



ITS Heartland

# Signalized Intersection Performance Measures WITHOUT Hardware

➤ Data-driven mobility insights from CATT Lab and INRIX

Rick Ayers

703.989.3221

rayers@umd.edu

cattlab.umd.edu



# Today's Presentation

- Background to probe-based signal analytics
- Source of data
- Fundamentals of intersection analysis
- Use case
- Time for questions



# Improving Operations with Traffic Signal Performance Measures

## Benefits

- Issues can be identified quickly
- Proactive instead of reactive response
- More efficient traffic signal operations
- Data to communicate outcomes



# Improving Safety and Sustainability Measures

## Reduction of Fuel Consumption and GHG Emissions

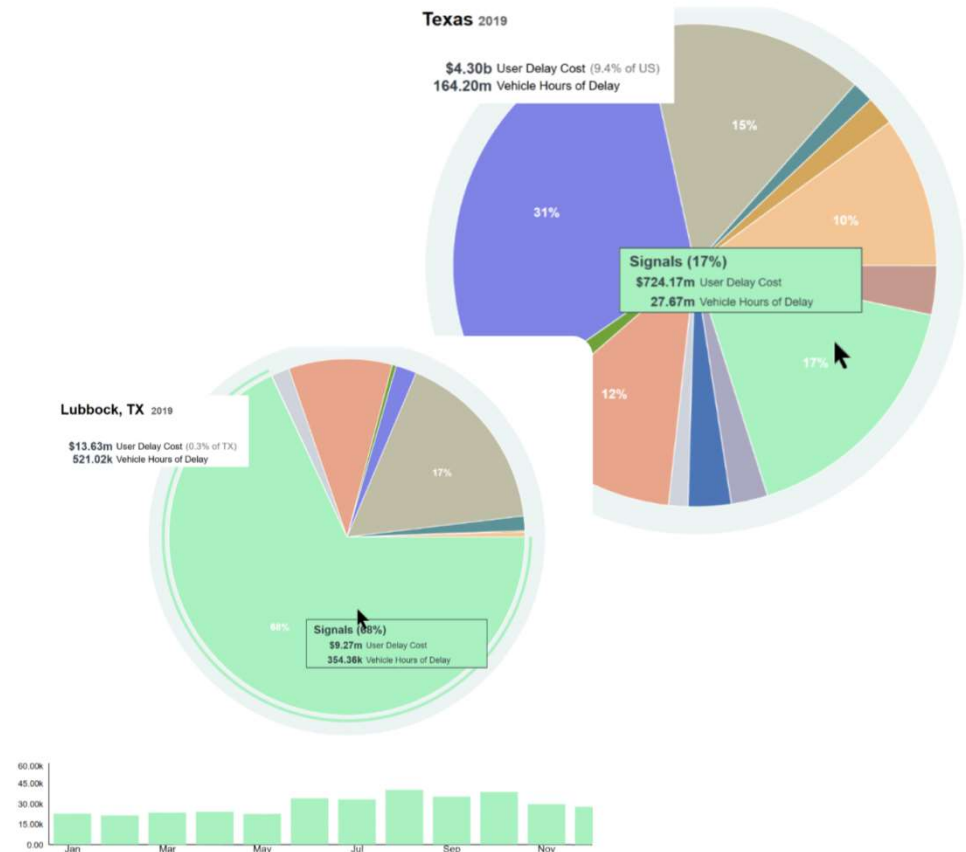
- Inst. of Transportation Engineers (ITE) estimates that properly timed signals decreases fuel consumption by 6% to 9%
- Aligns your with IJJA SMART program

## Improve Safety

- Where queues exist, correlation to safety issues
- Reducing split failures, reduces more aggressive driving behaviors

## Reduce Delay in Texas

- Recent estimates indicate that traffic signals account for roughly **164 million vehicle hours of delay** per year
- ITE reports, signal retiming projects reduce motorist delay by between 15% to 37%.



SOURCE: [HRG Report on Traffic Signal Retiming Cost Benefits](#)

Visit: <https://go.umd.edu/congestion>

# Traditional Traffic Signal Timing Processes

## Trigger

- Complaint
- 3-5 Year Retiming



## Design

- Hire a consultant
- Collect data and build models



## Implement

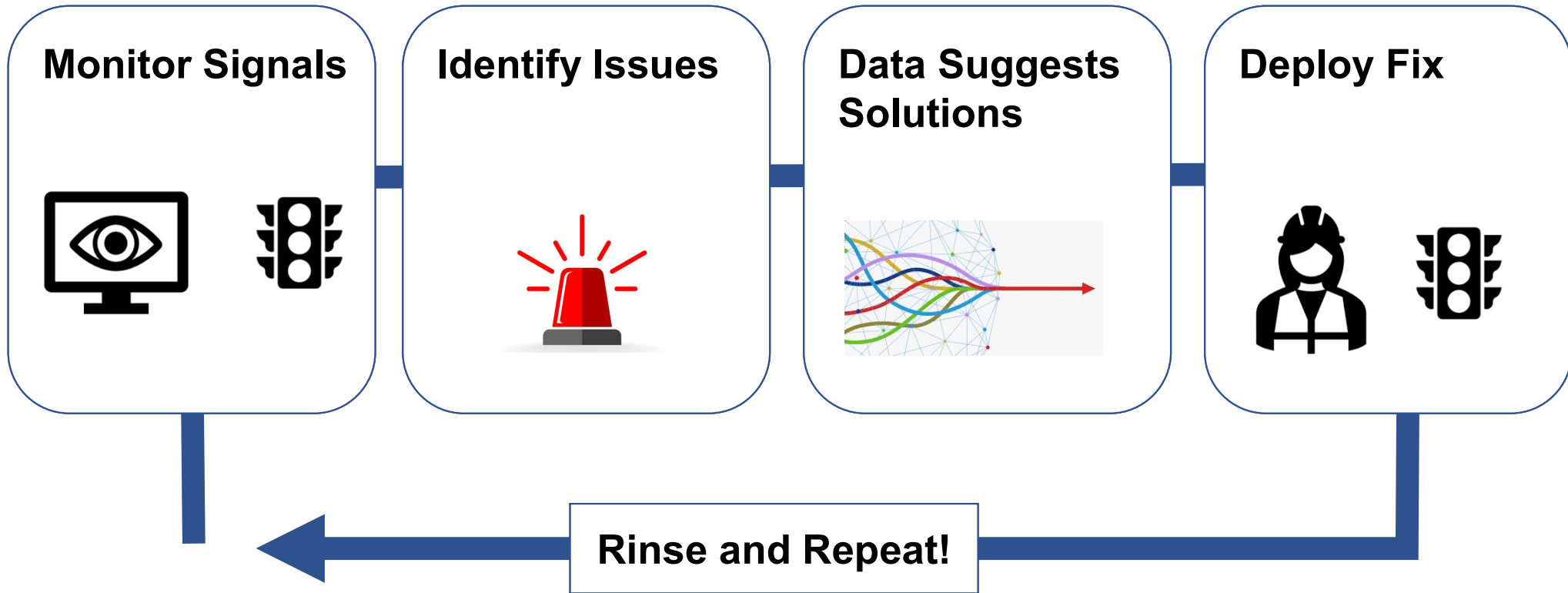
- Program
- Fine-Tune
- Evaluate



## Done?

Move on to the next corridor or signal when triggered by complaint or next retiming cycle

# Performance-Based Traffic Signal Timing



# Improving Operations with Traffic Signal Performance Measures

## Barriers

- Roadside detection infrastructure
- Signal controller upgrades
- Data storage and servers
- Software expertise



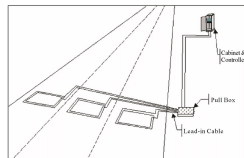
# Traffic Signal Performance Measurement

## Bottom-Up Approach

Derive traffic performance metrics

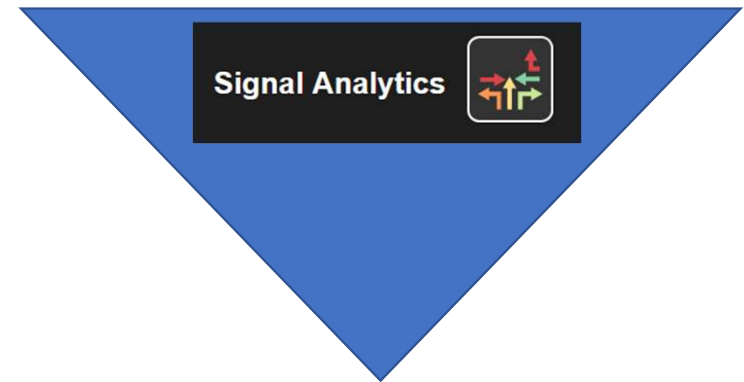


Start with high-resolution detector data...



## Top-Down Approach

Start with high-resolution CV data...



