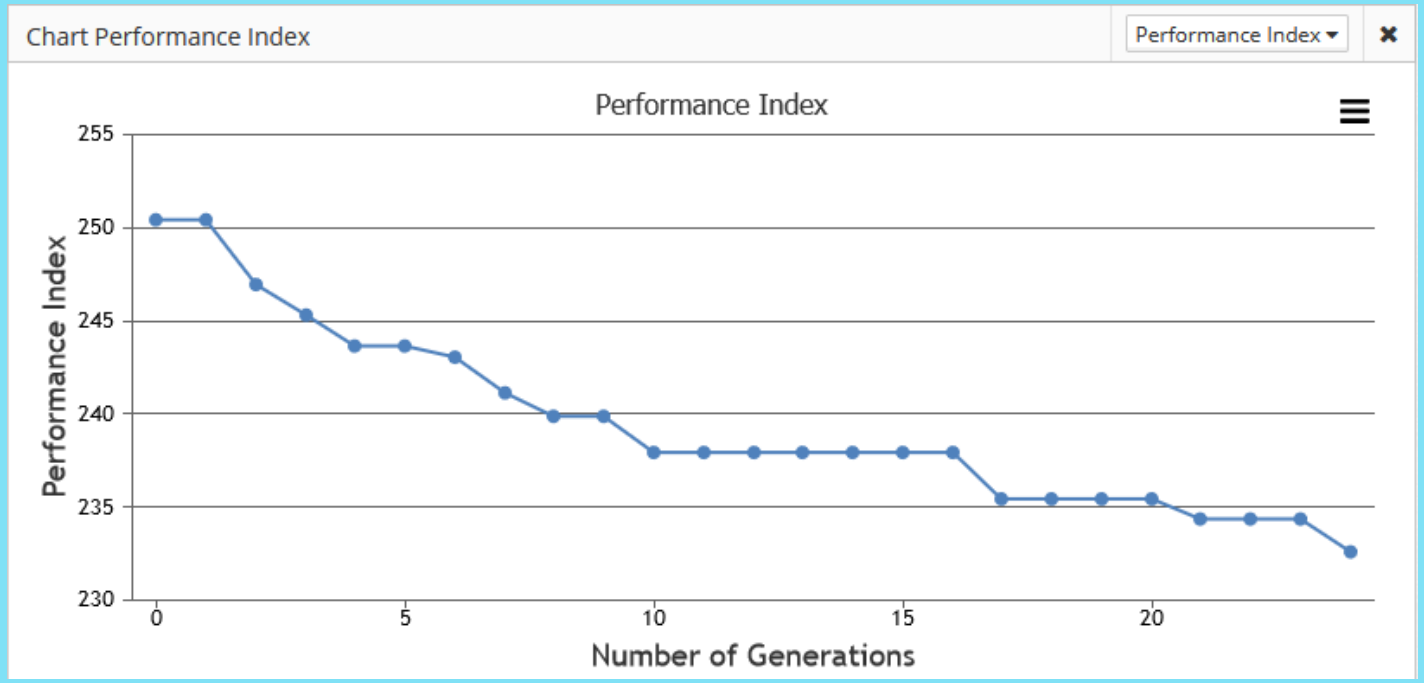
VM Nodes on MS Azure



VM tasks on MS Azure



Charts Updated Automatically



Optimization Facts

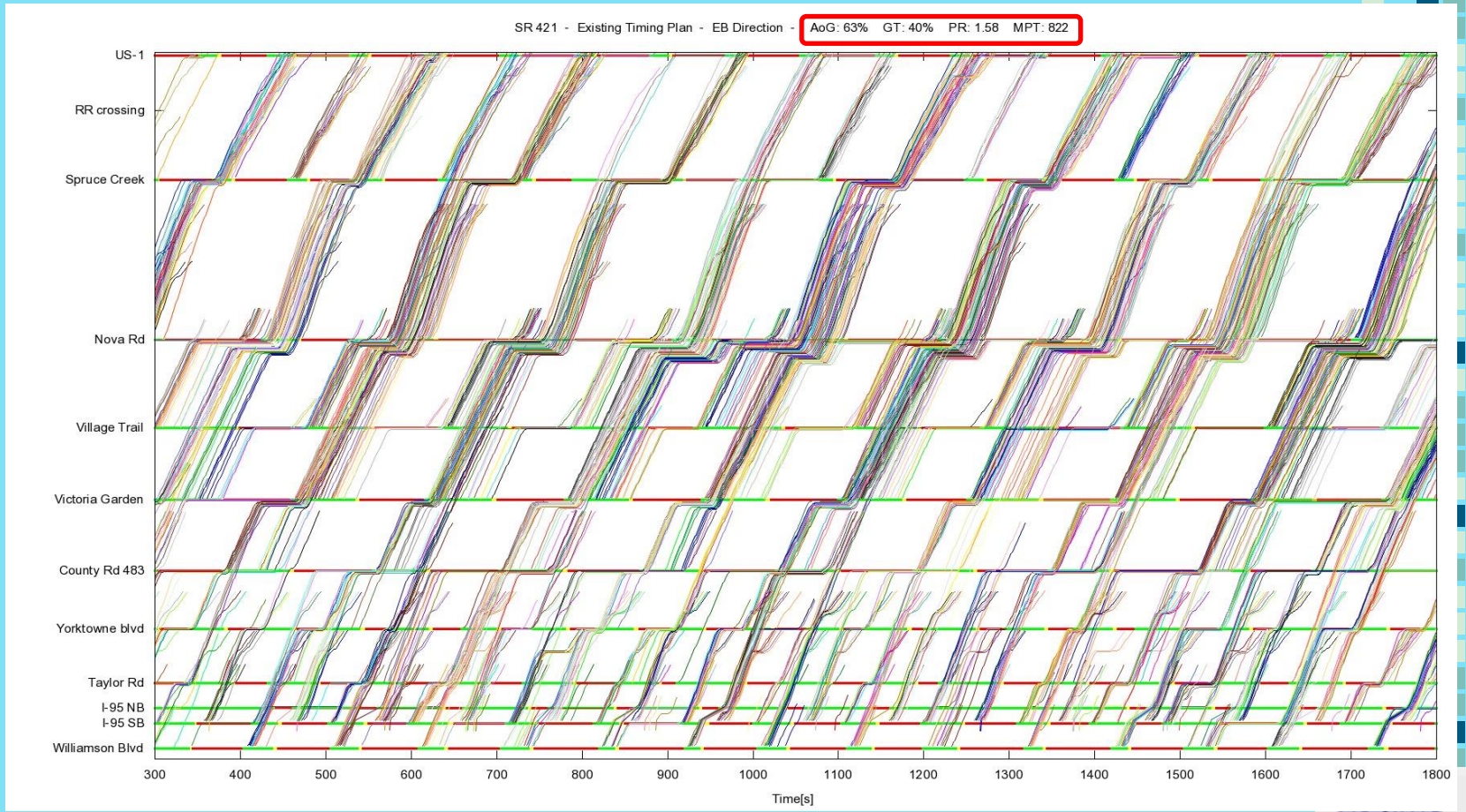
Basic Information	
Agency	
User	
Optimization	
Number of signals	
Number of coordinated groups	
Performance Measures	
Total delay [h]	54.1
Total stopped delay [h]	36.2
Delay latent [h]	285.8
Delay per vehicle [s]	58.73
Stopped delay per vehicle [s]	58.73
Performance Index	70.34
Number of stops	5,818
Stops per vehicle	1.75
Throughput [veh]	2,626
Vehicles in network [veh]	690
Demand latent [veh]	1
Demand latent base	0
Speed [mph]	36.88
Distance traveled [mile]	5,124,638.42