Derive intersection performance metrics

**No roadside infrastructure needed**  
**Rapidly scalable anywhere in the nation**



# Sensor/Detector Derived Performance Measures

## Strengths

100% of traffic

Includes signal timing information

Includes phase termination

Visualize detector actuations

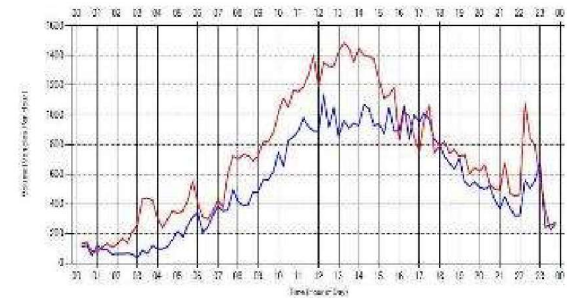
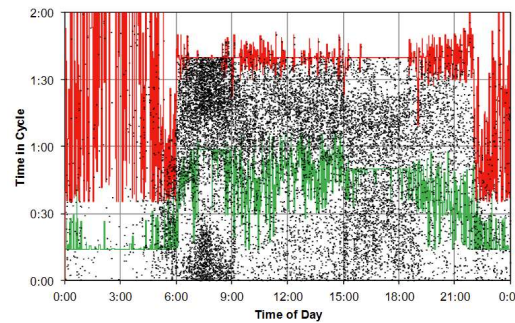
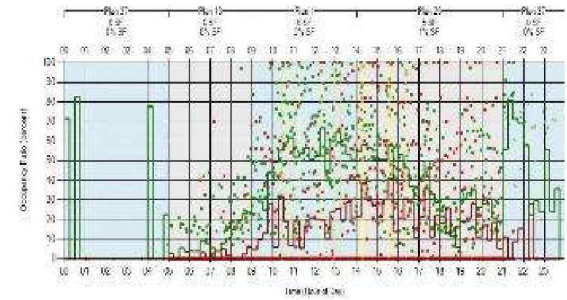
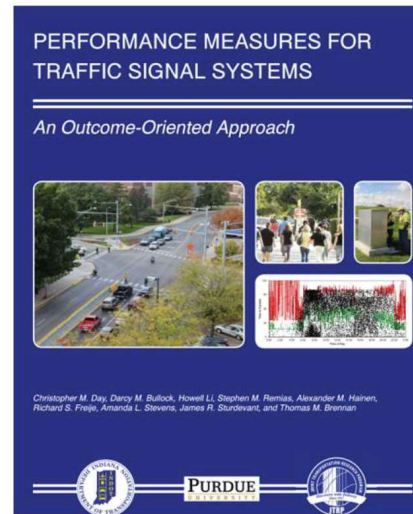
## Limitations

Complex detector layout

System-wide comparison difficult

Many points of failure

Some metrics are approximated



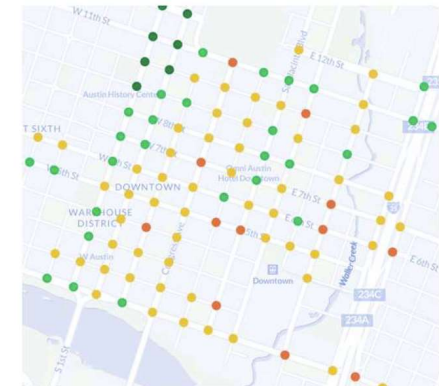
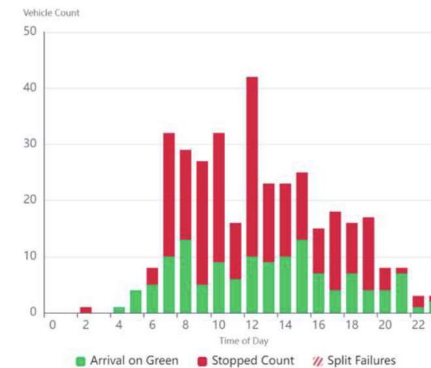
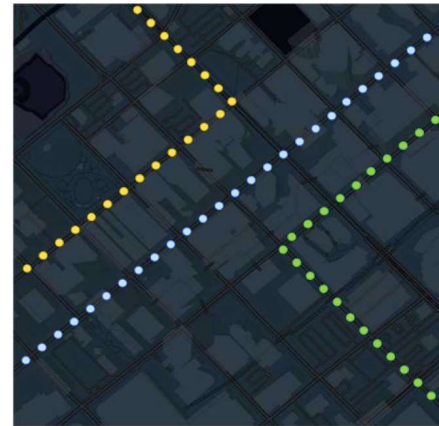
# Connected Vehicle (CV)/GPS Derived Performance Measures

## Strengths

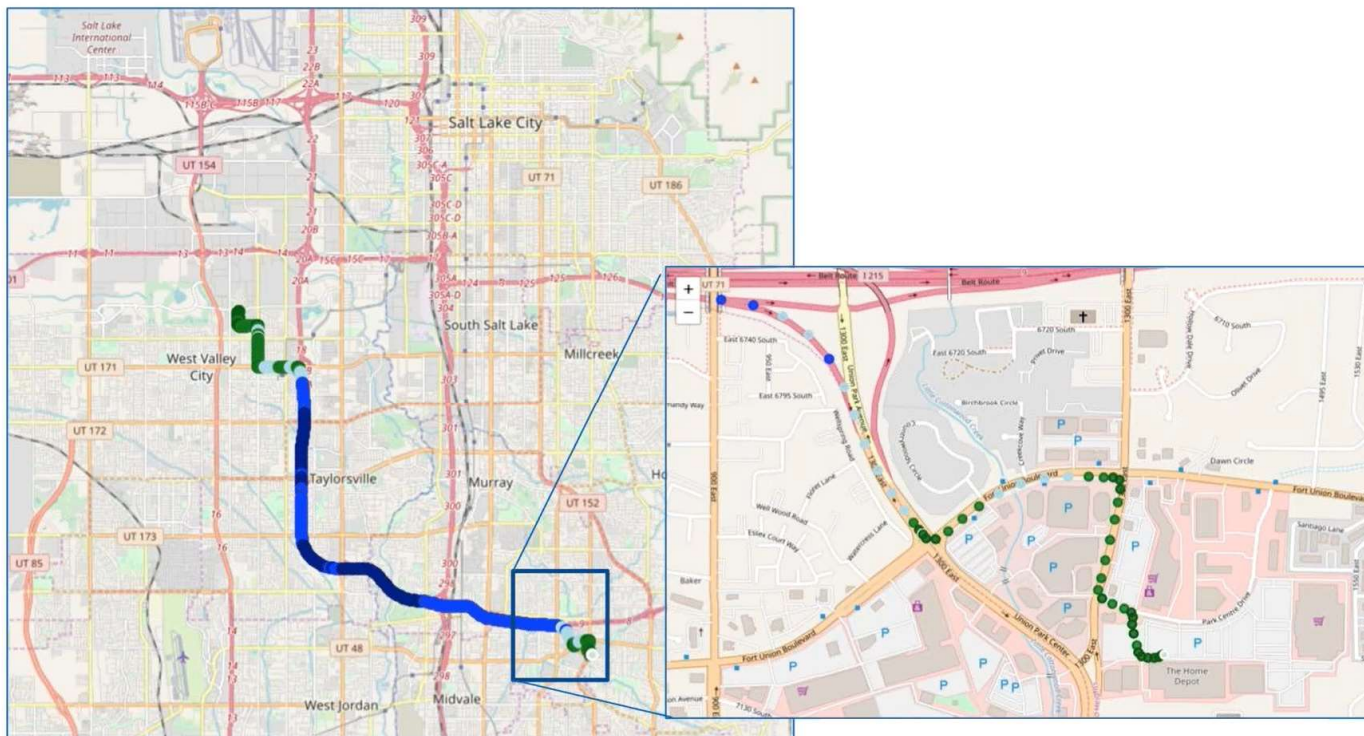
- Real 'observed' vehicles
- No added infrastructure
- Scale & Consistency
- Integrated Software

## Limitations

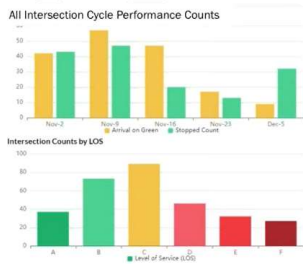
- Only a sample of vehicles
- No direct signal/phasing measurement
- Vehicle only
- Not in real time



# BASED ON HIGH-TEMPORAL DENSITY PROBE DATA



# WHAT IS SIGNAL ANALYTICS



## The Data

- 1 to 5 second frequency waypoints collected from connected vehicles
- Snapped to a free, open, and global map

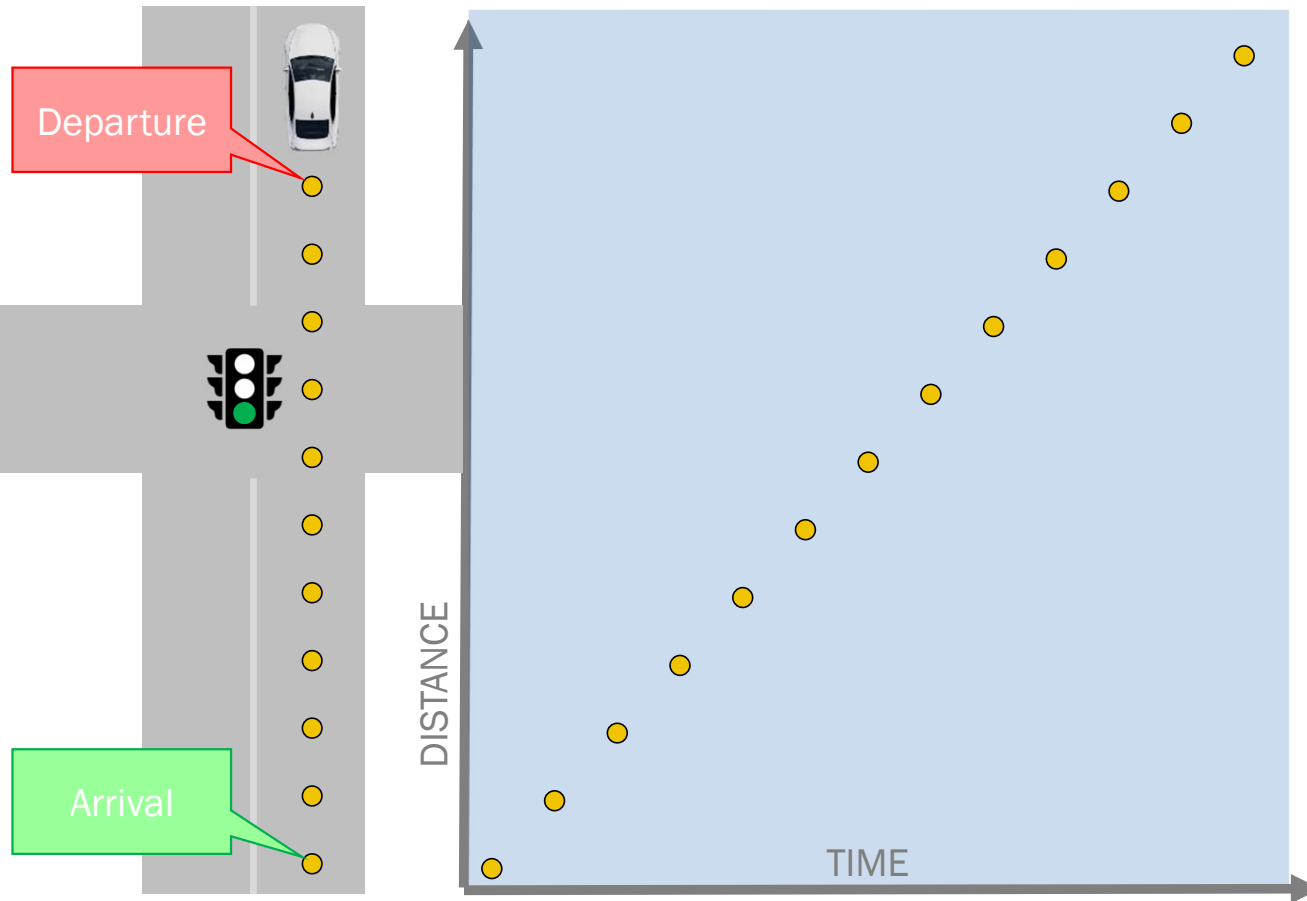
## The Metrics

- Individual vehicle waypoints are used to determine the travel time of a vehicle moving through an intersection
- Other vehicle attributes include turning movement, vehicle stop, approach speed, or vehicle split failure and volume