Optimization Results

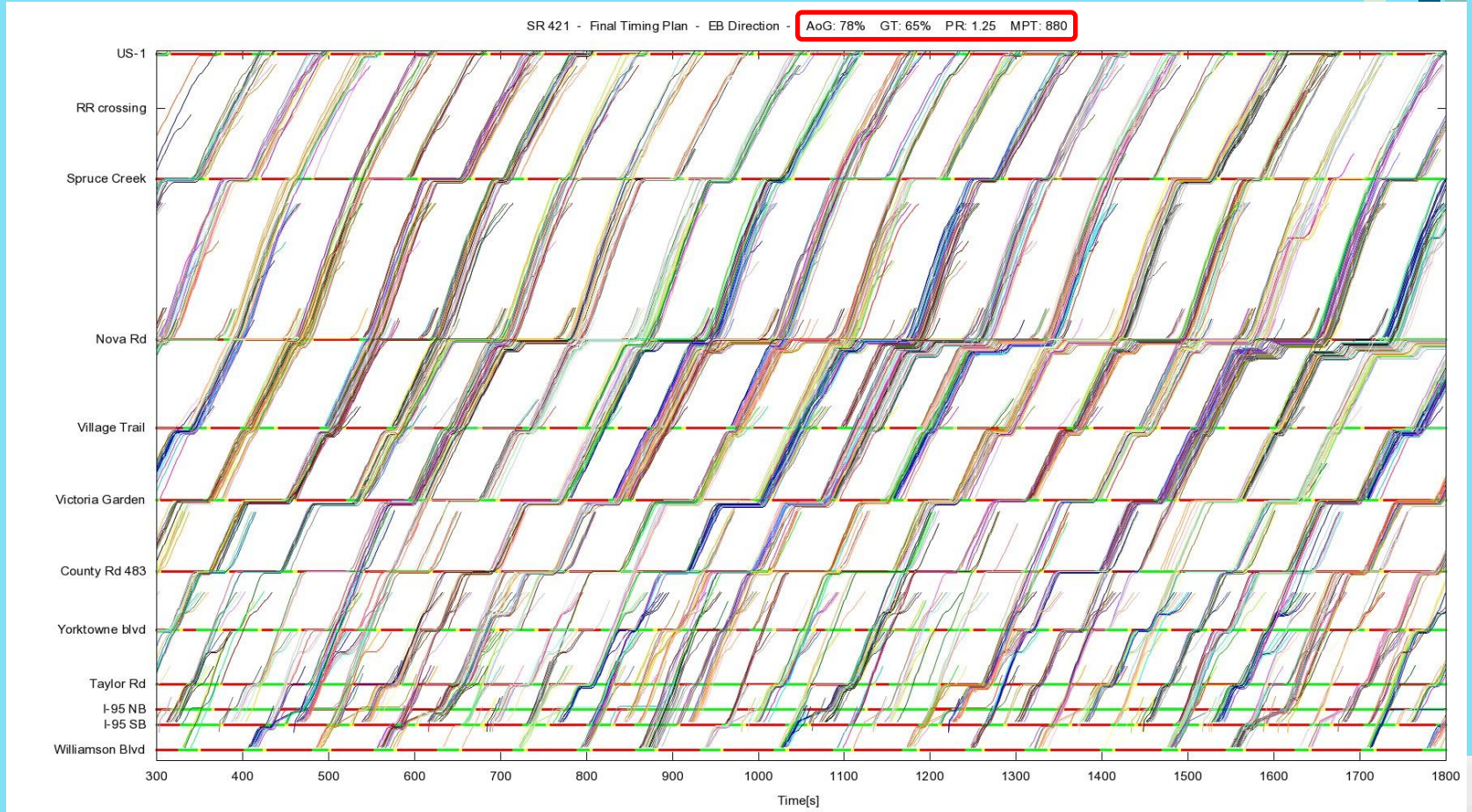
Number of stops	Throughput	Vehicles In	Total delay [h]	Total stopped delay [h]	Stopped delay per vehicle [s]	Delay per vehicle [s]	Speed [mph]	Distance traveled [mile]	Stops per vehicle	Delay latent	Demand latent	Demand latent base	Performance Index
5818	2626	690	54.1	36.2	58.73	58.73	36.88	5,124,638.42	1.75	285.8	1	0	70.34

Signal Id	Signal name	Cycle	Offset	Split 1	Split 2	Split 3	Split 4	Split 5	Split 6	Split 7	Split 8	R1.B1	R1.B2	R1.B3	R1.B4	R2.B1	R2.B2	R2.B3	R2.B4
1	SR421_Williamson	60	14	14	16	14	16	14	16	17	13	2	1	4	3	5	6	7	8
2	SR421_I95SB	60	38	0	40	0	0	12	28	0	20	2	0	0	0	5	6	0	8
3	SR421_I95NB	60	38	13	27	0	20	0	40	0	0	1	2	0	4	0	6	0	0
4	SR421_TaylorRd	60	58	0	24	0	36	11	13	0	0	2	0	0	4	6	5	0	0
5	SR421_YorktowneBlvd	177	81	85	34	0	58	85	34	0	0	1	2	4	0	5	6	0	0
6	SR421_CountyRd483	105	73	21	19	38	27	18	22	32	33	2	1	3	4	6	5	8	7
7	SR421_VictoriaGarden	105	105	32	42	15	16	11	63	19	12	2	1	4	3	6	5	8	7
8	SR421_VillageTrail	105	85	15	55	0	35	49	21	18	17	2	1	4	0	5	6	7	8
9	SR421_NovaRd	105	5	13	44	24	24	21	36	18	30	2	1	3	4	5	6	7	8
10	SR421_SpruceCreekRd	104	36	18	27	44	15	20	25	0	59	1	2	3	4	5	6	8	0
11	SR421_US1	104	90	36	34	19	15	30	40	11	23	1	2	4	3	5	6	8	7
12	SR421_SummerTreesRd	192	0	121	39	12	20	69	91	12	20	2	1	4	3	5	6	8	7

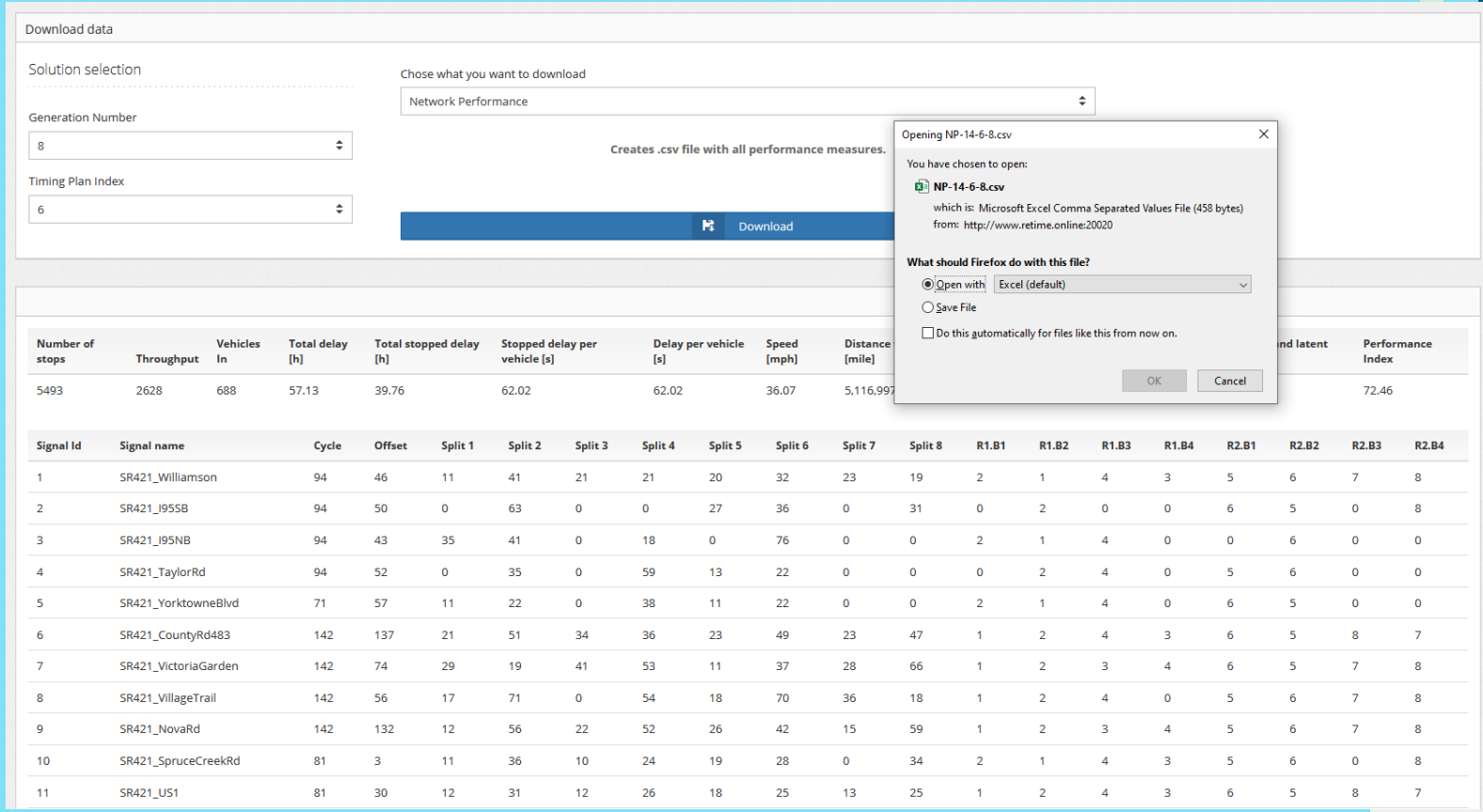
Time-Distance Chart – EB Initial



Time-Distance Chart – EB Final



Download Network Performance



Number of stops	Throughput	Vehicles In	Total delay [h]	Total stopped delay [h]	Stopped delay per vehicle [s]	Delay per vehicle [s]	Speed [mph]	Distance [mile]	nd latent	Performance Index
5493	2628	688	57.13	39.76	62.02	62.02	36.07	5,116,997		72.46

Signal Id	Signal name	Cycle	Offset	Split 1	Split 2	Split 3	Split 4	Split 5	Split 6	Split 7	Split 8	R1.B1	R1.B2	R1.B3	R1.B4	R2.B1	R2.B2	R2.B3	R2.B4
1	SR421_Williamson	94	46	11	41	21	21	20	32	23	19	2	1	4	3	5	6	7	8
2	SR421_I95SB	94	50	0	63	0	0	27	36	0	31	0	2	0	0	6	5	0	8
3	SR421_I95NB	94	43	35	41	0	18	0	76	0	0	2	1	4	0	0	6	0	0
4	SR421_TaylorRd	94	52	0	35	0	59	13	22	0	0	0	2	4	0	5	6	0	0
5	SR421_YorktowneBlvd	71	57	11	22	0	38	11	22	0	0	2	1	4	0	6	5	0	0
6	SR421_CountyRd483	142	137	21	51	34	36	23	49	23	47	1	2	4	3	6	5	8	7
7	SR421_VictoriaGarden	142	74	29	19	41	53	11	37	28	66	1	2	3	4	6	5	7	8
8	SR421_VillageTrail	142	56	17	71	0	54	18	70	36	18	1	2	4	0	5	6	7	8
9	SR421_NovaRd	142	132	12	56	22	52	26	42	15	59	1	2	3	4	5	6	7	8
10	SR421_SpruceCreekRd	81	3	11	36	10	24	19	28	0	34	2	1	4	3	5	6	0	8
11	SR421_US1	81	30	12	31	12	26	18	25	13	25	1	2	4	3	6	5	8	7

Retime

Download Signal Timings

Download data

Solution selection

Generation Number

8

Timing Plan Index

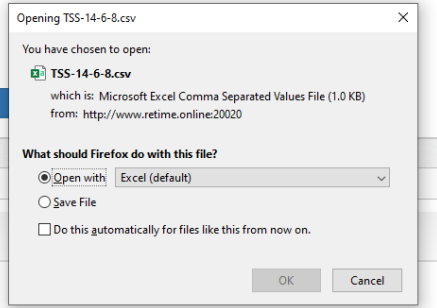
6

Chose what you want to download

Traffic Signal Settings

Creates .csv file with all timings and sequences.

Download



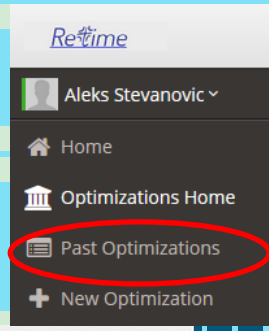
Number of stops	Throughput	Vehicles In	Total delay [h]	Total stopped delay [h]	Stopped delay per vehicle [s]	Delay per vehicle [s]	Speed [mph]	Distance traveled [mile]	Performance Index
5493	2628	688	57.13	39.76	62.02	62.02	36.07	5,116,997.42	72.46

Signal Id	Signal name	Cycle	Offset	Split 1	Split 2	Split 3	Split 4	Split 5	Split 6	Split 7	Split 8	R1.B1	R1.B2	R1.B3	R1.B4	R2.B1	R2.B2	R2.B3	R2.B4
1	SR421_Williamson	94	46	11	41	21	21	20	32	23	19	2	1	4	3	5	6	7	8
2	SR421_I95SB	94	50	0	63	0	0	27	36	0	31	0	2	0	0	6	5	0	8
3	SR421_I95NB	94	43	35	41	0	18	0	76	0	0	2	1	4	0	0	6	0	0
4	SR421_TaylorRd	94	52	0	35	0	59	13	22	0	0	0	2	4	0	5	6	0	0
5	SR421_YorktowneBlvd	71	57	11	22	0	38	11	22	0	0	2	1	4	0	6	5	0	0
6	SR421_CountyRd483	142	137	21	51	34	36	23	49	23	47	1	2	4	3	6	5	8	7
7	SR421_VictoriaGarden	142	74	29	19	41	53	11	37	28	66	1	2	3	4	6	5	7	8
8	SR421_VillageTrail	142	56	17	71	0	54	18	70	36	18	1	2	4	0	5	6	7	8
9	SR421_NovaRd	142	132	12	56	22	52	26	42	15	59	1	2	3	4	5	6	7	8
10	SR421_SpruceCreekRd	81	3	11	36	10	24	19	28	0	34	2	1	4	3	5	6	0	8
11	SR421_US1	81	30	12	31	12	26	18	25	13	25	1	2	4	3	6	5	8	7

Retime

POST-OPTIMIZATION ANALYSIS (WEB)

List of Previous Optimizations



Past Optimizations

#	Optimization Name	Time Started	Time Ended	Simulation Period	Population Size	Number Of Generations	Min Cycle Length	Max Cycle Length	Objective Function	Adjusted Parameters
1	SR Net Opt1	05/11/2019 13:05	05/11/2019 15:32	4500	20	200	40	200	Performance Index	Offsets, Splits, Phase Sequence
2	SR Net Opt2	15/01/2020 16:08	15/01/2020 18:54	4500	20	200	40	200	Performance Index	Offsets, Splits
3	SR Net Opt4	03/02/2020 15:25	03/02/2020 16:40	900	10	27	40	200	Performance Index	Offsets, Splits, Phase Sequence
4	SR Net Opt5	03/03/2020 15:22	03/03/2020 16:43	900	10	22	40	200	Performance Index	Offsets, Splits, Phase Sequence
5	SR Net Opt6	10/03/2020 15:03	10/03/2020 16:35	900	10	30	40	200	Performance Index	Offsets, Splits, Phase Sequence
6	SR Net Opt7	09/04/2020 16:27	09/04/2020 17:45	900	10	21	40	200	Performance Index	Offsets, Splits, Phase Sequence
7	SR Net Opt8	12/10/2020 17:05	12/10/2020 20:31	900	10	49	40	200	Performance Index	Offsets, Splits, Phase Sequence
8	SR Net Opt9	13/10/2020 19:54	13/10/2020 21:20	900	50	9	40	200	Performance Index	Offsets, Splits, Phase Sequence
9	SR Net Opt10	14/10/2020 13:24	14/10/2020 16:44	900	20	24	40	200	Performance Index	Offsets, Splits, Phase Sequence
10	SR Net Opt11	15/10/2020 16:38	15/10/2020 18:27	3600	10	9	40	200	Performance Index	Offsets, Splits, Phase Sequence
11	Sunrise Opt1	18/10/2020 01:27	18/10/2020 03:19	900	10	9	40	200	Performance Index	Offsets, Splits, Phase Sequence
12	Sunrise Opt2	19/10/2020 13:40	19/10/2020 19:10	3600	10	9	40	200	Performance Index	Offsets, Splits, Phase Sequence
13	Sunrise Opt3	20/10/2020 13:20	20/10/2020 21:18	900	20	24	40	200	Performance Index	Offsets, Splits, Phase Sequence

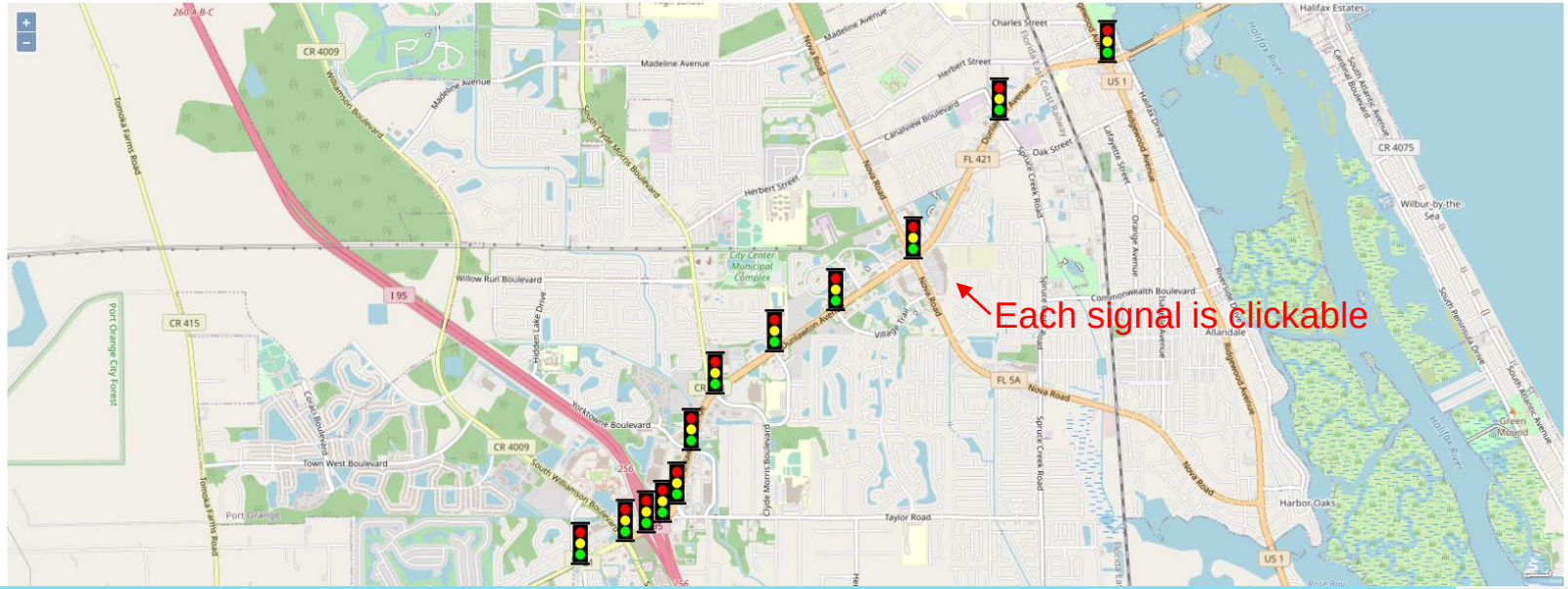
Map of Selected Optimization

Selected Optimization

Map | Performance Charts | Sorting | Pareto

Optimization Name	Date Started	Date Ended	Simulation Period	Population Size	Number Of Generations	Min Cycle Length	Max Cycle Length	Objective Function	Adjusted Parameters
SR Net Opt2	15/01/2020 16:08	15/01/2020 18:54	4500	20	200	40	200	Performance Index	Offsets, Splits