## The Tools – Cloud-based Solution as a Service

- Agency defines number of intersections to license
- Collaboration between CATT Lab and INRIX
- Aggregate the performance measures by intersection
- Report summary metrics over various time periods

# THE METRICS – FROM EACH VEHICLE



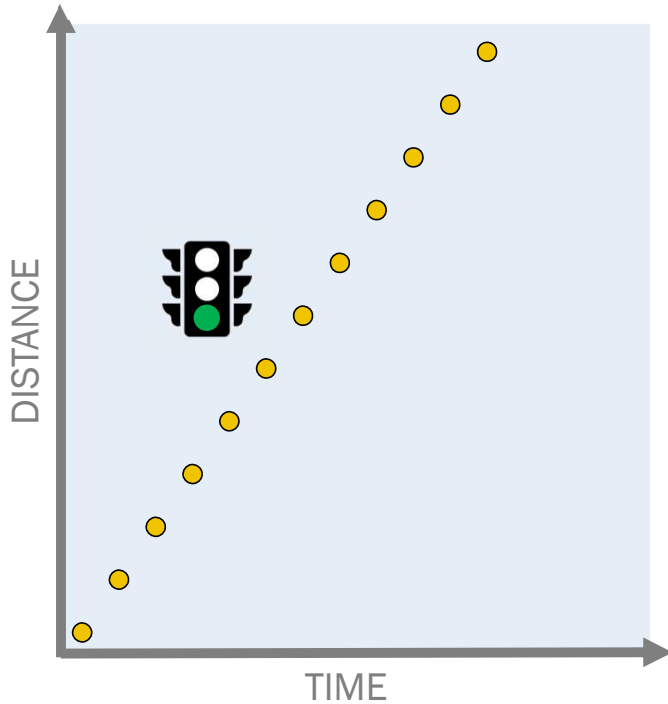
## Metrics for each vehicle

- Travel Time
- Approach Speed
- Vehicle Stop
- Vehicle Double Stop
- Movement (Left, Thru, Right)
- Volume

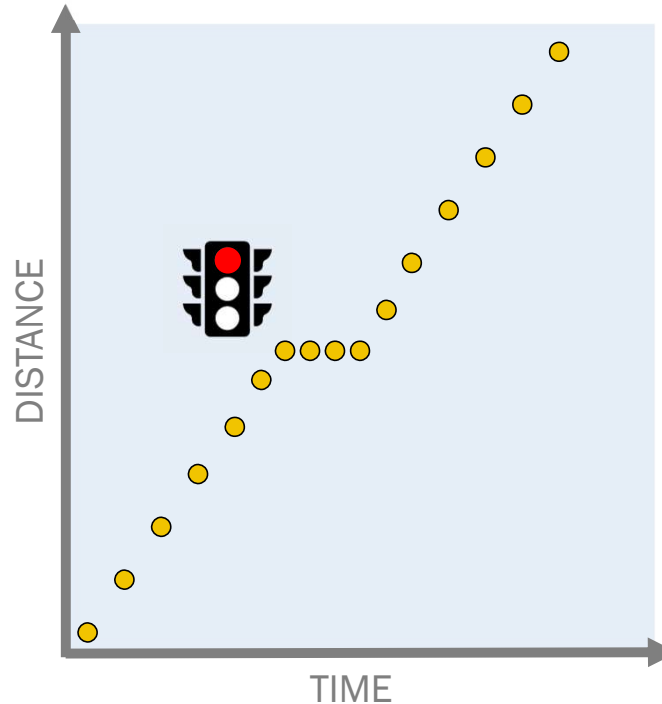
# THE METRICS – INTERSECTION BUSINESS LOGIC



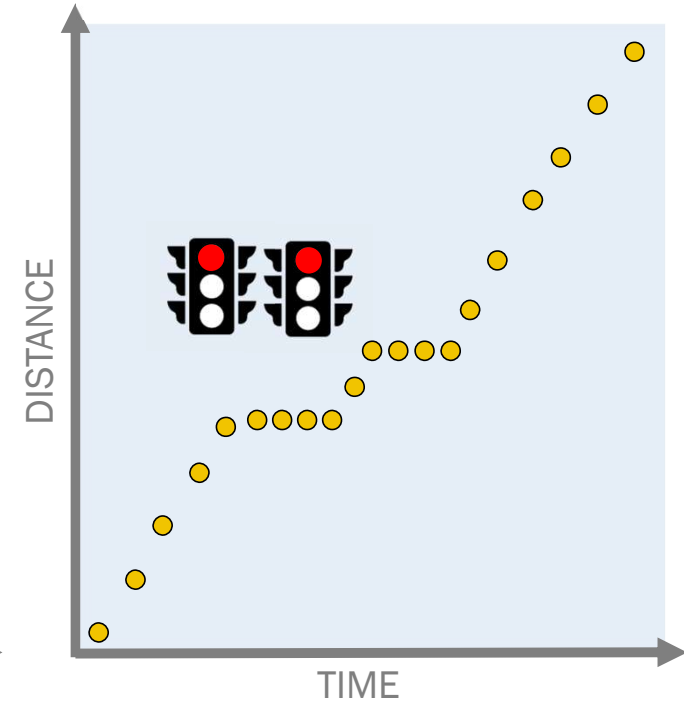
**42 sec**  
ARRIVAL ON GREEN



**61 sec**  
ARRIVAL ON RED

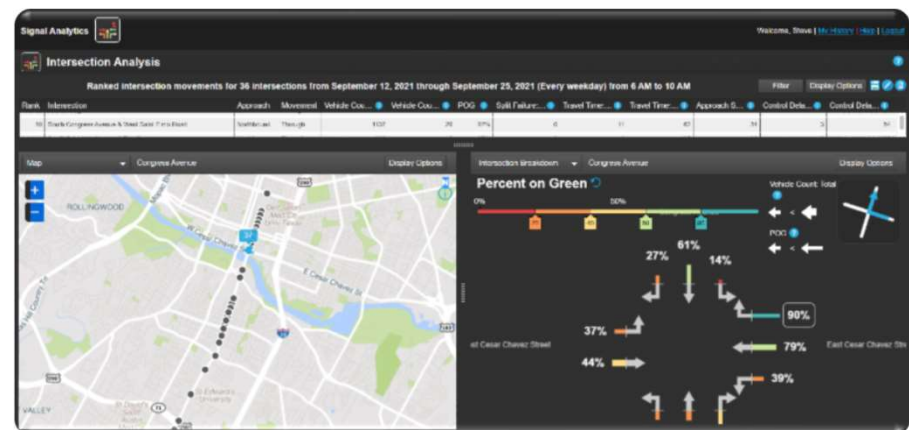
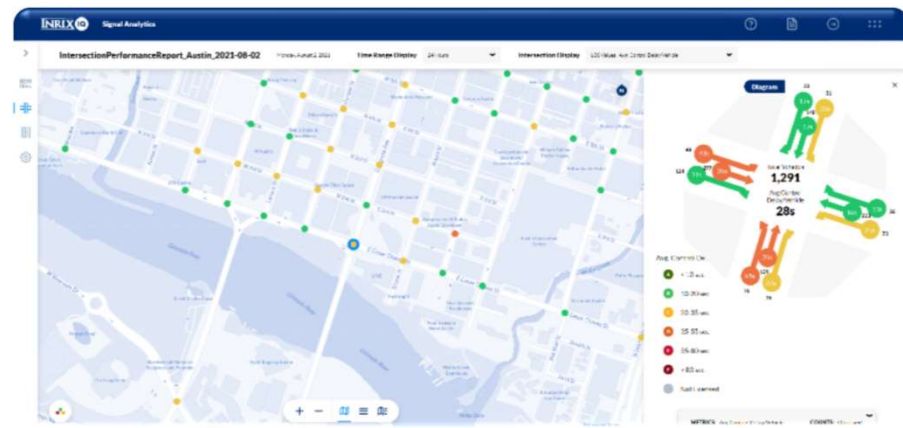


**100 sec**  
SPLIT FAILURE



# CORE USE CASES – SIGNAL ANALYTICS

- ❖ Safety and Emissions
  - Reducing split failures, reduces idling
  - Where queues exist, safety issues arise
- ❖ Project prioritization
  - Scan the entire traffic signal network to focus on problem intersections
- ❖ Performance
  - Identify underperforming intersections
  - Discover and measure iterative changes to signal timings
- ❖ Before and After studies
  - Did the retiming have a positive outcome
- ❖ Traffic Models
  - Validate the results of traffic modeling or simulation software