Map



Summary Info for Each Signal

Add another signal timing plan

Signal timing plan number: BEST

Generation number: 0

Select

Select another signal

Signal: SR421_VictoriaGarden

Select

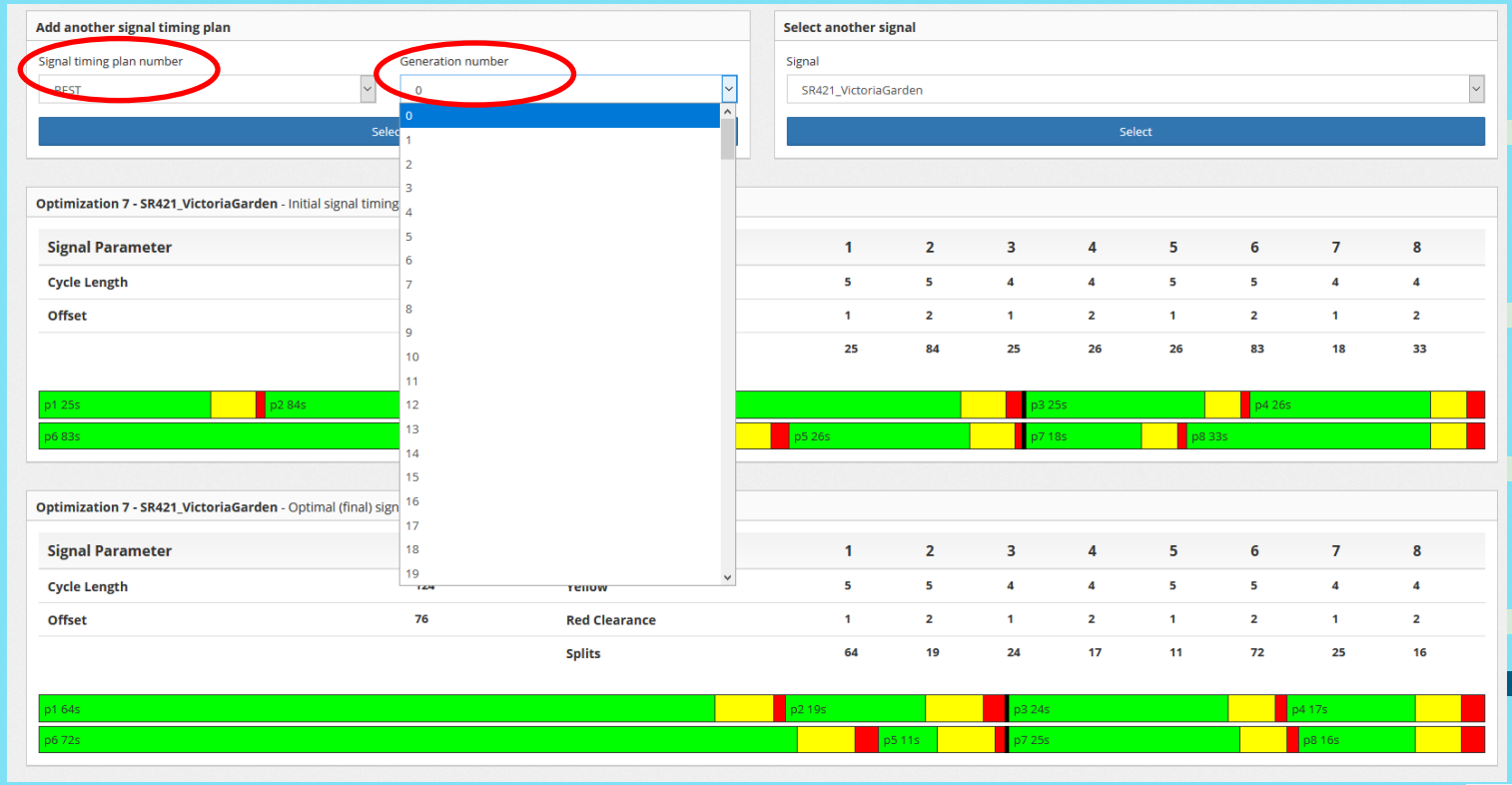
Optimization 7 - SR421_VictoriaGarden - Initial signal timing plan

Signal Parameter	Value	SG Number	1	2	3	4	5	6	7	8
Cycle Length	160	Yellow	5	5	4	4	5	5	4	4
Offset	89	Red Clearance	1	2	1	2	1	2	1	2
		Splits	25	84	25	26	26	83	18	33

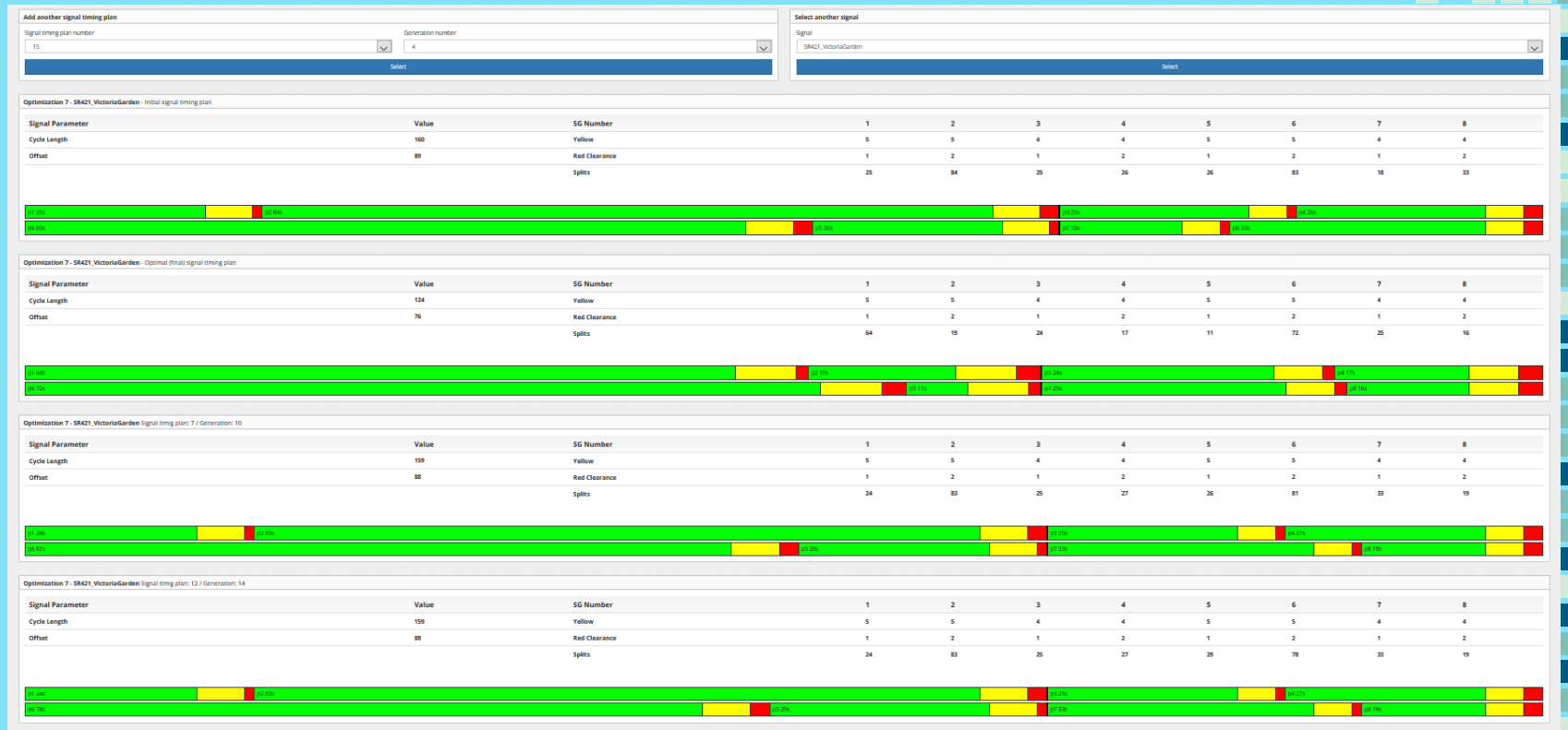
Optimization 7 - SR421_VictoriaGarden - Optimal (final) signal timing plan

Signal Parameter	Value	SG Number	1	2	3	4	5	6	7	8
Cycle Length	124	Yellow	5	5	4	4	5	5	4	4
Offset	76	Red Clearance	1	2	1	2	1	2	1	2
		Splits	64	19	24	17	11	72	25	16