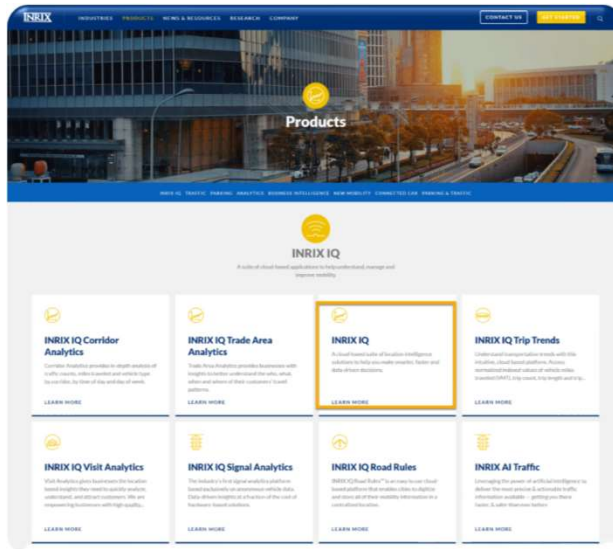


# Intersection Metrics Using Trajectory Data

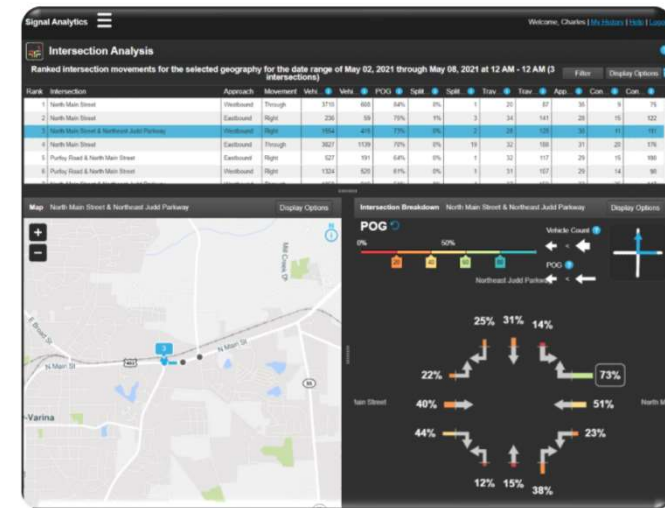




# Two Complimentary Tools

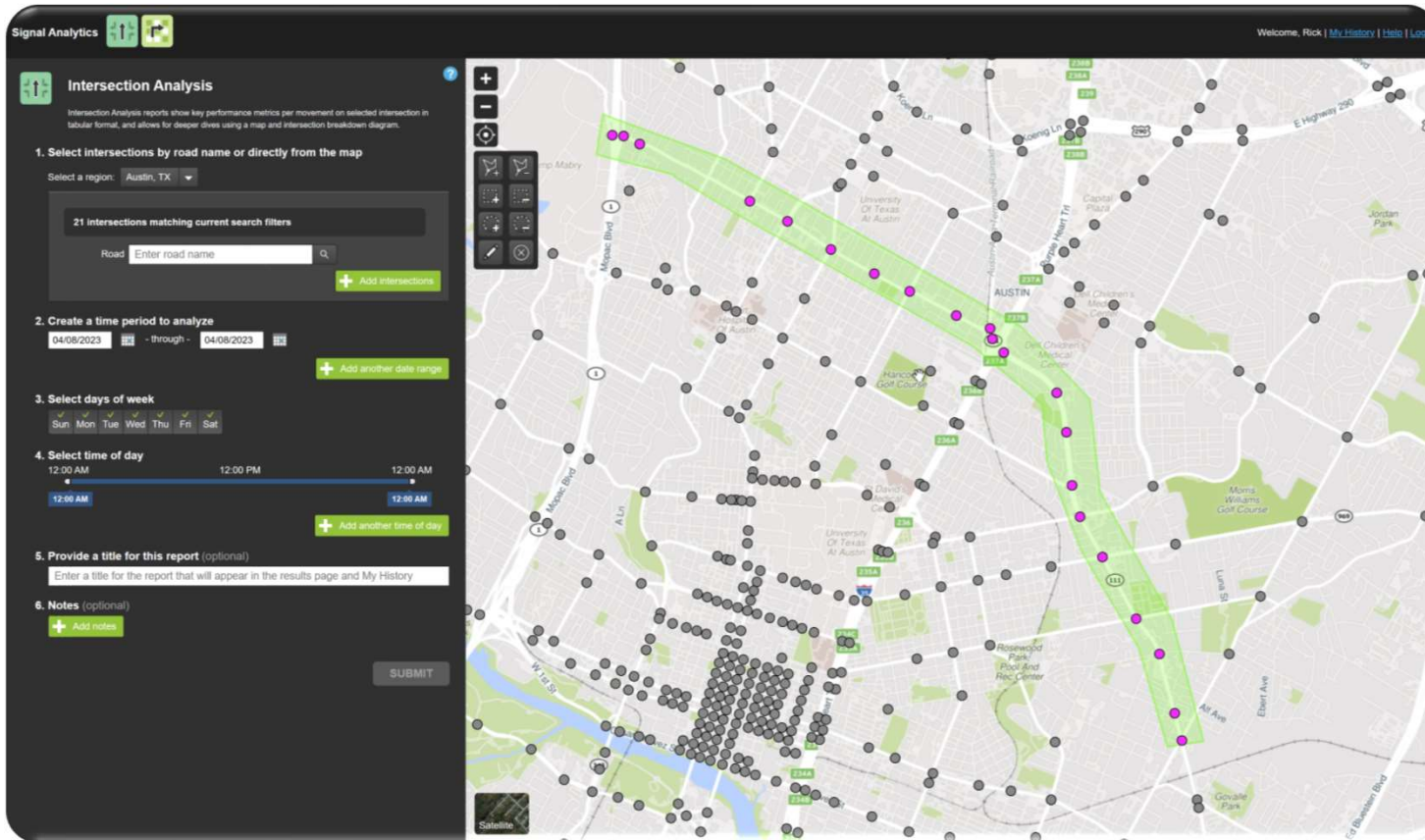


**INRIX IQ**  
Daily System Dashboard



**CATT Lab Signal Analytics**  
Deep Dive Analytics  
[signals.ritis.org](https://signals.ritis.org)

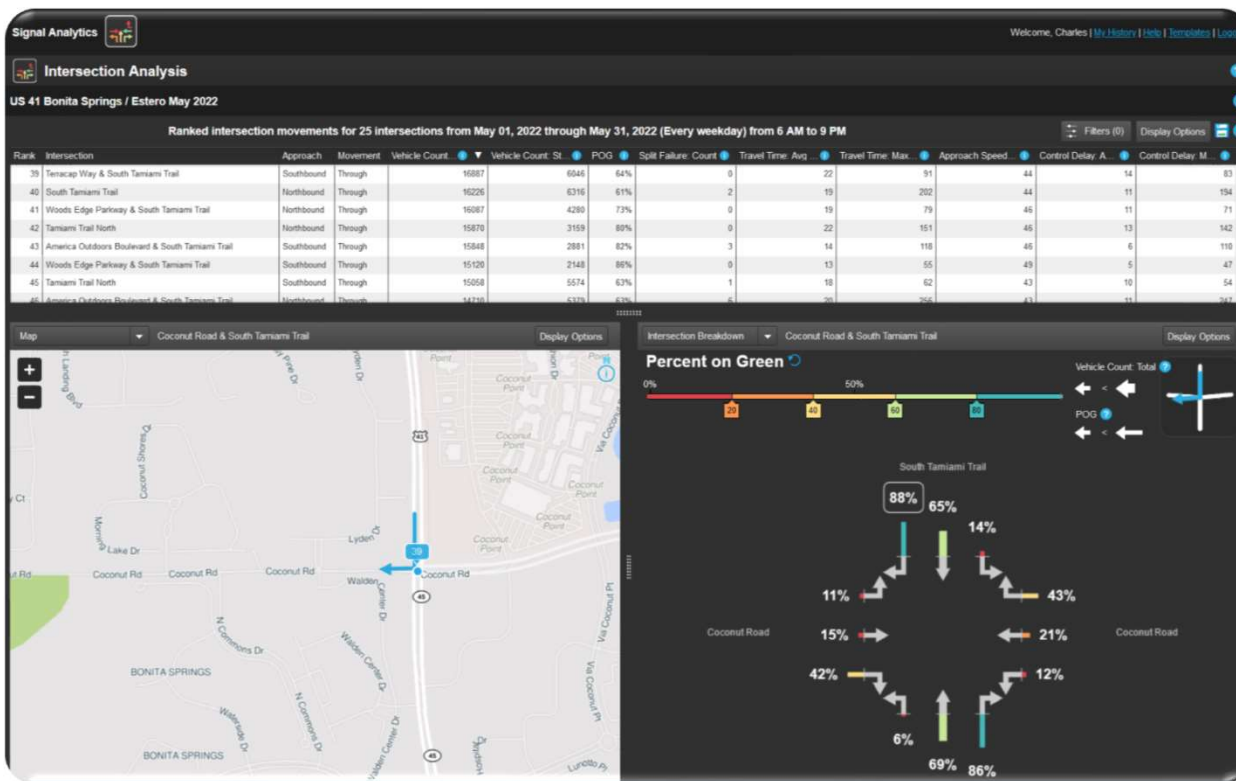
# Signal Analytics Intersection Analysis Tool



## User defines:

- Intersections or corridors
- Date range(s)
- Time(s) of day

# Signal Analytics Intersection Analysis Tool



- Table shows intersection performance ranked by metric
- Map shows location and orientation of each intersection movement
- Diagram visualizes performance of each metric by movement

# Signal Analytics Intersection Analysis Tool

**Ranked intersection movements for 25 intersections from May 01, 2022 through May**

Rank	Intersection	Approach	Movement	Vehicle Count	Vehicle Count: St.	POG
42	America Outdoors Boulevard & South Tamiami Trail	Southbound	Through	15543	4981	
44	Woods Edge Parkway & South Tamiami Trail	Southbound	Through	15120	2148	
45	Tamiami Trail North	Southbound	Through	15058	5574	
46	America Outdoors Boulevard & South Tamiami Trail	Northbound	Through	14710	5379	
47	Bonita Beach Road Southwest & South Tamiami Trail	Southbound	Through	13286	4434	
48	Bonita Beach Road Southwest & South Tamiami Trail	Northbound	Through	13136	8115	
49	South Tamiami Trail	Southbound	Through	316	255	
50	America Outdoors Boulevard & South Tamiami Trail	Northbound	Through	29	29	

**Filter Table**

Column: Movement  
Contains: through

Column: Approach  
Contains: north, south

+ Add another constraint

**Intersection Movement Diagram**

Coconut Road

11% (Left Turn), 15% (Through), 42% (Right Turn)