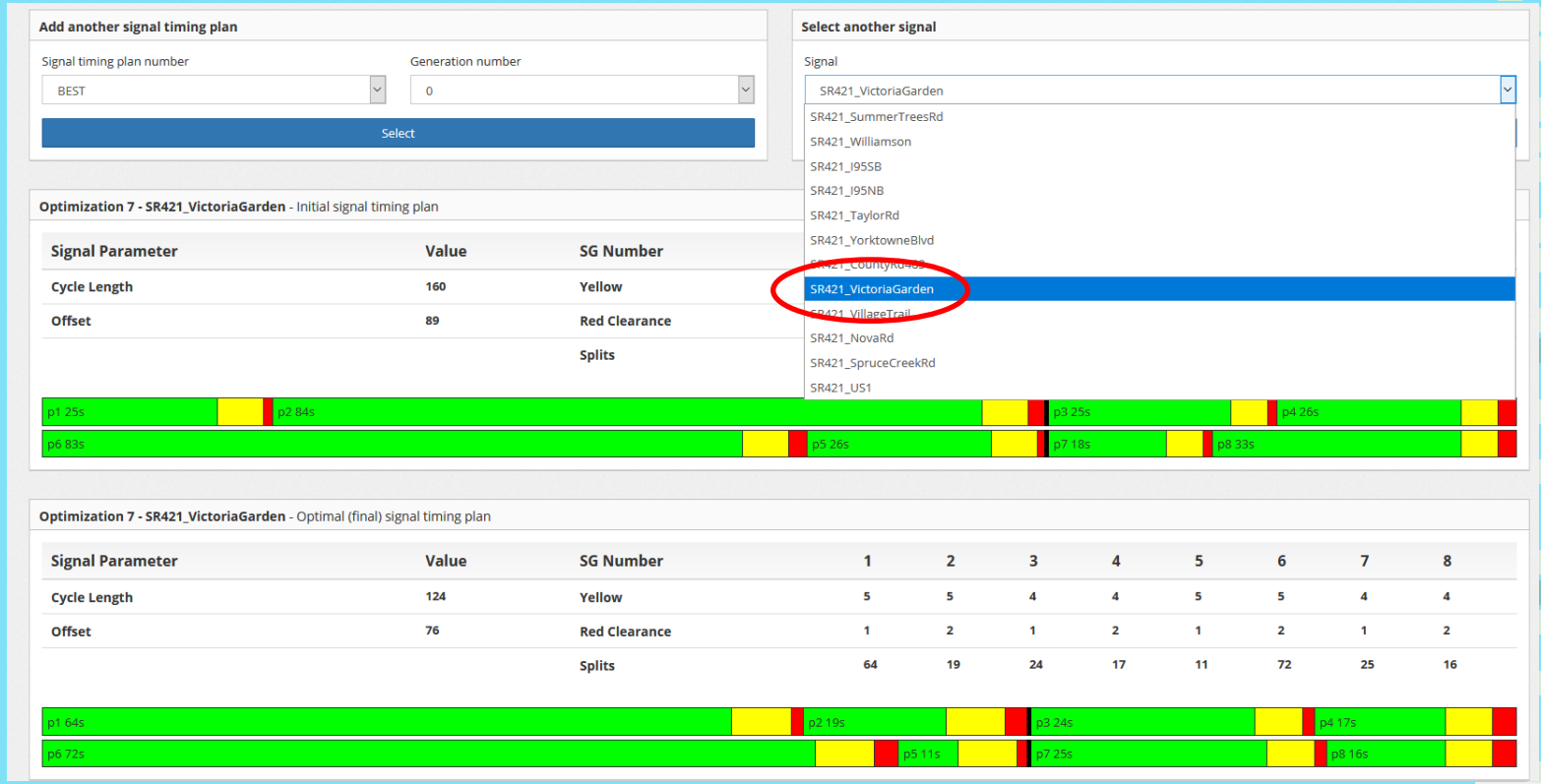
Select Any Signal Timing Plan



New Signal Timing Plans Added



Select Another Signal to Display



Move to a Different Tab

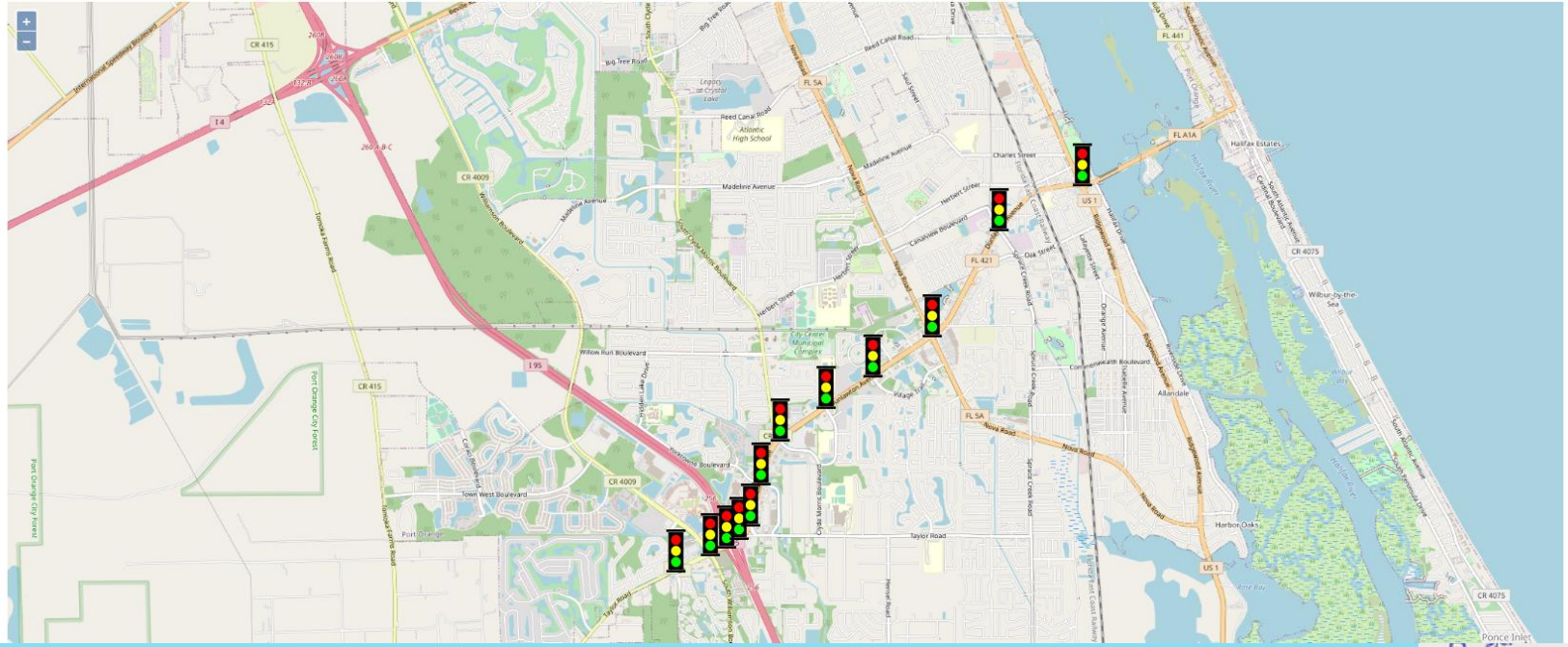
Selected Optimization

Map | Optimization Results | Performance Charts | Sorted Charts | Pareto Charts

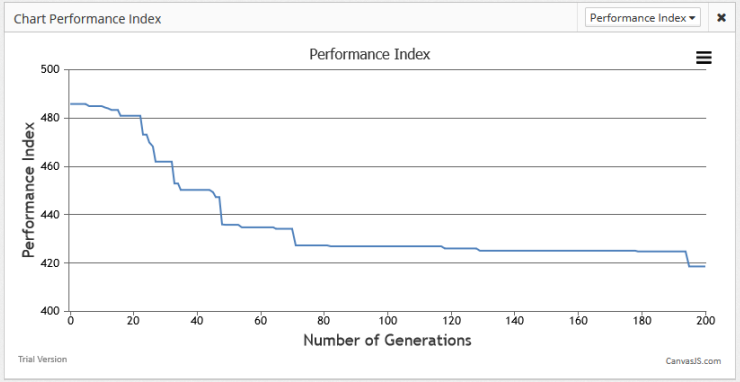
Optimization Name	Date Started	Date Ended	Simulation Period	Population Size	Number Of Generations	Min Cycle Length	Max Cycle Length	Objective Function	Adjusted Parameters
SR Net Opt8	12/10/2020 17:05	12/10/2020 20:31	900	10	49	40	200	Throughput	Offsets, Splits, Phase Sequence

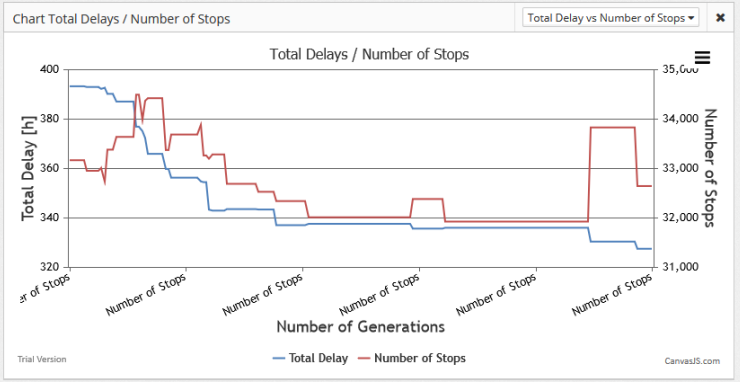
Available Tabs

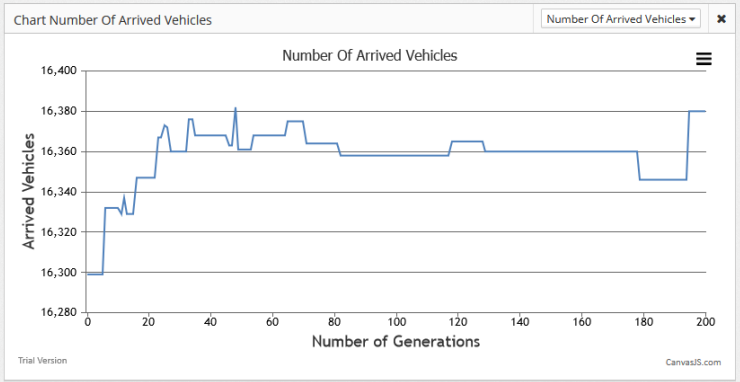
Map

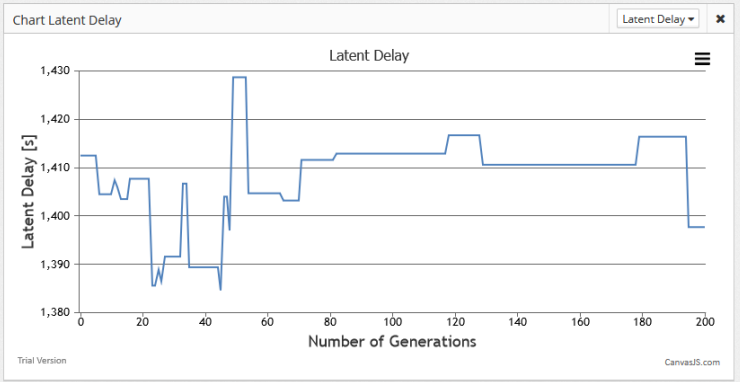


Performance Charts

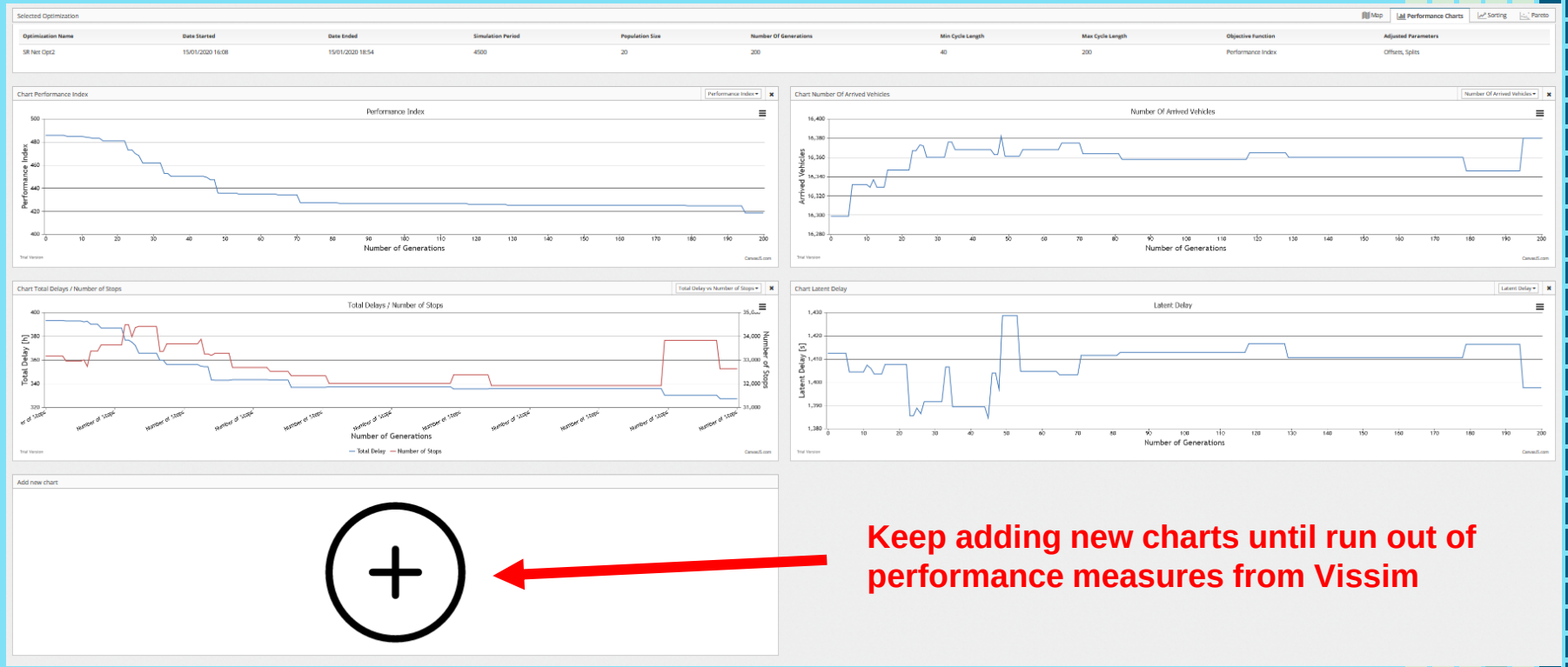






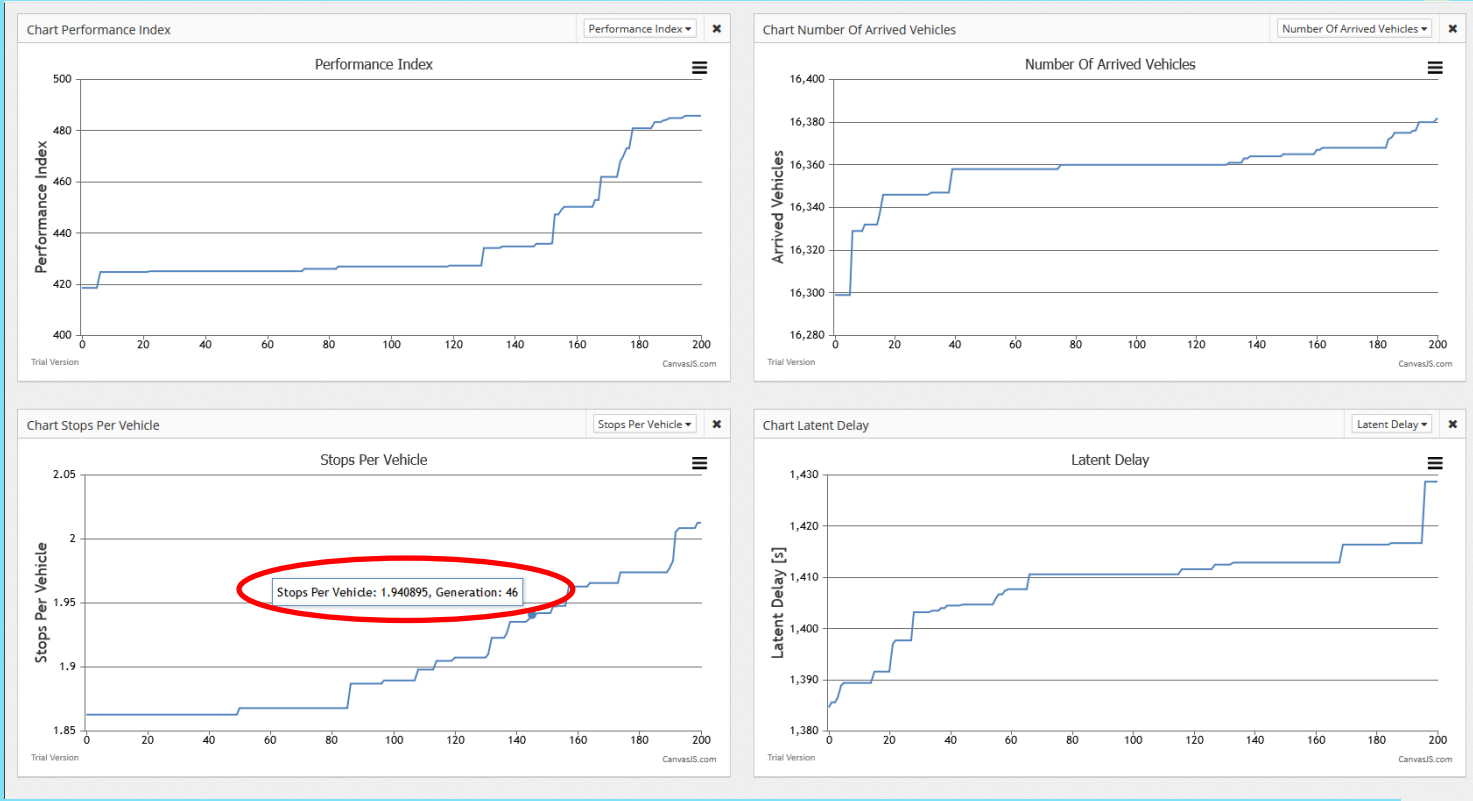


Unlimited # of Charts with PMs