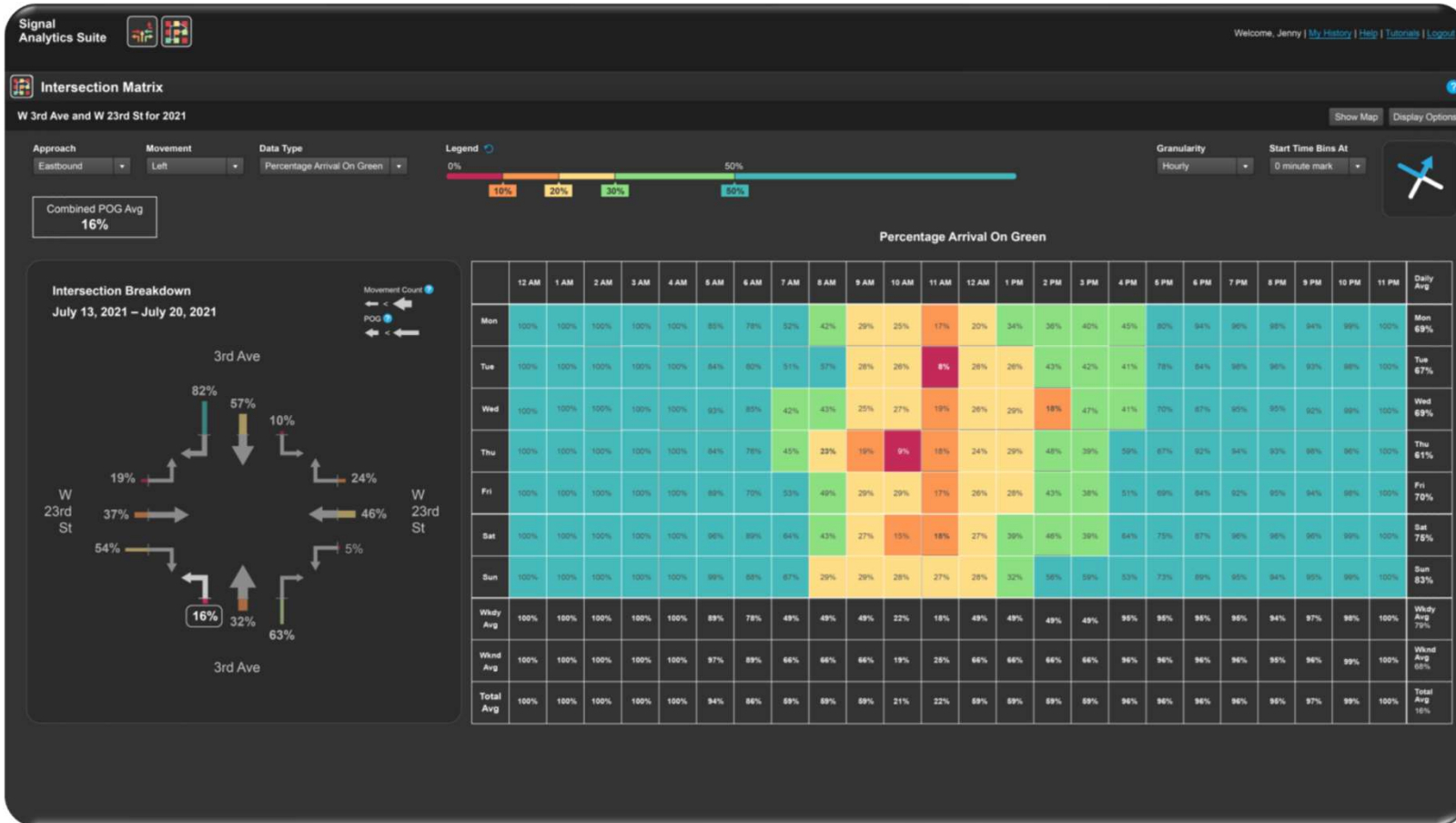
14% (Left Turn), 100% (Through), 43% (Right Turn)

6% (Left Turn), 69% (Through), 86% (Right Turn)


21% (Left Turn), 12% (Right Turn)

- Advanced table filtering allows ranking by approach, movement, and value
- Download table as CSV

# Intersection Matrix Tool



















































# My History Page Lists Previous Reports

Signal Analytics  Welcome, Charles | [My History](#) | [Help](#) | [Templates](#) | [Logout](#)

Intersection Analysis Reports

★ Favorites

STATUS	REPORTS	DATE CREATED	NOTES	FAVORITES	
In-Progress	 <b>US 41 Bonita Springs / Estero May 2022</b>  25 intersections <a href="#">Open report</a>	Jun 09, 2022 01:12 PM	Weekdays All Day	 ★	
Completed	 <b>US 41 Bonita Springs / Estero May 2022</b>  25 intersections <a href="#">Open report</a>	Jun 09, 2022 11:44 AM	Weekdays 4 PM to 7 PM	 ★	
Completed	 <b>US 41 Bonita Springs / Estero May 2022</b>  25 intersections <a href="#">Open report</a>	Jun 09, 2022 11:43 AM	Weekdays 6 AM to 9 AM	 ★	
Completed	 <b>US 41 Bonita Springs / Estero May 2022</b>  25 intersections <a href="#">Open report</a>	Jun 09, 2022 11:43 AM	Weekdays 6 AM to 9 PM	 ★	
Completed	 <b>US 41 Bonita Springs / Estero May 2022</b>  25 intersections <a href="#">Open report</a>	Jun 09, 2022 11:30 AM		 ★	
Completed	 <b>Seattle May 2022 PM Peak</b>  211 intersections <a href="#">Open report</a>	Jun 06, 2022 08:50 AM		 ★	
Completed	 <b>January 2021 Ocean City Mid-Day</b>  9 intersections <a href="#">Open report</a>	May 24, 2022 03:32 PM		 ★	
Completed	 <b>November 2021 Ocean City Mid-Day</b>  9 intersections <a href="#">Open report</a>	May 24, 2022 03:30 PM		 ★	
Completed	 <b>301 Weekday 3-7</b>  3 intersections <a href="#">Open report</a>	May 20, 2022 02:31 PM		 ★	
Completed	 <b>301 Weekday 3-7</b>  3 intersections <a href="#">Open report</a>	May 20, 2022 02:30 PM		 ★	
Completed	 <b>Orlando April 2022 PM Peak</b>  458 intersections <a href="#">Open report</a>	May 16, 2022 08:25 AM		 ★	
Completed	 <b>17-92 Test</b>  16 intersections	May 13, 2022 04:22 PM		 ★	

# Use Case 1: How are the signals in my county performing?

Washington County, OR

“Is there a way that I can rank the performance of my traffic signals across my entire county?”

“Can I see how much conditions change month by month?”

**Solution: Use the Signal Analytics Ranked Intersection Table**

**Consider ranking by weekday split failures**



# Selecting the intersections in my county...

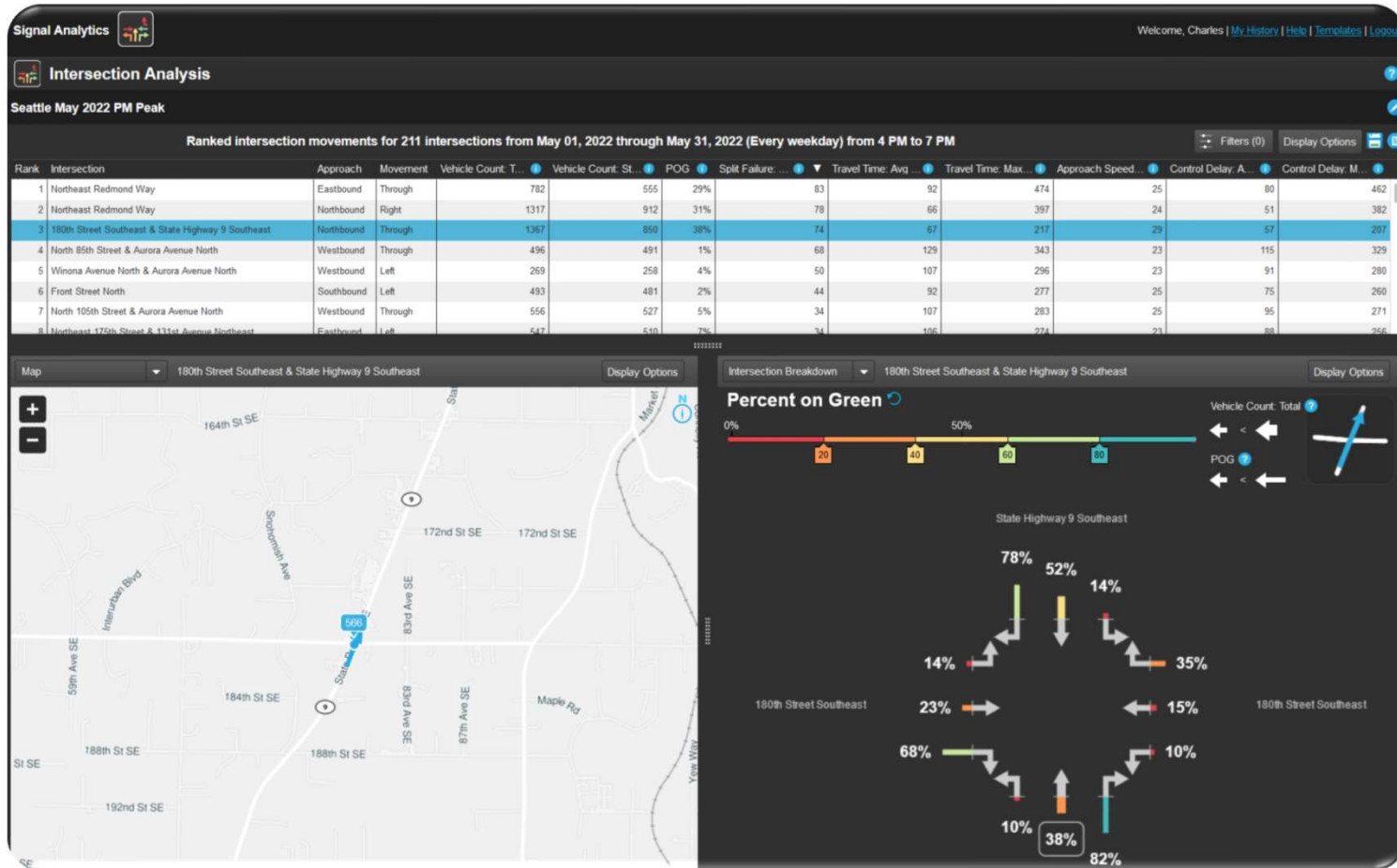
The screenshot displays the 'Signal Analytics' web application interface. The main section is titled 'Intersection Analysis' and includes a sidebar with the following steps:

- 1. Select intersections by road name or directly from the map**
  - Select a region: Washington County, OR
  - 55 intersections matching current search filters
  - Road:
  - + Add intersections
- 2. Create a time period to analyze**
  - 05/01/2021 - through - 05/30/2021
  - + Add another date range
- 3. Select days of week**
  - Sun Mon Tue Wed Thu Fri Sat
- 4. Select time of day**
  - 12:00 AM - 12:00 PM
  - 6:00 AM - 5:00 PM
  - + Add another time of day
- 5. Provide a title for this report (optional)**
  - Enter a title for the report that will appear in the results page and My History
- 6. Notes (optional)**
  - + Add notes

A 'SUBMIT' button is located at the bottom of the sidebar. The main map area shows a green circular selection over Washington County, Oregon, with 55 purple dots representing the selected intersections. The map includes labels for cities like Hillsboro, Beaverton, Tigard, Tualatin, and Lake Oswego, as well as major roads and parks.



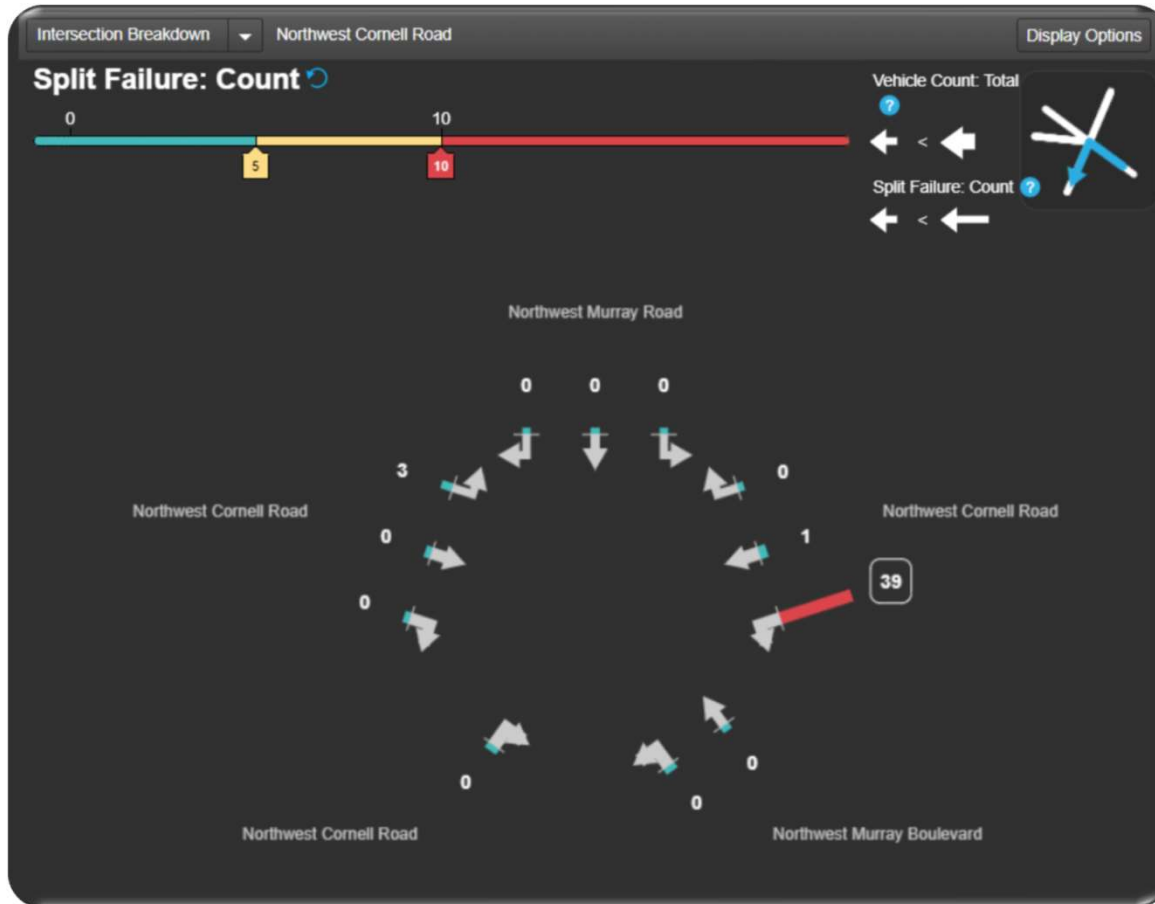
# Sort the ranked intersection movement table by split failures



# Countywide Analysis

Frequency in Top 10 for Total # of Weekday Split Failures, 5am-9pm								
Intersection	Approach	Maneuver	June	May	April	March	February	% in Top 10
Southwest Pacific Highway & TSR	Southbound	Through	1	2	5	3	6	100%
Southwest 124th Avenue & Southwest Tualatin Sherwood Road	Westbound	Through	2					20%
Northwest 185th Avenue & Northeast Evergreen Parkway	Eastbound	Left	3	3				40%
Southwest Durham Road & Southwest Upper Boones Ferry Road	Eastbound	Left	4	7	3, 7		9	60%
Northwest Cornell Road & Murray Road	Westbound	Left	5	4	1	4	10	100%
Southwest Durham Road & Southwest Upper Boones Ferry Road	Northbound	Through	6	10	4	9		80%
Southwest Pacific Highway & TSR	Northbound	Through	7	6	2	2	1	100%
Northeast Brookwood Parkway & Northeast Cornell Road	Eastbound	Left	8		10			40%
Southwest Tualatin Sherwood Road & Southwest Boones Ferry Road	Westbound	Left	9		8	5	8	80%
Northwest 185th Avenue & Northeast Evergreen Parkway	Southbound	Left	10					20%
Southwest Baseline Road & 185th Avenue	Northbound	Through				7	2	40%
Southwest Martinazzi Avenue & Southwest Tualatin Sherwood Road	Eastbound	Through		1			3	40%
Southwest Baseline Road & 185th Avenue	Northbound	Left					4	20%
Southwest 92nd Avenue & Southwest Durham Road	Northbound	Left				1	5	40%
Southwest Baseline Road & 185th Avenue	Southbound	Through		9	6	6	7	80%
Southwest Tualatin Sherwood Road & Southwest Boones Ferry Road	Eastbound	Through		5				20%
Northwest Cornell Road & 48th Avenue	Eastbound	Left		8				20%
Southwest Nyberg Street & Fred Meyer Entrance	Southbound	Left				8		20%
Southwest Tualatin Sherwood Road & Southwest Boones Ferry Road	Southbound	Through				10		20%
Southwest Pacific Highway & TSR	Southbound	Right			9			20%

## Let's take a look at the intersection diagram...



There are a lot more split failures on that left turn movement. **What would happen if I extended the max time for that movement?**



TransCore Unified Controller Manager

File Search View Actions Advanced Help

Refresh Edit New Delete Download All To Controller Upload All From Controller

Save Compare Close Print Reload Partial Compare

Messages Device List Archived Device List 8463.2

Control Function and Timing Local Detector Data Overlaps Service Plans Max Plans Coordination Data Time of Day Data Preemption Data Communication Data Miscellaneous Data Internal Logic Controller ID Strategy Mapping

Initialization Phase Timing Dual Entry Other Controller Functions

CONTROLLER FUNCTION AND TIMING

Upload From Controller Download To Controller Print Save Page

Journal entries for device 8463, version 2

Security, Sequence, Initial:	2017-03-20 15:58:04.517: [By shaun] Uploaded timing from field, 3-20-2017, S Quayle
	2021-01-25 16:38:47.203: [By shaun] 1-25-21, Shaun Q, uploaded timing
Lead Lag	2021-08-12 15:02:35.513: [By shaun] 8-12-21, Shaun Q, increased WBL phase 1 max time from 25 to 35 seconds based on Inrix IQ data
by coord plan or dock:	
Initialization	
1	

Logging CSV Logging Realtime Export

X X



# Use Case: How do I compare conditions before and after a signal timing change?

City of Austin, TX

“How can I measure changes to intersection performance if I don’t have detection on all my approaches?”

“Using corridor travel times to measure signal timing improvement can be good, but sometimes it seems they don’t tell the whole story. Are there additional measures I can use?”

**Solution: Use the Signal Analytics to compare split failures, control delay, and percent on green over time**



# Selecting intersections on McNeil Dr....

**Signal Analytics** Welcome, Charles | My History | Help | Logout

**1. Select intersections by road name or directly from the map**

Select a region: Austin, TX

Use the controls on the map to define your intersection set. Controls with a '+' allow you to add intersections while controls with a '-' allow you to remove intersections from your selection.