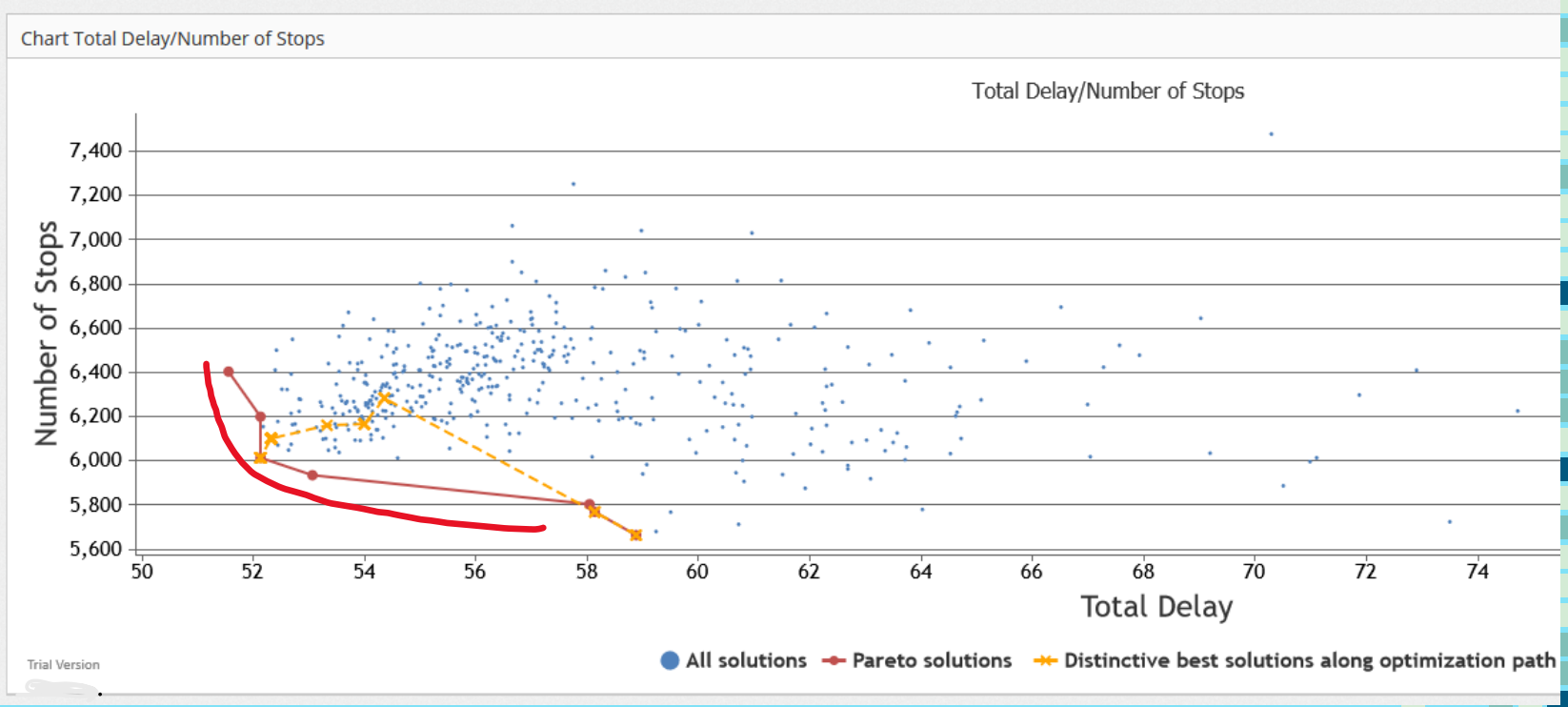


Keep adding new charts until run out of performance measures from Vissim

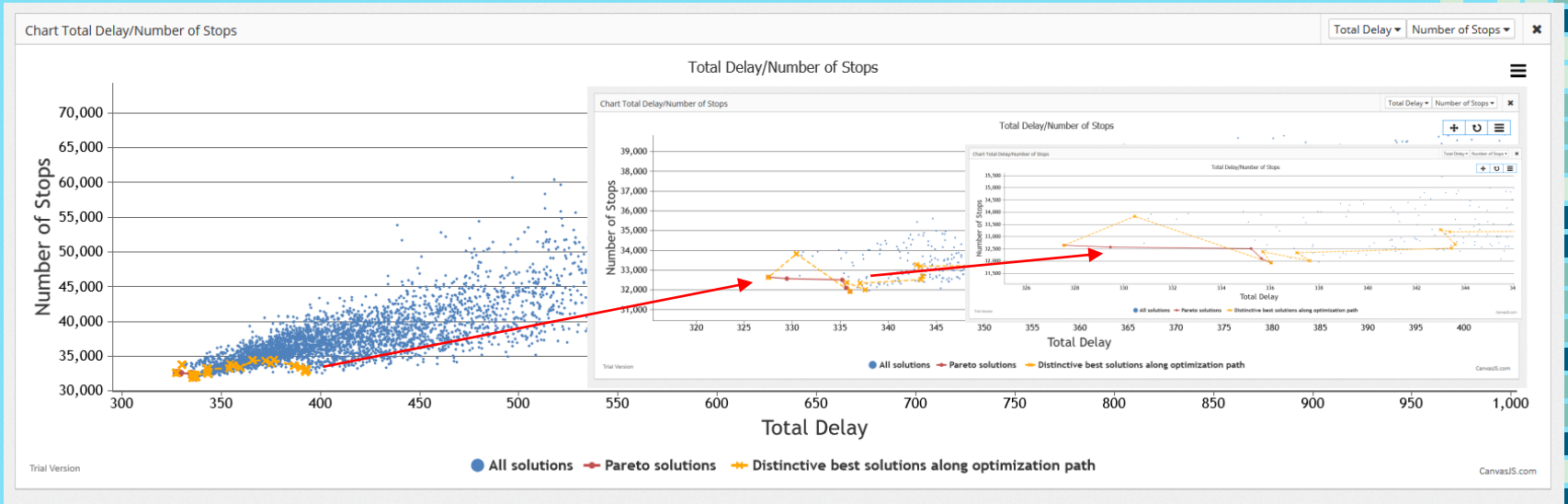
Charts with Sorted Solutions



Pareto Fronts – Trade off between PMs

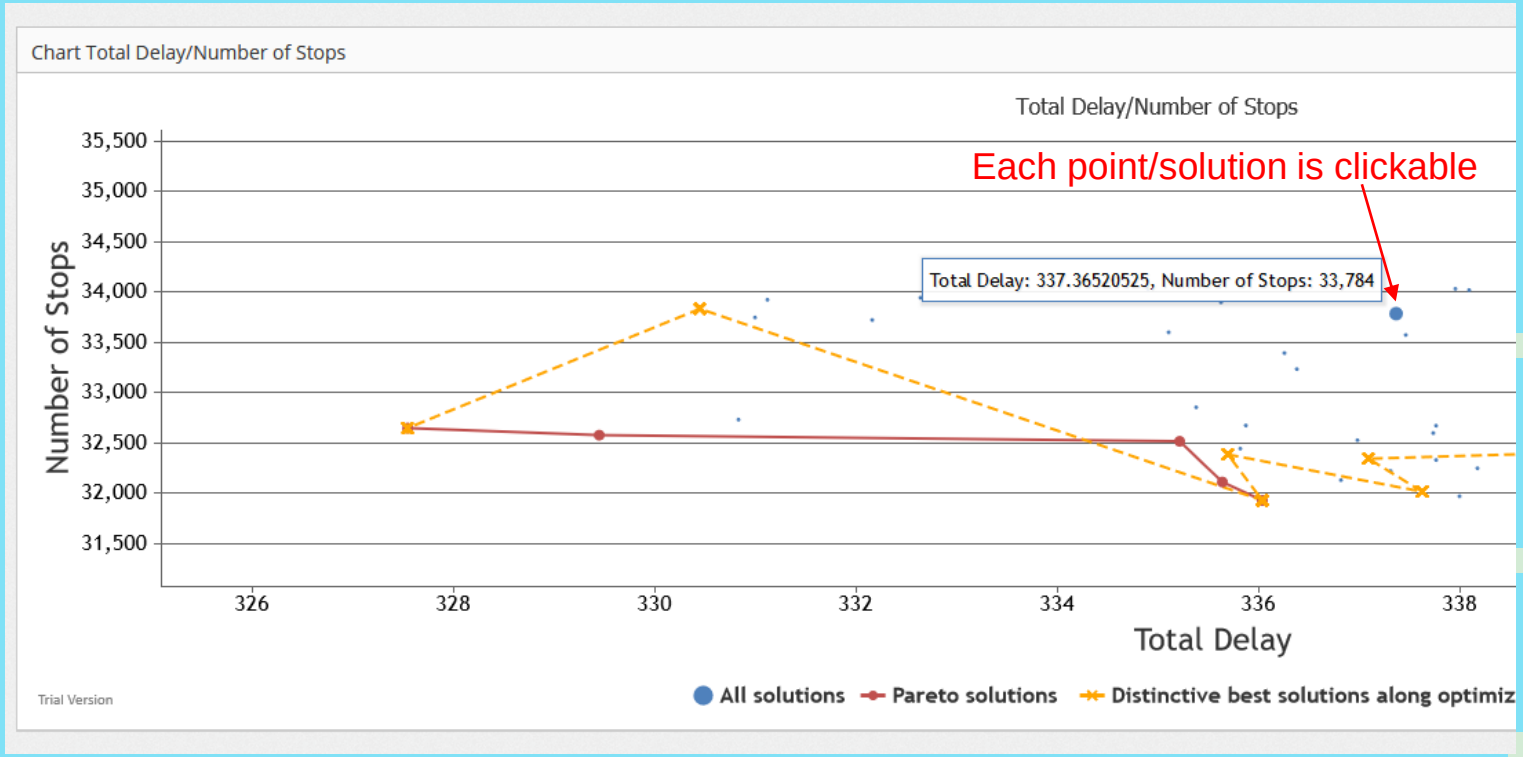


Pareto Front Charts (Zoomable)

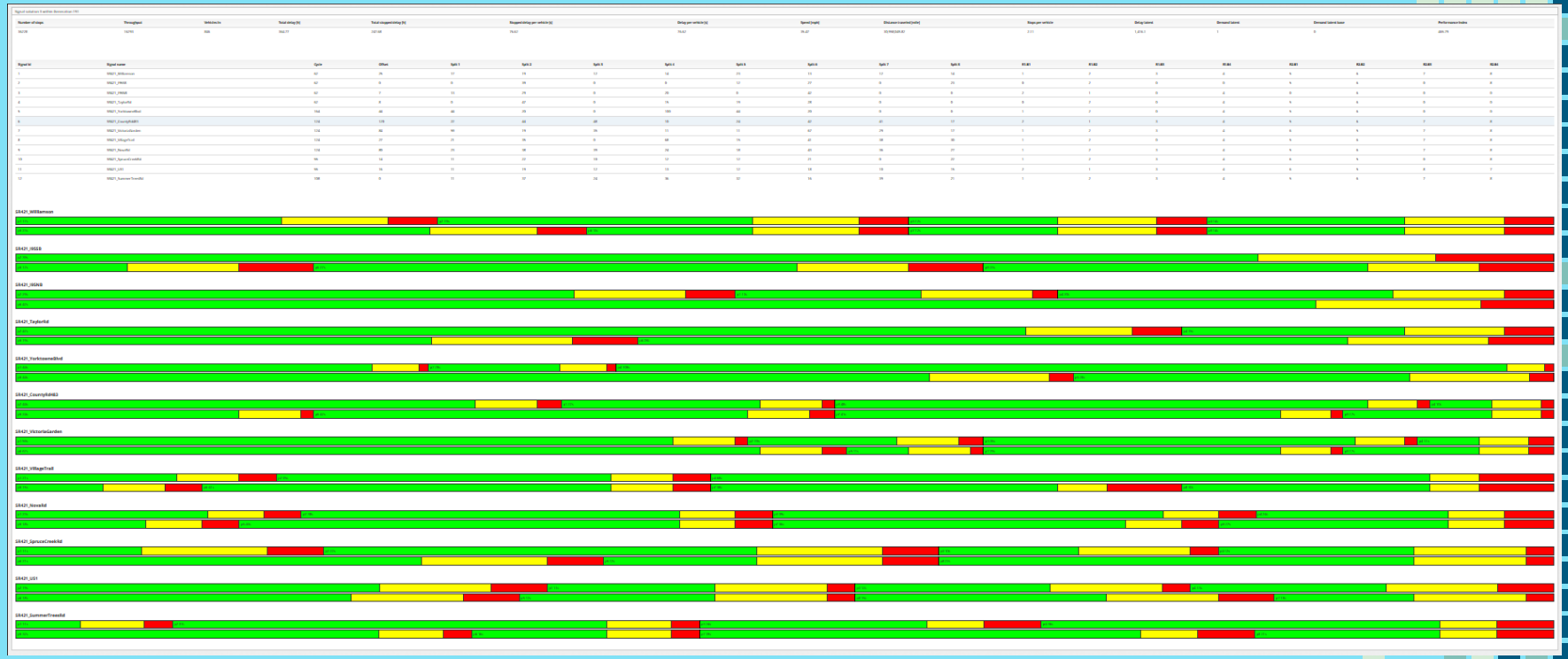


Pareto Front Charts – Any Pair of PMs

Solution (Set of Signal Timing Plans)



Each Solution Can be Analyzed



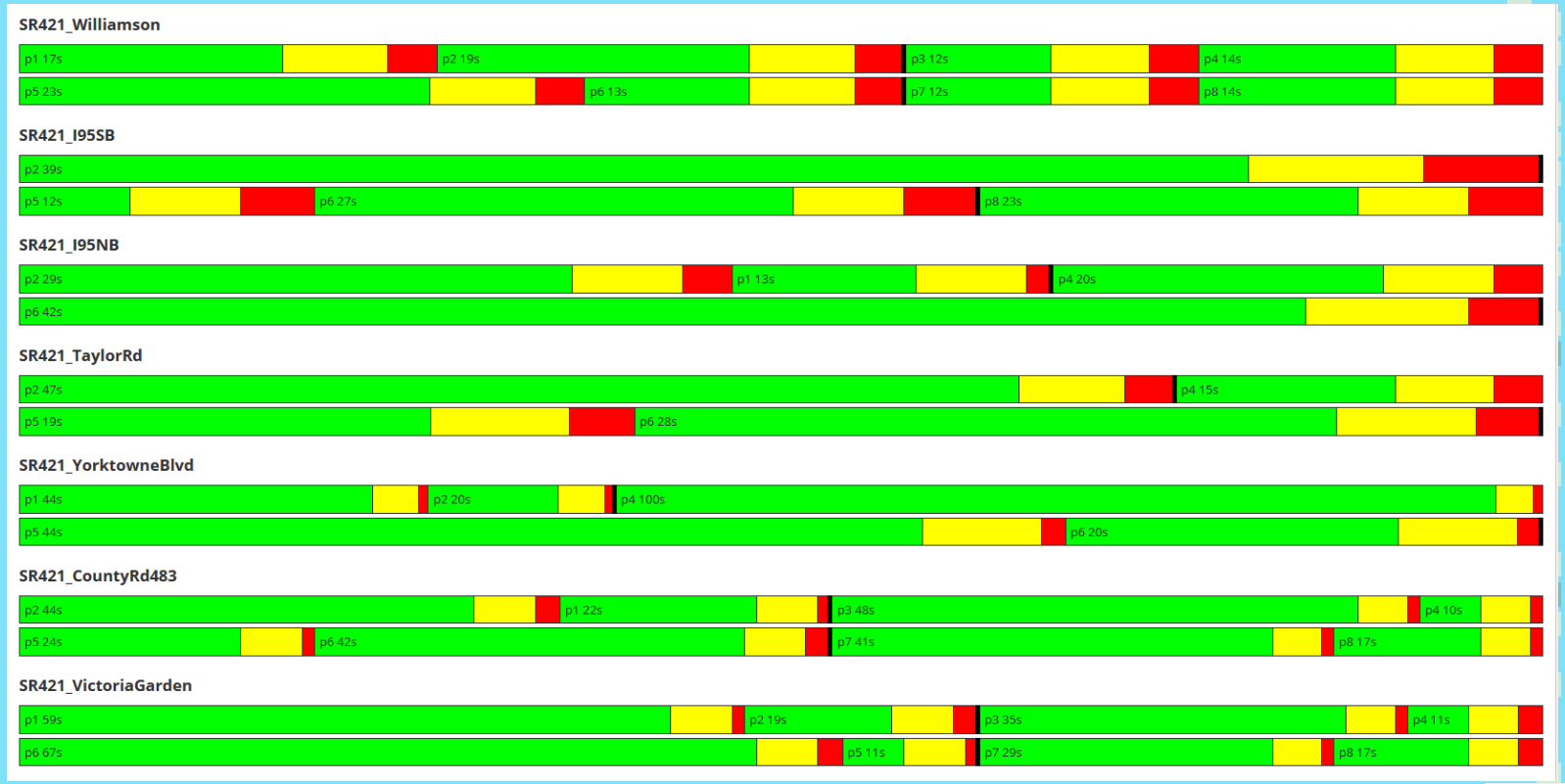
Performance & Table of Signal Timings

Signal solution 3 within Generation 191

Number of stops	Throughput	Vehicles In	Total delay [h]	Total stopped delay [h]	Stopped delay per vehicle [s]	Delay per vehicle [s]	Speed [mph]	Distance traveled [mile]	Stops per vehicle	Delay latent	Demand latent	Demand latent base	Performance Index
36228	16293	846	364.77	247.68	76.62	76.62	35.47	30,958,049.82	2.11	1,416.1	1	0	465.79

Signal Id	Signal name	Cycle	Offset	Split 1	Split 2	Split 3	Split 4	Split 5	Split 6	Split 7	Split 8	R1.B1	R1.B2	R1.B3	R1.B4	R2.B1	R2.B2	R2.B3	R2.B4
1	SR421_Williamson	62	25	17	19	12	14	23	13	12	14	1	2	3	4	5	6	7	8
2	SR421_I95SB	62	0	0	39	0	0	12	27	0	23	0	2	0	0	5	6	0	8
3	SR421_I95NB	62	7	13	29	0	20	0	42	0	0	2	1	0	4	0	6	0	0
4	SR421_TaylorRd	62	8	0	47	0	15	19	28	0	0	0	2	0	4	5	6	0	0
5	SR421_YorktowneBlvd	164	44	44	20	0	100	44	20	0	0	1	2	0	4	5	6	0	0
6	SR421_CountyRd483	124	120	22	44	48	10	24	42	41	17	2	1	3	4	5	6	7	8
7	SR421_VictoriaGarden	124	84	59	19	35	11	11	67	29	17	1	2	3	4	6	5	7	8
8	SR421_VillageTrail	124	27	21	35	0	68	15	41	38	30	1	2	0	4	5	6	7	8
9	SR421_NovaRd	124	80	23	38	39	24	18	43	36	27	1	2	3	4	5	6	7	8
10	SR421_SpruceCreekRd	55	14	11	22	10	12	12	21	0	22	1	2	3	4	6	5	0	8
11	SR421_US1	55	16	11	19	12	13	12	18	10	15	2	1	3	4	6	5	8	7
12	SR421_SummerTreesRd	108	0	11	37	24	36	32	16	39	21	1	2	3	4	5	6	7	8

RBC Diagrams – All Signals in a Solution



Work in Progress

- More options for downloading results
  - Signal timing plans in RBC format
  - Download entire database
  - Customized PDF reports with performance measures and RBC diagrams for each intersection
- Testing module (to test readiness of Vissim network)
- Multimodal performances
- Intersection layout with node performance measures
- Improved Time-Distance charts & other diagrams…

What are Next Steps?

- Affordable per-project service
  - One-time optimization service
  - Support available to check and modify Vissim files
- Subscription to use analytics at any time for all previous (and future) optimizations
- The first commercial beta version will be ready in early 2020
- Looking (**NOW!**) for partners interested in pilot projects

Retime

Retime, LLC

www.retime.online

Questions and comments?

astevanovic@retime.online

Retime