Road:  + Add intersections

Your selection: Remove all

- ▶ 8 intersections
- ▶ 6 intersections

**2. Create a time period to analyze**

08/30/2021 - through - 09/10/2021 + Add another date range

**3. Select days of week**

Sun Mon Tue Wed Thu Fri Sat

**4. Select time of day**

12:00 AM - 12:00 PM

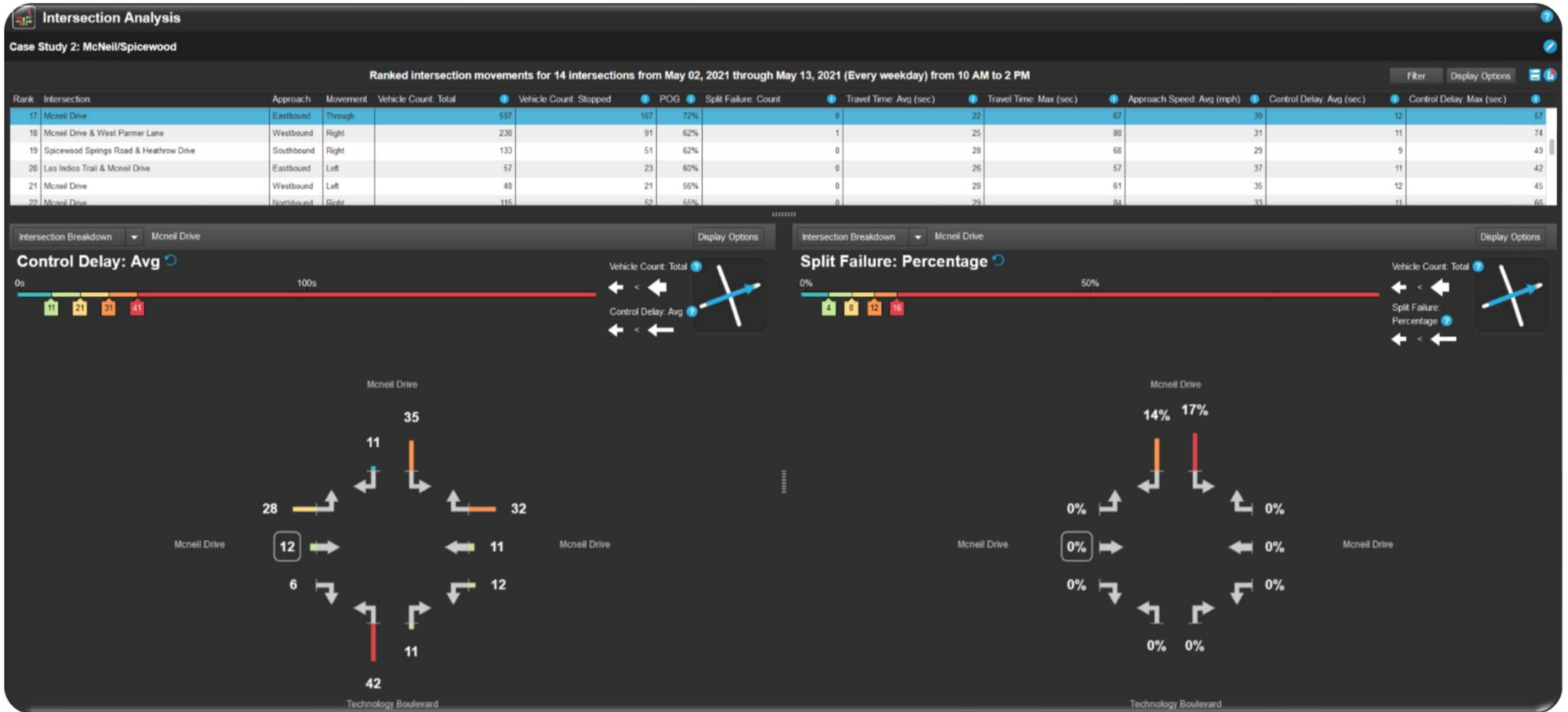
10:00 AM - 2:00 PM + Add another time of day

**5. Provide a title for this report (optional)**

**6. Notes (optional)**

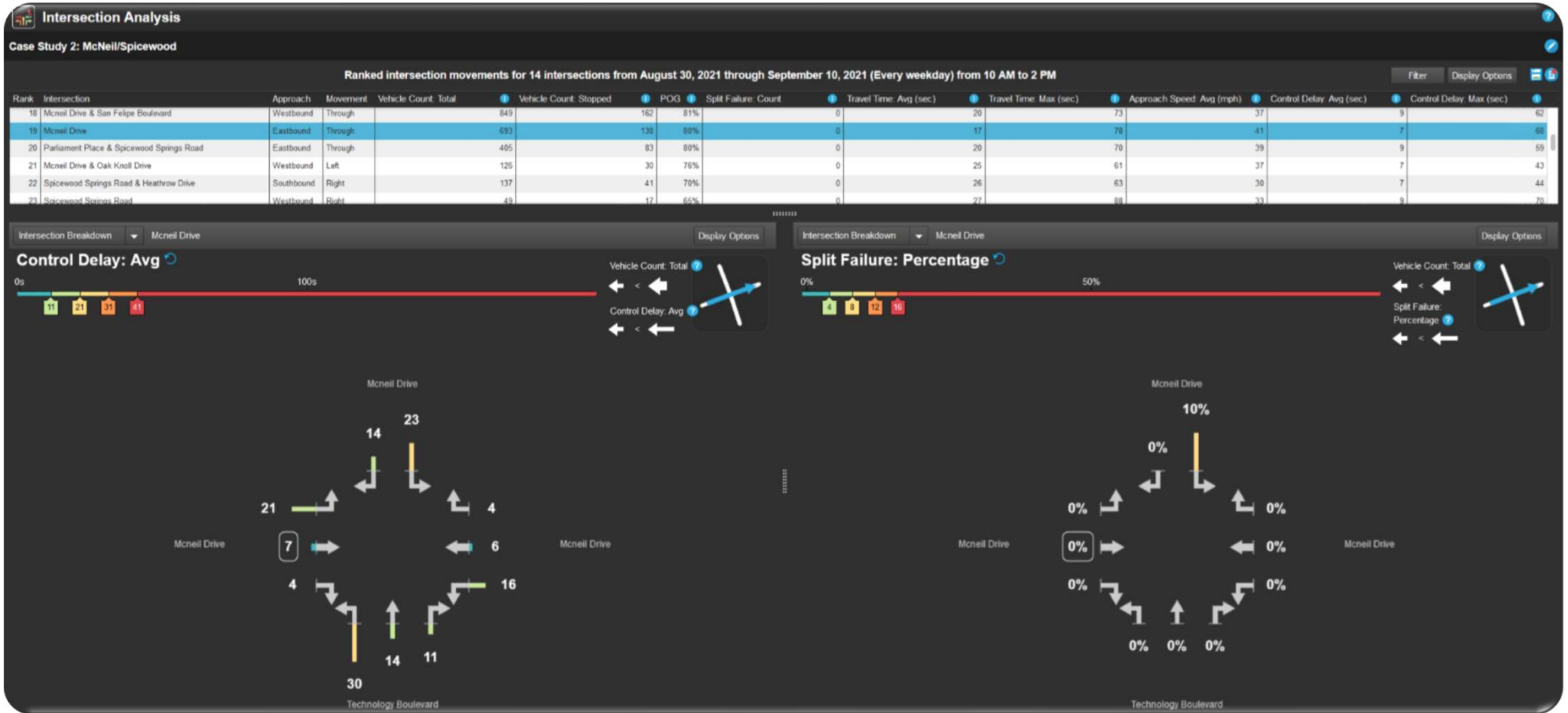
**SUBMIT**

# Before retiming

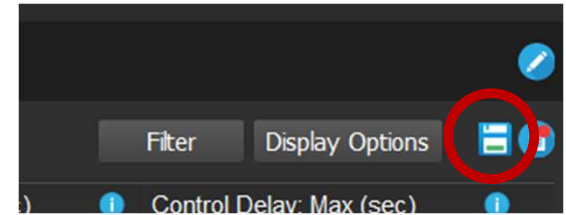




# After retiming



# Downloading Data



Rank	Intersection	Intersection ID	Latitude	Longitude	Approach	Approach ID	Movement	Movement ID	Vehicle Count: Total	Vehicle Count: Stopped	Vehicle Count: Through	Estimated Volume: Total	Estimated Volume: Stopped	Estimated Volume: Through
1	Mcneil Drive & Oak Knoll Drive	30.4394_-97.7542	30.4393591	-97.7542284	Westbound	30.4394_-97.7542-30.4394_-97.7542_3	Through	30.4394_-97.7542_X3Y2Z	852	15	837	25403	447	813
2	Rustic Rock Drive & Spicewood Springs Road	30.4301_-97.7812	30.43014345	-97.78122745	Eastbound	30.4301_-97.7812-30.4301_-97.7812_1	Through	30.4301_-97.7812_DE3F	342	10	332	12838	375	337
3	Rustic Rock Drive & Spicewood Springs Road	30.4301_-97.7812	30.43014345	-97.78122745	Westbound	30.4301_-97.7812-30.4301_-97.7812_3	Through	30.4302_-97.7813_2XW	317	10	307	11899	375	310
4	Mcneil Drive & Oak Knoll Drive	30.4394_-97.7542	30.4393591	-97.7542284	Eastbound	30.4394_-97.7542-30.4394_-97.7542_2	Through	30.4394_-97.7542_3H3G	808	42	766	24091	1252	794
5	Los Indios Trail & Mcneil Drive	30.4374_-97.7605	30.4373716	-97.7604817	Westbound	30.4374_-97.7605-30.4374_-97.7605_3	Through	30.4374_-97.7605_3Y	845	74	771	28414	2488	807
6	Mcneil Drive & Heinemann Drive	30.4424_-97.7464	30.4423753	-97.7464263	Westbound	30.4424_-97.7464-30.4424_-97.7464_2	Through	30.4424_-97.7465_3Y	787	72	715	25773	2358	715
7	Corpus Christi Drive & Mcneil Drive	30.4411_-97.7496	30.4411412	-97.74964205	Eastbound	30.4411_-97.7496-30.4411_-97.7496_1	Through	30.4411_-97.7496_4G	828	77	751	26539	2468	774
8	Mcneil Drive & West Parmer Lane	30.4438_-97.7424	30.44384835	-97.74239143	Southbound	30.4438_-97.7424-30.4438_-97.7424_2	Right	30.4439_-97.7425_4P2Y	185	19	166	6449	662	166
9	Corpus Christi Drive & Mcneil Drive	30.4411_-97.7496	30.4411412	-97.74964205	Westbound	30.4411_-97.7496-30.4411_-97.7496_3	Through	30.4412_-97.7497_5Y	853	89	764	27340	2853	775
10	Spicewood Springs Road & Heathrow Drive	30.4316_-97.7783	30.43162835	-97.77829435	Westbound	30.4316_-97.7783-30.4316_-97.7783_3	Through	30.4317_-97.7783_3Z	262	33	229	8993	1133	262
11	Mcneil Drive	30.4381_-97.7582	30.4381404	-97.7581562	Westbound	30.4381_-97.7582-30.4381_-97.7582_3	Through	30.4381_-97.7582_3Z3Y	824	109	715	23762	3143	715
12	Mcneil Drive & Heinemann Drive	30.4424_-97.7464	30.4423753	-97.7464263	Eastbound	30.4424_-97.7464-30.4424_-97.7464_1	Through	30.4423_-97.7464_4G	739	101	638	24201	3308	638
13	Spicewood Springs Road & Scotland Well Drive	30.4225_-97.7936	30.422528	-97.793613	Eastbound	30.4225_-97.7936-30.4225_-97.7936_1	Through	30.4225_-97.7936_2FEI	96	14	82	3797	554	82
14	Spicewood Springs Road & Scotland Well Drive	30.4225_-97.7936	30.422528	-97.793613	Westbound	30.4225_-97.7936-30.4225_-97.7936_3	Through	30.4225_-97.7936_aYWX	132	22	110	5220	870	110
15	Los Indios Trail & Mcneil Drive	30.4374_-97.7605	30.4373716	-97.7604817	Eastbound	30.4374_-97.7605-30.4374_-97.7605_1	Through	30.4374_-97.7605_5G	497	83	414	16712	2791	414
16	Spicewood Springs Road & Heathrow Drive	30.4316_-97.7783	30.43162835	-97.77829435	Eastbound	30.4316_-97.7783-30.4316_-97.7783_1	Through	30.4316_-97.7783_F2H	361	65	296	12391	2231	296
17	Mcneil Drive & West Parmer Lane	30.4438_-97.7424	30.44384835	-97.74239143	Southbound	30.4438_-97.7424-30.4438_-97.7424_2	Through	30.4439_-97.7425_6P	1167	219	948	40683	7635	948
18	Mcneil Drive & San Felipe Boulevard	30.4352_-97.7670	30.4352045	-97.7670345	Westbound	30.4352_-97.7670-30.4352_-97.7670_3	Through	30.4352_-97.7670_6Y	849	162	687	29480	5625	687
19	Mcneil Drive	30.4381_-97.7582	30.4381404	-97.7581562	Eastbound	30.4381_-97.7582-30.4381_-97.7582_1	Through	30.4381_-97.7582_4G2H	693	138	555	19984	3979	555
20	Parliament Place & Spicewood Springs Road	30.4333_-97.7727	30.4333065	-97.77269095	Eastbound	30.4333_-97.7727-30.4333_-97.7727_1	Through	30.4333_-97.7727_5H	405	83	322	15521	3181	322
21	Mcneil Drive & Oak Knoll Drive	30.4394_-97.7542	30.4393591	-97.7542284	Westbound	30.4394_-97.7542-30.4394_-97.7542_3	Left	30.4394_-97.7542_X3YV	126	30	96	3757	894	96
22	Spicewood Springs Road & Heathrow Drive	30.4316_-97.7783	30.43162835	-97.77829435	Southbound	30.4316_-97.7783-30.4316_-97.7783_2	Right	30.4317_-97.7783_2QRZ	137	41	96	4703	1407	137
23	Spicewood Springs Road	30.4283_-97.7831	30.4283	-97.78306185	Westbound	30.4283_-97.7831-30.4283_-97.7831_4	Right	30.4283_-97.7830_eD	49	17	32	1806	626	32
24	Mcneil Drive & West Parmer Lane	30.4438_-97.7424	30.44384835	-97.74239143	Northbound	30.4438_-97.7424-30.4438_-97.7424_4	Right	30.4438_-97.7422_4hG	89	32	57	3103	1116	57
25	Mcneil Drive & West Parmer Lane	30.4438_-97.7424	30.44384835	-97.74239143	Northbound	30.4438_-97.7424-30.4438_-97.7424_4	Through	30.4438_-97.7422_6h	792	329	463	27610	11469	463
26	Mcneil Drive	30.4381_-97.7582	30.4381404	-97.7581562	Northbound	30.4381_-97.7582-30.4381_-97.7582_4	Right	30.4381_-97.7582_2Cj2H	139	58	81	4008	1673	81
27	Mcneil Drive & West Parmer Lane	30.4438_-97.7424	30.44384835	-97.74239143	Westbound	30.4438_-97.7424-30.4438_-97.7424_3	Right	30.4440_-97.7423_ZyH	300	128	172	10458	4462	172
28	Los Indios Trail & Mcneil Drive	30.4374_-97.7605	30.4373716	-97.7604817	Eastbound	30.4374_-97.7605-30.4374_-97.7605_1	Left	30.4374_-97.7605_4G2i	51	23	28	1715	773	28
29	Mcneil Drive	30.4381_-97.7582	30.4381404	-97.7581562	Westbound	30.4381_-97.7582-30.4381_-97.7582_3	Left	30.4381_-97.7582_3ZRU	52	24	28	1500	692	28

# FY '22 ASR Analysis - McNeil/Spicewood



AUSTIN  
TRANSPORTATION

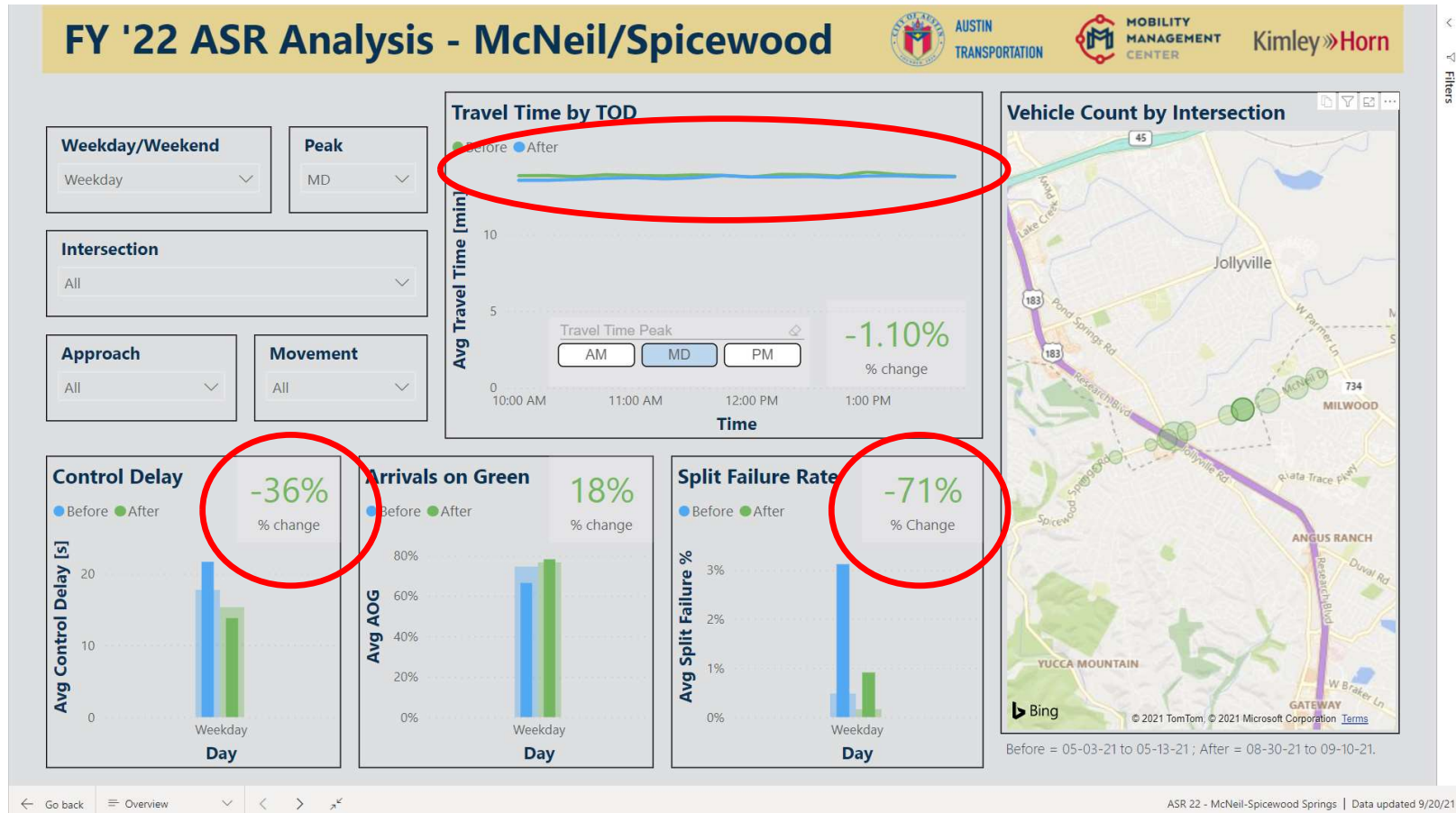


MOBILITY  
MANAGEMENT  
CENTER

KimleyHorn

Little improvement in travel time

Significant improvement in control delay and split failure rate



Source: Kimley-Horn

# More Data Fields

**Table Columns**

- All Columns
- Rank
- Intersection
- Intersection ID
- Latitude
- Longitude
- Approach
- Approach ID
- Movement
- Movement ID
- Vehicle Count
  - Total Vehicle Count
  - Stopped Vehicle Count
  - Through Vehicle Count
- Estimated Volume
  - Total Estimated Volume
  - Stopped Estimated Volume
  - Through Estimated Volume
- Percent Arrival On Green (POG)
- Turn Percentage
- Split Failure
  - Split Failure Percentage
  - Split Failure Count
  - Split Failure Estimated Volume
- Level of Service (LOS)
- Travel Time
  - Average Travel Time
  - Median Travel Time
  - Minimum Travel Time
  - Maximum Travel Time
  - 5% Travel Time
  - 25% Travel Time
  - 75% Travel Time
  - 95% Travel Time
- Approach Speed
  - Average Approach Speed
  - Median Approach Speed
  - Minimum Approach Speed
  - Maximum Approach Speed
  - 5% Approach Speed
  - 25% Approach Speed
  - 75% Approach Speed
  - 95% Approach Speed
- Approach Speed Stop
  - Average Approach Speed Stop
  - Median Approach Speed Stop
  - Minimum Approach Speed Stop
  - Maximum Approach Speed Stop
  - 5% Approach Speed Stop
  - 25% Approach Speed Stop
  - 75% Approach Speed Stop
  - 95% Approach Speed Stop
- Approach Speed Through
  - Average Approach Speed Through
  - Median Approach Speed Through
  - Minimum Approach Speed Through
  - Maximum Approach Speed Through
  - 5% Approach Speed Through
  - 25% Approach Speed Through
  - 75% Approach Speed Through
  - 95% Approach Speed Through
- Control Delay
  - Average Control Delay
  - Median Control Delay
  - Minimum Control Delay
  - Maximum Control Delay
  - 5% Control Delay
  - 25% Control Delay
  - 75% Control Delay
  - 95% Control Delay

# Thanks!



Rick Ayers 

703.989.3221 

rayers@umd.edu 

cattlab.umd.edu 